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ARTICLE ID: 01

APPLICATION OF UNMANNED AERIAL VEHICLES (UAVS) IN THROUGHOUT THE CROP CYCLE

Abstract

Unmanned Aerial Vehicles (UAVs) have emerged as revolutionary instruments in modern agriculture, providing major benefits across the agricultural cycle. UAVs are commonly used for soil analysis, crop health monitoring, precision irrigation, and effective pesticide and fertilizer application. In the early phases, UAVs outfitted with multispectral and thermal sensors evaluate soil parameters, allowing for accurate fertilizer management and land preparation. UAVs enable real-time monitoring of agricultural growth by recording high-resolution imagery, diagnosing stress conditions, and detecting insect infestations. UAV-based spraying systems ensure uniform pesticide distribution, which reduces input costs and improves crop protection. Furthermore, UAVs help with yield estimation and post-harvest assessments, allowing for more informed decision-making. UAVs are a crucial component of precision agriculture due to their rapid data collecting capabilities and higher accuracy, which contribute to increased productivity, resource efficiency, and sustainable agricultural methods.

Keywords: Agriculture, Crop cycle, Monitoring, UAVs

Introduction

The use of unmanned aerial vehicles (UAVs), sometimes known as drones, has transformed modern agriculture by improving precision, efficiency, and decision-making throughout the crop cycle. UAV technology provides considerable benefits in data collecting, real-time monitoring, and targeted interventions, making it an indispensable tool in precision agriculture. UAVs are equipped with advanced sensors such as multispectral, hyperspectral, and thermal cameras, which facilitate detailed assessments of soil conditions, crop health, and environmental stress factors (Tsouros et al., 2019). These features allow farmers to employ site-specific management methods, which improve resource use and lower input costs. During the pre-sowing stage, UAVs assist in land preparation by capturing topographic data for digital elevation models (DEMs), enabling identification of low-lying or erosion-prone zones (Zhang et al., 2020). UAVs with multispectral sensors examine soil fertility, moisture content, and organic matter distribution, providing useful information for field planning. In the sowing stage, UAVs equipped with seeding mechanisms provide precision seed placement, particularly in difficult terrain. Variable-rate seeding technology integrated with UAV systems optimizes planting density based on soil characteristics, promoting uniform crop establishment (Shamshiri et al., 2018).

In the vegetative growth stage, UAVs play a crucial role in detecting pest infestations, nutrient deficiencies, and weed proliferation. Multispectral imaging techniques such as the Normalized Difference Vegetation Index (NDVI) are commonly employed to assess crop vigor and identify stress conditions early (Yang et al., 2017). UAV-mounted thermal cameras successfully monitor temperature shifts, assisting farmers in identifying drought-stressed areas or irrigation concerns. Furthermore, UAVs provide precise spraying of insecticides and fertilizers, reducing waste and assuring focused application.

During the flowering and fruit development stage, UAVs facilitate canopy assessment, flowering intensity mapping, and detection of crop stress due to drought or nutrient imbalance. UAV-based spraying systems ensure efficient delivery of fertilizers, pesticides, and growth regulators, reducing environmental impact and enhancing crop productivity (Torres-Sánchez et al., 2018). As the crop approaches maturity, UAVs play a key role in harvesting stage operations by estimating crop yield through high-resolution imaging and predictive models. UAVs equipped with LiDAR and RGB sensors can identify mature crop zones, optimize harvesting schedules, and improve labour management (Huang et al., 2021). Post-harvest applications of UAVs include biomass assessment, field residue analysis, and land preparation for the subsequent planting season. UAVs equipped with thermal and multispectral sensors provide insights into post-harvest conditions, ensuring efficient field management (Madec et al., 2017).

The rapid growth of UAV technology, coupled with artificial intelligence (AI) algorithms, has substantially increased data analysis capabilities, allowing for predictive modeling and effective agricultural decision-making. By integrating UAVs throughout the crop cycle, farmers can achieve enhanced productivity, resource optimization, and improved environmental sustainability. As precision agriculture continues to evolve, UAVs are anticipated to become indispensable tools for ensuring global food security (Tsouros et al., 2019).

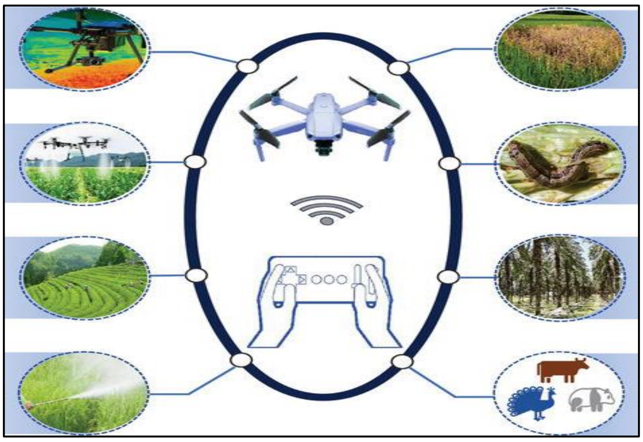

Figure 1. Application of UAVs in Agriculture

❖ Different UAV Applications throughout Crop cycle:

Following some ways of aerial and ground based drones will be used throughout the crop cycle,

a. A) Analysis of soil and field:

Soil analysis is one of the most important practice to determine exact amount of nutrients of Available crops. also, by tracking exact amount nutrient it will help to for adjusting the dose of fertilizer. UAVs can be extremely useful in the beginning of the agricultural cycle. They create exact 3-D maps for early soil analysis and seed planting pattern planning. Drone-assisted soil analysis gives data for irrigation and nitrogen management after planting.

b. B) Seed Planting:

Drone Seed planting, is a newer and less extensively used technology, but some companies are experimenting with it. Manufacturers are testing specialised systems that can fire seed pods into prepared soil. Drone start-ups have played an important role in the development of the industry. developing cutting-edge drone technologies to help with a variety of environmental and agricultural challenges, for example: Droneseed. The same drone technology may be developed and deployed to a variety of farm types, lowering total planting times and personnel costs.

C) Crop Monitoring:

The biggest challenge in farming is the size of the fields and the inefficiency of crop monitoring. Increasingly unpredictable weather conditions worsen monitoring issues, increasing risk and field maintenance costs. Satellite imagery was previously the most advanced way of surveillance. However, there were certain disadvantages. Images had to be requested ahead of time, could only be taken once a day, and were inaccurate. Furthermore, services were prohibitively expensive, and image quality degraded on occasion. Time-series animations may now depict the exact evolution of a crop and expose inefficiencies in production, allowing for better crop management.

1. **Crop Height:** Commonly used manual approaches for monitoring crop height are time consuming, labor intensive and impractical for large-scale commercial operations. Plant height estimation using multiple types of cameras and other sensors. With advances in unmanned aerial vehicle (UAV) technologies, routine monitoring of height is now feasible at any time throughout the growth cycle.

D) Crop spraying and Spot Spraying:

This is the most crucial step in the crop's life cycle. To maintain good yields, crops require regular fertilisation and spraying. This was formerly done by hand, with cars, or even by plane (in some parts of the world). These approaches are not only inefficient and time-consuming, but they can also be quite expensive. Large reservoirs can be fitted to drones, which can be filled with fertilisers, herbicides, or pesticides. Crop spraying with drones is significantly safer and more cost-effective. Drones can even be totally self-contained and programmed to follow certain routes and schedules. Distance-measuring equipment, such as ultrasonic echoes and lasers employed in the light-detection and ranging, or LiDAR, allows a drone to alter altitude as topography and geography change, avoiding collisions. As a result, drones can scan the ground and spray the appropriate amount of liquid, regulating distance from the ground and spraying in real time to ensure even coverage. As a result, efficiency has improved while the amount of chemicals leaking into groundwater has decreased. In fact, researchers believe that drones can accomplish aerial spraying up to five times faster than traditional apparatus.

E) Management and Monitoring:

Farmers have traditionally struggled with irrigation. With so much irrigation, problems are likely to develop. Drones with thermal cameras can help identify irrigation problems or locations that are receiving too little or too much moisture. Water and irrigation concerns are not only expensive, but they can also reduce crop production. These issues can be identified by drone surveys before they become a problem. Drones equipped with hyperspectral, multispectral, or thermal sensors can detect areas of a field that are dry or in need of improvement. Drones can also calculate the vegetation index, which describes the relative density and health of the crop, and reveal the heat signature, which is the amount of energy or heat the crop releases, once the crop is growing. Drones equipped with hyperspectral, multispectral, or thermal sensors can detect areas of a field that are dry or in need of improvement. Drones can also calculate the vegetation index, which describes the relative density and health of the crop, and reveal the heat signature, which is the amount of energy or heat the crop releases, once the crop is growing. Crops can be properly laid out with this knowledge to enhance drainage, adhere to natural land flow, and avoid water pooling, which can harm delicate crops.

F) Crop Health Assessment:

Assessing crop health and spotting bacterial or fungal infections on trees is critical. Drone-borne devices can identify which plants reflect different amounts of green light and near-infrared light by scanning a crop with both visible and near-infrared light. This data can be used to create multispectral images that track plant changes and indicate their health. A quick response may be able to save a whole orchard. Furthermore, once a disease has been identified, farmers can more accurately apply and monitor treatments. These two options improve a plant's ability to resist disease. In the event of crop failure, the farmer will be able to more easily document losses for insurance claims.

Conclusion

The use of Unmanned Aerial Vehicles (UAVs) throughout the crop cycle has greatly increased agricultural efficiency by allowing for exact soil analysis, optimum seed planting, effective crop monitoring, targeted spraying, and improved irrigation management. UAVs coupled with modern sensors such as multispectral, hyperspectral, and thermal cameras have transformed precision agriculture by lowering input costs, reducing environmental impact, and increasing crop yields. UAV technology remains critical to sustainable and smart farming operations because it enables data-driven decision-making and improves resource usage. substantially increased agricultural efficiency by enabling practices.

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ARTIFICIAL SOILS- A BRIEF

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Abstract

Man-made substrates called artificial soils, sometimes referred to as engineered soils or synthetic soils, are made to resemble natural soil characteristics for certain uses. To obtain the required physical, chemical, and biological properties, they are made by mixing different materials such sand, clay, organic matter, recycled trash, and industrial leftovers. The sustainability of agriculture is significantly impacted by the usage of artificial soil. Field crops and horticultural crops can be produced with artificial soil because of its high nutrient uptake, aeration, and water-holding capacity. Urban development, green roofing, landscaping, agriculture, and environmental cleanup all make extensive use of artificial soils. They also offer a sustainable way to deal with issues like urbanization, soil deterioration, and the need for arable land. With an emphasis on maximizing their composition to promote biodiversity, lessen their negative effects on the environment, and increase crop yield, research into artificial soils is progressing. This new area of study connects environmental sustainability, material engineering, and soil science.

Introduction

Naturally soils are formed by physical, chemical and biological factors. But the land is degrading now a days due to man made pollution due to that the productivity of the soils also decreasing. Due to many reasons world is suffering with the food shortage problems. One of the newest solutions to meet the demand for food is the technological creation of soil. All that constitutes artificial soil is the addition of materials or living things to the soil. Peat, granular soil, sewage silt created during the treatment of urban waste, for instance, and pulp sludge—a byproduct of the production of paper from wood pulp—are all included in the artificial soil composition. The primary goal of artificial soils is to address specific challenges in agriculture, urban development, and environmental management, where natural soils may be unsuitable or degraded. The development and optimization of artificial soils hold significant potential for promoting ecological balance, increasing agricultural productivity, and addressing the challenges of a rapidly urbanizing world. Artificial soils are being used more and more for environmental purposes, such as reclaiming contaminated lands, creating wetlands for water filtration, and waste reduction through the recycling of organic and inorganic materials.

Artificial soil based on brown coal crop

Smirnov et.al (2021) demonstrated that, using soil derived from brown coal crops will boost the number of Heavy Metals extracted from the soil and hasten the germination of the grass mixture. The outcome is obtained by first pre-applying the brown coal crop to the soil at a rate of 200–220 kg/ha, after which it is distributed, the surface is graded, and it is ploughed to a depth of 15–20 cm.

Organo mineral filler based on lignin and phosphogypsum sludge

Smirnov et.al (2021) demonstrated that, excess calcium is involved in the biochemical processes of HM and Sr substitution in plants when it is applied to the soil with phosphor gypsum and lignin sludge. The product offers a means of boosting the grass mixture's development efficiency and guaranteeing that Heavy Metals and rare earth metals are released into plants in a manageable quantity.

Advantages

1. Artificial soils can be designed to fulfil certain needs, such increased drainage, better water retention, pH level adjustment, or the provision of ideal nutrient profiles for desired plant growth.
2. To cut waste and encourage resource efficiency, they frequently use recycled materials like compost, biochar, and industrial leftovers.
3. Artificial soils can maximize plant growth circumstances with specific nutritional compositions and physical structures, resulting in increased crop yields and superior output.
4. Particularly in arid and semi-arid areas, artificial soils can be made to better retain moisture, which will save water use in landscaping and agriculture.
5. Artificial soils can maximize plant growth circumstances with specific nutritional compositions and physical structures, resulting in increased crop yields and superior output.
6. Artificial soils can be a more affordable option than importing or restoring natural soils in some situations, such as building green roofs or restoring land.
7. Artificial soils can be structured to encourage the growth of diverse plant species and support beneficial microorganisms, contributing to healthier ecosystems.

Conclusion

An appropriate choice for sustainable agricultural production is made up of the right combination of physical, chemical, and biological characteristics. Artificial soil works well for increased output because of its improved nutrient uptake, aeration, and water-holding capacity. It provides the essential nutrients that plants require for development, growth, and metabolism. The artificial soil combination provides breathing holes, a location for the roots to rest, and the capacity to hold enough water to sustain plant growth.

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BIO-INPUT RESOURCE CENTRES (BRC): CATALYSTS FOR INDIA'S NATURAL FARMING TRANSITION

Abstract

In a significant push to support the transition to chemical-free agriculture, the Union Ministry of Agriculture and Farmers' Welfare released detailed guidelines on April 23, 2025, for the establishment of Bio-Input Resource Centres (BRCs) under the National Mission on Natural Farming (NMNF). The move, aimed at setting up 10,000 such centres across India, offers Rs 1 lakh per centre in financial support. While this initiative aligns with the broader goal of promoting sustainable agriculture, several experts have raised concerns over the adequacy of funding, infrastructural limitations, and implementation gaps. This article explores the intent, framework, stakeholder responses, and the implications of this policy for Indian agriculture.

1. Introduction: The Case for Natural Farming in India

Promise, Potential, and the Road Ahead for Greener Agriculture

The rising cost of chemical inputs, deteriorating soil health, erratic weather due to climate change, and stagnant farm incomes are pushing India's agriculture sector toward a tipping point. Against this backdrop, natural farming—an agroecological approach that emphasizes local, low-cost, and chemical-free inputs has emerged as a sustainable alternative. The Government of India responded to this growing need by launching the **National Mission on Natural Farming (NMNF)** in November 2024. A cornerstone of this mission is the establishment of **1 0,000 Bio-Input Resource Centres (BRCs)** decentralized hubs designed to provide natural farming inputs and knowledge to India's 140 million farmers.

2. Understanding BRCs: What, Why, and How

BRCs aim to:

- **Supply ready-to-use bio-inputs** (e.g., Jeevamrut, Beejamrut, Ghana Jeevamrut, Panchagavya) at affordable rates.
- **Enable knowledge exchange** among natural farming practitioners.
- **Encourage farmer-to-farmer learning** through demonstration farms and peer-led training.
- **Reduce dependence** on chemical fertilizers and expensive commercial biofertilizers.
- **Support farmers with localized input solutions** that suit their unique agro-climatic and soil conditions.

These centres are **cluster-level micro-enterprises**, envisioned to operate as community-owned institutions managed by experienced or newly-trained natural farming entrepreneurs.

3. Highlights from the April 2025 Guidelines

- **Financial Assistance**: Rs 1 lakh per BRC in two installments.
- **Eligibility**: The group or entrepreneur must practice or start natural farming in the immediate season.
- **Local Relevance**: Input production must reflect local soil, crop, and climate conditions.
- **No Funding for Infrastructure**: Entrepreneurs must arrange for land, sheds, and buildings themselves.
- **Affordability Focus**: Inputs must be priced for accessibility, especially for small and marginal farmers.
- **Institutional Convergence**: BRCs may align with FPOs, SHGs, and other government schemes for implementation support.

4. Natural Farming in Action: Regional Insights

Andhra Pradesh – The Flag Bearer

Under the **ZBNF (Zero Budget Natural Farming)** programme, Andhra Pradesh has pioneered community-managed natural farming. The state's Rythu Sadhikara Samstha (RySS) has facilitated village resource persons and bio-input centres long before the NMNF guidelines. These experiences suggest that **continuous handholding, adequate funding, and peer learning** are essential for successful BRCs.

Sikkim – The Organic Trailblazer

As India's first fully organic state, Sikkim exemplifies how a strong policy framework and state support can lead to systemic change. However, the lack of local bio-input units has often led to reliance on external suppliers. BRCs, if introduced here, can solve this gap.

Arunachal Pradesh – Opportunity in the Northeast

Tribal farmers here already follow low-input traditional agriculture. BRCs can formalize and enhance these practices by making quality inputs consistently available. ICAR-KVKs in the region could play a pivotal role in training and mentoring new BRC operators.

5. The Rs 1 Lakh Question: Is It Enough?

Several experts have voiced concerns about the **inadequacy of financial support**:

Dr. Manjula M, Azim Premji University, points out:
"Rs 1 lakh is only viable where infrastructure already exists. For new entrepreneurs starting from scratch, it's insufficient. Infrastructure like sheds, pits, and bio-digesters cost money."

Indeed, creating a sustainable BRC requires at least:

- Basic infrastructure (shed, compost pit, water supply)
- Equipment (drums, sprayers, fermenting containers)
- Raw materials (livestock dung, urine, biomass)
- Training and working capital

A more **realistic startup package** of Rs 2.5–3 lakh per BRC, with staggered milestone-based disbursal, may better support the intended outcomes.

6. Women and Youth as BRC Champions

The guidelines open the door for **SHGs, youth groups, and FPOs** to operate BRCs. This is a unique opportunity to:

- **Empower rural women** who already have knowledge of composting and livestock care.
- **Engage unemployed rural youth** with training and entrepreneurship in natural farming.
- **Foster village-based enterprises**, reducing migration and enhancing local livelihoods.

Examples like Kudumbashree units in Kerala and Mahila Kisan Sashaktikaran Pariyojana (MKSP) groups in Maharashtra show how SHGs can manage agri-enterprises efficiently.

7. Aligning BRCs with Other Missions and Schemes

For greater impact and viability, BRCs should converge with:

- **FPO Scheme**: Collective marketing of bio-inputs and farm produce.
- **National Mission on Edible Oils – Oil Palm**: Use of organic inputs in palm oil clusters.
- **MGNREGA**: Support for compost pits and community sheds.
- **RKVY and Paramparagat Krishi Vikas Yojana (PKVY)**: Fund linkages and capacity building.
- **Krishi Sakhis**: Female farm extension workers who can double as BRC resource persons.

This kind of convergence can **reduce duplication, optimize resources**, and ensure integrated support systems for farmers.

8. Strengthening the Value Chain: A Holistic Approach

For long-term success, BRCs must not function in isolation. A **holistic value chain** approach is necessary:

- **Backward Linkages**: Supply of quality livestock-based raw materials, plant biomass.
- **Capacity Building**: Hands-on training, refresher courses, exposure visits.
- **Forward Linkages**: Tie-ups with organic marketing platforms, mandis, and digital marketplaces.
- **Monitoring**: Real-time MIS dashboards and mobile apps for performance tracking.

Such a system will ensure **efficiency, accountability, and scalability** in the BRC model.

9. Case Study – Community-Driven Bio-Input Centre in Maharashtra

In Amravati district, a women's FPO started a small-scale bio-input unit with state support. Despite a modest initial investment of Rs 2 lakh, they now serve over 800 farmers with Jeevamrut and herbal pest repellents. Their income grew by 40% in one year, and they plan to expand by adopting solar-powered fermentation tanks.

This example highlights how **community ownership, proper training, and forward market linkages** can make BRCs successful.

10. Looking Ahead: Policy Recommendations for Impactful BRCs

To unlock the full potential of BRCs, the following policy refinements are suggested:

1. **Enhanced Financial Support**: Minimum Rs 2.5–3 lakh per unit.
2. **Tiered Models**: Micro (village), Meso (cluster), and Macro (district-level) BRCs based on demand.
3. **Digital Integration**: E-learning platforms and AI-based advisory tools for BRC operators.
4. **Public-Private Partnerships**: Collaborate with natural input companies and NGOs for training and marketing.
5. **Certification Simplification**: Fast-track organic certification for BRC-supported farmers under PGS (Participatory Guarantee System).

Conclusion: BRCs as Building Blocks of Agroecological Transformation. The concept of Bio-Input Resource Centres is timely and transformative. If implemented thoughtfully, BRCs can become **anchor points of India's agroecological revolution**, bridging the gap between policy and practice.

While the intent is strong, its success will depend on:

- Adequate financing
- Community engagement
- Infrastructure support
- Integrated extension systems

Natural farming is not merely a production method—it is a movement for sustainable, ethical, and resilient agriculture. BRCs must be nurtured with the same care that natural farmers extend to their soil, seed, and surroundings.

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ARTICLE ID: 04

BIOFORTIFICATION IN CROPS: ENHANCING NUTRITIONAL VALUE FOR A HEALTHIER FUTURE

In recent years, biofortification has emerged as an innovative and sustainable approach to improving the nutritional content of staple crops. The process involves increasing the micronutrient levels—such as vitamins and minerals—in crops through conventional breeding, genetic engineering, or agronomic practices. This technique offers a potential solution to the global challenges of malnutrition, particularly in developing countries where dietary diversity is limited, and nutrient deficiencies are prevalent.

What is Biofortification?

Biofortification is the process of increasing the nutritional quality of food crops by enhancing their content of essential vitamins and minerals. Unlike fortification, which typically involves adding nutrients to processed foods, biofortification focuses on improving the nutrient density of the crops themselves during their growth. This is achieved through three main methods:

1. **Conventional Breeding**: This involves selecting and breeding plants with higher levels of specific nutrients. Over multiple generations, the nutrient content of the crop is increased without introducing foreign genes.
2. **Genetic Engineering**: Genetic modification involves inserting specific genes into crops that enable them to produce higher levels of desired nutrients, such as Vitamin A or iron.
3. **Agronomic Practices**: This method involves altering the environment or using fertilizers to enhance the nutrient content of crops during their cultivation.

Why Biofortification Matters

The importance of biofortification lies in its ability to combat malnutrition, which affects millions of people worldwide. According to the World Health Organization (WHO), micronutrient deficiencies, or "hidden hunger," are a leading cause of morbidity and mortality, particularly in developing countries. Key nutrients such as iron, zinc, and Vitamin A are crucial for healthy growth, immune function, and overall well-being. Biofortified crops are a practical way to address these deficiencies, particularly in regions where access to diverse and nutritious foods is limited.

For example, a staple food like rice, which is consumed in large quantities in many Asian countries, is often deficient in Vitamin A. Through biofortification, rice can be genetically modified to produce beta-carotene (a precursor to Vitamin A), providing a much-needed source of this vital nutrient to populations that rely

Success Stories in Biofortification

One of the most notable success stories in biofortification is *Golden Rice*. This genetically engineered rice variety was developed to produce beta-carotene, which gives the rice its characteristic golden colour. Golden Rice aims to combat Vitamin A deficiency, which is a significant public health issue in countries like India and the Philippines. The introduction of Golden Rice has been seen as a potential breakthrough in the fight against preventable blindness and other health issues caused by Vitamin A deficiency.

Another example is the biofortification of wheat and maize to increase their iron and zinc content. These crops are staple foods in many parts of the world and are often lacking in micronutrients. Through biofortification, these crops can be enhanced to provide a richer source of these essential minerals, improving the nutrition of millions of people who rely on them for their daily sustenance.

Benefits of Biofortification

1. **Cost-Effectiveness**: Biofortification can be a low-cost intervention, particularly when using conventional breeding techniques. Once biofortified crops are developed, they can be grown and consumed by local populations without the need for external supplements or fortified food products, making them a sustainable solution.
2. **Scalability**: Biofortified crops can be grown by smallholder farmers in rural areas, making it a scalable solution for addressing malnutrition. It can be integrated into existing agricultural systems without requiring major infrastructure changes.
3. **Improved Health Outcomes**: Biofortification directly addresses nutrient deficiencies that lead to a variety of health problems, including stunted growth, weakened immune systems, and even death. By improving the nutrient content of staple crops, biofortification helps improve overall public health.
4. **Sustainability**: Unlike fortified foods that require additional processing and transportation, biofortified crops provide a sustainable source of nutrition directly from the source. They can be grown and consumed locally, reducing dependence on external aid.

Challenges and Controversies

While biofortification holds great promise, there are challenges and controversies that need to be addressed. One of the primary concerns is the acceptance of genetically modified (GM) crops. Many countries have strict regulations regarding GM crops, and public resistance to genetically modified foods can hinder the adoption of biofortified crops like Golden Rice.

Additionally, there are concerns about the potential environmental impacts of introducing genetically modified crops into ecosystems. Thorough testing and regulation are necessary to ensure that these crops do not negatively affect biodiversity or lead to the development of resistance in pests or diseases.

Another challenge is ensuring that biofortified crops reach the people who need them the most. Effective distribution systems, education about the benefits of biofortification, and government support are essential to ensure that these crops are integrated into the diets of vulnerable populations.

The Future of Biofortification

Despite the challenges, the future of biofortification looks promising. Research continues to focus on developing new biofortified crops with higher nutrient content and better resilience to climate change. With advances in genetic engineering and precision agriculture, it is likely that biofortification will play a key role in global efforts to combat malnutrition and food insecurity.

International organizations, governments, and the private sector are increasingly investing in biofortification as part of their strategies to address global food and nutrition security. As these efforts progress, biofortified crops could become a cornerstone of sustainable agricultural practices, helping to ensure that everyone has access to nutritious, healthy food.

Conclusion: Biofortification is a groundbreaking approach to enhancing the nutritional value of staple crops, offering a sustainable solution to the global challenge of malnutrition. Through methods like conventional breeding, genetic engineering, and agronomic practices, biofortified crops can provide essential nutrients to populations in need. While there are challenges to overcome, including regulatory hurdles and public acceptance, the potential benefits of biofortification—improved health, cost-effectiveness, and scalability—make it a vital tool in the fight against hunger and malnutrition. As research and innovation continue to shape the future of food security, biofortification stands poised to make a lasting impact on global health and nutrition.

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Brucellosis: A REPORTABLE DISEADE

Introduction

Brucellosis is an infectious ailment induced by bacteria. Individuals may contract the sickness by contact with infected animals or animal products affected with the pathogens. Species most frequently afflicted include sheep, cattle, goats, pigs, and dogs, among others. Brucellosis is a transmissible disease resulting from the consumption of unpasteurized milk or inadequately cooked meat from infected animals, or by direct contact with the secretions of diseased animals. It is also referred to as undulant fever, Malta fever, and Mediterranean fever. Four species infect humans: Brucella abortus, Brucella canis, Brucella melitensis, and Brucella suis. B. melitensis predominantly induces illness in cattle. B. canis impacts canines. The species with the highest virulence is B. melitensis. It typically affects goats and, on rarely, sheep. B. suis primarily infects swine. Symptoms encompass excessive sweating and soreness in the joints and muscles. For many years, brucellosis has been known to occur in both humans and animals.

Etiology

Brucella species are small, gram-negative, non-motile, non-spore-forming, rod-shaped coco bacilli bacteria.

Reservoir host

Reservoirs host include sheep, cattle, swine, and goats. Bison and deer may also harbor Brucella spp.

Mode of transmission

Direct contact with infected animals or tissues, such as blood, urine, vaginal discharges, aborted pregnancies, and placentas, results in transmission. It may also be transmitted through the consumption of unpasteurized milk or dairy products from infected animals. Airborne transmission may occur by inhalation of aerosols in the laboratory. Human-to-human transmission is rare, but congenital brucellosis has been reported, and infected mothers may transmit to infants through breastfeeding.

The action of physical and chemical agent:

Killed by heating them to 60 °C for 10 minutes, Susceptible to acidic pH, disinfectants, and sunlight. Survive for a long time in the fetus. Remain for a long time in cold temperatures.

Clinical signs of brucellosis in animals:

Cattle and Goat: Abortion (7^{th}- 9^{th} month-cattle and 3^{rd} or 4^{th} month-sheep), Hygroma of the knee, Abortion is associated with retained placenta. Also, causes stillborn or weak calves and reduced milk yield. A seminal vesicle, ampullae, testicles, and epididymides are infected in bulls. Testicular abscesses. Long-standing infections may result in arthritic joints.

Sheep: Mastitis, diarrhea, lameness, and abortion Reduction in semen quality, Swelling of the epididymis, Spermatoceles comprise spermatic fluid. Tunics undergo thickening and fibrosis. Fibrous atrophy is seen in the testes.

Horse: Chronic inflammatory condition referred to as fistulous withers, poll evil, and joint infections. Fistulous withers occur in the supraspinous bursa. Poll evil occurring in the supra-atlantal bursa.

Pigs: Abortion, lameness, paralysis, infertility

Dogs: Abortion, early embryonic death, dermatitis of scrotum, testicular atrophy

Clinical signs of brucellosis in humans:

• Pyrexia • asthenia • general malaise • anorexia • cephalalgia • myalgia and arthralgia.

Certain symptoms may endure for an extended duration: recurring fever, arthritis, testicular and scrotal enlargement, endocarditis, chronic weariness, depression, and hepatosplenomegaly.

Public health significance:

- According to the WHO laboratory biosafety manual, brucellosis is classified in Risk group III.
- Humans can easily contract brucellosis, which can result in acute feverish sickness (undulant fever).
- In chronic infection, serious complications affecting the musculoskeletal, cardiovascular, and central nervous system
- Veterinary professionals and farmers who work with infected animals, aborted fetuses, or placentas are at risk.

Diagnosis:

• Rose Bengal Test • Standard Tube Agglutination Test • ELISA • PCR • Bacteriological isolation of organism

Treatment:

Antibiotics are used to treat the infection and prevention of disease. Longer courses of therapy may be needed if there are complications.

Prevention and control:

- High-level immunity is provided to calves vaccinated with live Brucella abortus strain 19 between the ages of three and six months. A single dose confers immunity until the sixth pregnancy.
- Proper disposal of aborted fetuses
- Pasteurization of milk and milk products
- Periodical testing of herd
- Prevention of human brucellosis is dependent on control of the disease in livestock
- Lack of human vaccines and effective control measures make it necessary for the veterinarian and other health care workers to take protective measures.

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BUMBLEFOOT DISEASE IN DUCKS: A CASE STUDY FROM BYRNIHAT, MEGHALAYA

Abstract

Bumblefoot, medically known as ulcerative pododermatitis, is a relatively common but often overlooked disease in waterfowl. This case study presents a focused examination of a bumblefoot outbreak affecting a flock of ducks at a research station in Byrnihat, Meghalaya. It explores the etiology, clinical manifestations, diagnostic approach, treatment, and control strategies, offering insights for both veterinarians and poultry farmers involved in duck rearing.

Introduction

Bumblefoot is a bacterial infection and inflammatory condition that affects the footpad of birds, particularly those raised in intensive or semi-intensive systems. It is caused by bacteria entering through abrasions or pressure wounds on the feet. This condition is painful and affects productivity and mobility. The present case occurred at the Goat Research Station in Byrnihat, where semi-intensive duck cum fish farming is practiced.

Etiology

The primary bacteria implicated in bumblefoot are *Staphylococcus aureus*, *Pseudomonas spp.*, and *Escherichia coli* (Coles, 2007). These pathogens enter through minor foot injuries often caused by walking on rough, hard, or sharp surfaces. Poor nutrition—such as an excess of protein or vitamin A deficiency—and elevated uric acid levels also predispose birds to this condition (Smyth, 1997; Mansell & Bailey, 1998).

Synonyms and Terminology

The condition is also known as:

- Ulcerative pododermatitis
- Paw burns
- Footpad ulcers

These terms highlight the ulcerative nature of the disease and its primary location on the plantar footpad.

History and Place of Occurrence

The outbreak was reported in March (winter), affecting 40 ducks from a single flock. The flock was housed in a semi-intensive duck cum fish farming system at the Goat Research Station in Byrnihat, Meghalaya. Ducks were observed limping and reluctant to move, with notable appetite loss and behavioral changes.

Clinical Signs

The affected ducks showed:

1. Brown/black scabs and swelling on the footpad
2. Lameness and limping
3. Reluctance to walk or stand
4. Loss of appetite
5. Depression
6. Behavioral withdrawal

These signs are consistent with the clinical features described in previous literature (Harcourt-Brown, 2002).

Diagnosis

Diagnosis was based on:

- **History** of rough flooring and changes in behavior
- **Clinical examination**, confirming characteristic footpad lesions
- **Lesion evaluation**, which included swelling and scab formation

Differential diagnoses were ruled out based on symptom specificity.

Treatment and Management

Treatment included local care and systemic antibiotic therapy:

1. **Topical soaks:** Affected feet were soaked in a warm potassium permanganate ($KMnO_4$) solution. This antiseptic treatment helped reduce bacterial load and soften the scabs (Fairchild & Ritz, 2006).
2. **Disinfection:** The duck shed was cleaned and disinfected using potash solution to prevent recurrence.
3. **Systemic antibiotics:** Dicrysticin was administered intramuscularly at 10 mg/kg body weight for 7 days. Antibiotic therapy was crucial in controlling infection and promoting healing.

Response to Treatment

- **Day 1:** Lesions were prominent, with swelling and dark scabbing.
- **Day 3:** Noticeable reduction in swelling and lesion size.
- **Day 7:** Lesions resolved, and the birds resumed normal activities and feeding.

Pictures:

Day1: Lesions

Day2: Injecting Dicristicin

Day3: Decreased lesions

Day7: No lesions

This reflects treatment efficacy as documented in poultry care manuals (Glisson et al., 2003).

Discussion

Bumblefoot can severely compromise the welfare and productivity of ducks. Early intervention is critical, as untreated cases may lead to chronic infections or systemic spread. Management factors like flooring and nutritional balance play a significant role in disease prevention. Regular inspection of footpads and improved hygiene can mitigate risks (Glatz, 2001).

Environmental contributors in this case included rough flooring and inadequate foot health monitoring. Duck cum fish farming systems, while economically advantageous, demand rigorous sanitation and design to prevent infections.

Prevention

Preventive strategies include:

- Using soft bedding or padded flooring
- Avoiding protein excess in feed
- Supplementing essential vitamins (A, E)
- Regular foot checks for early signs
- Biosecurity and regular shed disinfection

Good management practices are the first line of defense against bumblefoot and other opportunistic infections.

Conclusion

Bumblefoot remains a preventable yet impactful condition in duck rearing operations. The case at Byrnihat emphasizes the importance of early detection, combined therapeutic approaches, and environmental management to effectively control the disease. With proper care, affected birds recover well and resume normal productivity.

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CLIMATE CHANGE'S EFFECTS ON THE BIOLOGY AND ECOLOGY OF INSECT PESTS: CONSEQUENCES FOR CROP PRODUCTIVITY, PEST MANAGEMENT TECHNIQUES, AND FOOD SECURITY

Abstract:

The rapid growth of the global population and technological advancements have transformed agriculture and food production. However, climate change poses significant threats through rising CO_2 levels, frequent droughts, and temperature variations, which disrupt crop yields and food security. Insect pests, which are highly sensitive to environmental changes, are profoundly affected by these climatic shifts, leading to altered distribution, survival, and reproduction rates. Since crop production is closely linked to insect pest populations and climate variables, understanding these interactions is crucial for effective pest management. Advanced pest monitoring technologies and predictive tools offer potential solutions to mitigate the adverse effects of climate change on agriculture. By integrating these innovations into pest management strategies, agricultural productivity and food security can be safeguarded against climate-induced disruptions.

Keywords: *Climate change, insect pests, food security, crop production, pest management, monitoring technology, CO_2 levels, temperature variations, drought.*

1. Introduction:

Technological advancements have boosted agricultural production, but rapid population growth and climate change pose significant threats to food security (Pingali *et al.*, 2022). By 2050, rising food demand will require increased crop production, which must be achieved without expanding land. Climate change, including higher CO_2 levels, temperature fluctuations, and droughts, negatively impacts crop yields and alters pest biology, population dynamics, and plant-pest-enemy interactions (Lin *et al.*, 2022). These changes lead to increased pest outbreaks, reducing crop productivity. This review analyzes how climate change affects insect pest ecology and explores modern pest monitoring technologies and modified integrated pest management (IPM) strategies to combat pest pressure and ensure food security.

2. Climate change effect on crops and agricultural pest:

2.1. Climate change effect on crops-

Rising global temperatures from climate change threaten crop production, with a predicted 10% decrease in global crop yield by mid-century, risking food security (Priya *et al.*, 2019; Tai *et al.*, 2014).

By 2050, if daily calorie intake rises to 3600 kcal, a 70% increase in food production will be required (Alexandratos *et al.*, 2012). Increased heat, droughts, and floods will shorten growing seasons, while higher temperatures lead to greater water demand; further reducing crop yields (Lesk *et al.*, 2022).

Elevated CO_2 concentrations (ECC) enhance photosynthesis and plant growth, increasing crop yield (Holley, 2022). In C3 plants, yield can rise by up to 19% under ECC (from 353ppm to 550ppm), as shown in a review by Kimball (2016). However, results for C4 plants like maize are mixed. ECC reduces transpiration (Kimball, 2016) and stomatal conductance (up to 22%) (Purcell *el al.*, 2018), lowering evapo-transpiration (ET) by 10% (Kimball, 2016), potentially improving drought tolerance. FACE maize experiments showed a 41% yield increase (Manderscheid *et al.*, 2016). Despite potential yield gains, ECC may reduce food quality, with protein concentrations dropping by 9.8%–15% in barley, rice, wheat, and potatoes (Taub *et al.*, 2008), alongside reduced minerals and vitamins.

1.1. Climate change effect on agricultural pests-

Climate change, including higher temperatures and elevated CO_2 levels, significantly affects insect pests and crop production. Temperature increases insect metabolic rates, with a 10°C rise doubling metabolic activity, leading to faster development, higher populations, and earlier pest infestations (Dukes *et al.*, 2009). For example, global warming has accelerated the development of the western pine beetle (Robbins *et al.*, 2022), while whitefly populations rise with higher temperatures and humidity (Bale *et al.*,2002). Warmer temperatures also accelerate multivoltine insects like aphids, increasing their annual generations (Wang *et al.*, 2015). Elevated CO_2 enhances photosynthesis but decreases nitrogen in plants, weakening their defenses (DeLucia *et al.*, 2012). This shift makes pests like the cotton bollworm more harmful (Guo *et al.*, 2012). Changes in precipitation patterns also influence pest dynamics— droughts increase wireworm populations and bark beetle outbreaks (Gregory *et al.*, 2009), while heavy rainfall can reduce pests like aphids (Pathak *et al.*, 2012) but increase pests like the oriental armyworm due to the decline of natural predators (Sharma *et al.*, 2010).

2. Managing insect-pest infestation under climate change:

2.1. Approaches for modified IPM-

Climate change is disrupting traditional Integrated Pest Management (IPM), requiring new strategies. Adjusting crop planting times based on local climate and pest cycles can reduce pest exposure (Zyan, 2019). Using climate-resilient crops and enhancing biodiversity at field margins supports natural pest control (Barberi *et al.*, 2010). Modifying the use of pheromones and bio-control agents is essential, as they may lose effectiveness in changing climates (Smart *et al.*, 2014). Research into eco-friendly volatile organic compounds (VOCs) offers sustainable alternatives. Collaboration among farmers, experts, and policymakers, along with training and monitoring, is crucial for adapting IPM practices. Understanding pesticide efficacy and resistance is vital for future pest management success.

2.2. Pest monitoring-

Monitoring agricultural pests is crucial for effective pest management, especially with climate change. Accurate pest identification and population assessment form the basis for Integrated Pest Management (IPM). Methods like direct observation, trapping, and remote sensing help detect pest outbreaks, crop stress, and disease. Remote sensing, combined with GPS and GIS, provides valuable data for targeted interventions. Studies, like Yang *et al.*, 2009 on aphid damage, highlight its predictive power. Climate forecasting and models further enhance pest management by anticipating pest behavior and crop yield impacts. Embracing these technologies enables proactive pest control, reducing losses and improving decision-making.

2.3. Climate forecasting and development of models in agricultural pest management-

Climate change alters weather patterns, temperatures, and precipitation, affecting insect pest behavior and distribution. Climate forecasting and climatic models are vital strategies for managing these changes. Forecasting uses statistical methods to predict weather shifts, supporting agricultural decisions. Climatic models simulate climate impacts, including pest behavior, helping predict pest outbreaks and guide crop selection, planting, and pest management. For example, these tools aid in determining optimal pesticide use. Combining climate data with pest biology enables accurate predictions, making forecasting essential for future pest management.

3. Conclusion:

Agricultural insect pests threaten food security, especially with climate change. Effective management requires understanding pest biology, behavior, and environmental interactions. Monitoring through traditional methods, remote sensing, and citizen science is essential for early intervention. Integrated Pest Management (IPM) strategies, pest-resistant crops, and forecasting systems can minimize pesticide use and environmental impact. Insurance programs and education empower farmers to manage risks. By adopting these approaches, we can protect crops, enhance food security, and ensure sustainable agriculture in a changing climate.

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CLIMATE-RESILIENT URBAN ALLOTMENT GARDENS: A NATURE-BASED SOLUTION FOR LOCALIZED VEGETABLE PRODUCTION AND MENTAL WELL-BEING

Abstract

Urban allotment gardens—shared spaces for cultivating vegetables—are emerging as an innovative nature-based solution to address urban food insecurity, climate stress and psychosocial well-being. These gardens, rooted in sustainability and resilience, offer a multi-functional platform for local food production, community engagement and mental health recovery, especially in the context of climate change and post-pandemic urban challenges. This article explores the ecological, social and economic value of urban allotment gardens in the Indian and Odisha-specific context, supported by global and national data, scientific studies and policy frameworks.

1. Introduction

The burgeoning pressures that climate change is imposing alongside high rates of urbanization are compromising urban food systems are most immediately threatened in developing countries like India. At the Ministry of Housing and the Urban Affairs (MoHUA), officials predict that 2030 will witness India's urban population – exceeding 600 Million citizens. In addition, the prevalence and severity of serious weather events such as heatwave, capricious rainfalls, and storms become commonplace, threatening supplies of food, public safety, and mental well-being in urban environments (IPCC, 2021). UAGs have become the forefront of the planning within the cities because of their decentralized character, low-cost and climate-resilient approach, which contributes to the achievement of food sovereignty and ecological balance and health of the communities.

Urban allotment gardens refer to cleared spaces provisioned to members of the public or group(s) within the cities for planting produce such as vegetables, herbs, and fruits for personal or group use (Palliwoda *et al*, 2020). In addition to food production, UAGs contribute to urban cooling, preserving biodiversity, storing carbon and support people's mental health (Soga *et al*., 2017).

2. Environmental and Climate Resilience Benefits

2.1 Urban Heat Island Mitigation

Allotment gardens contribute the reduction of the surface temperature by a maximum of 5°C, according to the plant cover and evapotranspiration as studied by Klemm *et al.* (2015). Research in Delhi and Ahmedabad showed that urban garden areas were 3.2°C cooler than the built-up areas during the daytime in Delhi (Bhardwaj *et al.*, 2021).

2.2 Rainwater Management and Flood Control

Integration of raised beds, composting pits, and permeable soil in designs of gardens contributes to runoff as well as groundwater recharging. Studies in Bangalore showed that community gardens had increased infiltration rate in the area by 35% (Sharma *et al.*, 2020).

2.3 Biodiversity Corridors

UAGs act as micro-habitats for pollinators and soil microbes, enhancing biodiversity. In a survey of 72 urban gardens in Pune, **over 42 species of beneficial insects** were recorded (Kale & Patil, 2022).

3. Nutritional and Economic Security

3.1 Yield Potential and Dietary Impact

Allotment gardens can produce **up to 2–3 kg of vegetables per m²/month**, especially nutrient-dense crops like amaranth, spinach, okra, tomato and brinjal (Bhattacharya *et al.*, 2021). In Kolkata's North Dumdum municipality, 450 families grew vegetables covering 2.5 acres, yielding over **10 tonnes of produce in one season** (Raychaudhuri *et al.*, 2022).

3.2 Cost Savings and Food Access

A study in Mumbai showed that households with access to UAGs saved **₹600–₹1200/month** on vegetables (Joshi & Mehta, 2021). This is significant in low-income wards where vegetable prices fluctuate seasonally.

3.3 Odisha Case: Urban Kitchen Garden Program

In Bhubaneswar, the **Odisha Livelihood Mission** and **Horticulture Department** promoted urban gardens through SHGs and municipal parks. Over 750 households in **Saheed Nagar and Laxmisagar** developed rooftop and balcony gardens using grow bags and compost bins, reducing dependency on external markets (OUAT & DoH Odisha, 2023).

4. Psychological and Social Benefits

4.1 Mental Health and Stress Reduction

During COVID-19, gardening activities were linked with **25–30% lower anxiety and depression symptoms** in urban participants (Soga *et al.*, 2021). Regular gardening increased serotonin and dopamine levels, as documented in meta-analyses of >20 global studies (Van den Berg *et al.*, 2016).

4.2 Community Cohesion

UAGs serve as neutral public spaces fostering interaction, trust and collective identity. In Kerala, the "Haritha Nagaram" initiative showed that community gardens built during lockdowns improved social bonds and reduced gender isolation among women's groups (George *et al.*, 2022).

5. Policy Gaps and Institutional Challenges

Despite benefits, UAGs face challenges in India:

- **Land tenure insecurity** and lack of permanent zoning
- Absence of **urban agriculture policies** in most states

- Poor integration with **urban planning, smart city missions and food security schemes**

- **Awareness and technical skill gaps** among citizens and municipalities

In Odisha, while MIDH supports protected cultivation, no dedicated allotment garden framework or budget line exists in urban horticulture schemes.

6. Recommendations and Way Forward

6.1 Institutional Integration

- **Include UAGs in Smart City Plans**, AMRUT parks and ward-level resilience planning.

- Mandate allocation of 2–5% urban green space for edible landscaping and allotment plots (BMC Policy Draft, 2024).

6.2 Skill Building and Youth Engagement

- Partner with institutions like **OUAT, IIHR and NSS** for training modules on urban horticulture, composting, pest management.

6.3 Financial Incentives

- Provide subsidies for **rainwater harvesting kits, shade nets, seeds and composters** through state horticulture missions.

- Support urban farmer cooperatives with access to **FPO credit, market linkage** and agri-insurance.

6.4 Monitoring and Research

- Establish city-level **Urban Garden Registries** for mapping, impact tracking and policy feedback.

- Conduct **longitudinal health studies** on dietary diversity, mental well-being and social cohesion impacts.

7. Conclusion

Urban allotment gardens represent a low-cost, high-impact solution for addressing food, health and climate challenges in Indian cities. For Odisha, where urbanization is expanding and climate vulnerabilities are rising, UAGs can bridge nutritional gaps, empower communities and green the cityscape. With supportive policy, cross-sector collaboration and community mobilization, allotment gardens can become integral to India's urban resilience strategy.

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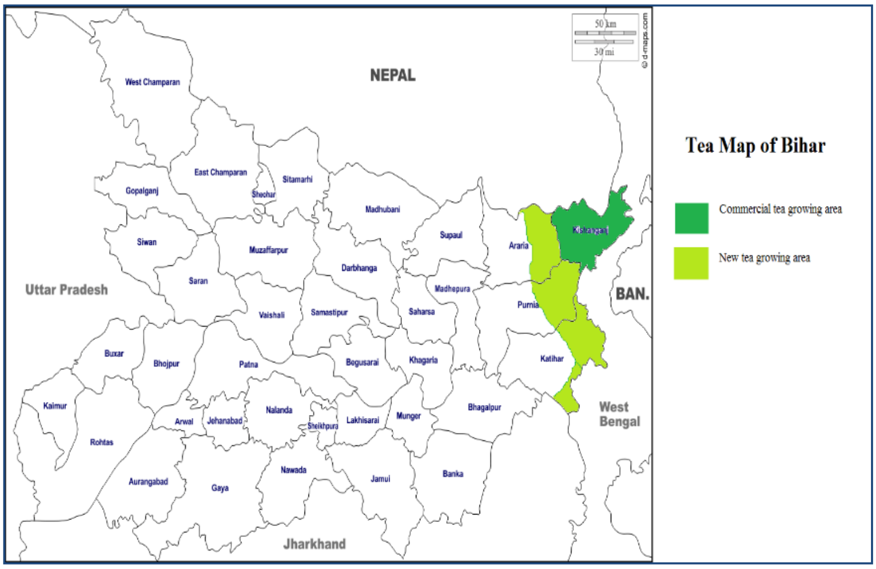
COMMERCIAL TEA PRODUCTION IN BIHAR: *A BRIEF OVERVIEW*

Introduction

Tea (*Camellia sinensis*) is an aromatic beverage prepared from cured leaves i.e., rich in *tannins and polyphenols.*After water, it is the most widely consumed drink in the world. Tea is native to East Asia and originated in Southwest China during the Shang dynasty, where it was used as a medicinal drink.

Globally tea is grown in more than 35 countries in which China is leading tea producing country followed by India, Kenya, Sri Lanka and Vietnam. Moreover, in terms of global export then Kenya is world leader followed by China, Sri Lanka, India and Vietnam. These five countries account for 83% of world production and 80% global exports. Tea was introduced in India by British national, Robert Bruce in 1838. Indian tea is among the finest in the world owing to strong geographical indications, heavy investments in tea processing units, continuous innovation, augmented product mix and strategic market expansion. The main tea-growing regions are in Northeast India (including Assam) and in north Bengal (Darjeeling district and the Dooars region). Tea is also grown on a large scale in the Nilgiris in south India. All varieties of tea are produced by India.



While CTC accounts for around 89 per cent of the production, orthodox/green and instant tea account for the remaining 11 per cent.India has acquired an exalted status on the global tea map with production of around 1,339 million kg. India is ranked fourth in terms of tea exports, which is around 257 million kg.

In India, the production of tea in West Bengal also accounted as 329.70 million kg out of total production in India. The other North Indian States including Tripura, Uttarakhand, Bihar, Manipur, Sikkim, Arunachal Pradesh, Himachal Pradesh, Nagaland, Meghalaya, Mizoram and Orissa contributed very little as compared to the production of individual state Assam and West Bengal. Again, in the south Indian states including Tamil Nadu, Kerala and Karnataka, the total production of tea was found only 224.58 million kg out of total production in India.

Under Horticultural crops Bihar ranks 8th in respects of fruit production and 4th in vegetable production in the country. Bihar is an agrarian state ranking 12th in terms of largest geographical area and second most populous state (10.38 crores) in the country. The state has abundant water, fertile soil and biodiversity, has best option for development through agriculture and agro-based industries. Agriculture is the vital source of livelihoods in the state as nearly 76 per cent of its population is engaged in agricultural pursuits.It is the largest producer of Litchi, 3rd producer of pineapple and 4th largest producer of mango in the country. During the 17th century, drinking tea became fashionable among Britons, who started large-scale production and commercialization of the plant in India. Zone-II (North-East Alluvial Plane zone) of Bihar comprises of Supaul, Khagaria, Saharsa, Madhepura, Purnea, Katihar, Kishanganj, Araria, Naugachia districts/ area which have very huge potential in horticulture sector. Kishanganj district is the first district in Bihar to produce tea at commercial scale. The climate of Kishanganj is suitable for most of the horticultural crops especially for tea, pineapple, dragon fruits, ginger and turmeric.

The Kishanganj district of Bihar has no hills like Assam but plenty of small rivers and highlands make the environment tea friendly. Kishanganj district is at the down belt of Darjeeling and it have appropriate climate to produce tea, which needs high rainfall and sloppy land. The tea plantation in Kishanganj is now spread over an area of 25,000 acres of land (mainly TV24, TV 25 & TV26 clones), giving livelihood to more than 30,000 people. In Kishanganj, district around 2,00,000 tonne of green tea leaves is produced annually. Tea Board of India has also observedthat adjoining districts of Kishanganj i.e., Purnia, Katihar and Arariadistricts are also suitable locations for tea plantation. Due to continuous popularity, expansion of commercial tea area & production recently (in the year 2022), the Government of Bihar has also recognized the logo of tea. So that the tea of Bihar comes on the world stage.

Tea Logo of Bihar

Commercial Tea Production:

1. *Soil & Climate*

The optimum temperature range for tea plant growth is 20° to 27°C and temperatures above 35°C and below 10°C can damage the tea plants growth. Virgin forest soils that are rich in humus and iron are the best suited soils for tea plantations. Tea requires well drained soil with high amount of organic matter and pH 4.5 to 5.5.

2. *Varieties*

Pandian, Sundaram, Golconda, Jayaram, Evergreen, Athrey, Brookeland, BSS 1, BSS 2, BSS 3, BSS 4 and BSS 5.

3. *Planting*

Planting can be done in April-June and September-October or October-November with adequate irrigation. Periods of heavy rains should be avoided. It is commercially propagated through cuttings that may take 10 - 12 weeks for rooting. Only 9 – 12 months old healthy plants with 40 cm to 60 cm high with at least 12 good mature leaves and of pencil (0.5 cm) thickness (at collar) should select for planting in field. Plant population of tea bushes vary from 14 to 18 thousand per ha.

4. *Manures and fertilizes*

Manuring should be done 2 months after planting. Phosphorous should be applied at 80 - 100 kg/ha as Rock phosphate once in a year. N : K ratio 2 : 3 (180:270, 240:360, 300:450 kg/ha, respectively) should be adapted for the first 3 years and a ratio 1 : 1 thereafter (300:300 kg/ha).

5. *Intercultural Operations*

*Centering*is done 3 - 5 months after planting to induce laterals by cutting of main leader stem and leaving 8 - 10 matured leaves.

*Tipping*is done at a height of 35 cm from the second tipping at 60 cm from ground level.

*Pruning*is done to maintain convenient height of bush and to remove dead and diseased branches.

6. *Harvesting & Yield*

Harvesting in tea involves the regular removal of young shoots comprising an apical bud and 2 or 3 leaves, immediately below it. Plucking stage is attained when tea plant is of 3 to 4 years old. However, plucking stage under ideal management conditions is attained in 18 to 20 months stage. Young leaves with more of *tannins* and *polyphenols*produce better quality tea than old leaves with less tannin content.

Maximum yields (stable/economical stage of yield) are obtained in 6th or 7th year i.e., 20 to 30 q per ha and there after the yields remains constant.

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COMPOST PREPARATION FROM KITCHEN WASTE

Introduction

In a world where environmental consciousness is gaining momentum, adopting sustainable practices is essential. One simple yet impactful way to contribute to a greener planet is by utilizing kitchen waste for preparation of compost. This eco-friendly method not only reduces the burden on landfills but also provide us a useful byproduct which can help us to enrich our soil with nutrients and organic carbon thus, promoting healthier plant growth. And if you enjoy gardening, there is nothing better than making your compost to nourish your home garden.

In this article we would provide a step-by-step guide which could help all of us to turn our kitchen scraps into black gold.

Understanding the Basics:

Composting is a natural process that decomposes organic matter into a nutrient-rich soil conditioner. Kitchen waste composting specifically focuses on diverting food scraps from landfills and transforming them into a valuable resource for your garden/soil.

Benefits of Kitchen Waste Composting:

1. **Reducing Landfill Waste:**

Kitchen waste, such as vegetable peels, fruit scraps, and coffee grounds, often ends up in landfills, contributing to the production of harmful greenhouse gases. Composting these materials at home significantly reduces the amount of waste sent to landfills, mitigating environmental impact.

2. **Enriching Soil Quality:**

Compost is a nutrient-rich organic matter that enhances soil fertility. When incorporated into garden beds or used as a top dressing, it improves soil structure, water retention, and nutrient content. This, in turn, promotes healthier plant growth and increases the yield of fruits and vegetables.

3. **Cost-effective Solution:**

Making compost from kitchen waste is a cost-effective alternative to purchasing commercial fertilizers. By recycling your organic waste, you not only save money but also contribute to a circular economy.

Materials Needed:

1. **Compost Bin or Pile:** Choose a suitable container or designate an area in your backyard for composting. Compost bins are available in various sizes and designs, but even a simple pile in a corner of your garden can serve the purpose.
2. **Brown and Green Materials:** Composting requires a balance of brown materials (carbon-rich) and green materials (nitrogen-rich). Brown materials include dried leaves, straw, and shredded newspaper, while green materials encompass kitchen scraps like fruit and vegetable peels, coffee grounds, and eggshells.
3. **Water:** Adequate moisture is crucial for the composting process. Keep a watering can or hose nearby to ensure the compost pile remains consistently damp, resembling a wrung-out sponge.

4. Aeration Tool: Proper aeration is essential for the decomposition process. Invest in a compost-turning tool or simply use a pitchfork to turn the compost regularly.

How to Make Compost from Kitchen Waste:

Step 1: Set Up Your Compost Bin or Pile
Choose a location for your compost bin or designate an area in your backyard for a compost pile. Ensure good drainage and easy access. If you opt for a compost bin, make sure it has proper aeration and drainage features.

Step 2: Gather Brown and Green Materials
Start collecting kitchen scraps, such as fruit and vegetable peels, coffee grounds, and eggshells, as your green materials. Supplement these with brown materials like dried leaves, shredded newspaper, or straw. Aim for a balanced ratio of roughly 3:1 (three parts brown to one part green) for optimal composting.

Step 3: Layering
Begin the composting process by layering brown and green materials. Start with a layer of brown materials at the bottom, followed by a layer of kitchen waste. Repeat this process, ensuring each layer is relatively thin (around 2-3 inches) to allow for proper aeration.

Step 4: Keep It Moist
Maintain the moisture level in your compost pile to facilitate decomposition. Water the pile as needed, ensuring it remains damp but not waterlogged. Remember, a well-hydrated compost pile promotes the growth of beneficial microorganisms responsible for breaking down the organic matter.

Step 5: Turn the Compost
Aerate your compost regularly by turning it with a pitchfork or using a compost-turning tool. Turning the compost introduces oxygen into the mix, accelerating the decomposition process. Aim to turn the compost every two to three weeks, or more frequently if you notice a strong odor or excess moisture.

Step 6: Patience is Key
Kitchen waste composting is a natural process that takes time. Be patient, and in a few weeks to several months, depending on various factors such as temperature and the size of your compost pile, you'll have a nutrient-rich compost ready for use.

Tips and Tricks for Successful Kitchen Waste Composting:

1. **Avoid Certain Kitchen Scraps:** While many kitchen scraps are compostable, some should be avoided, such as meat, dairy products, and oily foods. These items can attract pests and slow down the composting process.
2. **Crush or Chop Larger Items:** To expedite decomposition, chop or crush larger kitchen scraps before adding them to the compost pile. Smaller pieces break down more quickly and efficiently.
3. **Maintain the Right Balance:** To ensure a healthy composting process, maintain the right balance between brown and green materials. If your compost seems too wet and smelly, add more brown materials. If it's too dry and not decomposing, add more green materials.

4. **Utilize Compost Activators:** Speed up the decomposition process by adding compost activators, such as garden soil or finished compost, to introduce beneficial microorganisms into the mix.
5. **Temperature Considerations:** Composting is more active in warmer temperatures. If you live in a colder climate, consider insulating your compost pile with materials like straw or cardboard to retain heat.

Embarking on a kitchen waste composting journey is not just a step towards sustainability; it's a commitment to nurturing the environment. By diverting kitchen scraps from landfills and creating nutrient-rich compost, you're actively contributing to a healthier planet. Along with kitchen scraps, you can also efficiently manage your sewage and produce useful byproducts such as bio-gas and water that can be used for gardening. Simply switching to a high-quality bio-septic tank can help you manage your sewage and help the environment.

What Types of Kitchen Waste can be composted?

Even though it's easy to find items for kitchen waste compost, mistaking some food scraps for usable compost items can be tricky. Yes, greens are a must, but not all kitchen items are appropriate for kitchen waste composting.

For your reference, here are some of the following items you can add to your kitchen waste compost:

1. Dried leaves
2. Herbs and spices
3. Fruit peelings (e.g., banana, apples, oranges, etc.)
4. Grass and brush trimmings
5. Bread, cereal, wheat crumbs
6. Coffee grounds
7. Tea bags or tea leaves
8. House dust
9. Old and stale animal food (e.g., cat or dog food)
10. Shredded paper or cardboard
11. Hay, straw, or pet bedding
12. Organic manure (e.g., cow manure)
13. Toilet rolls or egg cartons (with no oil)
14. Pinecones
15. Nutshells

But be wary NOT to include the following in your compost pile:

1. All kinds of fresh meat
2. Animal products (e.g., fat, skin, gristle, bones, etc.)
3. Dairy products (e.g., Milk, yogurt, cheese, etc.)
4. All types of cooking oil
5. All kinds of oily products (e.g., grease from food)
6. Tissue papers or any other paper products that have oil
7. Twigs or branches
8. Animal feces (e.g., dog, cat, etc.)
9. Fish products (and skin)
10. Avoid including these items to prevent a smelly compost pit that decomposes for too long.

What are the Benefits of Composting Food Waste?

Composting will help reduce food waste and turn kitchen scraps into a valuable resource. But that's not all there is to it. Here are some of the benefits composting kitchen waste has to offer:

1. Get rid of restaurant waste

Making compost from kitchen waste means putting out less garbage. Plus, you can practice kitchen and food waste management without spending too much money.

2. Discover more food waste solutions

Food waste recycling is a problem in almost every establishment. Kitchen waste composting can resolve this issue, so you won't have to feel bad the next time you feel like any food or ingredient will end up getting spoiled.

3. Promote an eco-friendly lifestyle

Partaking in an eco-friendly lifestyle doesn't happen overnight. To be successful in it, be committed and consistent until it becomes a part of your lifestyle. Kitchen waste composting can help you and your business become more sustainable. It also helps lower your carbon footprint.

4. Start farm-to-table solutions

Kitchen waste composting can lead to a farm-to-table movement. Here, you can plant crops and harvest them for kitchen use. It is a phenomenal way to reduce carbon emissions from buying food outside.

Thus, kitchen waste composting is the act of using your kitchen waste and food scraps, which are organic materials (greens and browns), to create compost beneficial for enriching soil and growing plants and crops. Surprisingly, most people are unaware that food scraps are good sources of vitamins and minerals. These give the soil nutrients to become healthier, trickling down the minerals to the crops planted into it.

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CONSEQUENCES OF STARTUP FAILURE IN INDIA: A REVIEW

Abstract
Startups serve as crucial catalysts for innovation and economic advancement, yet a significant portion of them encounter failure, especially in developing economies like India. Even with the rise in entrepreneurial initiatives in the nation, the failure rate for startups continues to be remarkably high, with nearly 90% of new enterprises ceasing operations within their initial five years. This paper investigates the main factors contributing to such elevated failure rates in India, identifying critical challenges such as market misalignment, financial mismanagement, regulatory hurdles, and leadership weaknesses. Moreover, the study emphasizes how India's distinctive socio-economic and regulatory landscape, characterized by underdeveloped infrastructure and intricate taxation systems, intensifies the likelihood of failure. The paper further explores possible strategies to reduce these failures. By examining these matters, the paper presents actionable suggestions to assist in strengthening the resilience of the startup ecosystem in India.

Introduction
Startups are nascent enterprises that are generally established with the intention of addressing a particular issue or providing a novel solution in an innovative or distinctive manner. These firms are recognized for their capacity to grow quickly, often depending on technology or unique business models to disrupt current markets. They are usually marked by high levels of unpredictability and risk, while simultaneously presenting considerable prospects for growth and returns if they succeed. India has emerged as one of the most promising and rapidly evolving startup ecosystems worldwide.

Factors Contributing to Startup Failure in India
Lack of Market Demand
A primary cause of startup failure is the failure to address a considerable market demand. Unsuccessful startups frequently miscalculate the demand for their products or services, which leads to their incapacity to grow and maintain the business.
Financial Mismanagement
Inadequate financial management is another significant reason. Numerous Indian startups collapse due to poor budgeting, overspending, and failure to obtain reliable funding. This predicament is further intensified by India's complicated tax and regulatory frameworks.
Management and Leadership Challenges
Startups frequently experience challenges due to the inexperience and lack of expertise of their founders. Founders who possess insufficient managerial experience may find it difficult to make crucial decisions, which can result in operational inefficiencies and, ultimately, failure.

Product and Technological Failures

Startups that do not achieve product-market fit are at a heightened risk of failure. Numerous startups in India aim to build technology-heavy products without assessing whether there is genuine market demand for them.

Funding and Investment Issues

Many startups in India, especially within the technology sector, rely extensively on external funding for survival. It has been noted that the absence of dependable investment sources and the challenges in managing investor relations often contribute to the elevated failure rate of these enterprises. Additionally, funding remains one of the major obstacles faced by Indian startups.

Consequences of Startup Failures

The emotional and social consequences of startup failures are extensive and complex. These effects can go beyond financial setbacks and involve a variety of deeply personal influences that affect the entrepreneur's life and relationships.

Financial Losses

Financial setbacks are a clear consequence of startup failure, with entrepreneurs commonly losing their personal savings and encountering the disintegration of their financial resources. These financial challenges can linger long after the business has shut down, impacting future pursuits and creating continued economic strain.

Emotional and Psychological Impact

In addition to financial repercussions, the emotional consequences of failure are significant. Entrepreneurs often undergo grief and emotional turmoil, which can lead to profound psychological effects, such as depression, anxiety, and social withdrawal. The emotional wounds of failure may last for years and influence personal relationships and future business activities.

Loss of Jobs and Unemployment

Startups are essential sources of employment, especially for young professionals and skilled workers. The failure of startups often leads to large-scale job cuts, contributing to higher unemployment rates and lowering the nation's overall economic productivity.

Reduction in Investment and Innovation

Failed startups also dissuade potential investors from coming into the market, decreasing the availability of venture capital and risk funding for new entrepreneurs. Furthermore, the failure of startups suppresses innovation, as investors become more cautious, and entrepreneurs become reluctant to initiate new ventures.

Stagnation in Startup Growth

Failing startups frequently dissuade new entrepreneurs from entering the ecosystem, resulting in stagnation and diminished vibrancy in the startup community.

Negative Perception of the Startup Ecosystem

The view of high failure rates can foster a negative reputation for the startup ecosystem, making it harder to attract both local and international investors.

Preventive Measures and Strategies to Mitigate Startup Failures

The Indian market presents numerous opportunities for startups that can lead to economic growth and job creation. Nevertheless, despite significant advancements in the ecosystem over the last twenty years, startups in India still encounter major obstacles. To tackle these challenges, preventive measures should be taken in various area:

Enhancing the Economic Environment

Startups play a crucial role in the larger economic ecosystem, and enhancements in the general economic environment would significantly benefit them. Investments in both digital and physical infrastructure, like better internet connectivity, upgraded roads, improved public transportation, and dependable electricity supplies, are essential. These improvements would equip startups with the vital resources needed for efficient operation and scaling. Furthermore, a mature economic landscape, characterized by accessible markets and resources, is key to establishing a nurturing environment for startups to flourish.

Improving the Regulatory Framework

Even though the Indian government has rolled out numerous policies aimed at promoting startups, there remains potential for enhancement in their execution. Bureaucratic delays and complicated procedures often obstruct the seamless functioning of startups. Simplifying bureaucracy by minimizing paperwork, enhancing access to information, and standardizing operational processes would greatly alleviate hurdles. For instance, streamlining the process for bidding on government contracts or acquiring licenses would lessen the strain on startups and improve their operational efficiency.

Investing in Education and Talent Development

Allocating resources to education in order to develop a diverse talent base is critical for nurturing startups. Incorporating entrepreneurship courses into university programs will better prepare students for careers in startups, and fostering entrepreneurial thinking from an early age is vital. Despite a rise in angel and venture capital investments, fledgling startups still grapple with resource limitations, particularly when it comes to funding. Cultivating a talent pool with essential skills will ensure that startups can proficiently execute their ideas, closing the gap between entrepreneurial vision and successful realization.

Addressing the Funding Gap for Early-Stage Startups

While the funding landscape in India has seen improvements with heightened investments in startups, a gap persists in the early-stage funding sector. Numerous investors tend to concentrate on more established ventures, leaving early-stage startups with scant access to the capital required for prototype creation or market entry. To alleviate this issue, actions such as incentivizing angel investments, eliminating the angel tax, or providing tax incentives to investors could stimulate more financial flow into early-stage startups. The establishment of seed funds and grants to assist early-stage companies is also crucial. Furthermore, promoting acquisitions by larger firms could furnish the financial backing that smaller startups require.

Supporting Startups Outside Metro Cities

The majority of assistance and resources accessible to startups are focused in metropolitan areas, leaving those situated in smaller cities and rural locations at a disadvantage. To equalize the situation, it is essential to extend support to Tier 2, 3, and 4 cities. By expanding the reach of startup hubs throughout India, entrepreneurs in less developed areas will obtain access to resources and networks that are critical for their success. Promoting non-tech startups alongside tech-driven initiatives will diversify innovation in sectors such as manufacturing, retail, and agriculture, creating more opportunities.

Government Policies and Initiatives

The Indian government has launched various initiatives aimed at encouraging entrepreneurship and reducing startup failures. Programs like the StartUp India Scheme provide financial aid, tax benefits, and mentorship opportunities to emerging businesses. These initiatives are designed to lower the obstacles encountered by entrepreneurs, enhancing their prospects for success.

Conclusion

In conclusion, the Indian startup landscape offers a promising yet intricate environment, characterized by considerable growth potential tempered by serious challenges. Although the emergence of startups has been driven by influences such as economic reforms, a large and varied market, and advancing technology, the path to success is still filled with hurdles. The difficulties posed by regional diversity, scaling challenges, and fierce competition, together with the inherent risk of failure associated with disruptive innovation, necessitate that entrepreneurs implement a disciplined, strategic methodology. A crucial element in reducing failure is thorough pre-launch preparation, akin to the detailed planning done by pilots before taking off. Studies indicate that effective planning, organizing, and strategic communication are vital for navigating the unpredictable startup landscape. Furthermore, support from government entities, investors, and organizations is essential in tackling external issues like infrastructure deficiencies, regulatory environments, and funding limitations. Understanding the reasons behind startup failure in India demands a nuanced approach that acknowledges both internal and external aspects, such as market demand evaluations, strategic planning, and efficient management. Additionally, the impact of external factors, like government regulations and market competition, plays a key role in determining startup success. Ultimately, with the appropriate mix of preparation, strategic implementation, and supportive ecosystem frameworks, the survival and success rates of Indian startups can be greatly improved, contributing to the nation's economic growth and its increasing significance in the global entrepreneurial arena.

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Cracking the DNA Code: How GWAS is Unveiling the Secrets of Our Genes

Abstract

In the past decade, high-density SNP arrays and DNA re-sequencing have significantly expanded our understanding of genotypic diversity across various organisms, including humans, maize, rice, and Arabidopsis. For any researcher aiming to define and evaluate a phenotype among numerous individuals, Genome-Wide Association Studies (GWAS) serve as a powerful tool for linking this trait to its genetic foundations. These studies strive to identify variants at genomic loci associated with complex traits within the population, particularly focusing on uncovering associations between common single-nucleotide polymorphisms (SNPs). GWAS can provide valuable preliminary insights into trait architecture or potential candidate loci for further validation.

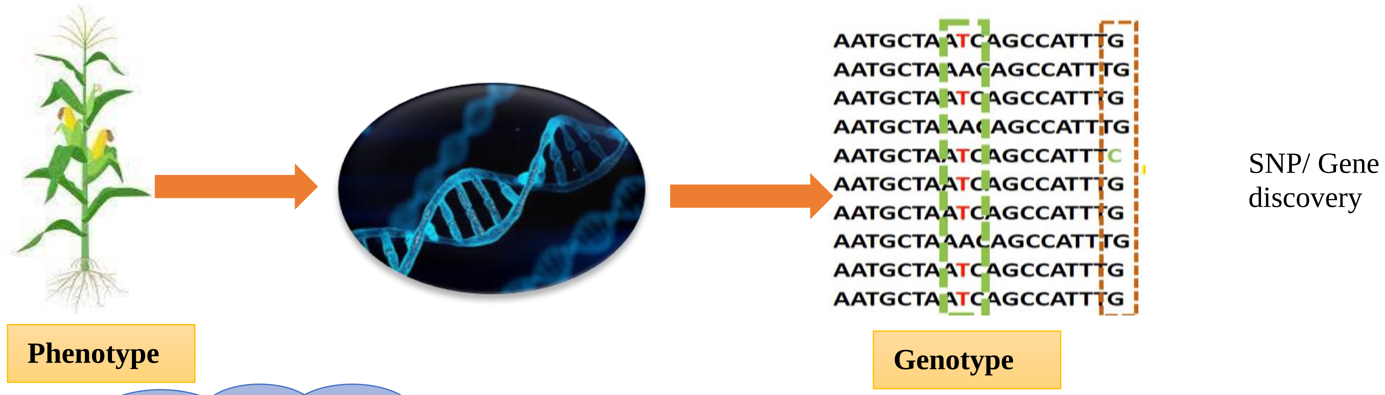
Introduction

The genetic architecture of complex traits is crucial for understanding the biology of various complex characteristics influenced by many genetic loci and environmental conditions. The rapid advancement in genomic technologies and the growing interest in studying trait variation across diverse genetic backgrounds were the major driving forces behind the initial wave of association mapping studies in model plant and crop species. Due to Continuous progress in sequencing technologies, genome-wide association studies (GWAS). Genome-wide association studies (GWAS) use samples from natural populations and cultivars to identify associations between individual single-nucleotide polymorphisms (SNPs) for genetic variants and phenotypes of interest and have become increasingly powerful with advances in high-throughput genotyping and phenotyping technologies. It also helps understand and elucidate the genetic variants underlying the biological pathways and associated with susceptibility to various biotic (disease, pest) and abiotic (drought, salinity, submergence) stress. GWAS has excellent potential for revealing the genetic basis of traits and understanding the interaction between genetic variation and environments. GWAS is more necessary in plants than animals because SNPs explain a more significant proportion of the phenotypic variation; these studies have successfully identified many loci associated with phenotypic expression and metabolic traits in multiple species.

Approaches for association mapping

1. GWAS (Genome-wide association studies)

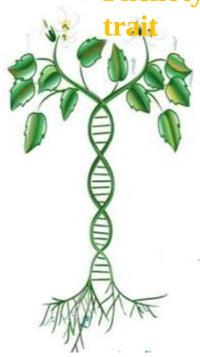
In genome-wide association studies (GWAS), the markers used for genotyping are distributed over the whole genome. The number of markers used for genotyping would be much more significant in cross-pollinated than in self-pollinated species because the linkage disequilibrium decays much faster in the cross-pollinated species. GWAS is a powerful tool for identifying QTL/SNP associated with gene variants across numerous individuals' genomes, aiming to establish genotype-phenotype associations. GWAS, also known as a whole genome association study, is employed to elucidate the genetic basis of complex traits more clearly.



Why GWAS is necessary in plants than animals

Plants

- SNPs explains a much greater proportion of the phenotypic variation.
- Rare variation can become sufficiently common in large families or population.
- GWAS studies have successfully identified enormous number of loci associated with phenotypic expression, and metabolic traits in multiple species.



Animals

- SNPs explains only a tiny fraction of the phenotypic variation in an individuals

Limitations for usage of SSR markers

- *Limited number of SSR motifs in the genome*
- *Multiple alleles per locus*
- *Making difficult to saturate a region with markers*
- *Low throughput and higher cost*

Advantage of SNP Markers

- Simple documentation
- Low cost assay
- Locus specificity
- Codominant inheritance
- Relatively low genotyping error rates
- High throughput analysis

Objective of GWAS

- GWAS is used to screen the entire genome of large numbers of individuals to identify association of genotypes with phenotypes by testing for differences in the allele frequency of genetic variants between individuals who are ancestrally similar but differ phenotypically.

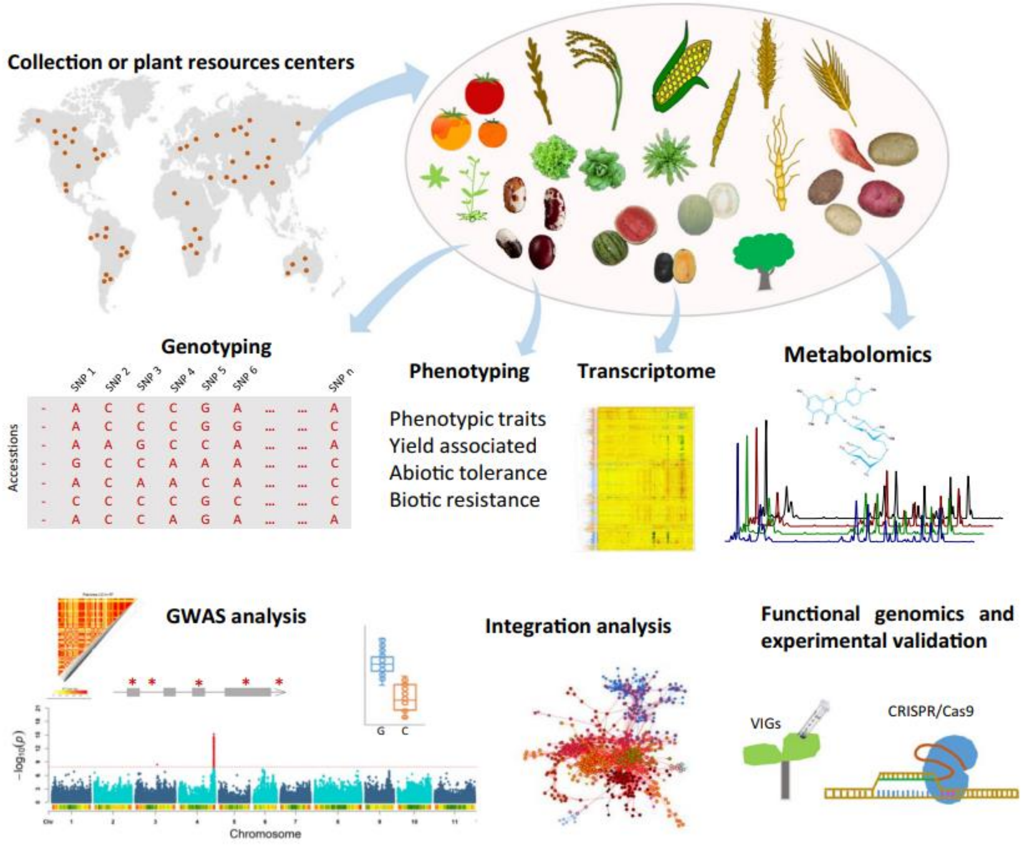


Fig. 1 A schematic view of GWAS in plants

Candidate gene approach

- Another way is to restrict the analysis to the genomic regions having the candidate genes/QTLs for the trait(s) of interest is known as candidate gene approach.
- Generally, information from several different sources, e.g., comparative genomics, genome sequence annotation, transcript profiling, QTL analysis, etc., is used to identify the candidate genes. After this, the genotyping effort is focused in the genomic regions with the candidate genes.
- This greatly reduces the target genomic region, which can be analyzed with a high density of markers. Further, the total number of markers used as well as the sample size will also be considerably reduced.
- A limitation of this approach is that the involvement of genes not included in the list of candidate genes in the development of the trait phenotype cannot be assessed.

Advantages of association mapping	Disadvantage of QTL mapping
More than 2 alleles in a population	Only 2 alleles in a population
High resolution mapping (<10 Cm)	Low resolution mapping due to less recombination
High marker density	Low marker density
Allele mining possible	Allele mining is not possible

Mutations, recombination - considered	Mutations, recombination - not considered
	Population specific
	High cost and time
Feasible	Feasible in biennial not in perennial crops

General analysis process of GWAS equipped with high throughput phenotyping

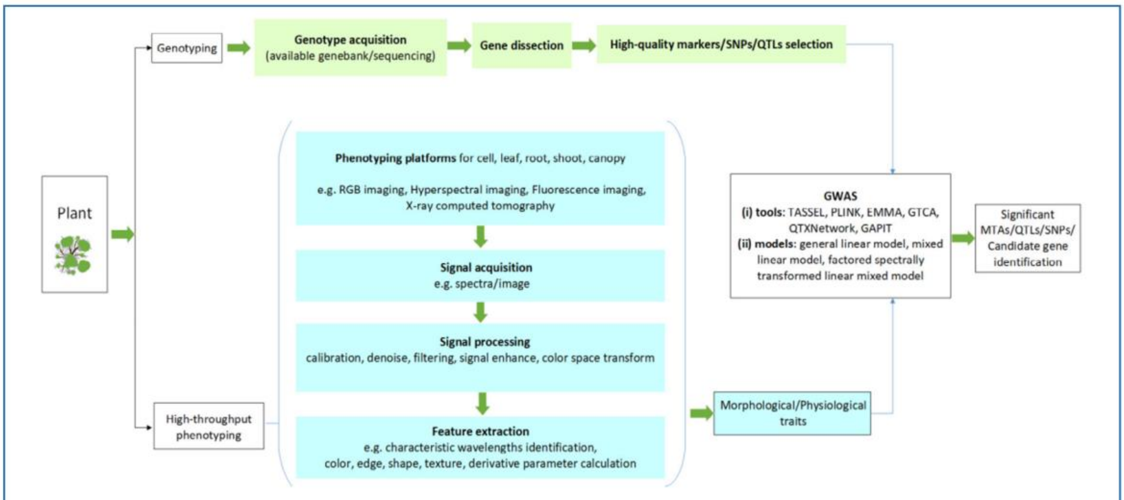
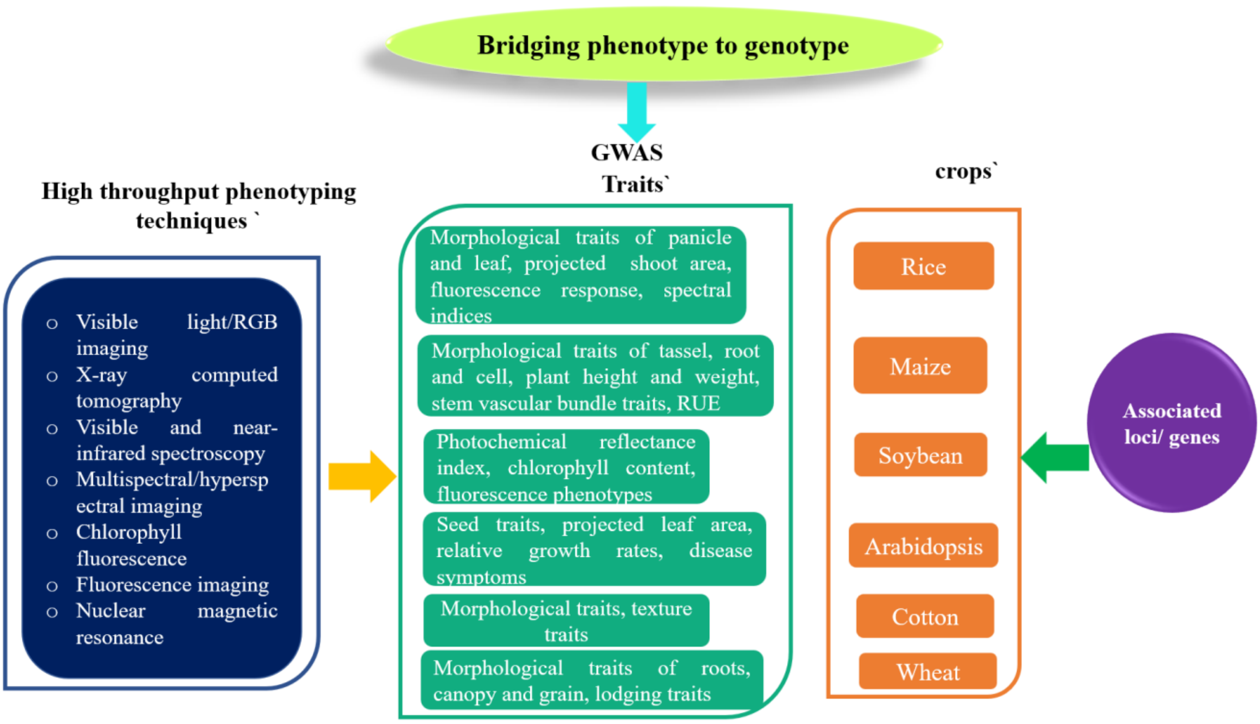


Fig. 1. General analysis process of GWAS equipped with high-throughput phenotyping.



ADVANTAGES OF GWAS	DISADVANTAGES OF GWAS
Discover novel genes **Robust data** **Reveal number of loci contributing to a trait** **Higher resolution** **Reduces false positive associations** **Identify the mutations explaining few percent of phenotypic variant** **Insight into ethnic variations of complex traits** **breeding point of view, it is used for** **1. Mining of markers for phenotype** **2. Maximizing yield** **3. Disease resistance**	Need pedigree data and updated software tools Rare alleles cannot be considered Low QTL detection power Requires large independent groups from different population Expensive dense marker coverage Results from association mapping are affected by several factors like population structure, kinship etc.., which may lead to false associations between QTLs and markers

Conclusion

- GWAS is a vital tool for uncovering the genetic underpinnings of various traits and diseases.
- Its ability to analyze the entire genome allows for the identification of specific SNPs associated with phenotypes, providing valuable insights into the genetic basis of complex traits.
- Replication and validation of GWAS results across diverse populations enhance our understanding of genetic contributions to these traits and have significant implications for personalized medicine and crop improvement in agriculture.

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CONVENTIONAL BREEDING APPROACHES FOR ABIOTIC STRESS MANAGEMENT IN HORTICULTURAL CROPS

Abstract:-

Horticultural crops are increasingly facing various abiotic stresses due to the effects of climate change. Factors such as drought, extreme temperatures, salinity, and nutrient deficiencies are leading to significant reductions in both yield and product quality. Consequently, the horticultural industry is actively seeking innovative and sustainable agronomic solutions to improve crop resilience against these adverse conditions. A recent review published in Agronomy, titled "Bio stimulants Application in Horticultural Crops under Abiotic Stress Conditions," authored by Bulgari and colleagues, examined the evidence supporting the use of bio stimulants for managing abiotic stresses in vegetable crops. These editorial aims to highlight the critical aspects of stress development in plants, including the timing and occurrence of multiple stress factors, alongside the application of bio stimulants. Given the multitude of factors that may contribute to enhancing crop tolerance to stress, there is a pressing need for intensified research efforts, particularly in field conditions and with clearly defined protocols. This endeavor is essential for the effective integration of bio stimulant products into the array of agronomic tools available for managing abiotic stresses in horticultural crops.

Introduction:-

Global climate change has profoundly impacted the growth and yield of various horticultural crops, primarily due to the accelerated emissions of greenhouse gases. The surge in human activities and rapid industrial development has led to significant alterations in weather patterns, resulting in severe consequences for the growth and productivity of key agricultural crops). Extreme weather events, including elevated temperatures, drought, salinity, and cold spells, pose a serious threat to horticultural crops and, by extension, to global food security. Furthermore, these abiotic stresses stem from external environmental factors that disrupt the physiological and biochemical functions of crop plants, leading to substantial losses in agricultural output worldwide. Experts in the field of plant science have long anticipated that elevated temperatures and extended periods of drought will have a more pronounced impact on agriculture compared to cold and salinity.

Recently, the Intergovernmental Panel on Climate Change (IPCC) has indicated that global climate change will modify hydrological cycles, ultimately altering rainfall patterns, with wet regions becoming wetter and arid areas facing increased drought susceptibility.

Global warming is likely to cause a significant rise in the average global temperature, which may result in reduced rainfall. This reduction can lead to the leaching of harmful chemicals, soil erosion, increased salinity, a decline in organic matter within soils, and delays in planting. Moreover, an increase in global mean temperature will exacerbate moisture loss from the soil and plants due to heightened transpiration rates. The productivity of crop plants is influenced by the interplay of numerous genes, effective agronomic practices, and, crucially, the capacity of genotypes to adapt and thrive under extreme climatic conditions. Crop plants mitigate the detrimental effects of abiotic-induced oxidative stress by regulating both enzymatic and non- enzymatic antioxidant defense mechanisms, as well as producing secondary metabolites. Reactive oxygen species (ROS) are a natural byproduct of aerobic metabolism and can lead to oxidative damage in plants when their concentration exceeds a certain threshold. The levels of ROS increase significantly under various abiotic and biotic stresses, but they are effectively neutralized by a range of antioxidant enzymes, osmolytes such as proline and glycine betaine, and non-enzymatic antioxidants like ascorbate and glutathione.

The ability of horticultural crops to adapt to future environmental changes is critically important for satisfying the food requirements of an ever-increasing global population, as well as the rising demand for fruits, vegetables, and other horticultural products. This emerging challenge necessitates a multidisciplinary approach to understand the mechanisms of stress tolerance and to develop strategies, methodologies, and specific traits for identifying varieties that are resistant or tolerant to stress. The integration of "OMICS" technologies—encompassing genomics, transcriptomics, proteomics, metabolomics, and the more recent epigenomics—alongside traditional breeding methods can significantly enhance this endeavor. The comprehension of structural, biochemical, and molecular roles of genetic variations is essential. Moreover, these advanced technologies can facilitate the discovery of stress-related traits, the identification of molecular markers to enhance marker-assisted selection of stress- responsive genes, and the development of high-throughput sequencing technologies. Such advancements will expand the genetic pool, ultimately aiding in the identification of new sources of stress tolerance in crop plants. Nevertheless, researchers within the plant scientific community must analyze and integrate the information derived from these techniques with traditional breeding methods to create new stress-resistant or tolerant genotypes and varieties, which remains a significant challenge. In the forthcoming years, next-generation advanced breeding techniques will heavily rely on germplasm resources, the uniqueness of mapping populations, efficient high-throughput phenotyping and genotyping technologies, large-scale data management systems, and various molecular biotechnological tools. These technological innovations, including genome editing tools such as the CRISPR/Cas system, are currently employed by the plant science community to identify suitable ideotypes with superior alleles or haplotypes, or to develop improved CIS genic and intragenic hybrids for breeding aimed at managing abiotic stress in crops. This chapter will review state-of-the-art strategies, recent biotechnological tools and techniques, and methods that can be integrated with conventional breeding technologies to develop stress-tolerant varieties and hybrids. Additionally, we will discuss recent developments and modifications introduced to create new breeding strategies, as well as the potential for utilizing diverse genetic resources with distinct allelic combinations to enhance crop adaptation to climate change through breeding programs. Finally, we will examine the significant contributions of computational biology tools and techniques in this context.

Abiotic factors impacting significant horticultural crops:-

In the field of horticulture, abiotic stresses such as elevated temperatures, cold conditions, drought, and salinity significantly impact crop growth, development, and reproduction. Field crops are particularly vulnerable to these abiotic factors, which hinder their ability to achieve optimal growth by disrupting physiological and biochemical processes. One of the initial effects of abiotic stress on plants is the reduced mobility of calcium or diminished calcium absorption, which in turn disturbs ion and osmotic balance. When subjected to these stresses, plants tend to lose excessive amounts of water, which carries calcium away with the transpiration stream, resulting in issues such as tip burn, necrosis, and blossom end rot. Therefore, this section will explore the various abiotic stresses that influence the physiological and biochemical mechanisms underlying stress tolerance in horticultural crops.

High-temperature stress:-

Plants that are consistently subjected to elevated temperatures, typically around 40°C, experience detrimental effects not only on their growth and development but also on seed germination and reproductive processes. At the biochemical and molecular levels, factors such as membrane fluidity, metabolic processes, enzymes, proteins, and nucleic acids are adversely impacted, leading to stunted growth and potential mortality. Furthermore, high-temperature stress has a pronounced effect on the photosynthetic efficiency of agricultural crops; while low to moderate heat stress can temporarily alter the photosynthetic rate, extreme temperatures result in irreversible damage to the photosynthetic machinery. Additionally, elevated temperatures disrupt photochemical reactions and carbon metabolism by significantly affecting the water status in leaves and stems, as well as increasing CO_2 levels due to stomatal closure. Nevertheless, the precise mechanisms through which high temperatures influence photosynthetic rates and carbon metabolism remain ambiguous and poorly understood. Researchers are diligently working to elucidate the specific mechanisms by which high-temperature stress inhibits plant functions, proposing two primary hypotheses: (1) high temperatures adversely affect the biosynthesis and functionality of the Rubisco enzyme, thereby diminishing the efficiency of the electron transport system, and (2) there is a reduction in the RuBP carboxylation rate coupled with an increase in the oxygenation rate.

Recent research has demonstrated that elevated temperatures impact the photosynthetic electron transport chain by impairing the repair mechanisms of photosystem II (PSII), which is known to be highly sensitive to temperature fluctuations. This impairment subsequently affects the activities of Rubisco and ATP synthase. Numerous studies have shown a direct relationship between PSII damage and the levels of light and temperature, with both intense light and heat waves, along with high temperatures, leading to the inactivation of oxygen- evolving complexes. A study by Yang et al. found that moderate to high temperatures induce photoinhibition in horticultural crops and disrupt the PSII repair system in wild tobacco plants. In contrast, transgenic tobacco plants exhibited a significantly reduced level of photoinhibition when higher concentrations of glycine accumulated. Betaine has been identified as a contributing factor to the enhanced high-temperature tolerance observed in transgenic tobacco plants. This increased tolerance may result from the accumulation of glycine betaine along with various enzymatic and non-enzymatic antioxidants, which appear to protect the oxygen- evolving complexes, thereby improving the thermostability of photosystem II (PSII). Additionally, the enhanced thermostability of PSII and the oxygen-evolving complexes may be attributed to a reduced accumulation of reactive oxygen species (ROS) due to the heightened activity of enzymes and the overexpression of stress-responsive genes, which effectively mitigated oxidative damage caused by heat stress in these transgenic plants. Moreover, another research group has noted that the pools of plastoquinone (PQ) are significantly impacted by high-temperature stress. Their findings indicate that seedlings, just four days old, subjected to high-temperature conditions exhibited pronounced oxidation of the PQ pool, which compromised the electron transport system by damaging the water-oxidizing complex. Collectively, these studies suggest that high temperatures induce oxidative damage to the redox state of the PQ pool, affecting its distribution within the thylakoid membranes and ultimately altering the functionality of the photosynthetic machinery under thermal stress.

Drought stress:-

In the field of agriculture, drought stress is recognized as a complex form of stress that profoundly impacts the morphological, physiological, biochemical, and molecular processes of all horticultural crops. Drought conditions arise when the rates of transpiration and evaporation exceed the levels of precipitation. Plants subjected to drought stress demonstrate a decline in leaf water potential, a reduction in turgor pressure, and an increase in the frequency of stomatal closure, all of which significantly hinder plant growth and development. Furthermore, exposure to drought conditions adversely affects chlorophyll production, nutrient metabolism, ion balance, and respiration, collectively leading to a decrease in photosynthetic efficiency. The inhibitory effects on growth in drought-stressed plants are primarily attributed to reduced root activity, which results in diminished root hydraulic conductance. Additionally, drought stress triggers the production of reactive oxygen species (ROS), which contributes to oxidative stress at cellular, biochemical, and molecular levels, causing ion imbalances, protein denaturation, and the alkylation or oxidation of nucleic acids, thereby posing a significant threat to crop viability. Numerous studies have indicated that plants experiencing drought, water deficits, or suboptimal temperatures exhibit reduced growth and metabolic functions, leading to a notable decline in agronomic and other economically significant traits.

A study by demonstrated that recurrent drought stress significantly hindered the growth, development, and productivity of barley plants. In a similar vein, found that when chickpea plants experienced drought stress during the reproductive phase, there was a sudden abortion of flowers, which resulted in poor pod formation and diminished productivity. Additionally, reported that drought stress adversely impacted stem elongation, reduced internode extension, caused spikelet mortality, distorted pollen tubes, led to flower abscission, resulted in poor fruit set, and decreased biomass accumulation in wheat and other grain crops. Numerous other studies have highlighted the detrimental effects of drought stress on growth and yield in crops such as maize, wheat, sugarcane, sunflower, tomato, cotton, and legumes. In legume crops, water scarcity can disrupt seed growth and yield by inducing flower abortion and limiting pod production, ultimately affecting the overall economic yield of these crops. This occurs through a reduction in the carbon fixation rate, which is caused by the restriction of metabolic processes or the limited entry of CO2 into the leaves. Drought stress also severely impacts the photosynthetic activity of plants, as various studies have indicated that oxidative damage induced by drought can disrupt the light-sensing capabilities of plants, thereby reducing Rubisco activity, decreasing the biosynthesis of photosynthetic pigments, and posing a significant threat to the photosynthetic machinery. Furthermore, extensive literature suggests that drought could lead to a 30% to 40% reduction in global production of chickpeas and soybeans. In conclusion, drought stress adversely affects yield and associated traits, as well as other agronomic characteristics in crop plants, likely due to modifications in cellular, biochemical, and molecular activities induced by drought stress, which negatively regulate the growth, development, and productivity of these crops.

Salinity stress:-

Salinity represents a significant and growing environmental challenge that adversely impacts plant growth and agricultural productivity. In freshwater and soil, salinity constitutes a critical abiotic stressor for agriculture, particularly in arid and semiarid regions, affecting approximately 700 to 800 million hectares of agricultural land globally. Soil is classified as alkaline when its electrical conductivity exceeds 4 dS/m, which corresponds to 40 mM of NaCl, resulting in an osmotic pressure of 0.2 to 0.4 MPa. This condition induces substantial alterations in the growth and development of horticultural crops. A primary consequence of soil salinity is the heightened ion toxicity, which leads to chlorosis and necrosis in crops due to the increased accumulation of Na^+, thereby disrupting the physiological and biochemical processes within crop plants. The detrimental effects of salt stress can vary based on plant species, environmental conditions, light intensity, and soil texture.

Genetic resources/gene pool: foundation for competitive plant breeding:-

A comprehensive comprehension of the acclimation and adaptive mechanisms of horticultural crops in response to climate extremes necessitates an in-depth understanding of their genetic components and phenotypic plasticity. Establishing a suitable mapping population is essential for examining and correlating trait variation with DNA polymorphisms, ultimately leading to the creation of a high-resolution genetic or linkage map. A contrasting mapping population can be formed by judiciously selecting proficient genetic resources from which diverse germplasm materials can be developed for use in breeding programs. Numerous studies have demonstrated that the resolution and efficiency of a mapping population are directly related to its size, recombination rate, and frequency. When strategically optimized, these factors can significantly aid in the identification of quantitative trait loci (QTLs) that control traits of interest with high heritability. Typically, plant breeders utilize two primary types of mapping populations: pedigree mapping populations and association mapping populations, to explore the genetic potential of crop plants under various abiotic stress conditions. Additionally, biparental and triparental mapping populations are currently employed for QTL mapping.

Mapping populations are typically created from two distinct individuals that exhibit differences in the trait of interest. Biparental mapping populations generally possess a limited gene pool, while triparental or multiparent mapping populations have a wider genetic base. This broader genetic diversity makes them valuable resources for exploring the genetic foundations of complex traits, as they tend to undergo a greater number of recombination events and often demonstrate enhanced phenotypic plasticity. Additionally, researchers have established mapping populations by intercrossing multiple parental lines, typically ranging from six to eight parents, to fully leverage their genetic potential. This approach is referred to as multiparent advanced generation intercross (MAGIC) mapping populations. Nevertheless, the creation Association mapping can be a lengthy process; however, it provides significant opportunities to identify and map genes associated with specific traits. The populations used for association mapping consist of advanced individuals sourced from various germplasm collections, including elite and traditional cultivars, landraces, and wild relatives, which contribute to enhanced genetic diversity. A key benefit of utilizing association mapping populations is the presence of contrasting allelic diversity, essential for constructing high- resolution quantitative trait locus (QTL) mapping. Additionally, researchers have created a nested association mapping population by integrating individuals from biparental or multiparent populations with association mapping populations. This approach aims to develop elite inbred lines with improved agronomic traits, which can be effectively employed in breeding programs focused on enhancing stress resistance and tolerance in cultivars and varieties. Of MAGIC mapping populations requires significant labor and effort.

Mutation breeding:-

Mutation breeding, also known as mutagenesis, refers to the method of generating genetic diversity through the application of physical, biological, or chemical agents. In the context of plants, this approach encompasses three primary techniques: (1) induced mutagenesis, which employs high-energy radiation such as gamma rays or X-rays; (2) the use of chemical agents like ethyl-methane sulfonate; and (3) the induction of site-directed mutagenesis through agrobacterium-mediated T-DNA or DNA transposable elements. For more than a century, plant breeders have utilized these mutagenesis methods to develop beneficial genetic variations aimed at enhancing key agronomic traits in crop species. A critical component of mutation breeding involves the analysis and identification of individual plants exhibiting target mutations through mutant screening, which entails selecting individuals with mutations in desired traits and subsequently confirming these mutations by re-evaluating the traits of interest within the population. Nonetheless, these procedures may lead to the detection of false mutants; thus, mutations involving single-base changes are considered more effective for the improvement of crops. An additional method for inducing mutations, aside from chemical, physical, and biological techniques, is the target-induced local lesions in genome (TILLING) approach, which employs a reverse genetic strategy to introduce mutations into the target genome. TILLING serves as an enhancement of the chemical mutation method, integrated with a refined DNA screening technique that evaluates mutagenized lines for gain-of-function, loss- of-function, and hylomorphic alleles related to specific traits of interest. Numerous studies have indicated that the TILLING approach, when combined with next-generation sequencing technology, has enabled the discovery of advantageous alleles. The TILLING by sequencing method has led to the identification of significant allelic variations that are crucial for economically important traits, particularly in response to biotic and abiotic stressors. For example, in wheat, TILLING has uncovered new allelic variants of heat shock protein 26, which markedly enhance the plants' tolerance to both heat and cold stress. Additionally, researchers have applied the TILLING by sequencing technique to create mutants in barley and to investigate nucleotide variations in the ABA1 gene, which regulates several downstream stress-responsive genes in drought-stressed wheat and soybean. Various adaptations of the TILLING method have been developed, such as deletion TILLING (de-TILLING), which is particularly effective for generating knock-out mutants. The Eco-TILLING approach, focuses on assessing the frequency of natural mutations in individuals, facilitating the identification of allelic variations that enhance growth, development, and stress tolerance in horticultural crops.

Conclusion:-

The escalation of global warming has led to significant changes in weather patterns, including extreme temperatures, excessive rainfall, water shortages, and heightened salinity levels. In recent years, agriculture has experienced notable shifts in production, primarily driven by the need to meet the food demands of a growing global population, compounded by the diminishing availability of arable land and the recurrent impacts of climate extremes. These unfavarable climatic conditions are likely to exacerbate abiotic stress, resulting in oxidative damage that affects various physiological, biochemical, and molecular processes in plants, thereby hindering their growth and productivity. Consequently, there is a pressing need to adopt innovative strategies, such as the development of gene pools, germplasm characterization, selection, and maintenance, to create advanced genetic resources for breeding new or improved climate-resilient, high-yield cultivars. This chapter emphasizes recent advancements in conventional breeding technologies, incorporating modifications that could establish the groundwork for next-generation climate-smart breeding, ultimately benefiting agriculture and ensuring food and nutritional security for the global population.

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DASHPARNI ARK, A NATURAL BIOPESTICIDE

Introduction: -

Dashparni Ark, it is a natural bio pesticide, and its alternative to chemical pesticides. Botanical pesticides are extracted from leaves having defensive characteristics naturally. It is a very effective in controlling various types of insect, pest and plant diseases. It is prepared by using all natural ingredients such as fermenting a mixture of plant leaves, spices, cow dung and cow urine in water for a period of 30-40 days. As the name suggests, it contains two words 'Dash' means 'ten' and 'Parn' means the plant or tree leaf. 'Extracts' means to remove the juice from leaves of various plants that's why it is called Dashaparni Arka or extract. It is become more popular due to its low production costs, it is highly biodegradable have various modes of action, are less toxic to humans and are non-pollutant. All the ingredients used in this are easily available in the field, every plant leaf has different anti-insecticidal and anti- fungicidal qualities, and it is used to control 34 different kinds of fungi and a variety of insects.The dashaparni is an organic extract, it decomposes biologically, so it does not leave any harmful residue in the soil and crops for a long time. Additionally, beneficial insects are not at risk.

It is a natural pesticide, which can be used on any agronomical and vegetable plants or fruit trees. It's a traditional or conventional organic method for pest control, provides sustainable alternative to chemical pesticides. It helps plants strengthen their total immunity and shows antiviral, antibacterial, and antifungal qualities. Due to its strong odour, it protects plants from pests and diseases infestation for a longer period. The farmers can prepare the solution at their own house.

Figure 1. Ingredients used for preparation

How it is prepare?

Ingredients required for preparation and their roles:-

- Neem leaves (*Azadirachta indica*)– 5 kg
- Papaya leaves (*Carica papaya*)-2 kg
- Nirgundi (*Vitex negundo*): 2 Kg
- Gulvel (*Tinospora cordifolia*):2 Kg
- Custard apple leaves (*Annona squamosa*)-2 kg,
- Karanja leaves (*Pongamia pinnata*)-2 kg
- Castor leaves (*Ricinus communis*)- 2 kg
- Ghaneri leaves (*Lantena camera*)-2 Kg
- Nerium leaves kanheri (*Nerium indicum*)-2 kg
- Rui leaves (*Calotropis procera*) -2 kg
- Green chili paste-2 kg

Leaves:- It contribute to the insecticidal and repellent properties of the Ark.

- Ginger-Garlic paste-1/2 kg
- Turmeric powder 200 g

Spices: - It gives repellent qualities of the Ark.

- Cow dung-3 kg,
- Cow urine-5 litre

It contribute to the fermentation process and improve efficacy of the Ark.

Preparation method:-

1. First to take water drum (either plastic or similar ones) having capacity of 200 litre.
2. In that, add green chili, ginger-garlic paste ½ kg and turmeric powder 200 g in 170 litre water and mixed well before one day.
3. Next day, crush all the plant leaves and mixed in water and keep up to one month for fermentation. Mix them well and leave it for 5 days. Leave the same as it is for 30 days with stirring continuosly (morning and evening).
4. Cover the utensil with mesh cloth and keep this drum in shade for 40 days.
5. Filtering after one month, the dashparni ark is ready to use.

b)

Figure 2. Preparation of Dashparni ark a) Add ingredients into water b) Mix well by using rod.

Method of Storage:-

1. It is best to store pesticide in the shaded area.
2. Covered the drum with a wire mesh or plastic mosquito net to prevent contamination from houseflies.
3. This is applicable during the preparation as well as during the shelf life of the pesticide.
4. The extract can be stored up to six months and is sufficient for one acre area.
5. The pesticide can be stored in good condition up to four months.

Problems and limitations in use:

1. The solutions have a short six-month storage life.
2. The raw materials particularly the leaves of all ten plants may not be available at each location.
3. The entire solution could be ruined by bacterial or other organism contamination.
4. The strong bad odour may make it difficult for farmers to prepare.

Conclusion

Alternative to chemical pesticides in organic farming and insect pest control is use of biopesticides and biological control methods. The long term use of insecticides can cause negative impact on human health and our ecosystem. Additionally, most synthetic and natural pesticides are susceptible to ineffectiveness due to resistance buildup in insects. Thus, the only viable solution for the integrated pest management in future.

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CARBON FARMING FOR RURAL PROSPERITY: HYPE OR HOPE?

Abstract

In India's quest for sustainable rural development, carbon farming has emerged as a promising yet complex frontier. Confronted by escalating challenges from climate change, declining soil fertility, and stressed rural livelihoods, India's agricultural sector stands at a pivotal crossroads. Carbon farming offers a transformative pathway not only as a climate solution but also as a new economic opportunity for millions of smallholder farmers. This article examines the evolving carbon farming landscape in India, highlighting key initiatives in agroforestry, regenerative agriculture, and biochar innovation. While policy momentum and pilot projects signal early promise, the ground-level impact remains limited, and meaningful financial benefits for farmers are still unfolding. The discussion underscores that carbon credit alone cannot sustain farmer engagement, immediate, tangible benefits such as soil health and land restoration, increased yields, and reduced input costs are crucial for long-term success. With the right convergence of farmer-centric business models, credible measurement frameworks, supportive policies, and private sector investments, carbon farming can not only address India's agricultural crisis but also unlock a new era of rural prosperity, climate resilience, and sustainable development.

Keywords: Carbon Farming, Sustainable Agriculture, Carbon Credits, Regenerative Agriculture, Soil Carbon Sequestration, Rural Prosperity, Carbon Market India.

Carbon farming and its status in India

To understand carbon farming, it is essential first to examine its two fundamental components: carbon and farming. Carbon is a natural element present in all living organisms, rocks, and minerals. It plays a critical role in essential life processes such as photosynthesis, respiration, and the global carbon cycle, continuously moving through the atmosphere, water, soil, and living systems in various forms.

Farming refers to the cultivation of land and the raising of crops and livestock to produce food, fuel, fiber, and other vital resources. It encompasses a wide range of activities, including land preparation, sowing, harvesting, animal husbandry, and the maintenance of agricultural systems.

Carbon farming merges these two domains. It involves agricultural practices that not only focus on producing food but also contribute to environmental restoration. These methods enhance soil health, boost agricultural productivity, and combat climate change by increasing the capture and storage of carbon in soils and vegetation while reducing greenhouse gas emissions.

One may ask how carbon farming differs from conventional farming, considering that both naturally involve carbon cycling. The distinction lies in the rate and extent of carbon sequestration. Conventional farming, often reliant on synthetic inputs, allows only a limited amount of carbon to be stored in the soil. In contrast, carbon farming, sometimes referred to as regenerative agriculture, employs sustainable techniques that significantly enhance the soil's ability to absorb and retain atmospheric carbon.

Ecosystem of carbon transactions in India

To better understand the carbon ecosystem in India and globally, it is essential to have a basic knowledge of carbon market dynamics, specifically the types of carbon transactions. Broadly, two types of carbon markets operate worldwide: the Compliance (Mandatory) Market and Voluntary Carbon Market (VCM).

Compliance Carbon Markets (Article 6):

As part of global efforts to reduce greenhouse gas (GHG) emissions and address climate change, several international organizations such as the UNFCCC and IPCC have spearheaded initiatives to achieve collective climate goals. Landmark agreements like the 1997 Kyoto Protocol and the 2015 Paris Agreement have been critical milestones, where countries committed to quantifiable targets for GHG emission reductions. These agreements laid the foundation for compliance carbon markets, which are often referred to as Emission Trading Systems (ETS). Article 6 of the Paris Agreement further outlined provisions for using market mechanisms, offering a framework to link national and international carbon markets in the future.

Voluntary Carbon Market (VCM):

As the name suggests, the Voluntary Carbon Market is a platform where companies, organizations, and individuals voluntarily buy and sell carbon credits outside of regulatory obligations. VCM transactions are governed by standardized processes and Monitoring, Reporting, and Verification (MRV) guidelines to ensure credibility. Major registries such as Verra, Gold Standard, and Puro.earth play a central role in certifying carbon credits, maintaining transparency, and channelizing the engagement of various players within the market.

In India, the policy framework supporting carbon transactions is centered around the Carbon Credit Trading Scheme (CCTS). Introduced through the Energy Conservation Act, 2001 and reinforced by the Energy Conservation (Amendment) Act, 2022, the CCTS is designed to incentivize reductions in GHG emissions. The framework authorizes the issuance of Carbon Credit Certificates (CCCs), each representing one tons of carbon dioxide equivalent (tCO_2e) reduced or removed from the atmosphere. It further empowers designated agencies to facilitate the establishment and functioning of a domestic carbon market. India, under the Paris Agreement in 2015, pledged to reduce the emission intensity of its economy by 33–35% from 2005 levels by 2030. In August 2022, India revised its Nationally Determined Contributions (NDCs), enhancing its commitment to a 45% reduction by

2030, demonstrating a strengthened climate ambition.[1]

Scope and Challenges in Indian context?

The Voluntary Carbon Market is witnessing rapid growth globally, and India is no exception. At an event organized at the India Habitat Centre, Delhi, on April 22, 2025, Mr. Rohit Kumar, Secretary General of the Carbon Markets Association of India, highlighted that nearly 90% of India's carbon trading activity is currently concentrated in the energy sector, with limited participation from the agriculture sector, particularly in areas like biochar production, mulching, and agroforestry. This reflects an untapped opportunity for agriculture, which could ultimately benefit Indian farmers significantly.

Recognizing this potential, in December 2023, the Government of India notified the Carbon Credit Trading Scheme for the agriculture sector. Under this initiative, entities and farmers can register GHG mitigation projects and receive carbon credit certificates, provided they meet the necessary standards and methodologies.[2]

The Road Ahead

India's vast agricultural landscape, spanning over 170 million hectares, holds immense potential for economic growth through carbon farming. By adopting practices that capture atmospheric carbon dioxide and store it in the soil, the country could unlock an estimated $63 billion. Establishing a market where farmers are financially rewarded for implementing carbon-friendly practices could enable them to sequester significant amounts of carbon dioxide and sell carbon credits to companies seeking to offset their emissions. However, this is just one face of the opportunity.[3]

The success of carbon farming in India hinges on the active engagement of buyers, companies, and the creation of supportive policies. Therefore, greater emphasis should be placed on highlighting the broader benefits of carbon farming, promoting it as a sustainable business model.

It is also important to note that enrollment in carbon credit programs does not guarantee immediate financial returns for farmers. As such, the focus should extend beyond monetary benefits to include non-financial advantages, such as improved soil health, increased crop yields, reduced input costs through sustainable practices, and better-quality farm produce. Relying solely on the expectation of direct monetary returns could lead to disappointment, potentially deterring farmer participation.

In conclusion, carbon farming for rural prosperity is not just a fleeting trend, it carries real hope. This hope, if grounded in the realities of implementation and executed with integrity, could catalyze a rural transformation, positioning Indian agriculture as a global model for climate resilience, economic empowerment, and sustainable development.

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FROM FIELDS TO FLIGHT: THE FARMERS EMBRACING DRONE TECHNOLOGY

Introduction

Agriculture, being a labor-intensive industry, needs a high amount of workforce for its various operations from cultivation to post-harvest management. Due to the changing or degrading environmental conditions, cropping patterns have been widely influenced. Whether say it is a locust attack or a sudden emerge of Cumulonimbus clouds causing rainfall, it has become difficult to facilitate agricultural operations efficiently. **DRONE** which is popularly known as **Dynamic Remotely Operated Navigation Equipment**, has emerged as a solution for these hurdles. Various agricultural operations are simplified using drone technology because once drones are programmed, they do not require manual supervision. Farmers do not need to physically remain present in their agricultural fields while these drones carry out their tasks. Instead, they can conveniently operate these drones remotely, providing specific instructions from a distance through a handheld controller or a computer-based application. After initial programming, drones autonomously perform functions such as monitoring crop health, spraying fertilizers or pesticides, and assessing field conditions. The embedded navigation systems, guided by GPS (Global Positioning System) coordinates and pre-set flight paths, allow drones to maintain precise movements over the fields, eliminating the need for real-time manual intervention. Consequently, this technology reduces labor effort, saves valuable time, and enhances farming efficiency, enabling farmers to manage their land effectively even while away from the site.

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, are transforming traditional agricultural practices by automating and accelerating tasks that were previously laborious, time-consuming, and costly. These aerial tools offer a bird's-eye view of farmlands, enabling large-scale monitoring and data collection within minutes. For instance, surveying hundreds of acres to assess crop growth, detect irrigation issues, or evaluate soil conditions can now be accomplished swiftly and with greater precision using drones equipped with high-resolution cameras and multispectral sensors. One of the most important benefit of UAVs lies in their ability to detect early signs of crop stress or disease. By capturing images in different wavelengths, drones can reveal subtle changes in plant health that are invisible to the naked eye. This allows farmers to identify and isolate affected areas well before the problem spreads, ensuring timely interventions and minimizing yield loss. Such proactive monitoring was previously difficult and expensive, often requiring multiple field visits and considerable manpower. In nutshell, drones provide farmers with a powerful surveillance tool: essentially "eyes in the sky" which enhances decision-making, optimizes resource use, and contributes to more sustainable and precise agricultural management.

Current Status in India:

India is currently utilizing 3000 drones in agriculture. This number is projected to exceed 7000 by the end of 2025, with expectations of reaching 10000 to 20000 in subsequent years. The market valuation of these drones was about $145.4 million in 2024 and is expected to reach $600 million by 2030, however India lags far behind in the race of adoption of drones in agriculture. IoTechWorld Avigation, a Gurugram-based drone manufacturing company, introduced the AGRIBOT, India's first agriculture drone to receive Type Certification from the Directorate General of Civil Aviation (DGCA). This certification signifies compliance with stringent safety and performance standards, marking a significant milestone in the integration of drone technology into Indian agriculture. Many Indian states are starting to use drones for agricultural operations, where Maharashtra holds the leading spot. The schemes like Namo Drone Didi prominently facilitate the uplifting of Agro-techno interaction over there. According to an American Consultancy Firm Indian Drone market will grow at 38.6% (Compound Annual Growth Rate (CAGR).

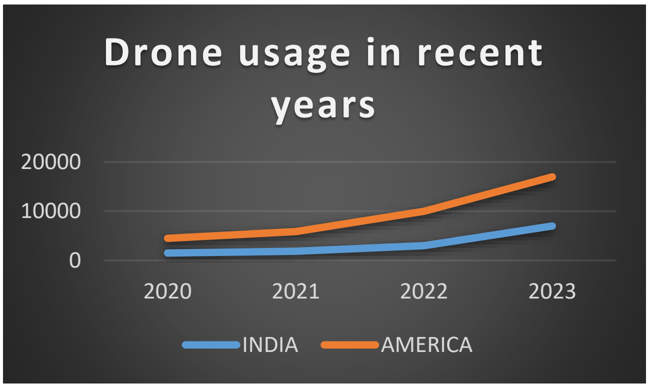

Figure 1: Drone usage in India and America

Reasons for India's Lagging Behind in Drone Usage:

The high initial investment required for drone acquisition. The drone price ranged from ₹60,000 to ₹2,00,000, poses a significant barrier for small and marginal farmers. Majority Indian farmers operate on average landholding of 1.08 ha, therefore using such technology makes cost-benefit ratio unfavorable. Additionally, ongoing expenses related to maintenance, training, and potential service contracts further exacerbate the financial burden, making drone technology less accessible to this demographic. A considerable number of farmers in rural India have limited exposure to advanced technologies, leading to apprehension and resistance toward adopting drone-based solutions. The complexity associated with operating drones, interpreting aerial data, and integrating these insights into traditional farming practices necessitates a level of digital literacy that is often lacking. This digital divide hampers the effective utilization of drone technology in agriculture. The deployment of drones requires reliable infrastructure, including consistent electricity supply, internet connectivity, and access to technical support services. Many rural areas in India suffer from inadequate infrastructure, which impedes the operation and maintenance of drone systems. Furthermore, the absence of localized service centers and trained personnel limits the feasibility of drone usage in these regions. Traditional farming practices are deeply ingrained in the rural Indian context, and there is often skepticism toward modern technological interventions. Concerns about job displacement due to automation, coupled with a preference for conventional methods, contribute to the reluctance in adopting drone technology. Moreover, the perception of drones as complex and inaccessible tools further deters farmers from exploring their potential benefits. Navigating the regulatory landscape for drone usage involves obtaining necessary permissions and adhering to guidelines set by aviation authorities. The complexity of these regulations, along with a lack of awareness among farmers, creates additional hurdles in the adoption process. Efforts to streamline policies and provide clear frameworks are essential to facilitate the integration of drones into agricultural practices.

Government Initiatives for promoting Drone Technology in India:

Namo Drone Didi

The Government of India launched a new central sector scheme on 30 November 2023 to promote drone technology among rural women. The scheme, known popularly as the Drone Didi Scheme, was introduced by the Ministry of Agriculture and Farmers' Welfare under the broader framework of the Deendayal Antyodaya Yojana – National Rural Livelihoods Mission (DAY-NRLM). The Hon'ble Prime Minister of India, Shri Narendra Modi, formally initiated the scheme with the aim of empowering Women Self Help Groups (SHGs). The core objective of the scheme is to provide drones to 14,500 selected Women SHGs during the financial years 2024–25 and 2025–26.

These SHGs will offer drone-based rental services to farmers. The drones will assist in various agricultural operations such as crop monitoring, spraying, and land surveys. This is expected to enhance both agricultural productivity and rural livelihoods. In January 2024, the scheme took a major step forward with the launch of an entrepreneurship development program in collaboration with IIT Mandi's iHub and HCI Foundation. This program focused on training women from Himachal Pradesh in drone operation, maintenance, and agricultural applications. The initiative not only aims to enhance technical skills but also seeks to establish women as agri-entrepreneurs in emerging drone-based services. This scheme represents a unique convergence of technology, rural development, and women's empowerment in Indian agriculture.

Components of Namo Drone Didi scheme:

- Drones will be supplied as packages to the SHGs, however certain purchases need to be performed.
- For the purchase of the drones, Central Financial Assistance 80% on the price of the drones will be given to the SHGs, which could extend upto 8 lakhs, the remaining would be financed by AIFs (Agriculture Infrastructure Financing Facility).
- The training of about 15 days of one of the members of the women SHGs will be included in the package, as guided by Director General of Central Aviation (DGCA).
- Rental services to farmers by the SHGs

Economic impact of the scheme

With the effective application of the scheme, it has been found that efficiency of the agriculture has been improved since the cost of input has decreased. The interaction of the women to drones has resulted in the knowledge expansion, raising the literacy level among the rural women. This scheme helps in Women Empowerment, improving their self-dependency. Using drone technology, Women of SHGs have improved their networking and social interaction skills. Annual income of around 1 lakh per group has been estimated from the rental services to local farmers. The services usually include spraying of pesticide, fertilizers over the field via drones, crop monitoring, etc.

Conclusion:

Drone technology is rapidly transforming Indian agriculture by reducing labor dependency, enhancing efficiency, and enabling precision farming. Despite its potential, the adoption of drones remains limited due to high costs, lack of digital literacy, and inadequate infrastructure in rural areas. Government initiatives, such as the Namo Drone Didi scheme, are playing a key role in bridging this gap by promoting awareness, offering financial assistance, and empowering women through technical training and entrepreneurship. These efforts not only support agricultural modernization but also contribute to rural development and women's empowerment. Going forward, continued investment in training, infrastructure, and simplified regulations will be essential to expand the use of drones and realize their full benefits in Indian agriculture.

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FUELING THE FUTURE: ECOLOGICAL GENOMICS OF WOOD-BORING INSECTS FOR BIOMASS CONVERSION

Abstract

The need for sustainable energy throughout the world has accelerated research into lignocellulosic biomass as a renewable resource for the manufacture of biofuel. Beetles, termites, and wood wasps are examples of wood-boring insects that have special ecological and genetic adaptations that allow for the effective breakdown of lignocellulose and provide a paradigm for cutting-edge biomass conversion technology. With an emphasis on microbial symbioses, the molecular processes of wood degradation, and their uses in biorefineries, this review summarizes current developments in ecological genomics. We use genomic methods such as transcriptomics, metagenomics, and genome-wide association studies (GWAS) in order to determine the genetic foundation of lignocellulolytic processes. Critical analysis is done on the difficulties of scaling these systems for industrial usage, including the effects on the environment, financial constraints, and legal restrictions. Wood-boring insects have the potential to transform sustainable biofuel production and open the door to a low-carbon energy future by fusing ecological genomics and biotechnology.

1. Introduction

The urgent need to combat climate change and reduce fossil fuel reliance is transforming global energy systems. The International Energy Agency predicts a 28% rise in energy demand by 2040, emphasizing the need for sustainable solutions. Lignocellulosic biomass, derived from wood, agricultural residues, and forestry waste, offers a renewable, potentially carbon-neutral energy source. Composed of cellulose (40–50%), hemicellulose (20–30%), and lignin (15–30%), its complex structure poses challenges for efficient conversion into biofuels like bioethanol, biodiesel, and biogas. Wood-boring insects, such as termites, wood wasps, and beetles, have evolved sophisticated mechanisms to degrade lignocellulose, often through symbiotic relationships with microbes. For example, bark beetles use fungal partners to break down host trees, while termites rely on diverse gut microbiomes. These natural systems inspire cost-effective, eco-friendly biomass conversion technologies. Ecological genomics, integrating genetic data with environmental contexts, leverages tools like metagenomics and transcriptomics to uncover the genetic basis of these interactions.

By identifying key enzymes and microbial communities, researchers can develop innovative strategies to overcome limitations in current enzymatic and thermochemical conversion methods, advancing sustainable biofuel production.

2. Ecological and Evolutionary Context of Wood-Boring Insects

2.1 Evolutionary Adaptations

Over millions of years, wood-boring insects have developed to take use of lignocellulosic substrates in a variety of biological niches, ranging from tropical environments to temperate woods. Adaptations that get beyond the chemical and structural obstacles of wood are responsible for their evolutionary success. Wood is extremely resistant due to the protective matrix that lignin, a complex polyphenolic polymer, creates around cellulose and hemicellulose (Tursi, 2019). To detoxify plant secondary metabolites and break down polysaccharides, insects such as the Asian longhorn beetle (Anoplophora glabripennis) and the mountain pine beetle (Dendroctonus ponderosae) have evolved expanded gene families, including cytochrome P450s, glycoside hydrolases (GHs), and laccases (Scully et al., 2013).

2.2 Ecological Roles

In forest ecosystems, wood-boring insects are essential for habitat development, nutrient cycling, and decomposition. For instance, termites recycle lignocellulosic material and improve soil fertility, making them keystone species in tropical forests (Brune, 2014). By focusing on weaker trees, bark beetles like Ips typographus affect forest dynamics and promote biodiversity and succession (Vega & Hofstetter, 2014). However, some species are invasive pests that seriously harm the environment and the economy, such as the emerald ash borer (Agrilus planipennis). According to a research, insect incursions in American woods cause yearly biomass losses of billions of dollars (Fei et al., 2019), underscoring the insects' dual function as ecological engineers and possible dangers.

2.3 Co-evolutionary Dynamics

Wood-boring insects' co-evolutionary interactions with microorganisms are closely related to their ecological success. While bacterial symbionts in termite stomachs generate cellulases and hemicellulases, fungal symbionts, such Ophiostoma species linked to bark beetles, emit enzymes that break down lignin (Schroeder, 2008). Complex signaling pathways and metabolic interdependencies control these interactions (Cornille & Croll, 2018). These connections are further strengthened via horizontal gene transfer (HGT), in which insects pick up microbial genes for the breakdown of lignocellulose. According to a study of termite HGT events, these processes may be used for biotechnological purposes (Plomion et al., 2016).

3. Genomic Insights into Lignocellulose Degradation

3.1 Metagenomic Approaches

Understanding the microbial populations of wood-boring beetles has been transformed by metagenomics. Researchers have discovered a variety of taxa that contribute to the breakdown of lignocellulose by sequencing the collective genomes of gut microbiomes, including Spirochaetes, Actinobacteria, and Firmicutes (Warnecke et al., 2007). A research that identified more than 100 glycoside hydrolase genes involved in the degradation of cellulose and hemicellulose described the gut microbiota of Reticulitermes flavipes (Raychoudhury et al., 2013). Enzymes that hydrolyze polysaccharides into fermentable sugars, like as β-glucosidases and xylanases, are encoded by these genes. Functional redundancy, in which several microbial taxa generate comparable enzymes, is also shown by metagenomic data. This ensures robust degradation under a range of environmental circumstances. To maximize energy extraction, the termite gut microbiome, for instance, demonstrates metabolic flexibility by alternating between aerobic and anaerobic pathways (Brune, 2014).

3.2 Transcriptomic Profiling

A dynamic picture of gene expression during lignocellulose breakdown is provided by transcriptomic analysis. Transcriptomic analysis of the Asian longhorn beetle revealed increased lignin degradation genes, such as laccases and peroxidases, indicating that insects directly aid in the breakdown of lignocellulose (Scully et al., 2013). Likewise, a research that examined the transcriptome of Dendroctonus ponderosae found that during host colonization, detoxification and degradation genes were expressed in unison (Keeling et al., 2013). These results provide targets for enzyme engineering by highlighting the interactions between microbial and insect enzymes. Variations in gene expression throughout time and space are also revealed by transcriptomic research. For example, termites' hindgut, which is home to a large concentration of microbial symbionts, has significant expression of cellulase genes (Tokuda et al., 2014).

3.3 Genome-Wide Association Studies (GWAS)

Genetic variations linked to lignocellulolytic effectiveness have been mapped using GWAS. GWAS found QTLs associated with cellulase activity in termites, exposing polygenic characteristics impacted by environmental variables such as microbial composition and wood type (Cornille & Croll, 2018). According to a study, degradation efficiency in Coptotermes formosanus is correlated with genetic variety, indicating that genetic engineering or selective breeding may improve the generation of biofuel (Li et al., 2017). Through the identification of genetic markers for invasive features, these methods can help to guide pest management measures.

3.4 Single-Cell Genomics

Researchers can now examine individual microbial cells in insect guts using newly developed single-cell genomics tools, which offer high-resolution insights into functional diversity. For example, new cellulase genes with high catalytic efficiency were discovered using single-cell sequencing of Spirochaetes in termite guts (Warnecke et al., 2007). According to Environmental Chemistry Letters, these methods can hasten the identification of enzymes with commercial potential (Solarte-Toro et al., 2021). Researchers may map microbial interactions and identify important taxa that drive degradation processes by using single-cell genomics.

4. Microbial Symbiosis and Biomass Breakdown

4.1 Bacterial Symbionts

The main cause of the breakdown of lignocellulose is bacterial symbionts found in the intestines of wood-boring insects. Complex polysaccharides are broken down into simple sugars by cellulases, hemicellulases, and pectinases produced by genera such as Enterobacter, Bacillus, and Clostridium (Brune, 2014). According to a study, termite intestines contain Enterobacter species that promote anaerobic digestion and generate biogas precursors including methane and acetate. Novel bacterial genes with potential uses in the generation of bioethanol and biogas have been discovered by metagenomic sequencing (Velvizhi et al., 2022). Syntrophic interactions, in which metabolic waste products from one species act as substrates for another, are another feature of bacterial communities. For instance, methanogenic archaea use the acetate produced by Spirochaetes fermenting carbohydrates in termite stomachs (Warnecke et al., 2007). These interactions may be reproduced in artificial microbial consortia and improve degrading efficiency.

4.2 Fungal Symbionts

Fungal symbionts are essential for the breakdown of lignin, especially those connected to bark beetles. For instance, the laccases and manganese peroxidases secreted by Ophiostoma fungus degrade the aromatic structure of lignin, making it easier to access cellulose (Vega & Hofstetter, 2014). According to one study, Ips typographus fungus symbionts accelerate the breakdown of wood, lowering the energy needed to produce biofuel (Schroeder, 2008). The intricacy of these relationships is demonstrated by the fact that these fungus also generate volatile chemical compounds that draw insects.

4.3 Protozoan and Archaeal Contributions

Protozoa and archaea in termites use specific metabolic pathways to aid in the breakdown of lignocellulose. Archaea like Methanobrevibacter promote methanogenesis, which turns degradation byproducts into biogas, whereas flagellate protozoa, including Trichonympha species, generate cellulases and hemicellulases (Tokuda et al., 2014). The possibility of multi-kingdom microbial consortia in biorefineries is demonstrated by these interactions.

5. Biotechnological Applications for Biorefineries

5.1 Enzyme Engineering

Enzymes from microorganisms and insects provide encouraging options for the conversion of industrial biomass. Escherichia coli and Saccharomyces cerevisiae have been shown to express cellulases and hemicellulases from termite gut bacteria, with increased activity in industrial settings (Velvizhi et al., 2022). In comparison to commercial enzymes, a research showed that Reticulitermes flavipes-engineered cellulases increased bioethanol yields by 20% (Sethi et al., 2013). Site-directed mutagenesis and directed evolution are two protein engineering methods that can further improve the stability and specificity of enzymes.

5.2 Synthetic Biology

The integration of microbial and insect genes into host species for effective biomass conversion is made possible by synthetic biology techniques. For instance, higher ethanol generation from lignocellulosic feedstocks has been demonstrated by yeast strains modified with fungal laccases and termite-derived cellulases (Ke et al., 2013). A research described how to simulate insect gut systems using synthetic microbial consortia that include bacterial and fungal enzymes (Solarte-Toro et al., 2021). The efficiency of degradation can be increased by customizing these consortia for certain feedstocks.

5.3 Biorefinery Integration

Integrating insect-inspired processes into biorefineries involves combining thermochemical and biochemical conversion methods. Hydrothermal liquefaction, inspired by insect gut conditions, can preprocess lignocellulose to enhance enzymatic hydrolysis (Velvizhi et al., 2022). A review highlighted the potential of hybrid systems that integrate insect-derived enzymes with thermochemical pretreatments, producing biofuels, biochemicals, and bioproducts with reduced environmental impact (Tursi, 2019).

7. Conclusion

Wood-boring insects, which combine genetic breakthroughs with ecological adaptations, provide an impressive paradigm for sustainable biomass conversion. The molecular processes behind the breakdown of lignocellulose have been revealed by developments in metagenomics, transcriptomics, and synthetic biology, opening the door for new approaches to the manufacture of biofuel (Warnecke et al., 2007). Researchers can overcome the limits of present biorefinery methods by designing enzymes for commercial application and simulating insect-microbe interactions (Ke et al., 2013). To fully utilize these systems, however, issues with scalability, environmental effect, and regulation must be resolved (Velvizhi et al., 2022). To fully realize the transformational potential of wood-boring insects and support a sustainable energy future, interdisciplinary collaboration combining genomes, biotechnology, and environmental research will be essential.

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GRAFTING: KEY TOOLS FOR QUALITY AND QUANTITY VEGETABLE CULTURE

Abstract:

Grafting of vegetable seedlings is a unique horticultural technology practiced for many years in Asia to overcome issues associated with intensive cultivation using limited arable land. This technology was introduced to Europe and other countries in the late 20th century along with improved grafting methods suitable for commercial production of grafted vegetable seedlings. Later, grafting was introduced to North America from Europe and it is now attracting growing interest, both from greenhouse growers and organic producers. Grafting onto specific rootstocks generally provides resistance to soil borne diseases and nematodes and increases yield. Grafting is an effective technology for use in combination with more sustainable crop production practices, including reduced rates and overall use of soil fumigants in many other countries. Nevertheless, there are issues identified that currently limit adoption of grafted seedlings. One issue unique to Asia is the large number of seedlings needed in a single shipment for large-scale, open-field production systems. Semi- or fully-automated grafting robots were invented by several agricultural machine industries in the 1990s, yet the available models are limited. The lack of flexibility of the existing robots also limits their wider use. Strategies to resolve these issues are discussed, including the use of a highly controlled environment to promote the standardized seedlings suitable for automation and better storage techniques.

Introduction:

India is 2nd largest producer of vegetables in the world after china. Average productivity of vegetable in India is 17.58 tons/ ha (Anonymous, 2013) as compare to Japan and other European countries. So there is huge need to improve productivity by means of new techniques. A number of studies have shown that grafting can be increase the production per unit area. Several researches have been said that grafted plants are more resistance to soil borne disease like, Fusarium wilt. Grafting of Muskmelon on *Cucurbita* rootstock decreased boron uptake by the grafted plants and reduced the effect of high boron concentration in the water on fruit yield & quality under saline and effluent irrigation. Though grafting is old age practices in other countries like China, Japan and some other European countries where land is intensive and continuous cropping is common. Grafting of a susceptible scion to a resistance root stock can provide a resistance cultivar without the prolonged screening and selection required to breed resistance into a cultivar. Intergeneric grafting is used in production of many fruit bearing vegetable like Cucurbitaceous and Solanaceous vegetables. Cucumber (*Cucumis sativus* L.) grafted on pumpkin (*Cucurbita moschata* L.), Watermelon (*Citrullus lanatus*) on White gourd (*Benincasa hispida* Cogn.). Interspecific grafting is generally applied to eggplant (*Solanum melongena* L.). Scarlet eggplant (*S. integrifolium* Poir.) and Solanum torvum are popular rootstock for eggplant production (Rodriguez-Burruezo, *et al.*, 2008).

Objective:

For successful rising of the crop under biotic and abiotic stress, precocity, improvement of quality and other horticultural attributes. Further crop wise objective is given in Table 1.

Table 1. Crop wise objective of grafting

Vegetable	Objective of grafting
Bitter gourd	Tolerance to Fusarium (*Fusarium oxysporum* f. sp. *momordicae*) (Lee, *et al*., 1998)
Cucumber	Tolerance to Fusarium wilt, *Phytophthora melonis*, cold hardiness, favourable sex ratio, bloomless fruit
Eggplant	Tolerance to bacterial wilt, (*Pseudomonas solanacearum*) *Verticillium albo-atrum*, *Fusarium oxysporum*, low temperature, nematodes, induced vigour and enhanced yield (Oda *et al*., 1996)
Melon	Tolerance to Fusarium wilt (*Fusarium oxysporum*), wilting due to physiological disorder, Phytophthora disease, cold hardiness, enhanced growth
Tomato	Tolerance to corky root (*Pyrenochaeta lycopersici*), *Fusarium oxysporum* f.sp. *radicis-lycopersici*, better colour and greater lycopene content (Oda *et al*., 1996), tolerance to nematode (Oka, *et al*., 2004)
Watermelon	Tolerance to Fusarium wilt (*Fusarium oxysporum*), wilting due to physiological disorder, cold hardiness and drought tolerance (Oka, *et al*., 2004)

Rootstock for grafting:

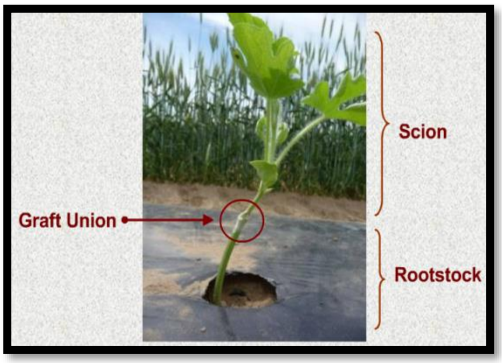
Intergeneric grafting is used in production of many fruit bearing vegetables. *i.e*. Muskmelon are being grafted to bottle gourd (*Lagenaria siceraria* (Mol.) Standl.), Pumpkin (*Cucurbita moschata* L.) bitter gourd (*Momordica charantia* L.) and tomato (*Lycopersicon esculentum* L.) on Brinjal (*Solanum melongena* L.). Other suitable and adaptable rootstocks are given in Table 2.

Table 2. Rootstock for grafting of vegetables

Scion	Rootstock
Cucumber	*Cucurbita moschata*, *Cucurbita ficifolia*, *Cucurbita maxima* *Sicyos angulatus*
Melon (for open field)	*Cucurbita sp.*, *C. moschata* X *C. maxima*, *Cucumis melo*
Melon (for greenhouse)	*Cucumis melo*, *Benincasa hispida*, *Cucurbita spp.* *C. moschata* X *C. maxima*
Watermelon	*Citrullus lanatus*, *Cucurbita maxima*
	C. moschata, *C. moschata* X *C. maxima*, *Lagenaria siceraria*
Bitter gourd	*Cucurbita moschata*, *Lagenaria siceraria*, *Luffa aegyptica*
Tomato	*Lycopersicon pimpinellifolium*, *L. esculentum* *Solanum nigrum*
Eggplant	*Solanum torvum*, *Solanum integrifolium*, *Solanum melongena* *Solanum nigrum*

What is Grafting?

Grafting is propagation technique where two portions of plant which have similar organic texture are joined in such a manner so as to continue their development as a single plant.



Care should be taken while grafting

1) It is important to increase the chances of vascular bundle of scion and rootstock to come into contact (Oda *et al.*, 1996) by maximizing the area of cut surface that are spliced together and by pressing spliced cut surface together.
2) Cut surface should not be allowed to dry out.
3) It should be carried out in a shady place or in polycarbonate house.
4) Expose the scion and rootstock to sunlight for two-three days before grafting.
5) Make sure that scions and rootstock have similar diameter of stem. (Oda *et al.*, 1996)

Materials

1) Scion seedlings at a beginning of first true leaf stage. The true leaf size is 2-3 mm.
2) Rootstock seedlings at a first true leaf stage. The long hypocotyls (7-9 cm) are desirable.
3) The true leaf blade size is ~2 cm.
4) Scalpel with handle works the best for this grafting method.
5) Perforating tool. A plastic soldering tool works well. Alternatively you can create a tool by sharpening the edge of bamboo chopsticks (pencil sharpener works great).

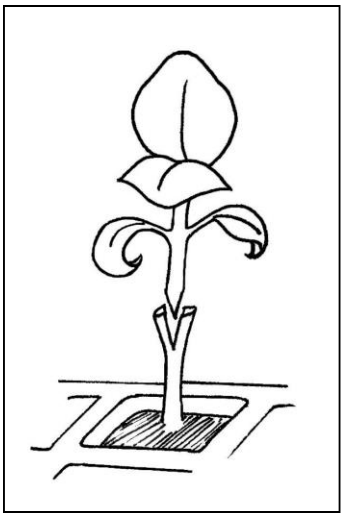
- New trays filled with well moistened substrate.

Types of grafting:

Grafting methods involve such techniques as cleft grafting, tube grafting, whip grafting, tongue grafting, spliced grafting, flat grafting, saddle grafting, bud grafting, hole insertion grafting, and tongue approach grafting etc. These methods of grafting are briefly described as under:-

1) Cleft grafting

Tomato plants are mainly grafted by this method of grafting as shown in Fig. 1. For practicing this method of grafting, seeds of the rootstocks are sown 5-7 days earlier than those of the scion. The stem of the scion (at the four leaf stage) and the rootstock (at the 4-5 leaf stage) are cut at right angles, each with 2-3 leaves remaining on the stem. The stem of the scion is cut in a wedge and the tapered end fitted into a cleft cut in the end of the rootstock. The graft is held firm with a plastic clip.



2) Tube grafting

This method of grafting was developed by Lee, *et al.* (1998). It makes possible to graft smalI plants grown in plug trays two or three times faster than the conventional method and is quite popular among Japanese seedling producers. Plants in small cells must be grafted at earlier growth stage and requires tubes with a smaller inside diameter. First the rootstock is cut at a slant. The scion is cut in the someway. Elastic

tubes with side slit are placed onto the cut end of the rootstock. The cut ends of the scions are inserted into the tube, splicing the cut surfaces of the scions and root stocks together. While practicing the tube grafting in eggplant the seeds of *S. lorvum* must be sown a few days earlier than those of the other rootstock species.

3) Tongue approach grafting

Melons and other cucurbitaceous plants are generally grafted by this method. It gives higher survival ratio because the root of the scion remains until the formation of the graft union. In this method, seeds of cucumber are sown 10-1 3 days before grafting and pumpkin seeds 7-10 days before grafting, to ensure uniformity in the diameter of the hypocotyl of the scion and rootstock. The shoot apex of the rootstock is removed so that the shoot cannot grow. The hypocotyl of the scion and rootstock are cut in such a way that they tongue into each other, and the graft is secured with a plastic clip. The hypocotyl of the scion is left to heal for 3-4 days and then crushed between the fingers. The hypocotyl is cut off with a razor blade three or four days after being crushed.

4) Slant cut grafting

Recently this method of grafting has got popularity. It has been developed for robotic grafting. In this method, it is essential to remove the first leaf and lateral buds when a cotyledon of rootstock is cut on a slant.

5) Mechanized grafting

Grafting is arduous task and efforts are being made to reduce the labour required. Attempts have been made to mechanize grafting since 1987. There are several basic factors which govern the success of grafting by machine or robot such as seedling shape, location of cut, seedling gripping, cutting method, fixing materials and tools etc. (Herde, et al., 1999). Grafting robots for plug have been developed by combining the adhesive and grafting plates (Kurata, 1994; Oka, *et al.*, 2004). This robot makes it possible for eight plugs of tomato, eggplant or pepper to be grafted simultaneously. Recently a fully automatic grafting system for Cucurbitace is vegetables have been designed (Fernandez-Garcia, et al., 2002) in which seedling quality estimation is clone by using fuzzy logic and neural network. Further, healing chamber with controlled atmospheric condition has also been designed to enhance the survival of graftage.

- **Effects of grafting:**

(i) **Vigour**. Rootstocks affect the growth and yield of scion plants and are often performed to provide vigor. However some rootstocks may also depress the growth and yield of scion plants.
(ii) **Stress tolerance**. Tolerance to temperatures, drought, flooding and salt stress may be influenced by the rootstock. The increased performance at low soil temperature with rootstocks is one of the main benefits of the grafting.

- **Problems associated with Grafting:**

Various problems are commonly associated with grafting and cultivating grafted seedlings. Major problems are the labor and techniques required for the grafting operation and post graft handling of grafted seedlings for rapid healing for approx. 7 to 10 days. An expert can graft 1200 seedlings per day (150 seedlings per hour), but the numbers vary with the grafting method. Similarly, the post graft handling method depends mostly on the grafting methods. In general, the problems could be minimized or easily overcome by careful cultural management and wise selection of scion and rootstock cultivars.

Conclusions:

Grafting vegetable plants onto resistant rootstocks is an effective tool that may enable the susceptible scion to control soil borne diseases, environmental stresses and increase yield. However, in these cases, the characteristics of the three areas might be affected by grafting as a result of the translocation of metabolites associated with fruit quality to the scion through the xylem and/or modification of the physiological processes of the scion. Possible quality characteristics showing these effects could be fruit appearance (size, shape, color, and absence of defects and decay), firmness, texture, flavor (sugar, acids, and aroma volatiles) and health-related compounds (desired compounds such as minerals, vitamins, and carotenoids as well as undesired compounds such as heavy metals, pesticides and nitrates). Grafting is an effective technology for use in combination with more sustainable crop production practices, including reduced rates and overall use of soil fumigants in many other countries. Thus, by vegetable grafting increase the production as well as quality attributes and reduce the cost of cultivation of the farmers.

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GREEN MANURING: A SUSTAINABLE APPROACH FOR SOIL HEALTH IMPROVEMENT

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Introduction

Green manuring, the practice of plowing or turning fresh green plant matter into the soil, is a sustainable approach to improve soil fertility and health by adding organic matter, nutrients, and promoting beneficial microbial activity. Green manuring improve its fertility, structure, and organic matter content, often using crops like legumes. It increases the soil fertility by direct addition of nitrogen to the soil through symbiosis and it also improves the soil structure, water holding capacity and microbial population of soil by addition of humus or organic matter. Upon decay, green manures enrich the soil with organic matter and to a lesser extent with nutrients such as N and P. Ample time for the green manure to decompose should be allowed between its incorporation in the soil and the planting of the next crop.

Dhaincha (*Sesbania aculeata*) is the most commonly used green manure among the farmers, although cultivation of sun-hemp and guar is also in vogue. Leguminous crops should be preferred as a green manure crop since it adds a lot of nitrogen into soil due to *Rhizobium* symbiosis. Incorporation of leguminous crop producing 8 to 25 tons of green matter per hectare will add up about 60 to 90 kg of N/ha, which is equivalent to application of three to ten tones of farmyard manure on the basis of organic matter and its nitrogen contribution.

Crops which are most commonly used for green manuring in our country are Dhaincha (*Sesbania aculeate*), Sunn hemp (*Crotolaraia juncea*), senji (*Melilotus parviflora*), berseem (*Trifolium alexandrinum*) etc. Sunn hemp is dominant among green manure crops and is well suited in almost all parts of the country; it also fits in well with the sugarcane, potato, garden crops and the second season paddy in southern India and with irrigated wheat in the north. Dhaincha as a green manure crop does well performs well in the waterlogged and alkaline soils.

Biomass production and N accumulation of green manure crops

Crop	Incorporation Age (Days)	Dry matter (t/ha)	N accumulated (kg/ha)
Sesbania aculeata	60	23.2	133
Sunn hemp	60	30.6	134
Cow pea	60	23.2	74
Pillipesara	60	25.0	102
Cluster bean	50	3.2	91
Sesbania rostrata	50	5.0	96

Criteria for Selection of Green manure

Criteria	Effects
High biomass production	Mobilization of nutrients from soil into vegetation; suppression of weeds
Deep rooting system	Pumping up of weathered and/or leached nutrients from soil layers not occupied by roots of main crop
Fast initial growth	Quick soil cover for effective soil protection; suppression of weeds
More leaf than wood	Easy decomposition of organic matter
Low CN ratio	Leading to enhanced availability of nutrients for succeeding crops; easy to handle during - cutting and/or incorporation into the soil.
Nitrogen fixing	Increased nitrogen availability
Good affinity with mycorrhiza	Mobilization of phosphorus leading to improved availability for crops.

Characteristics of an ideal green manure crop:

An ideal green manure crop should have following characteristics:

1) It must have deep rooting system, facilitating nutrient mining from subsurface soil.
2) They should have less nutrient requirement so that the main crop does not face the deficiency of nutrients.
3) They should have quick growth so that abundant biomass is produced
4) They should have less water requirement so that it does not compete with the main field crop for water uptake.
5) The biomass produced should have low fibrous material to facilitate quick decomposition.
6) Most preferably we must prefer leguminous green manure crop so that they may facilitate atmospheric N fixation.
7) It should produce more biomass so that more organic matter and more organic acids can be produced in the soil after the decomposition.

Some important facts to be kept in mind while taking a green manure crops:

1) The green manure crop should be sown in the month of April-May and they must be ploughed down in the June.
2) Mostly higher seed rate is recommended for green manure crops.
3) Green crops should be incorporated into the field at the stage just before the flowering which is mostly at the age of 6-7 weeks. The time interval between the incorporation of green crops in the main field and the sowing of the succeeding crop depends on the weather conditions of the area and the nature of buried material. Mainly warm and humid weather is more favorable for the decomposition of the green crops.
4) Sunnhemp and dhaincha are suitable for growing in April-May and can be buried in June-July before planting of main kharif crop.
5) Rhizobium species has the capacity to fix the nitrogen into the soil according to the nutrient demand of the plant.

Important Green Manuring Crops:
Green manuring crop must grow rapidly on varieties of soil and must decompose quickly enough to release the nutrients they contain in the soluble form, for the growth of crops.

A few most important green manure crops are as follows:

(i) Sunn hemp (*Crotalaria juncea*):
Sunn hemp is most suitable green manure crop for loamy soils. It is sown in May or June when the monsoon breaks. It grows very fast and attains a height of one to two metres. It can grow even on poor soils and add about 20 to 25 tons of fresh green plant material per hectare to the soil. Sunhemp is the most outstanding green manure crop. It is well suited to almost all parts of India

and can be accommodated in the growing seasons of sugarcane, potato and garden crop, irrigated wheat in north India and second season paddy crop in South India.

(ii) Dhaincha (*Sesbania aculeate*)**:**

It can tolerate water logging, salinity and dry conditions if the germination has been good. It grows up to a height of 1.5 to 1.8 meters in water logged paddy fields within a very short period of time. It is best suited for loamy or clayey soils where it adds about 10 to 20 tons of green material per hectare.

(iv) Moong (*Vigna radiata*):

Moong which is sown in the first week of July matures and yields about 3 to 4 quintals of seed per hectare by the first week of September. After picking the pods, the crop is ploughed down as green manure and wheat may be sown in the first week of November.

(vi) Gaur (*Cyamopsis tetragonoloba*):

It is a good fodder cum green manuring crop in the dry regions of north-western India where it grows even on poor soils.

(vii) Other pulse crops like horse gram, cowpea etc. can also be grown as green manure crops.

Technique of Green Manuring:

The seeds of green manure crop can be sown in May to June and ploughed down in July. Wheat fields in the north India can be green manured with sunhemp, dhaincha, cowpea, green gram, black gram, etc. Generally a higher seed rate is recommended for green manuring. Fertilization of green manures with phosphatic fertilizers can be done by broadcast, because it improves the availability of phosphorus to the succeeding crop as compared to phosphorus applied to succeeding crop.

Usually the field in ploughed, a little fertilizer i.e. 10 kg of nitrogen and about 30 kg of phosphorus (P_2O_5) per hectare is added to the soil. The fields are again ploughed and about 50 to 60 kg sunn hemp or Dhaincha seeds are sown in June when the monsoon breaks. An 8 week old green manure crop is succulent enough to be turned into soil for best response under rice. Various reports conclude that a green manure crop should be turned under at 7 to 8 week age, which coincides with flowering and maximum growth stage for most of the green manure crops. Dhaincha and sunn hemp add about 75 kg of nitrogen per hectare to the soil.

Time Interval between Burial of Green Manure Crop and Sowing of Next Crop

The time interval between the ploughing down of green manure crop and the sowing of the next crop depends on weather conditions and nature of the buried green material. The warm and humid conditions favor rapid decomposition of plant material. If the green manure crop is succulent, then paddy transplanting can be done immediately after turning over of the green manure crop. In case of the woody plant material, sufficient time interval should be allowed for proper decomposition of green plant material before paddy transplanting, e.g. when succulent green manure crop of around 8 weeks to be buried then paddy can be planted immediately without having any adverse effect on the yield. But when dhaincha become woody (12 weeks), it is necessary to bury it about 6 to 8 weeks first before transplanting paddy for its proper decomposition.

Advantages of Green Manuring

1) They absorb nutrient from the deeper soil layers and leave them in the surface soil.
2) The amount of green plant material buried stimulates the activity of the micro-organisms inhabitant to the soil. They respire and decompose the organic matter CO_2, which help in producing carbonic acid. The carbonic acid decomposes the soil minerals to release plant nutrients bind in them

3) Green material on decomposition also produces certain organic acids which enhance the availability of certain plant nutrients like phosphorus, calcium, potassium, magnesium and iron.

4) It improves the soil structure, moisture holding capacity and infiltration of water, thus decreasing the runoff and erosion.

5) Leguminous green manuring crop harbor N fixing bacteria, rhizobia in their root nodules and fix atmospheric N @ 60 to 100 kg N/ha in the soil which becomes available to the succeeding crop.

6) Regular practice of green manuring may increases the yield of the succeeding crops by 15 to 20 %

7) Increase the solubility of phosphates, trace elements etc., through the activity of the soil microorganisms and by producing organic acids during decomposition.

8) *Sesbania aculeata* (daincha) applied to sodic soils continuously for four or five seasons improves the permeability and helps to reclaim the sodic soils.

Some disadvantages of green manuring

Some disadvantages are also associated with green manuring mentioned as under:

1) Under rainfed conditions, proper decomposition of the green plant material and satisfactory germination of the succeeding crop may not take place if sufficient soil moisture is not available.

2) A satisfactory stand and growth of the green manure crops cannot be produced, if sufficient rainfall is not available.

3) The practice of green manuring may be uneconomical, especially in the regions where irrigation facilities are available along with easy availability of fertilizers. As it is more economical to add the quantity of N in the form of fertilizer which the crop is expected to fix from the atmosphere.

4) Green manure crops may also harbor some of the insects, pests and nematodes which could harm the succeeding crop.

5) **CONCLUSION:** Green manuring is one of the best alternatives to improve the soil health and meet the nutritional requirement of the succeeding crop. The loss of nitrogen can be prevented by the incorporation of green manure crops in the soil. Green manure crops are mostly leguminous crop because they help in the fixation of the nitrogen by the use of *Rhizobium*. The green manure crops improve physico-chemical properties of soil, biological and provide plant protection. By the use of green manuring we can helps in the restoring the soil quality and prevents the degradation of the land. Application of green manure supplements the chemical fertilizers and restores soil fertility. Therefore, it is an eco-friendly low cost technology to conserve the natural resources besides maintaining environmental quality in a sustainable manner. Green manuring, the practice of incorporating fresh green plant matter into the soil, can be an effective method for reclaiming salt-affected soils by improving soil structure, fertility, and reducing salinity, especially when using salt-tolerant species like Sesbania.

Objective:

For successful rising of the crop under biotic and abiotic stress, precocity, improvement of quality and other horticultural attributes. Further crop wise objective is given in Table 1.

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HETEROSIS BREEDING IN *Solanum melongena* L.

INTRODUCTION

Brinjal (*Solanum melongena* L.) is one of the major commercially and nutritionallyimportant vegetable crop cultivated extensively almost in all parts of India. Brinjal is a versatile crop adapted to various agro-climatic regions and can be grown throughout the year. It is commonly known as Eggplant, Poor man's crop, Aubergine or Guinea squash. It belongs to family Solanaceae and the basic chromosomal number is 2n=24. *Solanum insanum* is considered as the wild progenitor of common eggplant (Syfert *et al.*, 2016). Its immature fruits are consumed as vegetable and for other culinary purpose. Brinjal is a warm season, day neutral crop which is susceptible to severe frost. It grows well in tropical and sub-tropical regions. It can be successfully grown as a *kharif* season and summer season crop. It can be cultivated under a wide range of soils. The optimum temperature for its cultivation is 21-27^{O} C. Brinjal is usually a self- pollinated crop but the extent of cross pollination reported is as high as 29 % and hence it is consideredas often cross-pollinated crop. The rate of natural cross-pollination varies with genotype, location and insect activity.

AREA, PRODUCTION AND PRODUCTIVITY OF BRINJAL

Brinjal is believed to be native of India where the major domestication of large fruited cultivars occurred. Bangladesh and Myanmar are considered as Centre of diversity. In addition to India, brinjal is also cultivated in other countries like China, Turkey, Japan, Egypt, Italy, Indonesia, Iraq, Syria, Spain and Philippines. In 2022, China was the leading country in Brinjal production throughout Asia-Pacific region with 38.20 million of production followed by India with 12.70 million tons of production (Anonymous, 2022). In India, Brinjal is being cultivated in 682.80 thousand ha area with an average annual production of 12.9 million MT and productivity is 18.80 MT/ha. West Bengal had the highest brinjal production followed by Orissa and Gujarat with 3088.25, 2197.97 and 1589.36 thousand MT production respectively (Anonymous, 2024).

NEED OF HETEROSIS BREEDING

In past few years, farmer's interest and preferences for brinjal hybrids has significantly increasing. As brinjal is one of the most demanding vegetable crops, it is necessary to improve the locally preferred cultivars or develop new hybrid combinations for high yield, quality, consumer acceptability and meet diverse preferences of locals based on different color, shape, size, taste and presence or absence of spines etc.

However, due to continued selection, much of the variability has exhausted. Creation of genetic variation is crucial in order to broaden the gene pools in any given crop population. Therefore, the main emphasis needs to be laid on heterosis breeding to create variability and to identify the desirable segregants between the parents.

The ultimate objective of a plant breeder is to achieve desirable heterosis. Heterosis has been commonly used in many crops to enhance the output and increase the adaptability of the hybrids. In order to get most out of heterosis, the germplasm or parents must be divided into distinct heterotic groups. Heterotic groups are the germplasm that mix well when crossed with the genotypes from another heterotic groups (Reif *et al.*, 2003). The level of heterosis is strongly correlated with the diversity among the parents which integrate several favourable diverse alleles of differed genes. Factors like heterozygosity, non-allelic interactions (like epistasis and dominance) and maternal interactions can contribute to the manifestation of heterosis. The F_1 hybrids provide a number of benefits, including early maturity, high yield, better quality, uniformity and greater adaptability. They also aid in the distribution of dominant genes that confer disease and insect-pest resistance to the hybrids.

GENETIC BASIS OF HETEROSIS

Information about heterosis of parents and crosses is critical in crop improvement. Heterosis may be defined as the increase or decrease in performance of superiority of F_1 hybrid offsprings over mid-parent (average or relative heterosis), better parent (heterobeltiosis) and standard (economic) heterosis was computed for a particular character (Hayes *et al.,* 1965). According to dominance theory, heterosis results from the complementation of the deleterious alleles that were located in the inbred parental lines. Whereas, over-dominance hypothesis highlights that the hybrid's specific allelic interactions mean that the heterozygous alleles in the combination function better than any of the homozygous ones (Birchler *et al.*, 2010).

The researchers proposed the physiological and biochemical theory of heterosis years back (Virmani *et al.*, 2004). However, new developments in molecular genetics have demonstrated that heterosis is solely genetical (Birchler, 2015). Exploitation of heterosis has become a potential tool for improvement of brinjal because of its hardy nature, ease at crossing due to large size of flower, presence of large number of seeds per fruit and wider adaptability to varied agro-climatic conditions.

SALIENT FEATURES OF HETEROSIS

1. Superiority over the parents
2. Remained confined to F_1 generation
3. Governed by the nuclear genes
4. Heterosis is reproducible under the same set of environments
5. Fixation can be done by apomixis, asexual reproduction, balanced lethal system and polyploidy.

BREEDING OBJECTIVES OF BRINJAL

1. Development of high yielding varieties and hybrids.
2. Earliness
3. Fruit shape, size and color as per the preference of consumer.
4. Low proportion of seed and more pulp.
5. Soft and white flesh
6. Low solasodine content
7. Less fruit thickness
8. Resistant to diseases i.e., Bacterial wilt, Phomopsis blight, Little leaf, Root knot nematodes.
9. Resistant to Fruit and shoot borer

ESTIMATIONS OF HETEROSIS

The magnitude of heterosis was estimated in three different ways, *viz.*, as percentage increase or decrease of F_1 mean over the mean of better parent (BP) (Turner, 1953 and Hays *et al.*, 1955). Similarly, per cent superiority over the mid (MP) parent and standard hybrid check (SC) was also calculated.

A) Per cent heterosis over better parent (BP) i.e., Heterobeltiosis

$$\text{Per cent heterosis over BP} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

B) Per cent superiority over mid parent (MP) i.e., Mid parent heterosis

$$\text{Per cent heterosis over MP} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

C) Per cent superiority over standard hybrid check (SC) i.e., Standard heterosis

$$\text{Per cent heterosis over SC} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\overline{F_1}$ = Mean of the F_1 hybrid

$\overline{BP}$ = Mean of the better parent of that particular F_1 cross

$\overline{MP}$ = Mean of the two parents involved in the cross

$\overline{SC}$ = Mean of the Standard hybrid check of that particular character

DEVELOPMENT OF F_1 INVOLVES THE FOLLOWING STEPS:

1. Selection of floral bud: The flowers of female and male parents which were due to open during next morning are selected and were bagged or covered using cotton separately in the evening, one day before crossing.

2. Manual (Hand) emasculation: Usually, anthesis starts from 6 to 7.30 am and continues up to 11 am. Peak time for anthesis is 8.30 to 10.30 am. In the morning after anthesis, all the stamens of the flower are gently removed using fine pointed forceps without injuring the female parts.

3. **Pollen collection:** The pollen dehiscence starts from 9.30 to 10 am and remains viable for a day. The pollens are most fertile soon after anther dehiscence. The freshly dehiscing anthers are picked to collect the pollens on petridish.

4. Artificial pollination or Pollen dusting: Stigma receptivity ranges from a day prior to anthesis but is the highest during anthesis. The freshly collected pollens grains are dusted over the stigma using brush and are covered to avoid contamination. The pollinated buds were again bagged with paper bags and labelled. Sufficient crossed seeds were obtained at the end of crop cycle.

a) Floral bud selected for emasculation and pollen collection

b) Dusting of pollens on emasculated bud and covering using cotton

c) Labelling of crossed bud

d) Setting of fruit after artificial pollination

CONCLUSION

Heterosis breeding in brinjal is beneficial in order to develop the hybrids with increased yield, reproductive ability, adaptability, hybrid vigour, resistance to insect-pest and diseases and improved quality. Therefore, the exploitation of heterosis has become a potential tool for improvement of brinjal.

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HIGH-OLEIC SUNFLOWER OIL: A HEART-HEALTHY REVOLUTION

Abstract

High-oleic sunflower oil has gained significant attention as a superior cooking oil due to its high monounsaturated fat (oleic acid) content, which offers remarkable cardiovascular benefits, oxidative stability, and versatility in culinary applications. Unlike conventional sunflower oil, HOSO contains 70-90% oleic acid, making it resistant to rancidity and ideal for high-heat cooking. Research indicates that regular consumption of HOSO can reduce LDL cholesterol, improve heart health, and support metabolic function, positioning it as a healthier alternative to partially hydrogenated oils and other vegetable oils. This article explores its nutritional advantages, industrial applications, environmental sustainability, and future market potential, providing a comprehensive overview of why HOSO is revolutionizing the food industry.

Introduction

India is the 5th largest producer of sunflower oil, but most cultivated varieties are traditional (20-30% oleic acid). However, with rising demand for healthier oils, high-oleic (HO) sunflower (70-90% oleic acid) is gaining attention. The Indian Council of Agricultural Research (ICAR) and private seed companies are developing HO hybrids suited to Indian agro-climatic conditions.

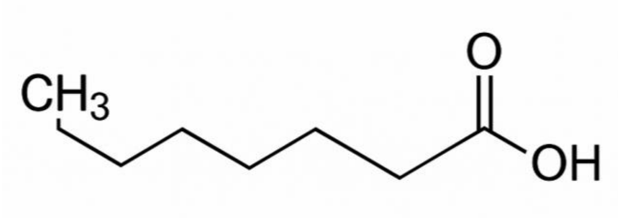
In recent decades, growing awareness of the link between dietary fats and cardiovascular health has driven significant changes in consumer preferences and food industry practices. As public health organizations continue to warn against the dangers of trans fats and excessive saturated fats, nutritionists and food scientists have sought healthier alternatives that deliver both functional performance in cooking and demonstrated health benefits. Among the various options that have emerged, high-oleic sunflower oil (HOSO) has distinguished itself as a particularly promising solution, combining an exceptional fatty acid profile with remarkable culinary versatility.

The health implications of this improved fatty acid profile are substantial. Numerous studies have demonstrated that diets rich in monounsaturated fats (MUFAs) can help reduce LDL ("bad") cholesterol levels while maintaining or even increasing HDL ("good") cholesterol, thereby supporting cardiovascular health (American Heart Association, 2017). Additionally, HOSO is naturally rich in vitamin E (tocopherols), a potent antioxidant that helps combat oxidative stress and inflammation—two key contributors to chronic diseases such as heart disease, diabetes, and certain cancers.

Beyond its health benefits, high-oleic sunflower oil is gaining traction for its economic and environmental advantages. Sunflower crops require less water than olive or palm oil cultivation, making them a more sustainable choice in an era of increasing water scarcity. Furthermore, the oil's extended shelf life reduces food waste in both household and industrial settings. The food industry has taken note, with HOSO now being used in everything from restaurant deep fryers to packaged snacks and plant-based dairy alternatives, replacing less stable oils like soybean and canola oil.

What is High-Oleic Sunflower Oil?

Oleic acid is a monounsaturated omega-9 fatty acid (MUFA) that serves as one of the most important dietary fats for human health. Chemically classified as cis-9-octadecenoic acid (C18:1), it is found abundantly in various plant and animal sources, with particularly high concentrations in olive oil, high-oleic sunflower oil, avocados, and nuts. Unlike saturated fats (which are solid at room temperature) and polyunsaturated fats (which are highly prone to oxidation), oleic acid offers a unique balance of stability, health benefits, and functional versatility in cooking and food processing.



High-oleic sunflower oil is extracted from specially cultivated sunflower seeds bred to contain 70-90% oleic acid, compared to 15-35% in conventional sunflower oil. This modification is achieved through selective breeding and genetic optimization, not genetic engineering, making it a non-GMO product in most cases.

Properties:

- Light golden color, neutral taste
- High smoke point (450°F / 232°C)
- Longer shelf life due to low oxidation rates

Nutritional Profile and Health Benefits

1. Heart Health & Cholesterol Management

- **Reduces LDL ("bad") cholesterol** while maintaining HDL ("good") cholesterol (*American Heart Association, 2020*).
- **Lowers cardiovascular disease risk** by replacing saturated and trans fats in diets.

2. Antioxidant & Anti-Inflammatory Effects

- Rich in **vitamin E (tocopherols)**, which combats oxidative stress.

- May reduce inflammation markers linked to chronic diseases (*Journal of Nutrition, 2019*).

3. Ideal for High-Heat Cooking

- Unlike canola, soybean, or corn oil, HOSO does not break down easily, preventing the formation of toxic aldehydes during frying.

4. Supports Metabolic Health

- Studies suggest improved insulin sensitivity in diabetic patients when replacing saturated fats with monounsaturated fats (*Diabetes Care, 2021*).

Comparison with Other Cooking Oils

Oil Type	Oleic Acid (%)	Smoke Point	Best For	Health Concerns
High-Oleic Sunflower	70-90%	450°F (232°C)	Frying, Baking	None (heart-healthy)
Regular Sunflower	20-30%	440°F (227°C)	Low-heat cooking	High in omega-6 (inflammatory in excess)
Olive Oil (EVOO)	55-85%	375°F (191°C)	Salads, Low-heat	Expensive, low smoke point
Canola Oil	55-65%	400°F (204°C)	General cooking	Often genetically modified
Palm Oil	40-50%	450°F (232°C)	Processed foods	Environmental & ethical concerns

Key High-Oleic Sunflower Varieties in India

Variety/Hybrid	Oleic Acid (%)	Developed By	Adaptation Zone
DSH-197 (HO)	80-85%	University of Agricultural Sciences (UAS), Dharwad	Karnataka, Maharashtra
KBSH-53 (HO)	75-80%	ICAR-IIOR, Hyderabad	Telangana, Andhra Pradesh
ProSun 825 (HO)	80-85%	Syngenta India	Punjab, Haryana
NK Armoni (HO)	78-83%	Bayer CropScience	Central & South India

Future Prospects: High-oleic sunflower oil (HOSO) is poised for significant global growth, with projections indicating a 6.2% CAGR (2024-2032) as health-conscious consumers and trans-fat regulations drive demand. In India, initiatives like the National Edible Oil Mission could triple HOSO production by 2030, reducing palm oil imports. Agricultural advancements, including CRISPR-edited varieties targeting oleic acid content (>93%) and drought resistance, will enhance yield and climate resilience. The food industry will increasingly adopt HOSO for clean-label snacks, plant-based dairy, and functional foods, while its stability makes it valuable for biofuels and nutraceuticals. Sustainability advantages—40% lower water use than olive crops and minimal GHG emissions—position HOSO as an eco-friendly choice. By 2030, HOSO may capture 15% of the global edible oil market, though cost competitiveness and farmer education remain challenges to address for full market potential.

Conclusion

High-oleic sunflower oil is reshaping the food industry by offering a healthier, more stable, and environmentally friendly alternative to traditional cooking oils. Its heart-protective properties, high smoke point, and versatility make it an excellent choice for both home cooks and food manufacturers. As scientific research continues to validate its benefits, HOSO is poised to become a staple in global kitchens, driving a heart-healthy revolution in nutrition.

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Himalayan Harvest: Unique *Plectranthus* and *Thymus* Honeys of Himachal Pradesh

The Beekeeping Landscape of Himachal Pradesh

Himachal Pradesh is a hilly state of India situated in the Himalayan foothills (350-2200 m above sea level). The state encompasses four agro-climatic zones *viz.*, Zone-1 (sub-tropical, low hill zone); Zone-2 (sub- humid, mid hill zone); Zone-3 (High hills, temperate wet zone) and Zone-4 (High hills, temperate dry zone). Beekeeping in Himachal Pradesh is contributing greatly to the state's agricultural and economic landscape. The exotic bee, *Apis mellifera* and Asian bee, *Apis cerana* are well suited to the climatic conditions of the state. The beekeeping with *A. mellifera* is done as migratory beekeeping and depending upon the availiabity of bee flora or its peculiarity, the colonies are sometimes migrated to high hilly regions which are rich in *Thymus* sp. and *Plectranthus* sp. to avail unique unifloral honey. These regions are also practicing stationary beekeeping with the naturally occurring indigenous bee, *A. cerana* or it is naturally found in local houses. Unifloral honey derived predominantly from a single floral source have special significance due to their distinct flavors, nutritional value and therapeutic properties.

Unique Unifloral Honeys: *Plectranthus* and *Thymus*

Among all agroclimatic zones, Zone-4 contains unique and specific floral compositions, distinguishing itself from other regions of India. This region is also isolated from industrial activities and human interference ensuring pure honey, free from contaminants that enhances its market value and appeal. However, this zone is not commercially practiced for beekeeping. Some beekeepers migrate their *A. mellifera* colonies during autumn season to avail honey from different floral sources *viz.*, *Thymus*, *Plectranthus* and *Fagopyrum*. *Plectranthus* is known for white honey production, it provides surplus honey during September to October month. *Plectranthus* and *Thymus* plants are found particularly in the Himalaya, the Southern Ghats, and the Nilgiri regions of India and highly valued in both traditional and modern medicine for their diverse therapeutic properties. These have ability to treat respiratory issues, digestive disorders, and inflammation, due to the presence of antimicrobial, antioxidant and anti-inflammatory compounds.

The Science Behind Himachal's Premium Honeys

Due to diversity in flora with altitude of the state, different floral honeys can be obtained. The floral origin of these honeys can be confirmed on the basis of melissopalynological analysis which deals with identification of pollen types in the honeys.

If the pollen content of particular plant species is more than forty-five percent of total pollen grains present in honey sample then this honey is classified as unifloral honey. For instance, *Plectranthus* pollen is round, oval in shape with radial symmetry (29.534 X 28.537 micron) and *Thymus* pollen is oblate, circular in shape with radial symmetry (35.694 X 32.052 micron) (Figure 1).

The unifloral honeys have unique physicochemical characteristics which should be within the standardized limits of FSSAI, CODEX, BIS and AGMARK limits to meet the quality at national and international level. The physical parameters *viz*., pH and EC are contents of honey indicating its freshness, high mineral content and ash content, which are as 4.11, 4.32 and 0.31, 0.12 mS/cm for *Plectranthus* and *Thymus* honey, respectively (FSSAI limit for EC is ≤0.8 ms/cm). The moisture content of honey indicating that honeys harvested at mature stage has ability to resist fermentation and granulation which are 17.59 and 15.89 per cent for *Plectranthus* and *Thymus* honey (FSSAI limit for moisture content is ≤ 20%, FSSAI). Lower moisture content also promotes longer shelf life during storage. Further colour variation can also be vary in different types of honeys due to pollen type and their contents in honey along with important minor, secondary and minor pollen contents. *Plectranthus* honey is white in colour while, *Thymus* honey is amber coloured. As honey is a sweet natural substance produce by honeybees from the nectar of flowers, the sweetness in honey is due to presence of various types of sugars. It contains more than thirty-five per cent of glucose, forty-five per cent of fructose and 5 per cent sucrose. High sucrose content indicates unripe or adulterated honey and that the sucrose was not transformed to glucose and produce due to lack of invertase enzymes. Adulteration of honey with fructose also results in high sucrose content. Sucrose content in *Plectranthus* and *Thymus* honeys is 1.02 and 1.26, respectively indicated that the honey extracted is ripened (FSSAI limit for Sucrose is max. 5%). The Fructose: Glucose ratio (1.02 *Plectranthus* and 1.26 *Thymus* honey) indicating high quality of honey. F: G ratio indicates the ability of honey to crystallize, since the glucose is less soluble in water than fructose (FSSAI limit for F: G ratio is 0.95-1.50). Honey crystallization is faster when the F/G ratio is below 1.0 and it slows when this ratio is more than 1.0. Acidity in honey (42.08 meq/kg *Plectranthus*; 39.52 meq/kg *Thymus* honey) due to gluconic, malic, succinic, formic, lactic, citric and acetic acids which are produced by action of glucose oxidase enzyme on glucose. Both acidity and vitamin C content indicating freshness of honeys and contribute to honey flavor, stability against microorganisms, enhancement of chemical reactions, antibacterial and antioxidant activity. Both *Plectranthus* and *Thymus* honey have acidity value less than 50 mg/kg (FSSAI) indicating honey is not fermented.

One important quality parameter of honey is the HMF (Hydroxymethyl furfuraldehyde) content which is related to the pH and acidity of honey. HMF content of honey is an indicator of improper heating, long storage or adulteration of honey with invert sugars. Higher the HMF content, lower the quality of Honey. HMF is an aldehyde which is generated by the decomposition of fructose in acidic conditions (Miaillard reaction-a non-enzymatic browning). Both the honeys have lower HMF content than 40mg/kg (FSSAI maximum limit for HMF is ≤ 80mg/kg) indicated proper heating, fresh or unadulterated honeys without any invert sugar. Total phenolic content and DPPH are good criteria to determine the quality and are responsible for antimicrobial and antioxidant activity of honey (free radicals' scavengers) which help in protection against various microbial diseases of humans. Among two honeys both phenol (106.07 mg/100g) and DPPH content (77.45 %) are high in *Thymus* honey indicating good antimicrobial and antioxidant properties of this honey.

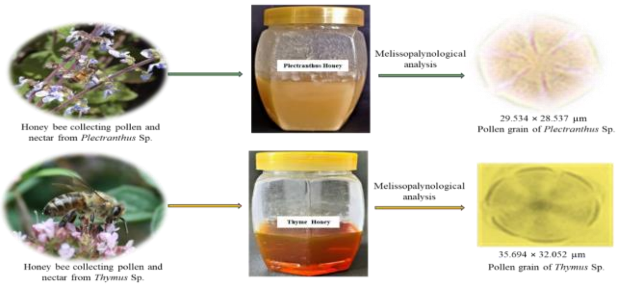

Figure 1. *Plectranthus* and *Thymus* Honey of Himachal Pradesh

Both the honeys are rich in minerals *viz*., magnesium, calcium, phosphorus, potassium, zinc, sodium, Iron and manganese content (Figure 2). Minerals in honey are indicator for a variety of environmental contaminants, including heavy metals, low-level radioactivity, and pesticides. Potassium is mainly the most abundant element, corresponding to one third of the total mineral content in honey.

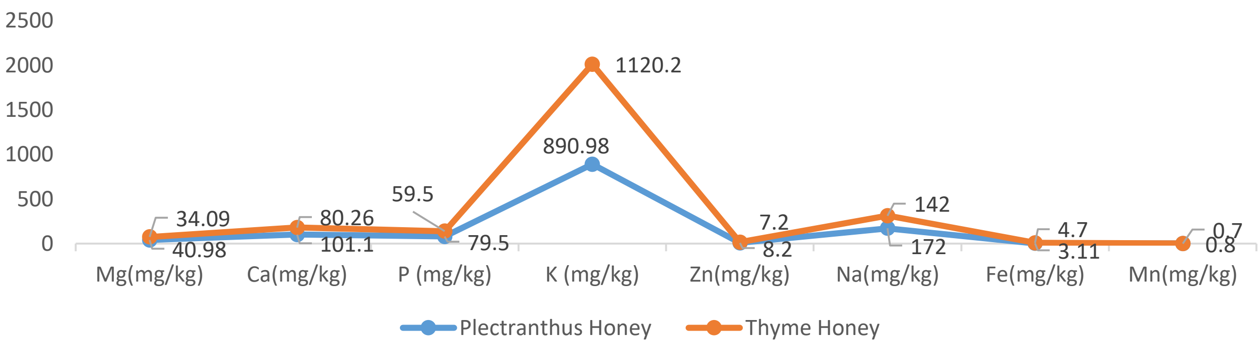

Figure 2. Mineral contents in *Plectranthus* and *Thymus* honey of Himachal Pradesh

Potassium content is very high in *Thymus* honey (1120.20mg/kg) as compare to *Plectranthus* honey (890.98 mg/kg). Several factors *viz*., diverse floral sources such as secondary, important minor, and minor ones, the timing of harvest, hive maturity, climatic conditions, processing methods, storage practices and the specific soil characteristics of the region affect the quality of honey.

Conclusion: A Treasure Trove of Health and Flavor

The temperate dry zone of Himachal Pradesh, especially in its high hills, is a treasure trove for beekeeping, offering rare and highly sought-after unifloral honeys from *Plectranthus* and *Thymus* species. These honeys not only meet the highest quality standards but also provide exceptional nutritional and therapeutic benefits, making them a valuable addition to both the domestic and international markets. As the world increasingly turns toward natural and health-promoting products, the honey from Himachal Pradesh stands out, offering consumers a unique blend of flavor, purity, and medicinal value - a testament to the rich biodiversity of this hilly state.

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INTERACTIONS BETWEEN ENVIRONMENTAL CONDITIONS AND FORM OF NITROGEN NUTRITION IN PLANTS

Introduction

The interactions between environmental conditions and the form of nitrogen nutrition in plants are crucial determinants of plant growth, development and overall performance. Nitrogen, an essential macronutrient, exists in various forms such as nitrate and ammonium, each influenced differently by factors like temperature, water availability, soil pH and light intensity. Understanding these interactions is vital for optimizing agricultural practices and enhancing crop productivity while minimizing environmental impacts. In this brief overview, we explore the intricate relationships between environmental conditions and nitrogen nutrition forms, highlighting their significance in plant physiology and agricultural sustainability.

Effects of Environmental Conditions on Nitrogen Uptake and Assimilation

Environmental factors, including temperature, water availability, soil pHand light intensity, influence the uptake and assimilation of nitrogen by plants.

1. Temperature:

Temperature plays a critical role in modulating nitrogen uptake and assimilation processes in plants. Optimal temperatures typically enhance these processes, facilitating efficient utilization of nitrogen resources for growth and development. At moderate temperatures, enzymes involved in nitrogen metabolism exhibit optimal activity, allowing for the efficient conversion of nitrogen compounds into organic forms utilized by plants.

However, extreme temperatures, both high and low, can disrupt nitrogen uptake and assimilation pathways. High temperatures can denature enzymes responsible for nitrogen metabolism, leading to reduced efficiency in nitrogen assimilation. Conversely, low temperatures can slow down enzymatic reactions, limiting the rate of nitrogen uptake and assimilation. As a result, plants may experience nitrogen deficiency under extreme temperature conditions, compromising their growth and productivity.

2. Water availability:

Water availability is essential for efficient nitrogen uptake and assimilation in plants. Adequate soil moisture ensures the movement of nitrogen from the soil solution to the roots, facilitating uptake by plant roots. Water is also required for various physiological processes involved in nitrogen assimilation, such as enzyme activation and transport of nitrogen compounds within the plant.

In contrast, water stress can severely hinder nitrogen uptake and assimilation processes. When plants experience water shortage, their ability to take up nitrogen from the soil is compromised. This is because water stress restricts the movement of nutrients in the soil solution, reducing the accessibility of nitrogen to plant roots. Additionally, water stress can lead to stomatal closure, limiting the uptake of carbon dioxide needed for photosynthesis. Reduced photosynthetic activity, in turn, affects the energy available for nitrogen assimilation processes, further exacerbating nitrogen deficiency in plants.

1. Soil pH:

The pH level of the soil profoundly influences the availability and uptake of nutrients, including nitrate, by plant roots. Neutral to slightly acidic soils, typically with pH values ranging from 6.0 to 7.0, are considered optimal for nitrate uptake. In such soils, nitrate ions remain relatively stable and soluble, facilitating their movement through the soil solution. The chemical speciation of nitrate in neutral to acidic soils allows for efficient root uptake, as the nitrate ions are readily available for absorption by plant roots. Consequently, plants growing in neutral to slightly acidic soils often exhibit robust growth and development, supported by the abundant availability of nitrate for essential metabolic processes.

Conversely, alkaline soils with pH values exceeding 7.0 may pose challenges for nitrate uptake due to limitations in nitrate availability. In alkaline soils, the chemical environment can influence the behavior of nitrate ions, potentially leading to reduced solubility and availability. At elevated pH levels, nitrate ions may undergo chemical transformations or interactions with soil minerals, such as adsorption or precipitation, which can decrease their mobility and accessibility to plant roots. As a result, plants growing in alkaline soils may encounter difficulties in acquiring an adequate supply of nitrate, which can compromise their nitrogen nutrition and overall growth potential.

The impact of soil pH on nitrate uptake underscores the importance of soil management practices in optimizing nutrient availability for plant growth. Agricultural strategies aimed at adjusting soil pH to neutral to slightly acidic levels can enhance the efficiency of nitrate uptake by plants, promoting optimal nutrient utilization and maximizing crop productivity. Soil amendments such as sulfur or acidifying fertilizers can be employed to lower soil pH in alkaline soils, thereby improving nitrate availability and supporting healthy plant growth. By considering the influence of soil pH on nitrate uptake, farmers can implement targeted soil management practices to ensure nutrient-rich conditions conducive to sustainable agricultural production.

2. Light Intensity:

Moderate to high light intensity plays a crucial role in promoting nitrate assimilation in plants, primarily through its stimulatory effect on photosynthetic activity. Light is an essential energy source for photosynthesis, the process by which plants convert carbon dioxide and water into organic compounds, utilizing energy derived from sunlight. In environments with moderate to high light intensity, photosynthetic rates are typically elevated, leading to increased production of carbohydrates and other organic molecules within plant tissues.

The availability of ample light energy facilitates the efficient assimilation of nitrate into organic compounds through a series of biochemical reactions within plant cells. Nitrate assimilation primarily occurs in the chloroplasts and other cellular organelles, where enzymes catalyze the conversion of nitrate ions into amino acids, proteins and other nitrogen-containing compounds. The energy generated during photosynthesis provides the necessary ATP and reducing power (NADPH) to drive these assimilatory processes, enabling the incorporation of nitrogen into organic molecules.

Furthermore, moderate to high light intensity can influence the expression and activity of key enzymes involved in nitrate assimilation pathways. Light-regulated enzymes, such as nitrate reductase and nitrite reductase, exhibit increased activity in response to light exposure, facilitating the conversion of nitrate to ammonium and subsequent incorporation into organic compounds. Additionally, light availability can influence the expression of genes encoding nitrate transporters and other components of the nitrogen assimilation machinery, further enhancing nitrogen uptake and utilization by plants.

Interactions Between Nitrogen Forms and Environmental Conditions

NITRATE NUTRITION:

1. **Temperature:**

- Nitrate uptake is generally favored under cooler temperatures, while high temperatures can reduce nitrate uptake efficiency.
- Cooler temperatures typically promote higher rates of nitrate uptake as they coincide with conditions that support increased root activity and nutrient absorption. Enzymes involved in nitrate uptake and assimilation may exhibit optimal activity levels under moderate temperature conditions, facilitating efficient nitrate acquisition.
- Conversely, high temperatures can inhibit nitrate uptake processes. Heat stress may lead to reduced root activity and impaired enzyme function, limiting the plant's ability to absorb nitrate from the soil solution.

2. **Water Availability:**

- Adequate water availability is crucial for nitrate uptake due to its high mobility in the soil.
- Nitrate ions, being highly soluble in water, can move freely with soil moisture, making them accessible to plant roots for uptake.
- Water stress, characterized by insufficient soil moisture, can lead to reduced nitrate uptake. In such conditions, the movement of nitrate towards the roots may be restricted, resulting in decreased availability for plant uptake.

3. **Soil pH:**

- Neutral to acidic soils are optimal for nitrate uptake, while alkaline soils may limit nitrate availability.
- In neutral to acidic soils, nitrate ions remain stable and soluble, facilitating their movement and uptake by plant roots.
- Conversely, alkaline soils may pose challenges for nitrate uptake. High pH levels can influence the chemical speciation of nitrate, potentially leading to reduced solubility and availability for plant uptake.

4. **Light Intensity:**

- Moderate to high light intensity promotes nitrate assimilation due to increased photosynthetic activity.
- Light serves as an energy source for photosynthesis, facilitating the conversion of nitrate into organic compounds within plant cells.

- Moderate to high light intensity enhances photosynthetic rates, providing the energy required for efficient nitrate assimilation and incorporation into plant biomass.

AMMONIUM NUTRITION:

1. **Interaction with Temperature:**

- Ammonium uptake is generally less affected by temperature variations compared to nitrate, as its uptake mechanisms are less dependent on temperature-sensitive processes.
- However, extreme temperatures can still impact the efficiency of ammonium uptake. High temperatures may lead to root damage or reduced root activity, affecting the plant's ability to absorb ammonium from the soil solution.

2. **Water Availability:**

- Ammonium uptake is relatively less dependent on water availability compared to nitrate. Unlike nitrate, which relies on water movement in the soil for uptake, ammonium can be directly absorbed by plant roots. However, water stress can still affect overall plant performance and, consequently, impact ammonium uptake indirectly. Water stress can lead to reduced root growth and physiological stress, hindering the plant's ability to absorb nutrients, including ammonium, effectively.

3. **Soil pH:**

- Acidic soils favor ammonium uptake and assimilation, as ammonium ions are more prevalent and stable under acidic conditions.
- In acidic soils, ammonium ions dominate over nitrate ions, providing an ample supply of ammonium for plant uptake.
- Conversely, alkaline soils may reduce the availability of ammonium for plant uptake. At high pH levels, ammonium ions may undergo chemical reactions or become bound to soil particles, limiting their mobility and accessibility to plant roots.

4. **Light Intensity:**

- Ammonium assimilation is generally less influenced by light intensity compared to nitrate, as it does not directly involve photosynthesis.
- While optimal light conditions are necessary for overall plant growth and metabolism, they have a lesser direct impact on ammonium assimilation.
- However, sufficient light availability is still essential for supporting plant growth and providing the energy required for various metabolic processes, including nitrogen assimilation.

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IoT-BASED MONITORING SYSTEM FOR INSECT DETECTION

Abstract

The Internet of Things (IoT)-based monitoring system for insect detection in stored grains integrates various sensors, data analytics, and connectivity to enable real-time pest surveillance and control. This system leverages environmental, acoustic, optical, and gas sensors to detect early signs of infestation, ensuring prompt interventions. Wireless sensor networks and smart traps enhance detection capabilities, while cloud computing and machine learning facilitate data-driven decision-making. Automation in ventilation and pest control, combined with blockchain for data integrity, strengthens grain storage management. This approach improves pest prevention, reduces chemical dependency, and enhances food security through efficient monitoring and predictive analytics.

Keywords: IoT, acoustic sensor, environmental sensor, wireless sensor and smart trap

Introduction

Securing food safety is one of the most important research topics for life sustainability well-being. However, various factors threaten sustainable food safety. Among them, the mixing of foreign substances is a representative problem that threatens food hygiene, and when consumers ingest these foreign substances, it can cause fatal injuries or diseases which affect health (James, 2001). Foreign substances are widely classified as animal, vegetable, mineral, and other abhorrent substances. In particular, because the mixing of insects can cause not only sanitary problems but also a sense of fear, it is crucial to consider the implementation of a monitoring and control system in food manufacturing and distribution spaces. Although foreign substance accidents in food are traditionally prevented by using X-rays, metal detectors, and optical detectors to monitor the mixing of foreign substances, it is very difficult to detect insects that have penetrated foods, because insects are usually small in size and have a soft body that is unlike metal.

Although IoT-based pest-repellent solutions have been applied in food safety, most rely on specific platforms and require integration with diverse devices, including conventional fumigation systems, which have notable limitations. Additionally, differences in wireless communication frequencies and protocols can hinder data exchange and system interoperability. To address these challenges, this paper presents a remote fumigation control platform that integrates Wi-Fi communication, LED-based light emission, and image processing technology.

Key Components of IoT-Based Monitoring for Insect Detection

1. Sensors for Environmental Monitoring

Temperature and Humidity Sensors: Changes in temperature and humidity can create favorable conditions for insect infestations. Continuous monitoring helps ensure optimal conditions for grain storage and to detect anomalies that may indicate pest activity. **CO2 Sensors**: Increased levels of CO2 in grain storage bins are often associated with insect respiration, indicating the presence of pests. **Oxygen Sensors**: Low oxygen levels can indicate that insects are consuming the grain, altering the atmospheric composition. **VOC Sensors** (Volatile Organic Compounds): These detect specific gases emitted by insects or microbial activity, serving as early indicators of infestation.

2. Acoustic Sensors

These sensors pick up the sounds made by insects inside the grain. Specific algorithms analyze these sound patterns to differentiate between pest species and levels of infestation.

3. Optical Sensors (Infrared and Near-Infrared)

Infrared Cameras: These can detect heat differences in stored grain, with hotspots indicating pest metabolic activity. Near-Infrared Spectroscopy (NIR): This technology is used to detect changes in the chemical composition of grain due to insect damage.

4. Wireless Sensor Networks (WSNs)

A network of sensors can be placed throughout the grain storage facility or bins to continuously monitor environmental conditions and detect pests at different points. These sensors communicate with each other and transmit data to a central hub for real-time monitoring.

5. Smart Traps

Automated Insect Traps: Traps embedded with IoT sensors can detect, count, and identify insects that are attracted to pheromones or light traps. These smart traps can send data directly to the monitoring system to notify about the presence of specific pests.

6. Connectivity and Data Transmission

Wireless Connectivity (Wi-Fi, LoRa, ZigBee): Sensors communicate via wireless technologies like Wi-Fi, ZigBee, or LoRa, enabling long-range data transmission even in large storage facilities. Edge Devices and Gateways: Data collected from the sensors is sent to edge devices or gateways, where it is processed locally or sent to cloud servers for deeper analysis and storage.

7. Cloud and Edge Computing

Data Processing and Analytics: The IoT system integrates cloud or edge computing to analyze sensor data in real time. The use of machine learning algorithms helps to identify infestation patterns and provide actionable insights for pest control. Predictive Analytics: Historical data, combined with real-time data, can help forecast pest outbreaks, enabling preemptive measures to protect grain stores.

8. Mobile and Web-Based Applications

Grain storage managers and farmers can access real-time data via smartphone apps or web dashboards. These apps can display environmental conditions, alerts about potential infestations, and recommendations for pest management actions.

9. Automation and Actuation

Automated Ventilation Systems: If the sensors detect conditions that are conducive to pest growth, the system can automatically trigger ventilation, aeration, or fumigation processes to control humidity or temperature. Automated Pest Control Systems: Some systems are integrated with automated chemical or biological control solutions, releasing pesticides or biocontrol agents based on real-time sensor data.

10. Blockchain Integration for Supply Chain Transparency

IoT-based systems can log all sensor data into a blockchain, ensuring that data related to grain quality and pest management is secure and transparent throughout the storage and supply chain.

Benefits of IoT-Based Monitoring Systems for Insect Detection

- Early Detection and Prevention: Continuous monitoring ensures that infestations are detected early before they cause significant damage.
- Real-Time Alerts: Automatic alerts enable quick response times, reducing the need for extensive pesticide use.
- Data-Driven Pest Management: Historical and real-time data enable precise and targeted interventions.
- Remote Monitoring: IoT allows grain storage facilities to be monitored remotely, reducing the need for frequent manual inspections.
- Cost Efficiency: Reduces losses due to infestations, minimizes chemical treatments, and optimizes storage conditions, saving costs in the long term.

Challenges

IoT sensors need regular calibration and maintenance to ensure accuracy, especially in harsh grain storage environments. Rural storage facilities might face connectivity challenges, requiring the use of low-power wide-area networks (LPWAN) like LoRa or ZigBee. IoT systems must ensure data security and integrity, especially when integrated with blockchain or cloud platforms.

Conclusion

IoT-based monitoring systems represent a significant advancement in the detection and management of insect pests in grain storage, offering real-time, data-driven insights that help optimize grain quality and reduce losses.

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MASTITIS IN LARGE ANIMALS: PATHOGENIC INSIGHTS AND CLINICAL IMPLICATIONS

Introduction

Mastitis, the inflammation of the mammary gland, is a prevalent and economically significant disease in large animals, particularly dairy cattle and buffaloes. It adversely affects milk production, quality, and animal welfare, leading to substantial financial losses in the dairy industry. This article contains etiology, pathogenesis, clinical manifestations, diagnostic approaches, treatment strategies, and preventive measures associated with mastitis in large animals.

Etiology and Pathogenesis: - Mastitis can be categorized based on its origin:

1. Infectious Agents: -

Bacterial Causes: Common pathogens include *Staphylococcus aureus*, *Streptococcus uberis*, and *Streptococcus bovis*.

Viral Causes: Buffalopox virus has been implicated in mastitis cases among buffaloes. Infected animals exhibit lesions on the udder and teats, leading to a significant reduction in milk yield.

2. **Environmental pathogens: -** *Escherichia coli*, *Klebsiella spp.*, *Streptococcus uberis*, *Pseudomonas spp.*

3. **Opportunistic Pathogens: -** *Coryneacterium bovis*, *Coryneacterium pyogens.*

hese pathogens invade the udder through the teat canal, colonizing the mammary gland and triggering an inflammatory response.

Mechanism of Infection and Disease Progression: -

a) Pathogen Entry and Adhesion: - The primary route of infection is through the teat canal. Bacteria adhere to the epithelial lining using adhesins and biofilm formation, preventing immune clearance.

b) Evasion of Host Immune System: - Pathogens such as *Staphylococcus aureus* and *Mycoplasma bovis* evade the immune system by: Producing capsules and biofilms to resist phagocytosis**,** Secreting toxins and enzymes (e.g., hemolysins, proteases) that damage mammary tissue and altering surface proteins to escape immune recognition

c) Inflammatory Response: - The host immune system responds to infection by activating:

- **Neutrophils:** First line of defense, migrating to the infection site and releasing reactive oxygen species (ROS) and enzymes to kill pathogens.
- **Macrophages and Cytokines**: Interleukins (IL-1, IL-6, TNF-α) are released, triggering inflammation, pain, and swelling.
- **Oxidative Stress and Tissue Damage**: Excessive inflammation causes oxidative stress, leading to mammary gland tissue damage and fibrosis.

Factors Influencing Mastitis Pathogenesis: - Several factors affect mastitis progression, including:

- **Host Factors:** Age, lactation stage, immune status, genetics
- **Environmental Factors:** Poor hygiene, milking practices, bedding material
- **Pathogen Factors:** Virulence, antibiotic resistance, biofilm production

Clinical Manifestations: - Mastitis presents in various forms:

1. **Subclinical Mastitis**: Characterized by the absence of visible symptoms, it leads to decreased milk production and altered milk composition but a high somatic cell count (SCC) and bacterial presence in milk.
2. **Clinical Mastitis:** Manifests with visible signs such as swelling, redness, heat, pain in the udder, and changes in milk appearance, including clots or discoloration.
   - **Mild**: Swelling, redness, and pain in the udder, with slight milk abnormalities.
   - **Moderate:** Pronounced swelling, clotted or bloody milk, and fever.
   - **Severe (Toxic Mastitis):** Systemic illness, high fever, depression, and potential death.
3. **Severe Cases:** May progress to systemic involvement, presenting with fever, lethargy, and anorexia.

Diagnostic Approaches: - Accurate diagnosis is pivotal for effective management:

- **Somatic Cell Count (SCC):** Elevated SCC in milk indicates an inflammatory response.
- **Microbiological Culturing:** Identifies the specific causative pathogens.
- **Molecular Techniques:** Polymerase Chain Reaction (PCR) assays enhance rapid and precise pathogen detection. For instance, PCR and restriction fragment length polymorphism analysis are useful for rapid confirmative diagnosis of fungal infection.

Treatment Strategies: - Treatment depends on the causative agent and severity of infections.

i) **Antibiotic Therapy:** Effective against bacterial infections; however, antibiotic susceptibility testing is crucial due to potential resistance.

ii) Antifungal Therapy: Agents like nystatin, ketoconazole, and amphotericin B are effective against fungal infections.

iii) Supportive Care: Includes anti-inflammatory medications and ensuring proper hydration and nutrition.

Mastitis Preventive Measures in Large Animals: -Preventing mastitis involves:

a) Hygiene Practices: Maintaining cleanliness during milking and proper sanitation of equipment.

b) Environmental Management: Reducing exposure to pathogens by keeping housing areas clean and dry.

c) Regular Monitoring: Routine screening for subclinical mastitis through SCC and microbiological testing.

d) Animal Health Management: Implementing vaccination programs where available and ensuring overall herd health.

Conclusion

Mastitis remains a significant challenge in large animal husbandry, impacting both economic outcomes and animal welfare. A comprehensive understanding of its multifaceted etiology, coupled with diligent management and preventive strategies, is essential for mitigating its effects. Effective control strategies should focus on improving hygiene, enhancing immunity, and adopting precision nutrition and vaccination programs. Further research on novel antimicrobials and immune modulators can help mitigate mastitis-related losses.

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MICROBES AT WORK: A NATURAL CLEANSE FOR SUSTAINABLE IRRIGATION AND CLIMATE RESILIENCE

Abstract

As the global agricultural sector grapples with intensifying water scarcity and pollution, the need for innovative and sustainable water management solutions has never been more urgent. Microbial water purification offers a paradigm shift in irrigation sustainability, leveraging naturally occurring microbial consortia to detoxify pollutants, regulate nutrient cycling, and enhance water reuse efficiency. This paper explores the biochemical underpinnings of microbial purification, its applications in sustainable irrigation, and its potential as a climate-resilient strategy. By delving into recent technological advancements and empirical case studies, this review highlights the transformative potential of microbial water purification in fostering agricultural resilience. With the integration of biotechnological innovations and policy frameworks, microbial-based purification has the potential to redefine water security in the agricultural landscape of the future.

Introduction

Agricultural systems account for the predominant consumption of global freshwater resources, yet the sector is increasingly constrained by water scarcity and contamination (FAO, 2021). Conventional water treatment methodologies, while effective, are frequently cost-prohibitive and reliant on energy-intensive processes, rendering them impractical for widespread agricultural implementation (Sharma et al., 2018). Microbial-based purification technologies leverage the metabolic capabilities of bacteria, fungi, and microalgae to degrade xenobiotic compounds, eliminate pathogenic entities, and improve overall water quality through bioaugmentation and bioremediation (Wu et al., 2020). The imperative to develop resilient and self-sustaining irrigation solutions has amplified interest in harnessing microbial consortia for water purification, particularly in response to climate-induced hydrological fluctuations.

Microbial Mechanisms in Water Purification

- **Bioremediation:** Specialized microbial taxa enzymatically degrade organic pollutants, pesticides, and heavy metals, facilitating the biotransformation of hazardous substances into environmentally benign metabolites (Singh & Cameotra, 2019).
- **Biofiltration:** Engineered microbial biofilms and constructed wetlands function as dynamic filtration systems, effectively sequestering particulate matter and catalyzing the oxidative decomposition of contaminants (Gupta & Ahmad, 2021).
- **Pathogen Suppression:** Competitive exclusion and antimicrobial metabolite production by beneficial microbes mitigate the proliferation of pathogenic bacteria, thereby enhancing the microbiological safety of irrigation water (Pang et al., 2022).

- **Nutrient Cycling and Regulation:** Microbial communities facilitate the bioavailability of essential macronutrients (e.g., nitrogen, phosphorus), thereby curbing eutrophication risks while concurrently maintaining agronomic soil fertility (Bashan et al., 2016).

Applications in Sustainable Irrigation

- **Reclamation of Agricultural Wastewater:** Microbial bioprocessing enables the effective recycling of irrigation runoff, mitigating dependence on depleting freshwater reservoirs while reducing environmental discharge of agrochemicals (Mandal et al., 2020).
- **Microbially Assisted Desalination:** Certain halotolerant bacterial species mediate bio-desalination processes, rendering brackish and saline water resources viable for crop cultivation (Lu et al., 2019).
- **Decentralized Bioreactor Systems:** On-site microbial bioreactors facilitate localized treatment and reuse of irrigation water, diminishing infrastructural costs associated with centralized water treatment facilities (Nancharaiah & Lens, 2020).
- **Enhanced Climate Resilience:** Microbial water purification enhances hydrological stability in agricultural ecosystems, mitigating drought susceptibility and improving yield consistency under fluctuating climatic conditions (Timmis & Ramos, 2021).
- **Carbon Sequestration and Environmental Mitigation:** Microbial consortia contribute to atmospheric carbon capture through biochemical sequestration mechanisms, aligning with broader climate change mitigation objectives (Kuzyakov & Blagodatskaya, 2015).

Empirical Case Studies and Technological Innovations Recent field-based studies have underscored the efficacy of microbial purification techniques in diverse agroecological settings. In India, biofilter implementation in rice paddies has demonstrated substantial reductions in pesticide and nitrate contamination in irrigation water (Shukla et al., 2022). In Israel, microbial desalination cells have successfully converted brackish water into freshwater sources suitable for irrigation (Kumar et al., 2021). Additionally, advancements in synthetic biology have facilitated the genetic optimization of microbial strains to enhance their biodegradative and bioaccumulative capabilities (Jaiswal et al., 2019). These technological strides underscore the potential scalability of microbial purification methodologies, positioning them as pivotal components of integrated water management strategies in precision agriculture.

Challenges and Prospects for Future Research

- Despite its promise, microbial water purification remains constrained by challenges related to scalability, microbial stability under variable environmental conditions, and regulatory complexities governing the application of bioremediation agents in agricultural contexts (Mitra et al., 2023).
- Future research should focus on engineering robust microbial consortia with enhanced functional redundancy to improve system resilience. Furthermore, the integration of microbial purification with sensor-based monitoring technologies in smart irrigation systems offers opportunities for real-time optimization of water quality (Zhang et al., 2021).
- Establishing policy frameworks to support the adoption of microbial water treatment systems is imperative for facilitating widespread implementation and fostering global water security (OECD, 2020).

Conclusion

Water is the lifeblood of agriculture, yet its scarcity and contamination pose existential threats to global food security. Microbial water purification presents an elegant synergy between nature and technology, harnessing the biochemical prowess of microorganisms to restore water quality and enhance agricultural sustainability. As the agricultural sector moves towards more resilient and regenerative practices, microbial purification systems offer a scalable, cost-effective, and environmentally harmonious solution to the water crisis. The successful implementation of these systems in nations such as India and Israel provides tangible evidence of their efficacy. With continued research, investment, and policy integration, this revolutionary approach could shape the future of irrigation, ensuring that water—our most precious resource—remains abundant and viable for generations to come.

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MILLETS: THE SUPERFOOD REVOLUTION – BENEFITS & IMPORTANCE UNVEILED!

Abstract

Millets, whole grains, coarse grains or nutri-cereals are emerging key components of the worldwide superfood revolution. These ancient grains once formerly overlooked are now being recognized for their exceptional nutritional profile, environmental sustainability and health benefits. Millets, which are high in nutrients like iron, calcium, magnesium, potassium, dietary fiber etc. are gluten-free, have low-glycemic index, making them best to control diabetes mellitus, cardiovascular problems and other lifestyle disorders like obesity, Polycystic ovary syndrome (PCOS), digestive disorders, hypertension etc. Beyond their nutritional facts, millets are drought resilient, require less water and inputs, making them a viable crop in the face of climate change and sustainability. This article explores the types of millets, their nutritional content and revitalizing traditional food systems. These efforts intents to stimulate a move towards better, food choices, by highlighting the significance of millets, ushering in a new era in the global food scene.

Keywords: Millets, sustainability, diabetes, obesity, hypertension.

Introduction

India is the largest producer of millets across the globe. Millets are produced in 21 states of India, with major contributors being Rajasthan, Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Haryana, Kerala, Jharkhand, and Uttarakhand. Rajasthan, in particular, is considered the primary producer, accounting for 29.05% of the total area dedicated to millet cultivation. Before the 1960s, millets were widely consumed in India, but later, the preference shifted towards wheat and rice to combat food shortages.

In India, after the green revolution, wheat and rice gained popularity due to the introduction of high yielding varieties, making them staple food of the country. Everchanging food habits, increased production and the commercialization of wheat and rice made them more appealing to the population. In rural parts of India, millets remained a part of their diet for a while. However, as the year passed, even rural communities gradually shifted to wheat and rice and leaving millets only a small portion on their plates. By increased production of wheat and rice scientists have successfully overcome the food scarcity. Henceforth, wheat and rice have become staple and consumed by every person since then. But do you know that consuming only wheat and rice and less and no consumption of millet has uprisen many health problems and related issues?

The situation worsens more when wheat flour is refined and converted into refined flour or all-purpose flour. Children and adults are becoming addicted to it, different food items like momos, noodles, thukpa, bread that are made up of refined wheat flour and have added flavors hurt one's gut.

As the time changes, people began to recognize the associated health issues with overconsumption of refined wheat, wheat and rice. This led to renewed awareness of the nutritional benefits of millets. Today, a global wave of interest is once again highlighting the health benefits of the millets, bringing them back into focus as a valuable part of a daily diet. The government realized that we had left our most nutritious gem far behind. Hence, in the year 2019 government of India and United Nations decided to reintroduce millets around the globe and celebrate 2023 as an International year of millets. Firstly, the advertisement was done by different media like TV, Radio, Newspaper, billboards, leaflets, etc. Later involvement of government departments/NGOs and autonomous bodies was initiated. Many programs, campaigns, free seed distribution schemes, and competitions related to millets were organized throughout the year. That was a successful notion in creating awareness among the population so far. Millets are now becoming popular not only in India but around the globe. Demands have increased in recent months. It is now being sold on online websites also. Farmers are getting good prices. We can say Millet was a talk of the year.

Millets are a group of small-seeded grains that belong to the grass family and are commonly grown in Asia and Africa. Millets are known to be 'mota anaaj' in Hindi, is a coarse grain, more nutritious than any other grains, rich in dietary fibre, protein, antioxidants, micronutrients like magnesium, iron, potassium, phosphorus, calcium etc.

Cultivating millets offers several advantages, such as the ability to withstand drought, quicker maturation (usually within 120 to 150 days), lower dependency on chemicals and fertilizers, and adaptability to barren or less fertile lands. Based on seed size, millets are divided into two categories: the first includes crops like sorghum and pearl millet, which have larger seeds, and the second comprises smaller-seeded crops like finger millet, foxtail millet, barnyard millet, little millet, and kodo millet. Apart from India, millets are also cultivated in certain regions of Africa and Indonesia. Due to the abundant presence of essential nutrients, millets are also referred to as "nutri-cereals" or popularly known as 'Shri Ann' in India. Consuming millets in our daily routine can help us combat serious issues like malnutrition, overcoming the disorders and diseases and promoting overall health.

Different types of millets and their nutritional value

There are various types of millets, let's explore some specific millets and their benefits.

Finger millet:

When we talk about millets, the first word that comes to our mind is 'Finger millet'. The scientific name of Finger millet is *Eleusine coracana*, locally Finger millet is known as 'Ragi' in the South and 'Mandua' in the North. One hundred grams of Ragi contains 344 mg of calcium, significantly higher than rice (7.49 mg) and wheat (39.36 mg). Adequate calcium intake helps prevent severe conditions like rickets, osteoporosis, osteomalacia, osteopenia, osteoarthritis, and dry skin diseases. For women facing calcium deficiency after menopause, consuming Ragi can be beneficial. For those who is unable to consume milk due to gas-related issues, Ragi is a good alternative for calcium, as 100 ml of milk contains 128.9 mg of calcium, less than what is found in Ragi. Besides calcium, Ragi is rich in protein (7.3 gm), iron (3.9 gm) and other micronutrients such as magnesium (137 mg) which aids not only in bone health but also in the proper functioning of the kidneys and heart.

Ragi is also a good source of Vitamin B3 (Niacin), which enhances brain function and also good for skin. It contains ample amounts of fibres that help maintain a healthy digestive system. In the southern states of India, Ragi is consumed in larger quantities, with Karnataka being the top producer of Ragi in the country. By preserving the value of Ragi, it can contribute to creating diverse and nutritious food items.


Pearl millet:

Continuing with other popular millets, another significant one is 'Pearl millet' commonly known as "Bajra" in Hindi. The scientific name of Pearl millet is Pennisetum *glaucum.* In India, Bajra is the third most cultivated grain after rice and wheat, with Rajasthan being the leading producer. A Bajra roti has 2.6 mg of iron, while a wheat roti contains 0.8 mg. 100 gm of bajra flour, has 8-10 mg of iron, compared to 0.65 mg in rice and 3.97 mg in wheat. Consuming iron-rich foods like Bajra helps prevent conditions like anemia. Additionally, Bajra is a source of other essential nutrients, including various types of Vitamin B, iron (11.6 gm) calcium (42 mg), and magnesium (137 mg), beneficial for heart health.


Indian millet:

Next on the list is 'Indian Millet', also known as Jowar, Sorghum. The scientific name of Indian millet is *Sorghum bicolor.* It is rich in protein, Vitamin B, magnesium, folate, and other essential nutrients. Jowar flour contains 39.4 mg of folate per 100 gm, helping prevent anemia, whereas wheat contains 3.1 mg and rice 9.32 mg. The magnesium (165 mg) in Jowar contributes to heart health, energy production, and protein synthesis. Jowar also contains protein (10.4 gm). calcium (13 mg), iron (3.36 mg) It is beneficial for women with ovarian cysts and individuals with high blood pressure. Jowar is gluten-free and contains flavonoids, providing resilience against diseases like cancer.


Proso millet:

The scientific name of proso millet is *Panicum miliaceum.* Local name of Proso millet is Cheena, which is considered one of the oldest grains consumed by humans. It contains vitamin B, fibre, magnesium, calcium, zinc, and iron. In 100 grams of Proso millet, there is 12.5 gm of protein, 112 mg magnesium, 1.6 mg zinc, 206mg phosphorus, 195 mg potassium etc. Consumption of Proso millet can protect against serious diseases like pellagra, characterized by symptoms such as loose motion, memory weakness, and skin diseases, ultimately preventing death.


Little millet:

The scientific name of Little millet is *Panicum sumatrense*. Little Millet, locally known as Kutki is a good source of magnesium, which helps prevent heart-related issues. It increases resistance to diseases and contains more folic acid than wheat and rice. In 100 grams of Kutki, there is 36.2 mcg of folic acid, 9.3 mg calcium, 2.1 mg zinc, 300 mg potassium, 220 mg phosphorus, 114 mg magnesium and it can be consumed by making sweets, snacks, etc.


Foxtail millet:

The scientific name of Foxtail millet is Setaria *italica*. Foxtail millet is commonly known as Kangani in Hindi is a traditional grain used especially in South India and other tribal regions. 100 gm of foxtail millet contains 12.3 gm of protein, 290 mg phosphorus, 31 mg calcium 250 mg potassium and 2.4 mg zinc, 81 mg magnesium. Kangani is good for diabetic patient, aids digestion and boosts energy.


Barnyard millet:

Moving on to the next millet, there is 'Barnyard millet' also known as Madira, Jhangora, or Sanwa. The scientific name of barnyard millet is *Echinochloa crus-galli*. It is cultivated in marginal lands where rice and other grains are less abundant. Barnyard millet has the shortest growth period among all millets, taking approximately six weeks. In many parts of the country, it is also used as fodder for livestock and is rich in nutrients such as iron, calcium, Vitamin B types, phosphorus, etc. Being gluten-free, Barnyard millet is suitable for those with gluten allergies, and it contains antioxidants that may help combat serious diseases like cancer. It also has beta-glucan, a type of soluble fibre that is good for heart, sugar management and immunity. Barnyard millet has gamma-amino butyric acid GABA, a neurotransmitter that helps in manage insulin production in the body and supports in diabetes management. 100 gm of barnyard millet has 6.2 gm of protein, 15.2 mg iron, 11 mg calcium, 280 mg phosphorus, 230 mg potassium etc.


Kodo millet:

The scientific name of Kodo millet is *Paspalum scrobiculatum*. Kodo Millet is commonly known as Koni, similar to rice but used after removing the outer husk. It contains Vitamin B1, B12, good fats, and fibres. Kodo millet helps prevent blood-related issues, supports DNA and nerve function, and is beneficial for those with Alzheimer's disease. It is gluten-free and aids in managing restless leg syndrome. 100 gm of Kodo millet has 9.8 gm protein, 27 mg calcium, 1.7 mg zinc etc. Including these millets in our diet can contribute to a healthier lifestyle and combat various nutritional deficiencies and health issues.


Conclusion

Each variety of millet holds its own unique sets of nutritional properties, making these ancient grains increasingly popular in modern diets. Rich in fibre, protein, essential minerals, antioxidants, millets are versatile and offer numerous health benefits. Their gluten free nature makes them an excellent choice for individuals with gluten intolerance or celiac disease, while their low glycemic index makes them idle for managing blood sugar levels. Millets can be used to prepare a wide range of delicious and nutritious dishes both traditional and modern. Millets are commonly consumed as rotis and sattus, but in order to enhance the taste of millets, it can be incorporated into various dishes like from ladoos, sweets, biscuits, and halwa for those with the sweet tooth to savoury options like samosas, idlis, dosas, namkeen, umpa and porridge. These grains fit seamlessly into a variety of meals. Additionally, millets are often incorporated into regional recipes across India, highlighting their cultural significance and culinary adaptability. Recognizing their immense potential, the United Nations and the Government of India declared 2023 as the international year of Millets. Indian Council of Agricultural Research (ICAR) institutes like Krishi Vigyan Kendra (KVK) in collaboration with Department of agriculture & farmers welfare have joined efforts to promote the millet production and consumption among farmers in remote villages. The Government of India has also distributed free millet seeds to farmers as a part of this initiative.

Additionally, ICAR institutes like Agricultural Technology Application Research Institute (ATARI) initiated the millet recipe competitions among farm women through various KVKs encouraging the inclusion of millets in daily diets. These initiatives aimed to promote the global production, consumption, awareness of millets encouraging farmers to grow these sustainable crops and motivating consumers to incorporate them into their diets. Millets not only support food security, but also help reduce the environmental impact of farming due to their low water and input requirements. Beyond human consumption, millets also serve as valuable for the livestock supporting the agricultural ecosystem. In some regions, they are even utilized as a source of biofuel and an integral to various traditional and sustainable practices. Given their numerous health benefits, and environmental advantages, it is highly recommended to include millets into one’s daily meal alongside staples like wheat and rice. Doing so not only promotes better health, but also contribute to sustainable agriculture and a more resilient food system.

Nutrient Cycling and Regulation: Microbial communities facilitate the bioavailability of essential macronutrients (e.g., nitrogen, phosphorus), thereby curbing eutrophication risks while concurrently maintaining agronomic soil fertility (Bashan et al., 2016).

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NON-DESTRUCTIVE TECHNOLOGIES FOR SEED GERMINATION ASSESSMENT

Introduction

Seeds are the building blocks of life on Earth. They are integral to agriculture, reforestation, and ecosystem restoration efforts, and they form the genetic basis for future generations of plants. The conservation of seeds not only ensures that plant species survive but also supports agricultural productivity, resilience to climate change, and biodiversity. With an estimated 1 million species at risk of extinction due to human activity and environmental degradation, the urgent need for effective seed conservation cannot be overstated. Seed conservation faces numerous challenges, such as the degradation of genetic diversity, loss of habitat, and the impact of invasive species. Furthermore, the task of evaluating seed quality, viability, and genetic health is complex and often resource-intensive. AI can address these challenges by automating seed analysis and improving the efficiency and accuracy of conservation efforts.

Key Terms for Seed Assessment

- **Germination Rate**: The percentage of seeds that successfully sprout under optimal conditions. This metric indicates the viability and quality of the seeds.
- **Seed Vigor**: The potential for rapid, uniform emergence and development of seedlings under a wide range of field conditions. High-vigor seeds are more likely to establish healthy plants.
- **Seed Quality**: The overall health and viability of seeds, including factors like size, shape, color, and surface texture. High-quality seeds are essential for ensuring strong crop performance.
- **Machine Learning**: A subset of AI that involves training algorithms to learn from and make predictions based on data. In seed assessment, machine learning models can classify seeds and predict germination outcomes.

Assessment Based on Germination Ability

Germination ability is a critical indicator of seed quality. Traditionally, assessing germination involves destructive testing, where seeds are sown and monitored for sprouting. AI-powered non-destructive technologies offer a more sustainable alternative by analyzing seeds' external and internal attributes using advanced imaging techniques. AI-based systems use advanced image recognition and deep learning algorithms to analyze seed images, providing rapid and objective assessments of germination status. These systems can distinguish between viable and non-viable seeds with high accuracy, ensuring that only the best seeds are used for planting.

Non-Destructive Technologies for Seed Assessment

Non-destructive technologies are essential for seed assessment, allowing for the evaluation of seed quality without damaging the seeds. Key non-destructive technologies include:

Machine Vision: This technology uses cameras and image processing algorithms to analyze seed images for size, shape, color, and surface texture. It can detect defects and classify seeds based on quality attributes (Grauda, Bubeck and Michalski, 2020).

NIR Spectroscopy: Techniques such as Near-Infrared (NIR) Spectroscopy measure the interaction of light with seed samples to determine their chemical composition and quality. This method is fast and accurate, providing insights into seed viability and vigor (Edelstein, Tikhomirov and Markin, 2022).

Hyperspectral Imaging: Capturing spectral information across a wide range of wavelengths, hyperspectral imaging can detect subtle differences in seed quality; identify defects, diseases, and variations in seed composition (Stensvand and Tveite, 2021).

Thermal Imaging: This technology measures the temperature distribution of seed samples, which can indicate their viability and moisture content. It is non-invasive and provides rapid results (Jones, Brown and Harper, 2019).

Electronic Nose: Using sensors to detect volatile compounds emitted by seeds, this method assesses seed quality based on their aroma profile, offering a unique approach to seed assessment (Smith & Anderson, 2023).

Role of Artificial Intelligence (AI)

Artificial Intelligence (AI) is playing a transformative role in enhancing non-destructive seed assessment technologies. By integrating machine learning algorithms and deep learning models, AI systems can process and analyze large datasets collected from these tools, leading to more accurate, consistent, and comprehensive seed evaluations. AI-driven models improve the precision of defect detection, pattern recognition, and predictive analytics, making the entire process more efficient and scalable.

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NUTRIENT DEFICIENCIES IN PLANTS: HOW TO IDENTIFY & TREAT?

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Introduction

To assess nutrients deficiency in plants, most agriculturists primarily depend on visual symptoms, soil analysis and plant tissue analysis. The seventeen essential plant elements are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl) and nickel. Carbon, hydrogen, and oxygen are obtained from air and water. Nitrogen, phosphorus, and potassium are derived from general fertilizers. Calcium, magnesium, and sulphur are variously derived from calcium carbonate (limestone), calcium hydroxide (hydrated lime), dolomite (calcium and magnesium carbonate), epsom salts (magnesium sulphate), elemental sulphur, and sulphate salts. Iron, zinc, manganese, copper, boron, and molybdenum are derived from minor element formulations, including soluble foliar fertilizers.

Generally, a nutrient deficit arises as a result of low soil nutrient levels. However, prevailing environmental conditions, soil properties, growth conditions and root diseases can restrict nutrient uptake and induce deficiencies in crops even if soil nutrient levels are estimated sufficient for optimum yield. For example, low or high soil pH, soil compaction and overly wet or dry soil may prevent nutrient uptake. A helpful diagnostic method to diagnose nutrient deficiency in crops is by visual examination of symptoms. However, this tool does not always provide a definitive diagnosis of the nutrient status of the plant. Keep in mind other conditions are capable of causing symptoms that closely mimic those of nutritional deficiencies. To counter this, visual signs should be corroborated with plant tissue and soil testing, and review of the background of nutrient applications to the field. Adequate knowledge of visual symptoms and tissue testing can help direct corrective actions in-season or preventive action in the following season to avoid yield loss.

Symptoms associated with deficiency can take many forms including chlorosis, necrosis and irregular development. Chlorosis occurs when the production of chlorophyll is reduced which results in a yellow to pale green leaf colour.

Nutrient deficiency is the main cause of stunted plant growth often leading to complete crop losses. Nonetheless, crop starvation for micro or macronutrients can be diagnosed visually, and prompt identification will save the affected yields.

Frequent visual symptoms of nutrient deficiency in plants comprise malformation, discoloration, dotting, crinkling, and even necrosis. When a visual examination is not feasible, satellite monitoring is another convenient way of preliminary nutrient deficiency diagnostics. Manifestations of different elements' undersupply can be similar, so it is critical to understand which one is lacking and provide it on time.

Nutrient deficiency symptoms and their remedial measures in plants

A. Older or lower leaves affected:

Nitrogen:

Plants light green light yellow, drying to light brown colour, stalks short and slender if element is deficient in later stages of growth. Application of recommended doses of N fertilizers is essential. If the deficiency is observed during the growth phase, 1% of urea can be used.

Phosphorus:

Plant dark green, often developing red and purple colour, lower leaves sometime yellow; turning to greenish brown black colour. Stunted shade plants but have stronger stems. Recommended doses of P and foliar spray of 2% DAP or 1 % super phosphate extract.

Magnesium:

Lower leaves mottled or chlorotic, without dead spots, leaves may redden as with cotton, sometimes with dead spot tips and margin turned or curved upwards, stalks slender. Soil application of Dolomite or Gypsum Salt or $MgSO_4$ or $7H_2O$ depending upon the deficiency and 0.5% of Gypsum salt as foliar spray is beneficial.

Potassium:

Spots of dead tissue small usually at tips and between veins, more marked at margins of leaves, stalks slender. Stocky appearance of stem with short internodes is also indicate potassium deficiency. Its deficiency is usually not observed in Indian soils but if occurs then foliar spray of K @1 % KCl or 1% K_2SO_4 is beneficial.

Zinc:

Spots generalized, rapidly enlarging and generally involving areas between veins eventually involving secondary and even primary veins, leaves thick, stalks with shortened inter nodes. Soil application of Zinc Sulphate at 12.5 - 25 kg/ ha and foliar spray @ 0.5% correct its deficiency.

B. New or bud leaves affected (symptoms localized)

Calcium:

Young leaves of terminal bud at first typically hooked, finally dying back at tips and margins so that latter growth is characterized by a cut out appearance at these points, stalks finally die at terminal bud. Lime application depending upon the pH and foliar spray of 1 % calcium nitrate (fruit crops).

Boron:

Young leaves of terminal bud becoming light green at bases, with final break down here; in later growth, leaves become twisted, stalk finally dies back at terminal bud. Soil application of Borax @ 10 kg/ ha and foliar spray of 0.5 % Borax will correct the deficiency of Boron.

Copper:

Young leaves permanently wilted or marked chlorosis; twig or stalk just below tip and seed head often unable to stand erect in later stage when shortages are acute. Soil application of Copper Sulphate at 10 kg/ha and foliar spray of 0.5% $CuSO_4$ will correct the copper deficiency.

Manganese:

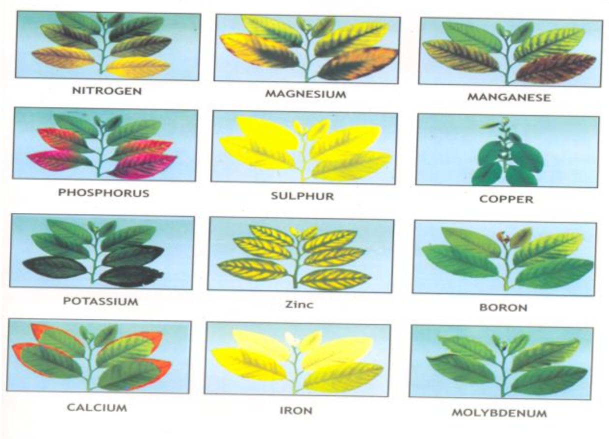
Sports of dead tissue scattered over the leaves smallest veins tend to remain green producing a checkered or reticulated effect. Soil application of Manganese sulphate at 25 kg/ ha and foliar spray of 0.2-0.4% $MnSO_4$ will correct its deficiency.

Sulphur:

Young leaves with veins and tissue between veins light green in colour. Any of the sulphur containing fertilizers application is most effective in correcting the deficiency symptoms of Sulphur.

Iron:

Young leaves chlorosis, principal veins green, stalks short and slender, thin and erect stems. Soil application of Ferrous sulphate at 50kg/ha and foliar spray of 0.5% Ferrous sulphate (for calcareous soil, only foliar spray is recommended) is the corrective measure for iron deficiency.



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Opuntia ficus-indica PRICKLY PEAR: THE DESERT FRUIT RISING IN THE HILLS OF JAMMU REGION

INTRODUCTION

Despite having origins in arid and semi-arid environments, the Prickly Pear cactus belonging to the *Opuntia* genus has adapted to diverse environmental conditions across the globe and has earned a reputation through its nutritional and ecological importance. Even though many species are cultivated these days, several varieties still exist in the wild and are cultivated for consumption, especially in rural and tribal communities. In India, species like *Opuntia elatior* and *Opuntia ficus-indica* are two widely known species, the latter having been introduced and naturalized in various arid zones, including parts of Gujarat, Rajasthan, and the Deccan Plateau. The Jammu region of the Union Territory of Jammu and Kashmir has recently proved to have potential for the production of *Opuntia ficus-indica*, especially in its Kandi (dry belt) region, where poor soil fertility and water stress hinder the cultivation of conventional crops. The low-maintenance cactus serves as an eco-friendly means for reclaiming land, checking soil erosion, and providing alternative livelihoods for cultivators in water-deficient areas.

Both the traditional consumption of the pads (cladodes) and the fruits (nopalitos or tunas) supply ample of dietary fiber, vitamin C, calcium, magnesium, potassium, and betalains and also they have antioxidant properties. Prickly Pear has anti-inflammatory, cholesterol-lowering and antidiabetic properties. It's also useful as wild and functional food.

The Taxonomy is given in the table below (table 1)

Table 1: Taxonomic Classification of *Opuntia ficus-indica* (L.) Mill

Domain	*Eukaryota*
Kingdom	*Plantae*
Subkingdom	*Viridaeplantae*
Phylum	*Tracheophyta*
Subphylum	*Euphyllophytina*
Infraphylum	*Radiatopses*
Class	*Mangoliospida*
Subclass	*Caryophyllidae*
Superorder	*Caryophyllanae*
Order	*Caryophyllales*
Family	*Cactaceae*
Genus	*Opuntia*
Species	*Opuntia ficus-indica (L.) Mill.Habitat:Shrub/Succulent Cactus*

Source: National Center for Biotechnology Information. (n.d.). *Opuntia ficus-indica* (L.) Mill. In NCBI Taxonomy Database. U.S. National Library of Medicine. https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=371859

Classification of *Opuntia ficus-indica*

The *Opuntia* genus includes more than 150 succulent plant species that are better known as prickly pears. It appears as a succulent cactus with thick flattened pad-shaped (cladodes) and colourful edible fruits called "tunas." In recent times, the region of Jammu, particularly its Kandi (dryland) belt, has experienced the rise of *Opuntia ficus-indica* as a climate-resilient, low-maintenance species.

Fig 1: Prickly Pear

It is found naturally in the wild and is gaining recognition for its potential in land reclamation, sustainable agricultural practices, and alternative food systems.. *Opuntia ficus-indica* occurs naturally and abundantly in India in the states like Gujarat, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, and Madhya Pradesh. It occurs in abundance in the arid tracts of Nashik, Solapur, Jalgaon, Ahmednagar, and Pune in Maharashtra, often used as fodder, erosion control, and for drought-resistant farming systems. It is also widely seen in the Kutch area of Gujarat and across the arid tracts of western Rajasthan, thriving on waste lands and supporting livestock nutrition and land regeneration.

Table 2: Regional Names of Prickly Pear

Language/Region	Names
English	Prickly Pear, Cactus Pear
Marathi	Phadya Nivadung
Hindi	Nagphani, Hatha Thoria
Kannada	Dabbagalli, Paapasu kalli
Punjabi	Nagphana, Tikanther
Assamese	Sagor-phena
Telugu	Nagajemudu, Nagadali, Pathi-donda
Tamil	Pirandai, Kalli
Bengali	Nagphana
Rajasthani	Thor, Bairi
Manipuri	Maepokpo

Source: India Biodiversity Portal. (n.d.). Opuntia ficus-indica. https://indiabiodiversity.org/species/show/265088

Traditional Uses of Opuntia ficus-indica

Opuntia ficus-indica (prickly pear) is a xerophytic cactus species used in traditional medicine for its anti-inflammatory, hypoglycemic, and gastroprotective benefits. In the Jammu region, especially areas like Kathua, Samba, and Udhampur some local dwellers such as the Gujjars and the Bakarwals feed the cladodes (pads) to livestock during droughts and apply mucilage on the skin to treat inflammation and joint pain. The fruit is also prized for its health benefits, aiding digestion and helping relieve ulcers.

Fig 2: Harvested Prickly Pears

Fig 3:Ripened Prickly Pears

Uses of Specific Plant Parts

- **Fruit:**
  In the dry foothill regions of Jammu such as Kathua, Samba, Udhampur, locals consume the ripe fruits to relieve the digestive issues like constipation and dyspepsia, owning to the fruit's rich mucilage and fiber. The pulp is used to treat sore throats and is believed to support liver function and reduce bile disorders.
- **Seeds:**
  In traditional rural remedies, older villagers crush the seeds and mix them with warm water to treat kidney stones over a 10–15 days period. This is attributed to the seeds mild diuretic and detoxifying effects, though these practices are under-documented in formal Ayurvedic literature.
- **Cladodes (Pads):**
  Young pads are used to address gastrointestinal problems such as bloating and ulcers. In Samba and Kathua, the pads are warmed, lightly coated with mustard or coconut oil, and applied as a poultice for joint swelling, goiters, or insect bites. The mucilage supports healing and inflammation reduction.

Table 3: Technological Applications of Prickly Pear Cactus

Component	Application	Technology	Value Added	Relevance to J&K
Fruit	Juice, Concentrates	Cold pressing, pasteurization, filtration	Rich in antioxidants and vitamin C	Suits nutraceutical and health drink market
Fruit Pulp	Jam, Jelly, Candy	Pulp extraction, evaporation, pectin use	Shelf-stable sweet products	Viable for small rural food enterprises
Cladodes (Pads)	Dietary Fiber Powder	Sun/cabinet drying, grinding	Food thickener, diabetic diet aid	Benefits dryland farmers in foothill regions
Cladode Gel	Skincare, Herbal Cosmetics	Mucilage extraction, preservation	Natural hydrator and anti-inflammatory	Opens opportunities for herbal cosmetic startups
Seeds	Edible Oil	Cold-press extraction	Oil high in linoleic acid and antioxidants	Export potential as niche health product
Peel	Natural Dye/Pigments	Solvent extraction, drying	Colorant for foods/textiles	Can support traditional textile and craft sectors
Whole Fruit Waste	Bioethanol, Compost	Fermentation, anaerobic digestion	Organic fertilizer, clean biofuel	Aligns with circular agriculture and sustainability goals

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Conclusion: Prickly Pear: A Dryland Solution to a Greener Future

Opuntia ficus-indica (Prickly Pear) stands out as a viable crop for Jammu's dryland zones, particularly the Kandi belt. Its adaptability to harsh conditions, along with its nutritional, medicinal, and commercial potential from antioxidant-rich fruits and healing pads to seed oil and natural dyes makes it an asset for land restoration and economic upliftment. By combining age-old wisdom with modern technology, this cactus can help turn degraded landscapes into productive farmland, support climate-resilient agriculture, and unlock fresh opportunities for rural growth in Jammu & Kashmir.

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Phytoplasma Diseases Vectored by Insects

Introduction

Phytoplasmas (formerly known as *Mycoplasma-Like Organisms* - MLOs) are important insect-transmitted pathogens causing over 700 plant diseases, many of them lethal. They are non-culturable, degenerate gram-positive prokaryotes closely related to mycoplasmas and spiroplasmas.

History

Doi & Ishii discovered wall less microorganism in phloem of mulberry plants infected with mulberry dwarf. Proposed Mycoplasma Like Organisms (MLO) or chlamydia like organisms.

Characteristics of Phytoplasmas

- Lack a cell wall (pleiomorphic or filamentous)
- Have a three-layered lipoprotein unit membrane (10 nm thick)
- Contain cytoplasm, ribosomes, and strands of nucleic acid
- Shape: Spheroidal, ovoid, or filamentous
- Present in the phloem sieve tubes of host plants
- Cannot be cultured on artificial nutrient media

Phytoplasma Taxonomic Groups

Main groups (16Sr series) Subgroups (As 16Sr I - A)

16Sr Group	Group Name	Species
16Sr I	Aster yellows	Ca. Ph. *asteris*
16Sr II	Peanut witches' broom	Ca. Ph. *aurantifolia*
16Sr III	X-disease	Ca. Ph. *pruni*
16Sr IV	Coconut lethal yellowing	Ca. Ph. *palmae*
16Sr V	Elm yellows	Ca. Ph. *ziziphi*, Ca. Ph. *Vitis* Ca. Ph. *ulmi*
16Sr VI	Clover proliferation	Ca. Ph. *trifolii*
16Sr VII	Ash yellows	Ca. Ph. *fraxini*
16Sr VIII	Luffa witches'-broom	Ca. Ph. *luffae*
16Sr IX	Pigeon pea witches' broom	Ca. Ph. *phoenicium*
16Sr X	Apple proliferation	Ca. Ph. *mali*, Ca. Ph. *pyri*
16Sr XI	Rice Yellow Dwarf	Ca. Ph. *oryzae*
16Sr XII	Stolbur	Ca. Ph. *solani*
16Sr XIII	Mexican periwinkle virescence	Undefined
16Sr XIV	Bermuda white lead	Ca. Ph. *cynodontis*
16Sr XV	Hibiscus witches'-broom	Ca. Ph. *brasiliense*

Taxonomic Position

Class: Mollicutes

Order: Acholeplasmatales

Family: Acholeplasmataceae

Genus: Phytoplasma (Candidatus Phytoplasma)

Other Related Genera:

- *Spiroplasma* - Helical, motile, infects plants & insects
- *Mycoplasma* - Infects animals & humans
- *Acholeplasma* - Infects animals, plants, or acts as saprophytes
- *Entomoplasma* - Infects insects and plants

Note: 'Candidatus' status indicates they cannot be cultured.

13 major sub-clades (groups) of phytoplasma

1. Stolbur
2. Aster Yellows
3. Apple Proliferation
4. Coconut Lethal Yellowing
5. Pigeon pea Witches Broom
6. X Disease
7. Rice Yellow Dwarf
8. Elm Yellows
9. Ash Yellows
10. Sunnhemp Phyllody
11. Loofah Witches Broom
12. Clover Proliferation
13. Peanut Witches Broom

Eight Novel Groups

1. Australian Grapevine Yellows
2. Italian Bineweed Stolbur
3. Buckthorn Witches Broom
4. Spartium Witches Broom
5. Italian Alfalfa Witches Broom
6. Cirsium Phyllody
7. Bermuda Grass White Leaf
8. Tanzian Lethal Decline

Symptoms of phytoplasma diseases

- Phyllody
- Virescence
- Witches Broom
- Yellowing
- Little leaf
- Reduction in leaf size
- Proliferation
- Numerous stem

Other Symptoms

- Necrosis (Death of cells / tissues)
- Dieback
- Stunting of plants
- Bunchy top

Mechanisms of Introduction into Host Plants

- **Vegetative propagation** (grafting)
- **Parasitic plant connections** (e.g., dodder *Cuscuta spp.*)
- **Vector insects** feeding on plants
- **Seed transmission** (e.g., Coconut lethal yellows, Alfalfa witches broom)

Mechanism of Spread

Feature	Details
Mode	Phloem feeders (Hemiptera)
Stages	Adults and nymphs both transmit
Feeding	Selective, specific, non-destructive
Pathogen relationship	Propagative and persistent
Transmission	Sometimes transovarial

Examples

- *Halyomorpha halys* transmitting witches' broom to *Paulownia spp.*
- *Stephanitis typica* causing Coconut root wilt

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Movement within the vector

- From gut lumen into epithelial cells
- Released into the space between plasmalemma and the basal lamina
- Move to the haemolymph (circulate)
- Replicate in various tissues including salivary gland cells
- Move into salivary ducts
- Introduced into the plant hosts

Important Phytoplasma Diseases Vectored by Insects

Diseases	Symptoms	Vector(s)
Sesame Phyllody	Vein clearing, phyllody, sterile plants	*Orosius albicinctus*
Eggplant Little Leaf	Small, bushy, sterile plants	*Hishimonas phycitis, Amrasca devastans*
Sugarcane Grassy Shoot	Profuse tillering, grassy appearance	*Proutista moesta, Rhopalosiphum maidis, R. sacchari*
Coconut Lethal Yellowing	Yellowing, nut drop	*Myndus crudus*
Sandal Spike	Spike-like branches	*Grafting, Dodder, Moonia albimaculata, Jasus indicus, Nephotettix virescens*
Potato Purple Top	Chlorosis, nodal swelling, aerial tubers	*Orosius albicinctus, Alebroides nigroscutellatus*
Chinese Jujube Witches Broom	Bushy growth	*Hishimonas chinensis*
Maize Bushy Stunt	Bushy, stunted plants	*Dalbulus maidis, D. eliminatus, G. nigrifrons*
Aster Yellows	Yellow star-shaped flowers, no seeds	*Macrosteles fascifrons*
European Stone Fruit Yellows	Yellowing in stone fruits	*Cacopsylla pruni*
Chrysanthemum Yellows	Yellowing, stunting	*Macrosteles quadripunctulatus*
Apple Proliferation	Proliferation, stunting	*Cacopsylla picta*

Spiroplasma Diseases

Disease	Details
Corn Stunt	Vector: *Dalbulus maidis*
Horse Radish Brittle Root Disease	Spiroplasma involvement

Conclusion

Phytoplasma diseases transmitted by insect vectors pose serious threats to global agriculture. Their persistence and complexity of transmission mechanisms demand integrated management strategies involving vector control, plant health monitoring, and clean planting materials.

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Phytoplasma Diseases Vectored by Insects

Abstract:

As the global population nears eight billion, the demand for cereals, grains, vegetables, animal protein, and energy continues to rise. Simultaneously, the impact of the covid-19 pandemic has led to a surge in world hunger. After staying relatively stable for five years, the prevalence of malnutrition (POU) rose from 8.4% to around 9.9% in just one year, making it even more challenging to reach the zero-hunger goal by 2030.

To sustainably boost agricultural productivity, it is crucial to implement optimal plant nutrition practices. A deficiency in any single nutrient can restrict crop growth, productivity, and quality. Since 2015, Polyhalite, a new natural mineral fertilizer, has emerged as a notable alternative. Polyhalite delivers four essential macronutrients -K, Ca, Mg, S, in one granule. It offers unique features, such as low salt content and long-lasting nutrient availability. Additionally, Polyhalite has a smaller carbon footprint compared to similar fertilizers and is suitable for organic farming systems. Research on Polyhalite as a sustainable multi-nutrient fertilizer consistently demonstrates its ability to enhance agricultural productivity, significantly improving the yield, health, and quality of various crops.

Introduction:

Food production is mostly reliant on agriculture, making effective management within production systems increasingly important as producers strive to boost agricultural output while maintaining environmental sustainability. The challenge lies in increasing productivity by producing more food with in a limited cultivated land. In this context, adopting best practices for proper plant nutrition is crucial to success. It is important to ensure that plants receive the right amounts of all the nutrients required by each species. The nutrient requirements of plants are interconnected, and a deficiency in any single nutrient can hinder the growth, productivity, and quality of crops, as explained by Justus von Liebig's "law of the minimum" (Browne *et al.*, 1942). This implies that, in addition to Nitrogen (N), Phosphorus (P), and potassium (K), attention should also be given to other macronutrients like Calcium (Ca), Magnesium (Mg), and Sulfur (S), as well as the management of micronutrients. Balanced fertilization is key to unlocking the full potential of crop yields.

Although Potassium (K) is present in most rocks and soils, its economic sources are primarily found in sedimentary evaporitic deposits in chloride and sulfate forms. Only a few potassium minerals are used in fertilizer production, with sylvinite and carnallite being the most common for manufacturing Muriate of Potash (Kcl), the most abundant potassium fertilizer. These mineral deposits were created millions of years ago through the evaporation of saline waters in confined basins, resulting in concentrated minerals at depths ranging from 300 meters to over 2,500 meters in some areas. Potassium fertilizers can also be extracted from lakes with high saline concentrations, such as those in Israel and Jordan, where Kcl is produced through evaporation from the dead sea (Roberts *et al* 2005). In addition to Kcl, other potassium sources like Potassium Sulfate (K_2So_4), double potassium-magnesium sulfate from langbeinite ($K_2So_4 \cdot 2MgSo_4$), and potassium nitrate (KNo_3) have been utilized in recent decades.

Formation and extraction of Polyhalite mineral

Polyhalite is a dihydrated sulfate of potassium, calcium, and magnesium ($K_2Ca_2Mg(So_4)4 \cdot 2H_2o$). It is a natural mineral formed through successive marine evaporation events over time and holds significant promise as a potassium fertilizer due to its low Chlorine (cl) content and its rich composition of K, Ca, Mg, and S. Polyhalite is commonly found as part of marine evaporites, alongside halite (NaCl) and anhydrite ($CaSo_4$). Deposits of Polyhalite are located in various regions around the world, with its initial discovery in austria and description by stromeyer (1818), followed by later findings in other parts of europe. Significant polyhalite deposits were later recorded in Texas and New Mexico, USA (schaller and henderson, 1932), then in Russia, and eventually in the zechstein basin in yorkshire, UK (stewart, 1949).

In recent years, Polyhalite has gained recognition as a potential fertilizer, partly due to rising KCl prices, which have encouraged the adoption of alternative Potassium sources. Additionally, Polyhalite provides Sulfur (S), supporting crop productivity and quality. Although its extraction volume remains relatively low compared to other fertilizers, production has significantly increased. The industry is evolving, with Israel chemicals limited (ICL UK) mining polyhalite at a depth of 1,200 meters in the boulby mine, yorkshire, UK , and distributing approximately 800,000 tons per year as fertilizer worldwide.

This naturally occurring mineral, known for its unique properties, serves as a multi-nutrient fertilizer. Notably, it is one of the few potassium sources suitable for Chloride-sensitive crops. The earliest recorded use of Polyhalite as a fertilizer date back to (Fraps *et al*,.1932), who conducted pot experiments with corn and sorghum in Texas, USA. His findings demonstrated that Polyhalite could effectively function as a potassium fertilizer, offering 96% potassium availability compared to KCl and K_2So_4 fertilizers.

Polyhalite characteristics and properties

Polyhalite is a distinct mineral with exceptional properties, making it a highly promising fertilizer for major crops, offering multiple benefits in terms of yield and quality.

Mineralogical composition

Polyhalite is an evaporitic mineral composed of hydrated Sulfates of Potassium, Calcium, and Magnesium. It crystallizes in the pseudo-orthorhombic triclinic system, though well-formed crystals are rare. Typically, it appears in massive to fibrous forms. The mineral is generally white to grey, as seen in the boulby mine in the UK, but can also exhibit a reddish hue in certain regions due to Iron Oxide inclusions. Polyhalite is a transparent, fluorescent, and non-magnetic, with brittle fractures resembling those of glass and other non-metallic minerals (bindi *et al*., 2005).

Chemical composition

Polyhalite is a naturally occurring mineral that contains four essential macronutrients: Potassium (K), Calcium (Ca), Magnesium (Mg), and Sulfur (S). The Polyhalite extracted from the UK's boulby mine is highly pure (95% Polyhalite) and contains less than 5% Sodium Chloride (NaCl). It also has trace amounts of Boron (B) and Iron (Fe) at concentrations of 300 mg/kg and 100 mg/kg, respectively. Its composition includes 48% So_3 (19.2% s), 14% K_2o (11.6% k), 6% Mgo (3.6% mg), and 17% CaO (12.2% ca), all of which are readily available for plant uptake. Although Polyhalite has a lower water solubility limit than other Potassium sources, when applied within its solubility range, it supplies sufficient K, Ca, Mg, and S to support plant growth (yermiyahu *et al*., 2017).

Natural mineral for direct use in agriculture

Since Polyhalite is a naturally pure mineral with minimal contaminants and nutrients in the form of soluble salts, its production involves only extraction, crushing, and sieving, without any chemical processing. This straight forward production method results in a low carbon footprint (fig. 2), a factor of growing significance for food producers and processors worldwide.

Polyhalite For Sustainable Agriculture

Preserving soil health is essential for sustainable agriculture, and incorporating polyhalite into farming practices can significantly enhance soil quality. Polyhalite contributes to increasing the soil's cation exchange capacity (CEC), which improves both fertility and structure. This improvement supports better moisture retention and stimulates the growth of beneficial microbes, key players in nutrient cycling and organic matter decomposition. Additionally, polyhalite can help to combat soil erosion by promoting stronger crop root systems, which enhance soil stability. By supporting microbial communities, polyhalite may also aid in restoring degraded soils, offering a practical solution for areas facing challenges with soil fertility.

Environmental consideration:

1.Reduced Carbon Footprint in production – Polyhalite is a naturally occurring mineral that undergoes minimal chemical processing, unlike highly processed synthetic fertilizers. This results in lower energy use and decreased CO_2 emissions during production.

2.Reduced Frequency of Fertilizer Applications – Due to its rich blend of essential nutrients like potassium, calcium, magnesium, and sulfur, polyhalite reduces the need for multiple individual fertilizers. This consolidation cuts down on application-related emissions, helping to lower the overall carbon footprint associated with fertilizer use.

3.Reduced Nitrous Oxide (N_2O) Emissions – Overuse of nitrogen fertilizers is a major source of N_2O, a greenhouse gas with a much greater impact than CO_2. Using polyhalite as part of a balanced fertilization strategy can enhance nutrient efficiency and lessen the dependence on nitrogen fertilizers, which may help lower N_2O emissions.

4.Enhanced Soil Carbon Storage – Polyhalite improves soil structure, boosts microbial activity, and supports stronger root growth, all of which contribute to better retention of organic matter and increased carbon sequestration. Healthy soils are more effective at storing carbon, helping to lower CO_2 levels in the atmosphere.

5.Lower Nutrient Runoff and Water Contamination – Polyhalite helps reduce leaching and surface runoff, decreasing the chances of eutrophication. This, in turn can limit methane emissions from damaged aquatic environments.

Conclusion

Polyhalite is a natural fertilizer that provides four essential macronutrients: Potassium (K), Calcium (Ca), Magnesium (Mg), and Sulfur (S). Its's low salinity makes it suitable for various management practices and a wide range of crops. One of its key advantages is the prolonged release of nutrients, making it an effective option for maintaining and optimizing crop nutritional balance.

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Recent Advances in Detection of Phytopathogenic Bacteria

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Introduction:

Plant protection has a major impact on crop yield, nutritional value, and disease. Disease-causing agents like bacteria are persistent problems in sustainable crop cultivation and cause significant losses in food production. Both gram-positive and gram-negative bacteria are the two primary categories of pathogenic bacteria that cause diseases in plant (Cui et al. 2020). Among these, gram-positive and gram-negative bacteria, such as *Pectobacterium carotovorum*, *Xanthomonas campestris*, *Ralstonia solanacearum* among others are particularly destructive. It is essential to diagnose these diseases and identify the bacterial species in order to put quick and effective control measures against them into practice. Large crop losses and an unexpected decrease in the quality of products can result from delayed diagnosis and failing to take proper management measures. Modern techniques that provide significant accuracy, simplicity, and high quality are becoming necessary in recent years due to many problems and difficulties in the use of traditional diagnostic methods which often lack the sensitivity, specificity, and speed required for timely intervention. More advanced techniques are available to detect bacteria in plants, such as polymerase chain reaction (PCR), reverse transcription PCR (RT-PCR), real-time PCR, flow cytometry, nucleic acid hybridization, AI, CRISPR Cas, Next-generation sequencing (NGS) etc. These advanced methods enhance the ability to identify plant-specific pathogens quickly and accurately, facilitating timely intervention and improved disease management. To decrease crop losses and to ensure food security, the ongoing development of detection techniques will be essential to sustainable agriculture.

Advantages of recent detection methods:

- PCR and LAMP are examples of advanced molecular techniques that provide quick and accurate detection, minimizing the detection period.
- Recent methods are able to detect smaller bacterial concentrations, which enables early disease detection before symptoms appear.
- High specificity can be achieved through DNA-based methods, which can differentiate between closely related bacterial strains.
- Mobile technology and biosensors enable on-site testing in the absence of a laboratory.
- Next-generation sequencing (NGS) and other technologies enable multiple diagnoses of several diseases in a single test.

Recent methods of detection of plant pathogenic bacteria:

1. PCR

PCR technique is widely used to detect plant pathogenic bacteria because of its quickness, sensitivity, and accuracy. It is especially useful when saprophytic bacteria interfere with traditional detection methods. Recent advances have improved its efficiency in considering challenges including contamination risk and cost-effectiveness. Factors such as primer specificity, polymerase type, buffer composition, and circulating settings affect how efficiently PCR detects bacteria. These days, PCR is a basic diagnostic technique that is frequently applied either by itself or in conjunction with other techniques. Example: Detection of *Ralstonia solanacearum* in potato using species-specific primers.

2. Real time PCR:

Real-time PCR (qPCR) makes it possible to measure the amount of bacterial DNA present in soil, water, or plant tissues, which helps with early disease detection and treatment. Advanced variants like Digital droplet PCR (ddPCR) increases sensitivity and precision even at low bacterial concentrations, and multiplex qPCR tests allow for the simultaneous identification of numerous bacterial diseases. For example, *Ralstonia solanacearum*, which causes bacterial wilt in a number of crops, and *Xanthomonas oryzae*, which causes bacterial blight in rice, have both been effectively detected using qPCR. These developments facilitate prompt disease management procedures, which support sustainable agriculture.

3. Flow cytometry

Flow cytometry uses a fluorescence-activated organism detector to find cells or particles in a liquid stream. This detector uses light scattering and fluorescence to figure out biological characteristics. This technique can simultaneously assess multiple characteristics such as cell size, fluorescence detection, and differentiation between live and dead cells (Alvarez, 2001). It has test sensitivity comparable to current methods and can distinguish between target and non-target bacterial populations as well as live and dead cells. This method can also be used to analyse antigenic markers, metabolic state, and bacterial viability. Example: Used for rapid detection of *Pseudomonas syringae* in tomato plants.

4. Nucleic acid hybridization techniques

Nucleic acid hybridization is a highly effective molecular method for detecting and identifying plant pathogenic bacteria. This method relies on the principle of complementary base pairing, where a labeled single-stranded DNA or RNA probe binds to its target sequence in the bacterial genome. This technique is highly specific making it particularly useful for distinguishing between closely related bacterial strains and detecting pathogens in complex plant or environmental samples. To identify bacterial pathogens in rice and bean seeds, such as *Pseudomonas syringae pv. phaseoli*, *Xanthomonas campestris pv. phaseoli*, *X. oryzae pv. oryzae*, *X. oryzicola*, and *P. glumae*, nucleic acid hybridization techniques have been successfully used, Dot-blot hybridization is used for detecting *Clavibacter michiganensis* in tomato.

5. DNA sequencing

The insufficient DNA-DNA Hybridization for classification and identification has been replaced by a radical shift in bacterial taxonomy made possible by the advent of quick, inexpensive DNA sequencing and searchable sequence databases. For many bacteria, phenetic or phylogenetic approaches make it simple to compare and evaluate sequences from any gene or from entire genomes. The development of a phylogenetic framework for comprehending the relationships among all creatures through the use of 16S rDNA sequences marked the beginning of the era of sequence-based categorization and identification. The most popular gene for categorization and identification is 16S rDNA due to its widespread use, reproducibility, and ease of use, as well as the abundance of sequences that can be retrieved from carefully curated searchable databases. Example: Whole genome sequencing of *Xylella fastidiosa* to track disease outbreaks.

6. Next-generation sequencing (NGS)

Next-generation sequencing (NGS) has changed the study of phytopathogenic bacteria by enabling comprehensive and objective analysis of plant-associated microbial communities. Unlike traditional diagnostic techniques that sometimes require prior knowledge of the pathogen, NGS allows the simultaneous detection and detection of several bacterial infections, including unexpected or new types. For instance, a study that employed next-generation sequencing (NGS) identified several bacterial infections, some of which had never been detected in the region. NGS is an essential tool for improving plant disease management strategies and deepening our understanding of bacterial phytopathogens due to its high-throughput nature and ability to generate massive amounts of data without the need for particular culture. Example: Metagenomic sequencing to detect *Candidatus Liberibacter asiaticus* (citrus greening pathogen).

7. CRISPR-Cas-based detection systems

The use of CRISPR-Cas-based molecular tools has transformed molecular biology by simplifying site-directed mutagenesis. Despite being widely employed for genome editing, their great specificity and versatility have drawn attention to their usage in plant bacterial detection. For pathogen identification, several Cas variations have been investigated; these usually entail DNA extraction and Cas protein binding to bacterial-specific DNA sequences. This system enables highly specific pathogen identification by using guide RNAs to direct Cas proteins to target bacterial DNA or RNA. Cas12 and Cas13 proteins, with their collateral cleavage activity, amplify detection signals, allowing sensitive and rapid diagnosis. They are perfect for point-of-care diagnostics since they are affordable, extremely sensitive, specific, and frequently need little equipment. This adaptability demonstrates the expanding influence of CRISPR-Cas systems beyond genome editing. Example: CRISPR-Cas12-based detection of *Ralstonia solanacearum* in soil.

8. Artificial intelligence (AI)

As a significant change in computers, artificial intelligence (AI) is revolutionizing robotics by allowing machines to carry out activities that normally require human intelligence. AI is essential to phytopathology because it advances our knowledge of, ability to treat, and ability to prevent plant diseases. AI helps manage disease by identifying minor trends in plant-pathogen interactions through the analysis of massive datasets. AI provides quick and accurate disease diagnosis, in contrast to conventional visual inspection techniques. Research indicates that AI can effectively use deep learning to identify complicated plant diseases like cassava infections. Convolutional neural networks outperform traditional methods and allow mobile-based field detection with over 90% accuracy, increasing the effectiveness and accessibility of disease detection. Example: AI-based image recognition for diagnosing bacterial leaf spot in lettuce.

Conclusion

Recent advances in phytopathogenic bacterial detection have greatly enhanced the detection of plant diseases by enabling the early and accurate identification of bacterial infections. Modern techniques like PCR, real-time PCR, flow cytometry, DNA sequencing, next-generation sequencing (NGS), nucleic acid hybridization, CRISPR-Cas-based detection, and artificial intelligence (AI) have revolutionized the field, whereas traditional methods frequently struggled with specificity, sensitivity, and rapid detection. By enabling early detection-even before visible symptoms manifest-these advanced methods provide faster disease management and lower agricultural losses. There are still issues due to these developments, like the high price of some technologies, the requirement for technical know-how, and the rapid evolution of bacterial pathogens. In the future, research needs to focus on developing more field-friendly devices, incorporating AI for automatic detection, and improving the accessibility and affordability of these diagnostic tools.

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REVOLUTIONIZING RICE CULTIVATION IN INDIA THROUGH GENOME EDITING: THE EMERGENCE OF DRR DHAN 100 (KAMALA) AND PUSA DST RICE 1

ABSTRACT:

Genome editing technologies, particularly CRISPR-Cas9, are ushering in a new era in agricultural biotechnology by enabling highly precise and efficient modifications in plant genomes. These tools are redefining how we enhance desirable traits in crops such as yield, nutritional quality, stress tolerance, and disease resistance. In a landmark achievement for Indian agriculture, two genome-edited rice varieties **DRR Dhan 100 (Kamala)** and **Pusa DST Rice 1** have been successfully developed and released using **Site Directed Nuclease 1 (SDN1)** technology. Unlike conventional genetically modified organisms (GMOs), these varieties do not contain foreign DNA, making them more acceptable to regulators and consumers. DRR Dhan 100 (Kamala), derived from the popular Samba Mahsuri variety, exhibits 19% higher yield, early maturity, drought tolerance, and improved nitrogen-use efficiency. Pusa DST Rice 1, developed from MTU 1010, demonstrates superior resilience to drought and salinity with significant yield advantages under stress conditions. For Indian farmers, especially those in climate-vulnerable and resource-constrained regions, the adoption of these genome-edited varieties could be transformative. These varieties reduce the risk of crop failure, lower input costs, and increase profitability by ensuring stable yields even under adverse environmental conditions. Additionally, early maturing crops allow farmers to grow multiple crops in a year, enhancing farm productivity and income. With increasing climate variability, shrinking arable land, and growing demand for food, genome-edited crops offer a sustainable solution to ensure food and nutritional security. The adoption of such innovative technologies aligns with India's vision of doubling farmers' income and building a climate-resilient agriculture system.

KEY-WORDS:
Genome Editing, CRISPR-Cas9, SDN1 Technology, Rice Improvement, Climate-Resilient Agriculture, DRR Dhan 100, Pusa DST Rice 1, Drought tolerance, Salinity Stress, Sustainable farming.

INTRODUCTION

Rice is not just a staple food it is a lifeline for more than half of the world's population. In India, rice occupies a central role in ensuring food and nutritional security, supporting rural livelihoods, and contributing significantly to the national economy. It is cultivated on over 44 million hectares, making India one of the largest producers and consumers of rice globally.

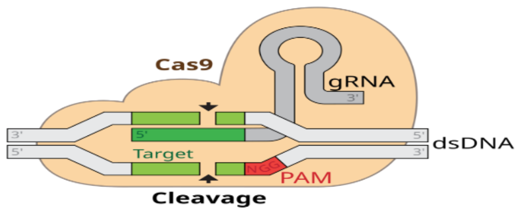
However, the sector faces growing challenges such as declining productivity, increasing biotic and abiotic stresses (like pests, diseases, drought, and salinity), depleting natural resources, and the looming threat of climate change. To address these challenges, Indian agriculture requires a transformative shift toward more efficient and sustainable crop improvement methods. While traditional breeding has contributed significantly to past agricultural gains, it is often slow, labour-intensive, and constrained by the limited genetic variability within cultivated rice varieties. Moreover, the development of high-yielding, climate-resilient varieties through conventional means typically takes 8–12 years.

Genome Editing: A cutting-edge biotechnological advancement offers a promising alternative. It allows precise, targeted, and efficient modifications to the DNA of living organisms without necessarily introducing foreign genetic material. This makes it fundamentally different from conventional genetic modification (GM) technologies and potentially more acceptable to regulators and the public. Among various genome editing techniques, the **CRISPR-Cas9** (Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-associated protein 9) system has emerged as the most powerful and versatile tool. First discovered as part of the bacterial immune system, CRISPR-Cas9 has been repurposed by scientists to locate, cut, and modify specific DNA sequences in plants, animals, and even humans. In plants, this technique is now being widely explored to enhance agronomic traits like yield, stress tolerance, disease resistance, and nutrient efficiency. The recent release of India’s first genome-edited rice varieties **DRR Dhan 100 (Kamala)** and **Pusa DST Rice 1** signals a major milestone in the application of this advanced technology in Indian agriculture. Developed through **Site Directed Nuclease 1 (SDN1)** technology, these rice varieties were improved without integrating foreign DNA, making them non-transgenic in nature. This distinction is crucial in terms of regulatory approval, consumer acceptance, and export potential.

Importantly, the development and adoption of genome-edited crops support national priorities under key government initiatives such as **Atma Nirbhar Bharat (Self-Reliant India)**, **National Mission on Natural Farming**, and the goal of **Doubling Farmers’ Income**. By delivering faster breeding cycles, climate-resilient performance, and higher yields, genome editing represents a scalable and science-based solution for the future of Indian agriculture.

CRISPR-Cas9 Mechanism

1. **Guide RNA (gRNA):** A custom-designed RNA molecule guides the Cas9 enzyme to a specific sequence in the genome.
2. **Cas9 Enzyme:** Cas9 makes a precise cut in the DNA at the targeted site.
3. **DNA Repair:** The cell's natural repair processes are triggered. Scientists can use this stage to disrupt, remove, or insert genes.



Two main types of repairs are:

- **Non-Homologous End Joining (NHEJ):** Often introduces small mutations, disabling a gene.
- **Homology-Directed Repair (HDR):** Allows insertion of new DNA sequences.

Application of Genome Editing in Rice Development: Genome editing offers transformative potential for crop improvement, especially in rice, which is integral to India’s food security and rural economy. Genome editing particularly using CRISPR-Cas9 and Site-Directed Nuclease 1 (SDN1) techniques facilitates the development of next-generation rice varieties tailored for climate resilience, higher productivity, and resource efficiency.

Key Agronomic Traits Enhanced Through Genome Editing

Genome-edited rice varieties can be tailored to express multiple desirable characteristics, such as:

- Increased grain yield
- Drought and salinity tolerance
- Early flowering and maturity
- Enhanced nitrogen-use efficiency (NUE)
- Improved disease and pest resistance
- Better post-stress recovery

These traits are crucial in minimizing crop losses, reducing input costs, and enhancing income in diverse agro-climatic regions of India.

India's Milestone: Release of Two Genome-Edited Rice Varieties

India has taken a significant leap forward by releasing two genome-edited rice varieties using SDN1 technology. Since these crops do not contain foreign DNA, they are **not classified as GMOs**, facilitating easier public acceptance and regulatory clearance.

1. DRR Dhan 100 (Kamala): A Yield-Boosting Innovation

- **Developed by**: Dr. Satendra K. Mangrauthia, Dr. R.M. Sundaram, and team at **ICAR-Indian Institute of Rice Research (IIRR), Hyderabad**.
- **Parent Variety**: Derived from the popular **Samba Mahsuri**.
- **Target Gene**: **CKX2 (Cytokinin Oxidase 2 or Gn1a)**. Editing this gene increases cytokinin levels, which enhances grain number per panicle.

Key Agronomic Features

1. **19% higher grain yield** than Samba Mahsuri
2. **15–20 days earlier maturity** enables double/multiple cropping
3. **Moderate drought tolerance**, suitable for variable rainfall zones
4. **High nitrogen-use efficiency**, reducing urea dependency
5. Retains **premium grain quality**, aroma, and cooking characteristics
6. **Excellent market acceptability** due to similar sensory traits

Farmer Benefits

- Suitable for both **rainfed and irrigated ecosystems**
- Reduces **input cost**, especially on fertilizers
- **Early harvesting** increases cropping intensity and profitability
- **Enhanced income** due to yield and quality premium
- Fits well into **integrated nutrient management** and sustainable farming systems

2. Pusa DST Rice 1: A Stress-Resilient Game Changer

- **Developed by**: Dr. Chinnusamy Viswanathan and team at **ICAR-Indian Agricultural Research Institute (IARI), New Delhi**
- **Parent Variety**: **Maruteru 1010 (MTU 1010)**
- **Target Gene**: **DST (Drought and Salt Tolerance gene)**, edited using SDN1

Key Features

1. **Reduced stomatal density**: minimizes water loss
2. **Improved tillering and leaf area**, contributing to yield stability
3. **High tolerance to stress conditions**:
    - **200 mM salinity**

   - **Drought pressures** of -70 to -90 KPa
4. **Superior recovery yields** post-stress:
   - 30.4% increase in **coastal saline soils**
   - 14.66% in **alkaline soils**
   - 9.67% in **inland salinity areas**

Farmer Impact

- Ideal for **coastal, saline-prone, and drought-affected regions**
- Reduces **crop failure risk** under extreme weather events
- Contributes to **yield stability** and **income assurance**
- Encourages **climate-smart and conservation agriculture**
- Reduces the need for **excessive irrigation and salinity mitigation**

Significance for Indian Agriculture

Genome editing technologies like CRISPR-Cas9 have the potential to **reshape Indian rice farming** by offering faster, scalable, and locally adaptable solutions to longstanding challenges:

Strategic Advantage	Impact
Rapid variety development	Reduces breeding time from 8–10 years to just 2–3 years
Non-GMO categorization	Easier regulatory pathway; greater consumer and export acceptance
Climate resilience	Helps stabilize production under erratic weather and degraded soils
Sustainability	Promotes input efficiency and reduces environmental footprint
Food and income security	Improves farm-level profitability while ensuring food availability
Policy support	India's recent exemption of SDN1 and SDN2 crops from GMO regulation promotes innovation and encourages public-private partnerships

CONCLUSION

Genome editing is revolutionizing Indian agriculture by offering precision, speed, and flexibility in crop improvement. The successful release of **DRR Dhan 100 (Kamala)** and **Pusa DST Rice 1** highlights the immense potential of genome-edited crops to meet the dual goals of **food security** and **climate adaptation**. These varieties not only address agronomic challenges but also support economic and environmental sustainability. As India strengthens its regulatory framework, research infrastructure, and farmer outreach programs, genome editing is poised to play a **central role in future-ready agriculture**. Empowering farmers with such high-performing varieties can significantly boost rural incomes, reduce vulnerability to climate stress, and advance the goals of **Atma Nirbhar Bharat**, **Sustainable Development Goals (SDGs)**, and **Doubling Farmers' Income**.

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ROLE OF AGROFORESTRY IN CLIMATE CHANGE MITIGATION

ABSTRACT

The impact of climate change on ecosystems, particularly forest and agroforestry systems, is a global concern. This article synthesizes research assessing the potential shifts in forest ecosystems and the role of agroforestry in mitigating climate change impacts. Agroforestry practices demonstrate remarkable carbon storage capabilities, sequestering 5.05 Mg C ha^{-1} yr^{-1} for tree densities between 100 and 10,000 trees. Species such as *Poplar deltoides* provide significant biomass and economic benefits, underlining agroforestry's potential to alleviate rural poverty while combating greenhouse gas emissions. Studies highlight the value of agroforestry in stabilizing ecosystems, reclaiming degraded lands, and enhancing farm productivity through carbon storage ultimately benefitting in carbon sequestration. Moreover, agroforestry contributes to REDD+ goals by reducing deforestation through sustainable timber and fuel wood production. To maximize these benefits, strengthening research, market infrastructure, and policy frameworks is vital. Agroforestry not only addresses food and environmental security but also promotes economic sustainability, offering a robust response to climate change challenges. These findings underscore the necessity to integrate agroforestry into broader climate action and land management strategies.

KEYWORDS

Agroforestry, climate change, carbon sequestration, forest.

INTRODUCTION

According to United Nations, Climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, but since the 1800s human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas. According to USDA, Climate change is a long-term change in the average conditions, like temperature and precipitation, over more than a thirty-year period.

CAUSES OF CLIMATE CHANGE

1. NATURAL

- Volcanoes
- Forest fires
- Seismic activities

2. ANTHROPOGENIC

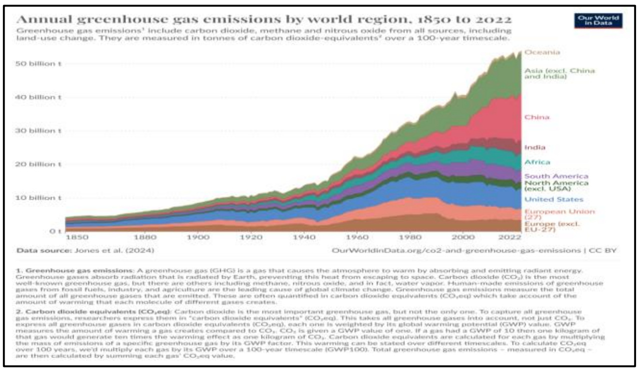
- Changes in land management practices
- Burning of agricultural residues
- Burning fossil fuels
- Widespread deforestation
- Increased industrial emissions

EFFECTS OF CLIMATE CHANGE

- **Hotter temperatures**: As **greenhouse gas concentrations rise**, so does the global surface temperature. The last decade, 2011-2020, is the warmest on record.
- **Increased drought**: Climate change is changing water availability, making it scarcer in more regions
- **Loss of species**: Climate change poses risks to the survival of species on land and in the ocean. Exacerbated by climate change, the world is losing species at a rate 1,000 times greater than at any other time in recorded human history.
- **Not enough food**: Changes in the climate and increases in extreme weather events are among the reasons behind a global rise in hunger and poor nutrition. Fisheries, crops, and livestock may be destroyed or become less productive.
- **More health risks**: Climate impacts are already harming health, through air pollution, disease, extreme weather events, and forced displacement, pressures on mental health, and increased hunger and poor nutrition in places where people cannot grow or find sufficient food.
- **Poverty and displacement**: Climate change increases the factors that put and keep people in poverty. Floods may sweep away urban slums, destroying homes and livelihoods. Heat can make it difficult to work in outdoor jobs. Water scarcity may affect crops.

WHAT ARE GHG's ?

Greenhouse gases (also known as GHGs) are gases in the earth's atmosphere that trap heat. The gases act like the glass walls of a greenhouse – hence the name, greenhouse gases. But human activities are changing earth's natural greenhouse effect with a dramatic increase in the release of greenhouse gases. Scientists agree greenhouse gases are the cause of global warming and **climate change**. Since the Industrial Revolution, humans have been releasing larger quantities of greenhouse gases into the atmosphere. In the past century that amount has increased dramatically, with the knock-on effect of global warming. Global temperatures have accelerated in the past 30 years and are now the highest since records began.

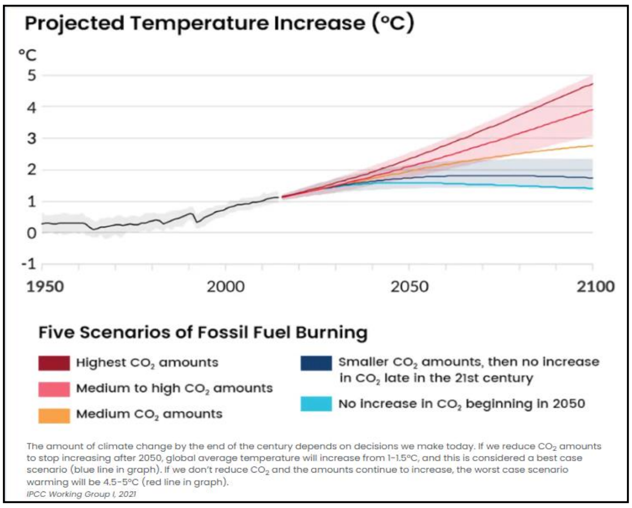


IMPACT OF CLIMATE CHANGE ON FOREST

Forests are the global regulators of the world's climate (FAO 2018). As Climate Change induces specific changes in the typical structure and functions of ecosystems it also impacts forest health, climate change and has several devastating consequences such as forest fires, droughts, pest outbreaks (EPA 2018), and last but not the least is the livelihoods of forest-dependent communities. Surging temperature regimes causes alterations in usual precipitation patterns, which is a significant hurdle for the survival of temperate forests (Flannigan *et al.*, 2013), letting them encounter severe stress and disturbances which adversely affects the local tree species. Decrease in forest biodiversity and extinction of some species. Decrease in quality of groundwater

WHAT IS CLIMATE CHANGE MITIGATION AND WHY IT IS REQUIRED?

Impacts of climate change will be severe and widespread. According to **UNDC**, Climate change mitigation refers to any action taken by governments, businesses or people to reduce or prevent greenhouse gases, or to enhance carbon sinks that remove them from the atmosphere. Greenhouse gases reached record observed levels in 2023. Real time data indicate that they continued to rise in 2024. The atmospheric concentration of carbon dioxide (CO2) has increased from around 278 ppm in 1750 to the current level of 420 ppm, an increase of 51%. **(UN STATE OF THE CLIMATE REPORT 2024)**. Climate models predict that Earth's global average temperature will rise an additional 4° C (7.2° F) during the 21st Century if greenhouse gas levels continue to rise at present levels. **(https://scied.ucar.edu)**



(SOURCE: https://scied.ucar.edu)

FORESTS AS CLIMATE MITIGATORS

Healthy forests are powerful carbon sinks, meaning they absorb and store carbon dioxide. Estimates show that globally, between 2001-2019, forests absorbed twice as much carbon as they emitted, or 7.6 billion metric tonnes of CO_2 per year. (World Resources Institute 2021). Forests provide a crucial capacity to remove greenhouse gases (GHG) from the atmosphere and help us avoid the worst impacts of the climate crisis. According to findings from the **Intergovernmental Panel on Climate Change (IPCC)**, the agriculture, forestry sector can provide up to 30 percent of the GHG emissions reductions needed to limit global warming to 2°C, at a relatively low cost. Since forest is large carbon sink but there is no scope to increase the forest area in the country. But there is lot of scope to increase carbon storage through afforestation, reforestation and agroforestry.

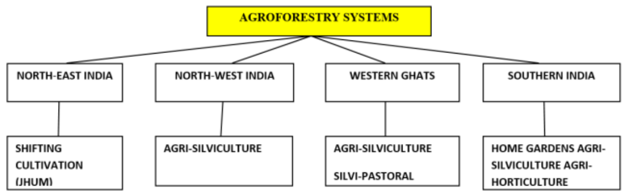
CARBON SEQUESTRATION

The term "carbon sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the terrestrial environments (vegetation, soils, and sediments), and geologic formations. Terrestrial sequestration (sometimes termed "biological sequestration") is typically accomplished through forest and soil conservation practices that enhance the storage of carbon (such as restoring and establishing new forests, wetlands, and grasslands) or reduce CO_2 emissions (such as suppressing wildfires).

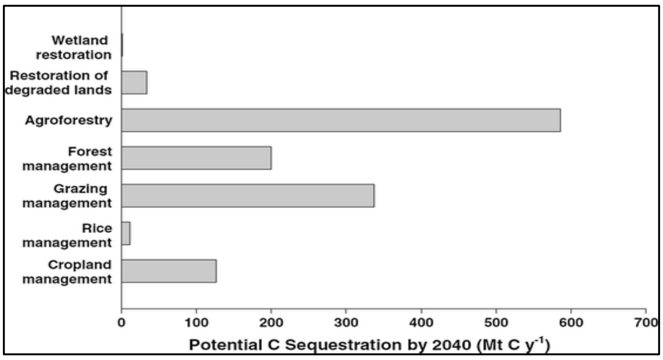
AGRFORESTRY SYSTEMS

Agroforestry the practice of growing trees and crops in interacting combinations and is recognized worldwide as an integrated approach for sustainable land-use. The World Agroforestry Centre (ICRAF) defines it as "a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels." According to the UN Food and Agriculture Organization (FAO), more than 1.2 billion people around the world practice agroforestry on around 1 billion hectares (ha) of land (FAO, 2017). Agroforestry was recognized by IPCC as having high potential for sequestering C as part of climate change mitigation strategies (Watson *et al.*, 2000). It can increase and stabilize agricultural yields and reduce soil erosion (Prinsley,1990)

TRADITIONAL AGROFORESTRY SYSTEMS IN INDIA (Murthy *et al.*, 2013)



CARBON SEQUESTRATION POTENTIAL OF DIFFERENT LAND USE SYSTEMS AND MANAGEMENT OPTION



ADAPTED FROM IPCC 2000

CARBON SEQUESTRATION OPTION FOR CLIMATE CHANGE MITIGATION (Nair *et al.*, 2011)

- Agroforestry system recognized as a carbon sequestration strategy because of its applicability in agricultural lands as well as in reforestation programs.
- Agroforestry offers the highest potential for carbon sequestration

Direct role: Carbon sequestration rates ranging from

1.5 to 3.5 tonne C ha−1 yr−1 in agroforestry systems.

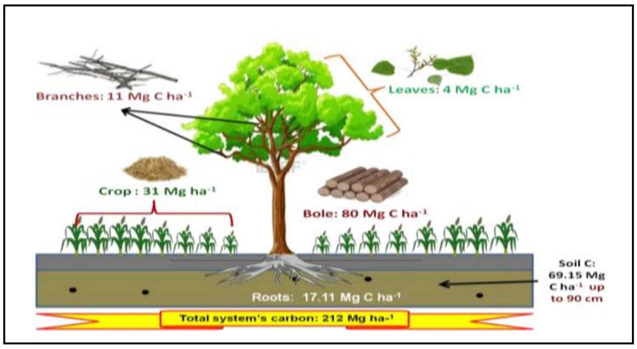
Indirect role: Agroforestry has also some indirect effects on C sequestration since it helps to reduce pressure on natural forests.

ROLE OF AGROFORESTRY IN CLIMATE CHANGE MITIGATION

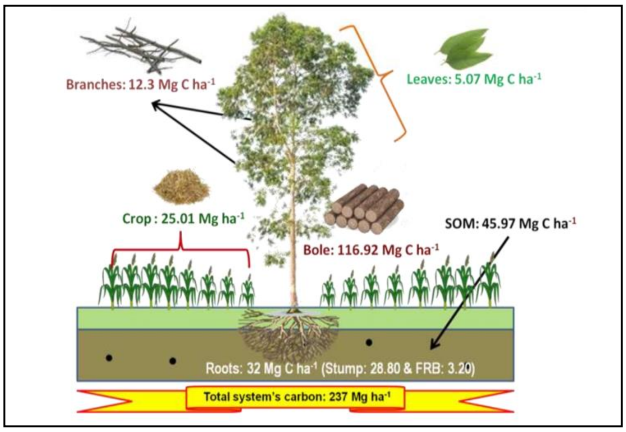
AGROFORESTRY MODELS	CARBON STORAGE CAPACITY	REGION	REFERENCES
BLOCK PLANTATION (Aged 6 years)	4.1-5.77tC/ha / year	Central India	Swamy *et al.*, (2003)
Populus deltoides 'G-48' + wheat	18.53 tC/ha	Tarai Region of central Himalayas	Yadava (2010)
Silvipastornalism(aged 5 years)	6.55 tC/ha/year	Kerala,India	Kumar B.M. *et al.*, (1998)
Indonesian Homegardens (aged 13.4 years)	8.00 tC/ha/year	Sumatra	Roshetko M.*et al.*, (2002)

The carbon absorption capacity of different agroforestry models

CARBON SEQUESTRATION POTENTIAL OF COMMERCIAL AGROFORESTRY SYSTEMS IN INDO-GANGETIC PLAINS OF INIDA: POPLAR AND EUCALYPTUS BASED AGROFORESTRY SYSTEMS (Chavan *et al.*, 2023)



Total carbon stock of sorghum-berseem crop rotation in poplar (5 m × 4 m) over a complete rotation of 8 years.



Total carbon stock (Mg ha−1) of Dhaincha - barley crop rotation in eucalyptus-based agroforestry system (3 m × 3 m) over a rotation of 8 years.

WHAT IS REDD+?

REDD+ stands for Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. REDD+ was introduced in 2008 at the UNFCCC COP 14 in Poznan, Poland. The Warsaw Framework for REDD+ (WFR) was adopted at COP 19 in Warsaw in December 2013. Forests mitigate climate change because of their capacity to remove carbon from the atmosphere and to store it in biomass and soils. When forests are cleared or degraded, they can become a source of greenhouse gas (GHG) emissions by releasing that stored carbon. It is estimated that globally, deforestation and forest degradation account for around 11 percent of CO_2 emissions.

AGROFORESTRY AND REDD+

- Reducing emissions from deforestation and degradation
- Conservation of forest carbon stocks
- Sustainable management of forests
- Enhancement of Carbon stocks

CONCLUSION

Agroforestry acts as a substantial carbon sink and encourages sustainable land-use practices. Agroforestry is essential in mitigating the effects of climate change. By stabilizing agricultural output, reducing soil erosion, and improving carbon sequestration, integrating trees into agricultural systems further supporting socioeconomic and environmental benefits. The above strategy supports international programs like REDD+ by lowering greenhouse gas emissions and improving carbon stocks. Many regionally specific agroforestry models in India, including systems based on poplar and eucalyptus, show significant promise for storing carbon and providing ecosystem benefits.

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SCOPE OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN ENTOMOLOGY

Introduction

Insects comprise the largest animal species on Earth, yet recent studies suggest a sharp decline in their populations, though comprehensive data is lacking. Traditional monitoring methods are often inefficient and labor-intensive, challenging insect research despite the growing threats from climate change, habitat loss, and invasive species (Hoye *et al.*, 2021). As a result, entomology has become increasingly important, with scientists exploring insect behavior, ecology, evolution, and pest control. Advances in artificial intelligence (AI) and deep learning now offer innovative, non-invasive ways to monitor insects using cameras and sensors. These technologies help estimate insect abundance and diversity, providing valuable ecological insights. AI's ability to analyze complex data sets has already transformed fields like healthcare and climate science, yet its role in entomology remains underexplored. First introduced by John McCarthy in 1956, AI now supports tasks such as image recognition, language processing, and decision-making, and its integration into agriculture is expanding rapidly (Angermueller *et al.*, 2016).

What is Artificial Intelligence?

Artificial Intelligence (AI) is a field within computer science that focuses on building systems capable of performing tasks that typically require human intelligence. These tasks include recognizing speech, interpreting images, making decisions, and understanding language. First introduced as a concept by John McCarthy in 1956 during the Dartmouth Conference, AI has since evolved into a multidisciplinary area that draws from machine learning, robotics, natural language processing, and data modeling. AI is especially useful for addressing complex problems that are difficult to solve using conventional programming methods. By learning from data and adapting over time, AI technologies aim to enhance precision, automate processes, and improve performance across various industries with minimal human oversight (Choudhury, L.K., 2022).

What is Machine Learning?

Machine Learning (ML) is a branch of computer science that focuses on developing algorithms that enable systems to learn from data and improve their performance without direct programming. It is widely used in applications like web search, predictive analytics, image recognition, and natural language processing. ML works by identifying patterns in data to make decisions or predictions, making it essential for handling large datasets and extracting useful insights. As the field has evolved, it has become central to modern AI technologies, offering scalable solutions across various industries. Different algorithms are applied based on the specific problem, data type, and desired outcome, emphasizing that no single approach fits all scenarios (Jordan and Mitchell, 2015).

Artificial Intelligence (AI) comprises various branches that simulate human intelligence to solve complex tasks. Among them, Machine Learning (ML) allows systems to learn from data and improve without explicit programming, with techniques like supervised, unsupervised, and reinforcement learning applied in fields such as language processing and agriculture. Deep Learning (DL), a subset of ML, mimics brain functions using neural networks like CNNs and RNNs, and is especially effective in image and time-series analysis (Chen *et al*., 2011). Natural Language Processing (NLP) enables machines to interpret and respond to human language, while expert systems emulate human decision-making in specific domains. Robotics combines AI with engineering to create autonomous machines capable of performing physical tasks, while machine vision equips these machines with the ability to analyze and interpret visual data beyond human capability.

AI has a wide range of practical applications, including in healthcare, transportation, manufacturing, and scientific research. Systems like DAISY and ABIS help automate species identification, while tools like chatbots, diagnostic software, and recommendation engines enhance user interaction and operational efficiency. Innovations like self-driving vehicles, medical imaging, and smart assistants showcase the growing influence of AI in daily life. With the integration of AI into mobile apps, robotics, and precision agriculture, it continues to evolve as a powerful tool for automation, decision-making, and problem-solving across industries.

The development of AI dates back to the 1940s and 1950s, with foundational work by Alan Turing and the formal birth of the field at the 1956 Dartmouth Conference. Initial research focused on symbolic logic and rule-based systems. However, unrealistic expectations led to a period known as the "AI Winter" in the 1970s and 1980s, marked by reduced funding and slowed progress. The field resurged in the 1990s with advances in computing power, machine learning, and data availability. Today, driven by deep learning and big data, AI is at the forefront of innovation, powering technologies like voice assistants, image recognition, and autonomous systems.

Use of AI in Entomology

Artificial Intelligence is revolutionizing agriculture by enhancing efficiency, sustainability, and productivity. Precision farming uses AI to analyze data from satellites, drones, and sensors to guide targeted planting, irrigation, and fertilization, improving yields while reducing resource use. Predictive models forecast weather, pest outbreaks, and diseases, allowing farmers to take proactive steps to protect crops. AI-driven drones and imaging systems monitor crop health, while autonomous machinery handles repetitive tasks like seeding and harvesting. Additionally, AI supports soil health analysis, supply chain optimization, livestock monitoring, and helps develop climate-resilient crop varieties. Integrated farm management systems offer real-time insights, streamlining operations and decision-making (Nadaf *et al.*, 2021).

Role of AI and ML in Entomology

AI and machine learning are significantly transforming entomology, especially in areas like insect classification, pest management, and ecosystem monitoring. AI enhances species identification through image recognition and deep learning models such as CNNs. These tools can analyze photos and video footage to classify insects rapidly and with high accuracy. ML algorithms also track species distribution, helping detect invasive insects early. Combining image and acoustic data enables the identification of visually indistinct species, while integration with DNA barcoding provides deeper insights into insect taxonomy and behavior, supporting conservation efforts (Raibagi, 2021).

Applications in Pest and Disease Management

AI contributes substantially to pest monitoring and control. It supports early detection of infestations using drones equipped with image recognition systems. Deep learning models help identify pests with greater precision than manual methods. Predictive analytics can forecast outbreaks by evaluating weather data and historical trends. Integrated Pest Management (IPM) strategies use AI to suggest targeted treatments, reducing pesticide use. Unmanned Aerial Vehicles (UAVs) equipped with computer vision can perform real-time, localized pesticide applications, making treatment more efficient and sustainable (Prabha *et al.*, 2021).

Broader Ecological and Scientific Contributions

Beyond pest control, AI is applied in disease vector surveillance, biodiversity studies, and ecological impact assessments. It models insect population trends under varying environmental conditions and simulates ecosystem interactions. AI also plays a vital role in insect genomics, identifying genes linked to pest resistance and supporting innovations like CRISPR-based solutions. By analyzing large, diverse datasets from field sensors, labs, and satellites, AI enhances understanding of insect behavior, population dynamics, and environmental impacts, offering a holistic view of entomological systems.

Technological Tools and Global Initiatives

Various AI-powered tools are advancing entomology. Systems like DAISY and ABIS support fast insect identification, while mobile apps like LeafByte measure plant damage. In India, Wadhwani AI and Google developed tools to detect pest levels in cotton crops. ICRISAT's innovation hub created apps like Plantix and Kalgudi to connect researchers with farmers, enabling real-time disease detection and alerts. In Switzerland, AI monitors Varroa mite infestations in bee colonies. These technologies demonstrate AI's capacity to enhance precision agriculture by enabling targeted interventions based on data-driven insights.

Advantages and Disadvantages of AI and ML

Artificial Intelligence (AI) brings significant advantages across multiple sectors by automating routine tasks, improving accuracy, and enabling around-the-clock operations. It enhances decision-making through rapid data analysis and contributes to cost savings and innovation. In agriculture, healthcare, transportation, and customer service, AI helps optimize resources, personalize services, and improve safety. Moreover, AI plays a vital role in economic development by creating jobs in emerging tech fields like data science and robotics, while also advancing fields such as personalized medicine, predictive analytics, and real-time system monitoring.

Despite its benefits, AI poses notable challenges. High development and maintenance costs, limited creativity, and overdependence on automated systems can hinder adaptability. Job displacement and ethical concerns—such as algorithmic bias, data privacy, and security risks—raise social and legal issues. Complex AI models can be difficult to interpret or correct, making transparency and accountability critical. Furthermore, heavy reliance on AI may affect human interaction and widen economic disparities if access and benefits are unevenly distributed. Responsible AI deployment requires thoughtful regulation, ethical design, and continuous oversight to ensure inclusive and safe technological progress.

Conclusion

Artificial Intelligence in agriculture serves more as a supportive tool than a replacement for human labor, enhancing the efficiency and decision-making capabilities of farmers. By automating tasks such as crop monitoring and anomaly detection, AI reduces the need for manual scouting, saving time and labor. Its adaptability across various domains fosters innovation in agricultural research and development. For AI to truly revolutionize Indian agriculture, government support is essential, particularly in utilizing extensive agricultural data already in public possession. Additionally, training programs in cognitive science for entomologists would help bridge the gap between traditional practices and modern technology, ensuring smoother adoption of AI-driven methods (Hoye *et al.*, 2021).

Despite its benefits, the widespread implementation of AI in agriculture faces several challenges. Issues like high costs, limited technical knowledge, and the inaccessibility of remote farming areas hinder adoption, especially for small and medium-scale farmers. Technologies like pest detection, irrigation management, and agrochemical application powered by machine learning can offer improved accuracy, cost-effectiveness, and better resource use. However, infrastructure limitations such as poor network coverage and the impracticality of deploying numerous sensors over large areas make operationalization difficult. Moreover, many farmers remain skeptical, lacking confidence in technology's ability to match human judgment, which further limits its integration into everyday farming practices (Raja, K, A., 2022).

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Significance of Vachellia nilotica in our life

Introduction

The Babool tree, scientifically known as Acacia nilotica, is a medium-sized deciduous tree characterized by its distinctive bipinnate compound leaves and rough, dark gray bark. Native to Africa and the Indian subcontinent, it adapts well to arid regions. The tree produces small, fragrant, pale yellow flowers in spherical clusters, eventually developing into long, twisted pods. Its thorny branches contribute to its resilience, deterring herbivores. Babool is valued for its hard and durable wood, extensively used in carpentry. Additionally, its bark and gum have traditional medicinal applications in Ayurveda and other traditional healing systems for various ailments.

Other name of Babool

Acacia nilotica, Indian Gum Arabic tree Babul, Thorn mimosa, Egyptian acacia, Thorny acacia, Babla, Black Babul, Babaria, Baval, Kaloabaval, Kikar, Gobbli, Karijali, Karivelan, Karuvelum, Babhul, Vedibabul, Babhula, Bambuda, Baubra, Sak, Kaluvelamaram, Karrivelei, Karuvael, Karuvelam, Nallatumma, Tumma, Tuma

Interesting Facts

Medicinal Uses: Babool finds an important place in Ayurvedic and Unani healthcare systems.

1. Extracts from the bark are employed in traditional medicine to treat various skin disorders and wounds.
2. Babool gum, known as "Babul gond," is used in Ayurveda for respiratory conditions and as a natural adhesive.
3. The Babool tree is known for its potential in managing dental issues, with twigs traditionally used as natural toothbrushes.
4. Oral problems: Chewing small pieces of fresh bark of babool tree can be good for oral health. It not only help strengthen the teeth but heals the gum due to its Kashaya (astringent) property.

5.Diarrhea and Lose motion
Babool bark helps to treat diarrhea and lose motion because Babool has Kashaya(astringent) and reduce Ama(Ama (toxic remains in the body due to improper digestion) properties which help to improve metabolism, give strenght to intestine and control diarrhea or lose motion

6.Leucorrhea
Chew 5-8 Babool leaves and drink a glass of water in the morning daily to cure vaginal white discharge in female and Dhat rog in male due to its coolant and astringent effects.

7.Cough and Cold
Babool Bark is helpful in the treatment of cold symptoms as well as relieving sore throat that is associated with cold and cough due to its Kapha balancing property which helps to melt excessive sputum and give relief from a cough and cold.

8.Arthritis and Fractured bone
Babool gum works on arthritis pain as well as also helps in the fracture to fasten the union of fractured ends for proper healing of internal injuries when its taken orally due to its Vata balancing and Ropan(healing) nature.

9.Wound: Babool gum is an excellent healer due to its Ropan (healing) and Kashaya(astringent) (properties. As a result, balool gum is used to heal and checks bleeding when applied externally minor wound or skin injury.

10. Skin disease: Babool bark powder cures skin problems like eczema and fungal infection due to its Kashaya (astringent) quality.

11. Bleeding Piles: Babool powder shows good result in pain or bleeding piles due to its Sita (cold) potency and Kashaya (astringent) properties.

12. Burn Injuries: Babool bark powder helps to cure burn injuries because it stimulates the healing process of burn injuries and controls the scar formation due to its Kashya(astringent) and Ropan(healing) property

Culture and Tradition:

1.Babool's hard and durable wood has cultural importance in carpentry and construction. It is also used to make tools, such as handles for agricultural implements.

2.It's twigs are used by several cultures as tooth brushes.

3.Farmers use Babool's leaves and pods as **animal feed**.

4.The bark of the Babul tree is high in tannins, which are used in the leather industry to tan animal hides and produce leather products such as shoes, belts, and bags.

5.It finds extensive use in traditional medicine systems such as Ayurveda and Unani.

Environmental Impact: The Babool tree (Acacia nilotica) plays a vital role in environmental conservation. Thriving in arid regions, it contributes to soil conservation with its deep-rooted system, preventing erosion. Its nitrogen-fixing abilities enhance soil fertility, supporting the growth of other plants. The tree offers shade, reducing surface temperatures and providing a habitat for diverse wildlife. Additionally, Babool's thorny branches act as a natural deterrent, protecting against overgrazing by herbivores. Its resilience to harsh climates makes it a valuable species for afforestation and reforestation efforts, promoting biodiversity and contributing to the overall health and sustainability of ecosystems

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Sorghum (Jowar): The Nutrition, Benefits and Uses

1. Introduction

India has committed to positioning itself as the 'Global Hub for Millets,' aiming to make the International Year of Millets 2023 a 'People's Movement.' This Millet Revolution is spurred by initiatives to revive ancient agricultural practices, support small-scale farmers, and heightened awareness of the health and environmental advantages of millets. **Sorghum (*Sorghum bicolor* L. Moench),** popularly known as jowar in India, is a staple food in many parts of the world and a powerhouse of nutrition. With its rich history and numerous health benefits, sorghum is an ancient grain that deserves a place in our diet. Sorghum is a versatile grain that has been cultivated for more than 5,000 years. It is primarily grown in Africa and Asia, but has gained popularity around the world due to its nutritional benefits and adaptability to a variety of climates. Sorghum is a member of the grass family and is used for feed, food, fodder, and biofuel production. It is an important food crop cultivated in various countries of South Asia, Africa, and Central America (Ingle et al., 2023). It is mainly grown in marginal and stressed suburban and semi-arid environments, called semi-arid regions. Let's dive into the world of sorghum and learn about its nutrition, benefits, and uses.

2. Cultivation of millets in India

The cultivation of millets in India has deep roots in the country's agricultural practices, with millets being grown for thousands of years. Millets are hardy, drought-tolerant crops that thrive in dry and semi-arid regions, making them particularly suited to India's diverse climate conditions. Although millets were once staples, their cultivation has declined in favor of more popular crops like rice and wheat. In recent years, there has been a renewed focus on promoting millet cultivation due to its nutritional value, environmental sustainability, and climate resilience.

The types of millets grown, the regions where they are cultivated, and the nutritional importance is discussed briefly hereunder:

2.1. Types of Millets Grown in India: India is home to several types of millets, each with distinct characteristics suited to various environmental conditions. The main millets grown in India include:

a. Pearl Millet (Bajra): Pearl millet is one of the most widely grown millets in India, particularly in Rajasthan, Uttar Pradesh, Haryana, and Maharashtra. It is a drought-resistant crop, ideal for semi-arid regions.

b. Finger Millet (Ragi): Ragi is widely cultivated in southern India, especially in Karnataka, Tamil Nadu, Andhra Pradesh, and Odisha. Ragi is known for its high nutritional value, especially its calcium content.

c. Foxtail Millet: Grown primarily in southern and central India, foxtail millet is used for both food and fodder. It thrives in dry conditions and is often grown as a rotation crop.

d. Kodo Millet: Grown mainly in Madhya Pradesh, Maharashtra, and Odisha, Kodo millet is a hardy crop that requires minimal water and can grow in poor soil conditions.

e. Little Millet: Little millet is cultivated in states like Tamil Nadu, Andhra Pradesh, and Karnataka. It is considered an ancient grain and is often used in traditional recipes.

f. Barnyard Millet: Barnyard millet is commonly grown in the states of Tamil Nadu, Karnataka, and Uttar Pradesh. It is one of the fastest-growing millets and is resistant to pests and diseases.

2.2. Regions of Cultivation: Millet cultivation is concentrated in specific regions of India, primarily in areas that face water scarcity or poor soil fertility. The main millet-producing regions are:

a. North-Western India: Rajasthan is the largest producer of pearl millet (bajra) in India. Other states like Haryana and Uttar Pradesh also contribute to millet production.

b. Southern India: Finger millet (ragi) is most commonly grown in Karnataka, Tamil Nadu, Andhra Pradesh, and Odisha, where the climate and soil conditions are ideal for its growth.

c. Central India: Madhya Pradesh, Maharashtra, and Chhattisgarh are significant producers of millets, including Kodo, Foxtail, and Little millets.

d. Eastern India: Odisha, West Bengal, and parts of Bihar also have millet cultivation, particularly finger millet and little millet.

2.3. Growing Conditions for Millets: Millets are well-suited for India's diverse climatic conditions. They thrive in regions with low rainfall and poor soil fertility. Their growing conditions are:

a. Water Requirements: Millets are drought-resistant and require less water compared to other staple crops like rice and wheat. Most millets are grown in rainfed conditions, making them ideal for dryland farming. However, some irrigation can help boost yields, particularly in areas with irregular rainfall.

b. Temperature: Millets grow well in warm climates with temperatures ranging from 25°C to 35°C. They are also tolerant of heat and can withstand high temperatures during the growing season.

c. Soil: Millets can grow in a wide range of soil types, including sandy, loamy, and alkaline soils. They thrive in well-drained soils with low to moderate fertility.

d. Sowing and Harvesting: The sowing period for millets typically begins with the onset of the monsoon in June-July, and they are harvested from September to November, depending on the type of millet and regional climate conditions.

3. Nutritional details of Jowar (Sorghum)

Jowar is a nutritional powerhouse that is packed with essential nutrients. This impressive sorghum nutrition information highlights why sorghum is considered a superfood (Chandel et.al., 2014). Its high levels of protein, fiber, and important minerals make it an excellent part of a balanced diet. The details of the major nutrients found in jowar are:

Nutritional details of Sorghum	
Nutrients	Quantity per 100 g
Calories	329 kcal
Carbohydrates	72.1 grams
Protein	10.6 grams
Thick	3.5 grams
Fiber	6.7 grams
Iron	4.4 mg
Calcium	13 mg
Magnesium	165 mg
Phosphorus	289 mg
Potassium	363 mg
Zinc	1.6 mg
Thiamine (B1)	0.35 mg
Riboflavin (B2)	0.14 mg
Niacin (B3)	2.1 mg
Folate (B9)	20 micrograms

Sorghum [Sorghum bicolor (L) Moench] is the fifth most important cereal crop in terms of production and area.

4. Health Benefits of Jowar

4.1. Supports digestive health:

Jowar is high in dietary fiber, which plays an important role in maintaining digestive health. The fiber in jowar helps in regular bowel movements, prevents constipation and promotes a healthy digestive system. Additionally, fiber helps in bulking up the stool and facilitating its passage through the digestive tract, reducing the risk of gastrointestinal disorders like diverticulosis. Fiber-rich foods, such as jowar, also promote the growth of beneficial gut bacteria, which are essential for overall gut health and immunity. Jowar benefits digestive health in several ways, ensuring that your gut remains healthy and functional.

4.2. Helps manage blood sugar levels:

- With a low glycemic index, jowar is an excellent choice for people with diabetes or those looking to manage their blood sugar levels.
- Foods with a low glycemic index release glucose slowly into the bloodstream, preventing a sudden rise in blood sugar levels. This slow-release glucose helps maintain stable energy levels and reduces the risk of insulin resistance.
- Consuming jowar as part of a balanced diet may aid in the long-term management of diabetes and support metabolic health.
- The benefits of jowar in controlling blood sugar are important for people with diabetes and those aiming to keep their glucose levels stable.

4.3. Gluten-free:

- Jowar is naturally gluten-free, making it an ideal grain for individuals with celiac disease or gluten sensitivity. Many common grains, such as wheat and barley, contain gluten, which can cause digestive issues and other health problems in those who are intolerant.
- Jowar offers a safe and nutritious alternative, allowing individuals to enjoy a variety of dishes without compromising their health. Its versatility in cooking and baking ensures that people following a gluten-free free do not miss out on essential nutrients.
- Sorghum benefits those who require a gluten-free diet, as it provides a nutritious and flexible grain alternative.

4.4. Rich in antioxidants:

- Sorghum is rich in antioxidants, which help fight oxidative stress and reduce inflammation in the body. Antioxidants neutralize free radicals, unstable molecules that can damage cells and cause chronic diseases such as cancer, heart disease, and diabetes.
- Sorghum antioxidants, including tannins, phenolic acids, and flavonoids, provide protective benefits by supporting the body's natural defense mechanisms.
- Regular intake of antioxidant-rich foods like jowar can contribute to improving overall health and longevity. Jowar benefits overall health by providing a rich source of antioxidants.

4.5. Increases energy:

- The complex carbohydrates present in jowar provide sustained energy, making it an ideal food for athletes and individuals with an active lifestyle.
- Unlike simple carbohydrates that cause rapid fluctuations in blood sugar levels, complex carbohydrates are digested more slowly. This slow digestion ensures a constant supply of energy,

helping to maintain stamina and endurance throughout the day.

- Adding jowar to the diet boosts physical activity and improves overall performance. Jowar benefits energy levels by ensuring a constant and long-lasting source of fuel.

4.6. Supports bone health:

- Jowar is a good source of essential minerals like magnesium, calcium, and phosphorus, which are important for maintaining strong and healthy bones.
- Magnesium plays an important role in bone formation and the regulation of calcium levels in the body. Calcium is essential for bone density and strength, while phosphorus contributes to the formation of bone tissue.
- A diet rich in these minerals, which includes foods like jowar, can help prevent bone-related disorders like osteoporosis and maintain overall skeletal health. Jowar has a great benefit for bone health due to its high mineral content.

4.7. Improves heart health:

- The fiber, antioxidants, and magnesium present in jowar contribute to heart health in several ways. Dietary fiber helps lower cholesterol levels by binding to cholesterol molecules and facilitating their excretion from the body.
- Lower cholesterol levels reduce the risk of heart disease and stroke. Antioxidants protect the cardiovascular system from oxidative damage, while magnesium helps regulate blood pressure and maintain a normal heart rhythm.
- Consuming jowar as part of a heart-healthy diet may promote cardiovascular health and reduce the risk of cardiovascular disease. Jowar benefits cardiovascular health by addressing several factors that contribute to heart disease.

5. Uses of Jowar:

Sorghum is incredibly versatile and can be used in a variety of culinary applications:

5.1. Traditional Dishes: In India, jowar is used to make bhakri (a type of flatbread), roti and porridge. These dishes are a staple food in many rural areas and are enjoyed for their nutritional value.

5.2. Jowar flour: Sorghum flour is a popular gluten-free alternative to wheat flour. It can be used in baking to make breads, cookies, cakes, and muffins. The flour is also used to thicken soups and stews.

5.3. Popped Sorghum: Just like popcorn, jowar grains can be popped and eaten as a healthy snack. Popped jowar is smaller but its taste and texture is similar to popcorn.

5.4. Sorghum syrup: In the southern United States, sorghum syrup is a traditional sweetener made from the juice of sorghum cane. It is used as a topping for pancakes, biscuits, and waffles.

5.5. Smoothies and Bowls: Add cooked sorghum to your smoothie or breakfast bowl for an extra nutritional boost. It adds a chewy texture and nutty flavour, enhancing the overall taste.

5.6. Salad: Cooked millet grains can be a great addition to salads. They add weight, fiber, and a delicious crunch, making your salad more nutritious and filling.

6. Other Uses of Jowar

- Fifty percent of sorghum grain yield is directly consumed as food, usually in the form of porridge (thick or thin) and bread. Especially in Australia and the USA, it is used as a major staple feed for livestock (33%). Dried fodder made from stover is especially useful during the dry season in Asia.
- Sorghum's rapid growth, high green grass production capacity and high quality make it an optimistic fodder source.
- Sweet sorghum has recently emerged as an important bioweal crop, adding to its already impressive list of uses to include feed, food, fodder, fuel, and fibre. Hence, people commonly call it the 'smart crop or star crop'.
- Green sorghum plants and crop waste are used for manufacturing and as a cooking fuel, especially in arid areas (Chandel & Paroda, 2000).
- Sorghum is also used to make paper and cardboard, molasses, and ethanol.
- Sorghum is considered to have industrial potential as a raw stock. Its industrial use makes it viable for self-reliant farmers to cultivate it.

- It is used in wine specialties, malt, beer, liquor, loose, emulsifiers, adhesives, core binders for metallurgy, mineral processing, and packaging, to name just a few of the other stock uses.
- The tannins in red sorghum provide antioxidants that protect cells from damage, a major factor in disease and aging.
- The pro-nutrients and starch in sorghum grains are digested more slowly than those in other grains. This characteristic is very beneficial for diabetic individuals; this is why sorghum is considered a healthy food.
- Sorghum is a potential substitute for wheat flour for individuals with celiac disease, as the starch in sorghum grains does not contain gluten.

Figure 1: Various uses of sorghum. A. Alcoholic beverages; B. Jowar roti (flatbread); C. Jowar cake; D. Jowar biscuit; E. Green fodder for animals; F. Dried fodder; G. Sweet sorghum juice.

7. **Specially bred sorghum is commonly used for various purposes.**

- Tips to Include Jowar in Your Diet: Some practical tips to include jowar in your daily diet:
- Opt for rice or quinoa: Use cooked millet in place of rice or quinoa in your meals. It pairs well with vegetables and sauces, and provides a nutritious alternative.
- Baking: Use sorghum flour in place of wheat flour in your baking recipes. It works well in gluten-free baking and adds a unique flavor to your baked goods.
- Breakfast cereals: Make a nutritious breakfast by cooking jowar grains with milk or any other plant-based alternative. Add fruits, nuts, and a little honey to it for a balanced meal.
- Energy bars: Add popped sorghum to homemade energy bars. Mix it with nuts, seeds, and dried fruits for a convenient and healthy snack.

8. Conclusion:

Jowar or sorghum is a nutritional powerhouse with myriad health benefits. From improving digestive health to controlling blood sugar levels, sorghum is a versatile grain that can be easily incorporated into a variety of recipes. Its gluten-free nature and rich nutrient profile make it an excellent choice for health-conscious individuals. By understanding the benefits and uses of jowar, you can make informed decisions about including this ancient grain in your diet. Start experimenting with jowar today and experience its countless health benefits.

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SOWING THE SEEDS OF CHANGE: YOUTH IN MODERN AGRICULTURE

Abstract

Agriculture remains a fundamental pillar of global economies, providing food, employment and raw materials for various industries. However, the sector is facing significant challenges, including an aging farming population, climate change and a declining interest among youth. Engaging young people in modern agriculture is crucial for ensuring the sustainability and advancement of the industry. Youth bring innovation, technology and entrepreneurial skills that can revolutionize traditional farming practices, making them more efficient and sustainable. However, several barriers hinder their participation, including limited access to land and financial resources, inadequate agricultural education and negative perceptions of farming as a low-income profession. To overcome these challenges, targeted strategies must be implemented, such as integrating digital technology into farming, expanding financial support for young farmers, modernizing agricultural curricula and promoting agripreneurship. By fostering an environment that supports and encourages youth involvement, agriculture can be transformed into a dynamic, technology-driven and lucrative sector. This article highlights the need for proactive policies and initiatives to empower young people, ensuring the future of agriculture is innovative, productive and resilient.

Keywords: Employment, Innovation, Modern Agriculture, Modern Technology, Youth

Introduction

Agriculture, the backbone of human civilization, is undergoing a profound transformation in the 21st century. Faced with pressing global issues such as climate change, declining soil health, food insecurity and rural depopulation, the agricultural sector stands at a crossroads. In many parts of the world, farming populations are aging and younger generations are increasingly moving away from agriculture in search of better economic opportunities. However, this trend is beginning to shift as a new generation of young people equipped with digital skills, innovative mindsets and a commitment to sustainability is stepping forward to lead a modern agricultural revolution. Youth today are not only consumers of technology but also creators of change. They are redefining farming by integrating cutting-edge tools such as drones, sensors, mobile apps and artificial intelligence with time-tested agricultural practices. From launching agri-tech startups to championing organic farming, young innovators are making agriculture more efficient, profitable and environmentally friendly. At the same time, they are challenging outdated perceptions of farming and proving that agriculture can be a dynamic and fulfilling career path. Despite their potential, young people face significant barriers including restricted access to land, capital, training and decision-making spaces.

Addressing these challenges requires a multi-stakeholder approach involving governments, private sector actors, educational institutions and local communities. This article aims to explore the vital role of youth in shaping the future of agriculture, examine the hurdles they encounter and highlight successful examples of youth-led agricultural transformation across the globe. In doing so, it seeks to emphasize the urgent need to invest in youth as catalysts of sustainable agricultural development and rural renewal.

Why Younger Generations Are Moving Away from Agriculture?

1. **Perception of Agriculture as Unattractive or Low-Status**
   Many young people view farming as physically demanding, low-income and outdated. It's often seen as a "last resort" career, lacking the prestige or excitement of modern professions like technology, finance or medicine.
2. **Limited Economic Opportunities**
   Traditional farming often brings uncertain and low financial returns due to factors like fluctuating market prices, rising input costs and climate-related crop failures. For youth looking for stable income and career growth, agriculture may seem too risky and unprofitable.
3. **Lack of Access to Resources**
   Young aspiring farmers often face barriers to accessing essential resources such as land, credit, quality inputs, technology and markets. Land is typically owned by older generations and financial institutions often hesitate to lend to inexperienced youth.
4. **Urban Migration and Education**
   As access to education and urban opportunities increase, many youth move to cities in search of white-collar jobs, leaving rural areas behind. This migration trend is driven by the belief that urban life offers more financial stability, social mobility and personal freedom.
5. **Insufficient Support and Training**
   In many countries, there's a lack of agricultural education, mentorship and practical training for youth. Without proper support systems, young people may feel unprepared or unmotivated to enter the agricultural sector.
6. **Climate Change and Environmental Risks**
   With agriculture being highly vulnerable to extreme weather, droughts, floods and soil degradation, many young people see it as too unpredictable and dependent on external conditions beyond their control.
7. **Outdated Infrastructure and Technology**
   In regions where agriculture still relies on traditional methods and lacks modern equipment or infrastructure, it can feel inefficient and labor-intensive, which turns youth away.

Despite these challenges, it's worth noting that **a growing number of young people are returning to agriculture**, especially when it's connected to innovation, sustainability and entrepreneurship. With the right incentives, training and technology, agriculture can become an appealing and viable career for the next generation.

Solutions to Attract and Retain Youth in Agriculture

1. **Access to Land and Finance**

Challenge: Land ownership and financing are two of the biggest barriers young people face.

Solutions:

- Land leasing programs or youth land banks that allocate unused public land to young farmers.
- Government-backed loans and grants tailored for youth in agriculture.
- Microfinance and agri-focused investment platforms that reduce financial risk.

2. **Agri-Tech and Digital Innovation**

✓ Integrating technology into farming—like **drones**, **mobile apps**, **precision farming** and **automated irrigation**—makes agriculture more efficient and appealing to tech-savvy youth.

- ✓ Digital platforms also connect young farmers to **markets**, **training** and **real-time information** (like weather forecasts and crop prices).

3. **Education and Training Programs**
   - ✓ Agricultural colleges, vocational centres and online platforms offering **practical training**, **entrepreneurship courses** and **business development support**.
   - ✓ Integrating agriculture into school curriculums can also spark interest from an early age.
4. **Policy and Institutional Support**
   - ✓ National programs like India's **"Agri-Clinics and Agri-Business Centres"** or Nigeria's **Youth in Agriculture Program (YIAP)** offer financial and technical support.
   - ✓ Encouraging youth representation in policy-making ensures their voices are heard and their needs addressed.
5. **Access to Markets and Value Chains**
   - ✓ Helping youth connect to local and global markets ensures they can earn from their produce.
   - ✓ Training in value addition (like turning raw tomatoes into ketchup or jam) boosts income and reduces waste.
6. **Mentorship and Peer Networks**
   - ✓ Programs pairing young farmers with experienced mentors create knowledge-sharing systems.
   - ✓ Youth-led farming cooperatives and online communities foster collaboration, innovation and support.
7. **Recognition and Awareness Campaigns**

✓ Celebrating young agricultural entrepreneurs through awards, media coverage and public campaigns helps change outdated perceptions and highlight agriculture as a modern, rewarding career.

Indian youth success stories in modern agriculture

1. **"Satyam Kumar's Organic Revolution in Bihar"**

- **Name-** Satyam Kumar
- **Residents:** Deepnagar village, Bihar
- **Age:** 23 years old
- **Educational Background:** Graduate in Chemistry
- **Key Initiative:** Organic farming practices
- **Achievement:** Became the youngest chairperson of the Agriculture Technology Management Agency (ATMA)
- **Aim:** To change the perception of agriculture among youth and promote sustainable farming in his community.

2."Mahesh Asabe: Dragon Fruit Farming in Sangola"

- **Mahesh Asabe – Maharashtra**
- **Name:** Mahesh Asabe
- **Background:** Engineer from Maharashtra
- **Cultivation Focus:** Dragon fruit farming
- **Location:** Sangola taluka, a drought-prone region
- **Innovation:** Modern farming techniques
- **Impact:** Agriculture in unprofitable lands revitalized
- **Profitability:** ₹10 lakh per acre
- **Vision:** To introduce sustainable agriculture in challenging environments

3."Akash Chaurasiya's Multi-Layer Farming Success"

- **Name:** Akash Chaurasiya
- **Region:** Sagar district, Madhya Pradesh
- **Farming Technique:** Multi-layer farming
- **Crops Cultivated:** Ginger, amaranthus, ivy gourd, and papaya

- **Impact**: Enhanced soil health and increased crop yield
- **Acknowledgment:** Recognized for promoting sustainable agriculture

4 "Intercropping Success by Swapna James"

- **Name:** Swapna James
- **Residence:** Palakkad, Keral a
- **Farm Size:** 15 acres
- **Farming Approach:** Intercropping combined with organic practices
- **Achievements:** Annual income increased to ₹30 lakh, nearly double her previous earnings
- **Award:** Recipient of the Innovative Farmer Award from ICAR
- **Key Practices:** Mixed cropping, vermicomposting, and cultivating indigenous crops

5."Samir Bordoloi: Nurturing Green Commandos in Assam"

- **Name:** Samir Bordoloi
- **Region:** Assam
- **Initiative:** Green Commandos, training youth in ecological farming techniques
- **Learning Centre:** SPREAD NE Farm Learning Centre
- **Impact:** Over 2,000 Green Commandos trained; plans to launch Green Juniors for rural school students
- **Awards Received:**

✓ National Pragati Puraskar for Organic Farming (2016)
✓ Best Agripreneur of the Country Award (2017)
✓ Krishak Ratna Award (2018)
✓ IARI Innovative Farmer Award (2019)

6.Vidyut Mohan: Revolutionizing Waste Management with Takachar".

- **Name:** Vidyut Mohan
- **Location:** New Delhi, India
- **Background:** Mechanical engineer
- **Startup:** Co-founder of Takachar

- **Innovation:** Converting agricultural waste into valuable products like activated carbon and organic fertilizers
  - **Environmental Impact:** Reduces crop residue burning and mitigates air pollution in northern India
  - **Awards:**

✓UN Young Champion of the Earth (2020)
✓Earthshot Environmental Prize (2021)

Future Prospects of Youth in Modern Agriculture

The future of agriculture lies in innovation, sustainability and youth-driven transformation. As the world grapples with climate change, population growth and food security concerns, the role of young people in agriculture is becoming increasingly vital. With supportive ecosystems in place, agriculture is poised to become a dynamic, tech-savvy and profitable sector for the next generation. Future prospects can be as follows:

1. Agri-Tech Startups and Digital Agriculture

- **Opportunities**: Young entrepreneurs can harness AI, IoT, drones, mobile apps and data analytics to create scalable agri-tech solutions—from precision farming to digital marketplaces.
- **India's Potential**: The Indian agri-tech market is projected to reach **$24 billion by 2025**, but only a fraction has been tapped. This leaves huge room for youth-led innovation.

2. Climate-Smart and Sustainable Farming

✓ **Need**: With agriculture contributing to climate change, there's an urgent need for sustainable practices.

✓ **Youth Role**: Young farmers can lead the shift toward **climate-resilient crops**, **organic farming**, **permaculture** and **regenerative agriculture**.

- ✓ **Support**: Programs like **FAO's Youth in Climate-Resilient Agriculture** offer training and funding for green innovations.

3. Agri-Entrepreneurship and Value Addition

- ✓ **Growth Areas**: Food processing, agri-tourism, cold storage logistics and direct-to-consumer (D2C) farm brands offer exciting business opportunities.
- ✓ **Success Path**: With proper business training, access to capital and digital tools, youth can become **agripreneurs**—turning small farms into profitable ventures.

4. Urban and Vertical Farming

- ✓ **Urban Shift**: With more people moving to cities, the demand for local, fresh produce is growing.
- ✓ **Youth Focus**: Young urbanites are increasingly exploring **hydroponics**, **aeroponics** and **indoor farming**, especially in metro areas like Delhi, Mumbai and Bengaluru.

5. Education and Agri-Research

- ✓ **Scope**: With agriculture evolving rapidly, there's a growing need for trained professionals in **agronomy**, **soil science**, **genetics** and **biotech**.
- ✓ **Pathways**: Institutions like **IARI**, **Punjab Agricultural University** and **TNAU** are key launchpads for careers in agri-research and policy-making.

6. Global and Government Support

- ✓ **Schemes and Incentives**: Initiatives like **Startup India**, **PM-KUSUM** and **RKVY-RAFTAAR** provide funding, incubation and technical assistance to young agripreneurs.
- ✓ **Global Linkages**: FAO, IFAD and World Bank projects increasingly include youth as stakeholders, opening international avenues for exchange and funding.

Conclusion

Youth hold the key to the future of agriculture. As the world faces growing challenges like climate change, food insecurity and declining rural economies, the active involvement of young people in agriculture is more crucial than ever. Despite existing barriers such as limited access to land, capital and training, a new generation of young agripreneurs, innovators and climate champions is emerging, transforming agriculture into a sector of innovation, sustainability and opportunity. Through the adoption of modern technologies, sustainable practices and entrepreneurial ventures, youth are redefining what it means to be a farmer in the 21st century. Their fresh ideas, digital literacy and willingness to experiment are breathing new life into traditional farming. With the right policies, institutional support and investment in youth-centric agricultural programs. An inclusive and resilient agri-system has the potential to meet global food demands while empowering rural communities and safeguarding the environment. Investing in youth today is essential, as they represent not only the future of agriculture but also its present. Their empowerment is a critical agricultural, social, economic and environmental necessity.

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Success Story on Shifting from Conventional to Drip Irrigation Method -A leap towards Scientific Water Application

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Abstract: Sh.Ghansyam Yadav S/o Jagannath Yadav of village Suhana, Digod, Kota in Left main canal area of Chambal Command has taken a lead role in adopting the drip irrigation method including fertigation. On the advice of researchers of AICRP on Irrigation Water Management, Agriculture Station, Kota, he adopted drip irrigation and fertigation technology in cucumber grown in *Kharif* season instead of soybean crop irrigating by flood method of irrigation. He was astonished to observe that by taking cucumber crop under drip fertigation system instead of soybean crop under surface method of irrigation, he could able to enhance net income by approx. 7 times and saved water by 60-70 per cent respectively. The saved water he could utilized to irrigate other crops in his farm. His adoption encouraged other farmers also adopted drip irrigation in crops and area under this technology is being increased.

Introduction

The village Suhana, Digod tehsil, district Kota is irrigated by Tube wells having water level of 350 ft to 750 ft deep. Farmers of the area were irrigating their field by flood method of irrigation without paying attention towards wastages of irrigation water, soil health and crop production. Soybean/urd-wheat/mustard/gram cropping systems are the predominate cropping systems in the area. In *Kharif* season, most of the farmers grow soybean crop and they were totally dependent on rainfall. Due to uncertainty, uneven distribution, erratic pattern of rainfall and early withdrawal of monsoon, one or two irrigations in soybean crop were applied through flood method of irrigation.

Soybean crop before drip irrigated cucumber crop in previous year at the field of Sh.Ghansyam Yadav	Sh.Ghansyam Yadav in his drip irrigated cucumber field

Since last few years, the situation has changed considerably. Looking to the situations of the area, AICRP on Irrigation Water Management conducted an experiment regarding scientific water management for increasing water use efficiency and water productivity in *Kharif* crops. After thorough investigations, some portion of the irrigated land can be replaced by vegetables/cucurbits with drip irrigation and it was advised that cucumber crop irrigated every third day based on 80 per cent evaporated water by drip irrigation method (30-35 minutes) and applying 100 per cent recommended dose of fertilizers (100:40:40:: N:P:K) in combination of water soluble fertilizers in 10 equal splits at an interval of 7 days, which notably improved cucumber yield and conserved irrigation water.

Table 1: Comparison of surface and pressurized irrigation at farmers field of Suhana village

Crops	Cost of cultivation (Rs./ha)	Yield (t/ha)	Gross return (Rs./ha)	Net return (Rs./ha)	Water applied (M^3)	Water Productivity (Rs./M^3)	Saving of water over surface method (M^3)
Soybean	23,000	1.350	60,750	37500	1000 *	37.5	-
Cucumber	2,10,000	38.2	4,96,600	2,86,600	300 - 400 *	955-716	600 - 700

* Excluding rainfall

The AICRP on Irrigation Water Management, Agricultural Research Station in Kota, in partnership with the department of horticulture and state government extension agencies, has initiated efforts to promote pressurized irrigation methods in the region. This advice was provided to extension agencies and other government departments at a Zonal Research and Extension Advisory Committee meeting. These agencies informed farmers about the advice and government subsidies for drip irrigation, and they demonstrated the benefits by conducting exposure visits to the Irrigation Water Management centre, Kota, and convincing some of them to install drip irrigation in their farms.

A surface drip irrigation system was exhibited for a cucumber crop in the field of Sh.Ghansyam Yadav in the Suhana village of Kota district during Kharif season of 2024. He utilizes high-quality cucumber seed variety *ALEKHYA F1* obtained from Kota. The farmer has twenty-five hectares of irrigated land. The drip system was set up in 0.5 hectare. Seedlings were planted at a spacing of 1 m x 1 m. The survival percentage for seedlings was 90-95%.


Drip irrigated cucumber field


Drip irrigated cucumber fruits

Sh.Ghansyam Yadav was surprised to learn that cucumber crops yielded a net revenue of ₹ 1,43,300 from 0.5 hectares of land in 4 to 5 months due to high quality and consistent size of produce. Water savings ranged between 60-70 %. In addition, he also saved a significant amount of money on agricultural irrigation labour costs.


Field visit by AICRP on IWM Scientists at the field of Sh.Ghansyam Yadav in Suhana village


Field Day organized at the field of Sh.Ghansyam Yadav by AICRP on Irrigation Water Management

A huge number of farmers from neighbouring areas came to see the cucumber drip irrigation demonstration. They are convinced after witnessing the advantages of drip irrigation on a cucumber crop such as vine. The farmer's name stated that using drip irrigation on cucumber crops boosted not just productivity but also produce quality, and that the crop was ready for harvest at least one week earlier than with traditional (flood) irrigation. Many farmers came forward and expressed an interest in using drip irrigation systems for various crops.

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Survival Tactics: The Incredible Defense Mechanisms of Insects

Survival Strategies: The Amazing Défense Mechanisms of Insects

Insects are among the most hardy and varied animals on the planet, with millions of species thriving in nearly every nook and cranny of the globe. Their survival strategies are some of the most creative in the natural world, from camouflage to chemical warfare Insects, with their intriguing range of adaptations, have evolved numerous defense mechanisms to defend themselves against predators. While many of these defense strategies are effective, each comes with its own set of advantages and disadvantages. This article explores eight of the most extraordinary survival tactics employed by insects, providing insight into how these remarkable creatures outwit and evade danger in their environment

1. Camouflage: Blending into the Environment

Camouflage is a survival technique found most abundantly in insects. Leaf insect and stick insect impersonate their environment with their very appearance, rendering them almost invisible to predators. Their body contours replicate leaves, twigs, or bark and allow for a degree of protection that is unmatched.

• **Predator Avoidance:** The foremost advantage of camouflage is that it enables insects to escape detection. Predators seek prey using visual signals, and camouflage allows insects to blend into the surroundings, thereby decreasing the likelihood of being detected.

• **Energy Efficiency:** Camouflage needs minimal to zero energy cost after the insect adapts to the environment. It is a passive defense mechanism that does not necessitate active locomotion or chemical use.

Limitations:

• **Limited Mobility:** Camouflaged insects are frequently restricted from free movement. When they relocate, they may briefly lose their defensive camouflage and hence become easy targets for detection.

• **Environmental Dependency:** Camouflage is only effective if the insect finds itself in an environment that complements its color. Environmental shifts, like the change of seasons turning the leaves a different color, will make the camouflage useless.

Camouflage is an extremely efficient survival strategy for most insects, enabling them to remain concealed from predators with little energy cost. It has its limitations, though, especially when environmental fluctuations interfere with the insect's camouflage ability.

2. Chemical Warfare: Poison and Bad Smells

Several insects, such as bombardier beetles and stink bugs, employ chemical compounds as a defense tactic. The bombardier beetle, for instance, blasts out a hot, poisonous chemical spray from its abdomen when threatened. Other insects, such as stink bugs, emit strong-smelling secretions to deter predators.

Advantages:

• **Instant Threat Repellent:** Chemical defense may be very useful in repelling predators instantly. The foul odor or painful property of the chemicals deters the majority of the predators from further approaching the insect.

• **No Requirement of Physical Conflict:** Insects employing chemical warfare do not need to fight back physically, which is dangerous. The chemical strike offers a danger-free method of protection.

Drawbacks:

• **Energy-Expensive:** The manufacture of chemical defenses can be energetically expensive. Insects have to absorb certain nutrients in order to synthesize these chemicals, and this may restrict their availability.

• **Limited Effect Against All Predators:** There are predators that can develop resistance to the chemicals, making them less effective. Some birds or mammals, for instance, will not be repelled by the toxic chemicals.

Chemical warfare is a potent defense system that provides rapid and effective protection from predators. It has energy costs, however, and is not always effective against every predator.

3. Mimicry: Appearing to be Something Hazardous

Mimicry is the process by which insects emulate the look of other animals or toxic substances to escape predators. Perhaps the most well-known example is the viceroy butterfly, which mimics the poisonous monarch butterfly. In imitating dangerous or distasteful species, harmless insects tend to be left alone by predators.

Benefits

• **Deceptive Protection:** Mimicry has the potential to effectively deceive predators into believing that an insect is more hazardous or less edible than it really is. This will cause the insect to be spared.

• **Long-Term Survival:** Insects mimicking toxic or harmful insects enjoy the protection of having learned avoidance by the predator. After a predator has received the penalty of attacking an offending species, the predator will stay away from similar species.

Disadvantages:

• **Vulnerability to Errors:** Mimicry will be effective only if the predator links the mimic with the dangerous species. A predator who has never seen the dangerous species or who has learned to play the mimicry trick can remain still attack the insect.

• **Energy Cost of Imitation:** Producing and sustaining mimicry is an energy-demanding activity. It needs the insect to possess the correct patterns, forms, and behaviors in order to deceive predators, which could take away from their other functions.

Mimicry is a sophisticated defense tactic that takes advantage of the learned behaviors of predators. Although it is very effective, it can fail if predators are not trained to steer clear of the mimic or are not sufficiently convinced by the mimic.

4. Armor and Physical Defenses: Hard Shells and Spines

Certain insects have developed physical defenses such as hard exoskeletons or spines to defend against predators. Beetles, for example, the rhinoceros beetle, possess hard, Armor-like shells to serve as shields against predators. Caterpillars such as the Lonomia also bear venomous, sharp spines.

Advantages:

• **Physical Protection:** Armor and spines offer perfect physical protection against predators. The beetle's hard shell or the caterpillar's sharp spines render predators unable to eat or damage them.

• **Durable and Reliable:** Being physical structures, once evolved, these defenses are very reliable and don't need much energy to be maintained.

Disadvantages

• **Limited Mobility:** The weight of the heavy exoskeletons of certain insects can limit their mobility. Thickly armored insects can be less agile and quicker to catch because they are slower and less mobile.

• **Vulnerable to Specialized Attackers:** Although armor offers protection against common predators, there can be specialized predators that might still be able to penetrate the defense, e.g., birds with powerful beaks or mammals with sharp incisors.

Armor and spines are a classic defense system, providing effective cover. But even their efficacy may be compromised by specialist predators or by the bodily restriction they impose on the freedom of movement of the insect.

5. Flight and Speed: Flight from Peril

Flight is perhaps one of the most efficient means by which insects can elude predators. Insects like dragonflies and grasshoppers make use of their remarkable speed and flying skills to elude capture. These insects are able to rapidly leave the ground, outmaneuvering most predators.

Advantages:

• **Rapid Escape:** Flight enables insects to rapidly create distance between themselves and a predator, usually before the predator can respond.

• **Enhanced Range:** Insects travel long distances when searching for shelter or food, and with flight, their options of reaching more secure zones on being threatened get enhanced.

Disadvantages:

• **Highly Energy Consuming:** Flight is an energy-draining function. Insects utilizing flight a great deal may quickly tire out if they have predators to flee from constantly.

• **Vulnerability During Landing:** Although flying offers a means of escape, insects remain vulnerable during landing or in the process of transitioning from flight to ground, where they are open to ambush.

Flight is a very efficient defense strategy, giving insects the capacity to escape quickly from threats. Yet the high energy requirements and the susceptibility to vulnerability at landings mean that it is not an absolute defense.

6. Warning Coloration: Bright and Bold Signals

Warning coloration or aposematism is the use of striking, vivid colors by insects to warn predators that they are distasteful or toxic. Examples are the orange-and-black coloration of monarch butterflies and the yellow-and-black stripes on wasps.

Benefits:

• **Predator Deterrent:** The striking coloration sends a strong warning to predators that the insect is dangerous or distasteful and hence tends not to be attacked.

• **Long-Term Survival:** The moment a predator understands that bright colors signal negative experiences, the survival of the insect is promoted, as predators will avoid such markings in subsequent encounters.

Disadvantages:

• **Attracting Attention:** Although warning coloration serves to deter predators, it also makes the insect conspicuous. In situations where camouflage would be more useful, bright colors become a hindrance.

• **Dependence on Toxicity:** The effectiveness of warning coloration depends on the insect's actual toxicity or distastefulness. A non-toxic insect using warning colors might still be targeted by predators that ignore the warning.

Warning coloration is a successful way of warning off predators, but it only has a chance to be effective if the insect really does have the characteristics it is warning off. In certain situations, this strategy will expose the insect to more danger instead of less.

7. Startle Displays: Warning Off Predators

Startle displays are defense mechanisms that startle or scare predators away. Certain insects, like the giant walking stick, abruptly display vibrant coloration or inflate their bodies upon threat to deter potential predators.

Advantages:

• **Immediate Effect:** Startle displays have the ability to instantaneously shock predators, making time for the insect to flee or seek cover.

• **Low Cost:** As compared to chemical or physical defenses, startle displays do not take a lot of energy resources, and thus are an effective method of defense.

Disadvantages:

• **Temporary Effect:** The surprise value of a startle display tends to last for a brief duration. When the predator regains from the surprise, it will try to attack once more.

• **Ineffectiveness Against Certain Predators:** Some predators, especially those familiar with such displays, might not be deterred by such measures.

Startle displays are a cheap, immediate defense that may give a temporary edge. But they are not infallible and are generally only effective temporarily.

8. Self-Amputation: Giving Up a Part to Save the Whole

Certain insects, such as some beetles and crickets, have the ability to lose a limb or appendage to free themselves from the jaws of a predator. This is termed autotomy or self-amputation. The insect is able to regrow the lost appendage with time.

Benefits:

• **Opportunity to Escape**: Through the sacrifice of a limb, the insect is able to free itself from the grip of a predator, thus staying alive.

• **Minimum Long-Term Cost:** In most instances, the insect can regrow the lost limb, enabling it to function normally after the wound heals.

Disadvantages:

• **Physical Disability:** The loss of a limb may decrease the insect's mobility or capacity to obtain food, rendering it weaker against future attacks.

• **Energy Cost to Regrow:** To regrow a lost limb requires energy and time, which may put the insect at a disadvantage while recovering.

Self-amputation is a radical yet effective protective device that gives the last resort in fleeing from enemies. But this comes at a physical and energy cost during healing.

Conclusion

Insects have developed some of the most remarkable defense strategies to endure in a predator-infested world. Whether it is through camouflage, chemical warfare, or flight, each of these mechanisms brings something special with its own set of advantages and disadvantages. No defense strategy is impermeable, but the creativity behind these strategies demonstrates the resilience and versatility of insects. These survival strategies not only ensure the persistence of insects but also provide amazing glimpses into the miracles of evolution and natural selection.

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Tiny Fish, Big Regeneration: Exploring Zebrafish Healing Powers

Abstract

When tissues in the body get damaged, they may either heal fully and grow back or they may leave behind scars and lose some function. How the body responds to such damage can be different depending on the type of tissue and the species. By studying animals that naturally heal and regenerate well, scientists can find ways to improve recovery in species like humans, where regeneration is limited. The **zebrafish (Danio rerio)** is a small freshwater fish that has become one of the best vertebrate models for studying regeneration. In this article, we look at the tools used to study regeneration in zebrafish, explain how the process works at the cellular and molecular level, and explore how this research could help in developing treatments for humans in the future.

Keywords: Zebrafish, genes, regeneration.

Introduction

In vertebrates, tissues are in a constant state of turnover, meaning that cells that no longer function properly are regularly replaced by new ones. However, the rate and extent of this cellular turnover differ from tissue to tissue. For example, cells in the skin and intestines are rapidly replaced, whereas more complex cells, such as heart muscle cells (cardiomyocytes) and neurons, are typically not replaced once damaged in adulthood. In the case of neurons, cell replacement is mostly limited to specific regions within the brain. When tissues suffer injury, the response can follow two paths: either repair through the formation of scar tissue or regeneration, where the damaged tissue is restored by the growth of new cells that are similar to the ones lost. Regeneration is a complex process that begins with immune cells infiltrating the injury site to clear dead tissue and prevent infection. Next, a structure called the extracellular matrix (ECM) is deposited, which provides a scaffold for new tissue to form. If the regeneration process is successful, the damaged tissue is fully replaced, and the original function of the organ or tissue is restored, often without leaving a permanent scar. However, not all species have the same regenerative capacity. In mammals, including humans, regenerative abilities are quite limited, typically confined to tissues such as the skin and liver, and even then, regeneration only occurs within specific time windows or during early development. On the other hand, certain vertebrates, like the axolotl, are capable of regenerating entire limbs, organs, and even parts of their heart. Among vertebrates, the zebrafish (*Danio rerio*) has emerged as one of the most well-known and widely studied models for tissue regeneration. These small, freshwater fish have the remarkable ability to regenerate a wide variety of tissues, including the heart, brain, spinal cord, fins, retina, and even the liver. This ability has made zebrafish an ideal organism for studying how regeneration works at the molecular and cellular levels, providing insights into the genetic and biological mechanisms involved in tissue repair and regrowth.

Exploring Regeneration in Zebrafish: Key Tools and Methods

Zebrafish have become an essential model for studying how organisms regenerate tissues and organs due to their **easy accessibility**, **genetic tools**, and the ability to observe them **live**. These features make zebrafish ideal for researchers to explore regeneration processes. Below, we'll dive deeper into the methods used to study regeneration in zebrafish.

Tissue Injury Models

To study how zebrafish regenerate tissues, researchers use different **injury models**. These models simulate tissue damage using physical, chemical, or genetic methods. By causing controlled damage, scientists can observe how zebrafish repair and regenerate the affected areas. Some models involve physical injuries like cutting or freezing tissue, while others use **genetic tools** to specifically target certain cells for destruction.

Physical Injuries

Amputation (Resection)

One of the most common injury models is amputation, where part of the tissue is cut off, such as the fin or heart. For example, when zebrafish lose part of their fin, the first thing that happens is that a protective epidermal cap forms over the injured area. This cap protects the wound and helps it heal. Underneath the cap, undifferentiated cells (cells that haven't yet specialized) start to multiply and form a blastema, a group of cells that will later become the new fin. After these cells divide, they will redifferentiate, or turn back into the specialized fin cells needed for regeneration. Over time, this results in a fully regenerated fin. A similar process occurs in the heart. After part of the heart is removed (resection), a blood clot forms at the injury site. This clot is replaced by a fibrin clot, a type of protein mesh that helps the heart heal. Over time, the damaged heart tissue grows back, eventually looking almost identical to the surrounding tissue.

Cryoinjury (Freezing Injury)

Cryoinjury is another method where very cold metal is used to freeze and kill cells in a specific area. This technique is most commonly used for studying heart and fin regeneration. After the frozen tissue dies, it eventually falls off in the fin, and regeneration begins just like in the amputation model. However, the process in the heart is a bit different. First, fibroblasts (cells that help repair tissue) come in and deposit an extracellular matrix (ECM), a framework of proteins to support new growth. Over time, the scar tissue created by this repair shrinks, and new heart tissue forms to replace it.

Stabbing (Injury to the Nervous System)

Stabbing is used to injure the central nervous system, particularly the spinal cord. This method involves making a small puncture in the tissue, which leads to an immune response. After injury, glial cells (cells that support neurons) gather at the damaged site, and progenitor cells (cells that can become different types of cells) start multiplying. These progenitor cells will eventually turn into new nervous tissue, helping the zebrafish recover from spinal cord injury.

Chemically Induced Cell Damage

Aside from physical injuries, chemicals can be used to damage organs in zebrafish. These chemicals can either be injected into the fish, given orally, or added to the water for the fish to ingest. Once the fish is exposed to these chemicals, they cause cell death, which is followed by a regeneration process.

Gentamicin (Kidney and Lateral Line Damage): Gentamicin is an antibiotic that can damage specific cells in the kidney or lateral line (a sensory organ). This method helps scientists study how zebrafish regenerate these organs after injury. After the cells die, healthy cells in the area will begin to proliferate (multiply) and migrate to replace the damaged tissue.

Acetaminophen (Liver Damage): Acetaminophen (commonly known as Tylenol) is another chemical that can cause liver damage. It is used to simulate liver injury in zebrafish. After the damage occurs, the cells in the surrounding area will begin to proliferate and migrate, eventually repairing the damaged liver.

These methods help researchers understand how zebrafish regenerate their organs, but they also come with some challenges. For instance, the chemicals might affect cells that weren't the intended target, leading to uneven injuries. Also, the drugs might not spread evenly in the water, causing inconsistent results.

Genetic Ablation (Targeted Cell Destruction) Genetic tools provide researchers with a more precise way to study regeneration by allowing them to **target specific cell types** for destruction. This can help scientists study how the body reacts to the loss of particular cells.

Diphtheria Toxin (Cell Death Regulation):
In transgenic zebrafish (fish genetically altered to carry certain genes), scientists can control the expression of diphtheria toxin, a substance that can kill specific cells. When the toxin is activated, it destroys only the targeted cells, allowing researchers to observe how the body regenerates after certain types of cells are lost.

Killer Red (Light-Activated Cell Death):
Another genetic method uses a fluorescent protein called Killer Red, which can kill cells when exposed to intense light. By shining light on specific areas of the fish, researchers can induce **cell** death and study how the surrounding cells regenerate the lost tissue. This method is useful for studying tissue regeneration at a very precise level. These genetic techniques give researchers better control over which cells are damaged and help them study how specific tissues and organs regenerate after injury.

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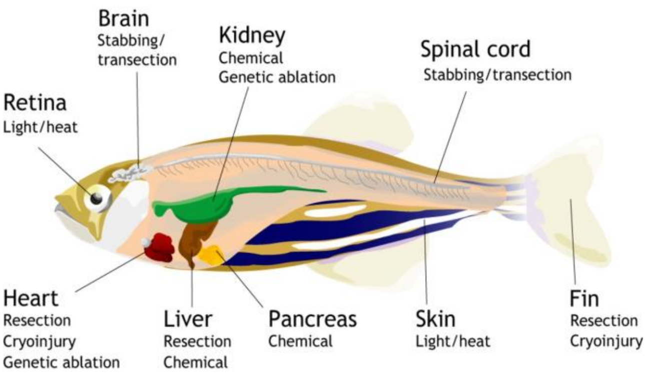

Figure 1. Organ regeneration in the zebrafish. Summary of some of the organs and tissues used for regeneration studies in zebrafish. Preferred injury models are annotated for each organ.

Applications of Zebrafish Regeneration Research
Zebrafish (*Danio rerio*) have emerged as one of the most valuable models in regenerative biology due to their remarkable ability to regenerate various organs and tissues throughout their lifespan. This regenerative capability makes them not only fascinating subjects for basic science but also powerful tools for advancing medical research, drug development, and tissue engineering.

One of the most significant applications of zebrafish research is in the field of biomedicine, especially for understanding how to heal damaged human tissues. Zebrafish can regenerate heart muscle, spinal cord, brain tissue, liver, kidney, retina, and fins. Since they share about 70% of their genes with humans, and nearly 84% of human disease-related genes have a zebrafish counterpart, discoveries made in zebrafish often provide valuable insights into human biology. For instance, zebrafish heart regeneration studies have revealed how cardiomyocytes (heart muscle cells) can proliferate and repair damage without forming permanent scar tissue—something that human hearts are incapable of. This has inspired research into activating similar repair mechanisms in human cardiac tissue, especially after myocardial infarctions (heart attacks).

Similarly, zebrafish have shown a strong capacity for nervous system regeneration. They can regenerate the spinal cord and retinal neurons, offering a model for studying neurodegenerative diseases like Alzheimer's and Parkinson's, as well as spinal cord injuries. Understanding how zebrafish reprogram glial cells and neural progenitors to replace lost neurons can help scientists uncover why the human nervous system lacks this ability and how it might be enhanced through medical intervention.

Beyond studying regeneration itself, zebrafish are an exceptional system for high-throughput drug screening. Their embryos are transparent, develop externally, and grow rapidly, which allows scientists to visualize organ formation and regeneration under a microscope in real time. This transparency, combined with genetic manipulation techniques, allows researchers to label specific tissues with fluorescent markers, making it easier to track regeneration processes during drug testing. Thousands of compounds can be tested efficiently and cost-effectively in zebrafish to identify those that enhance or inhibit regeneration. Pharmaceutical companies and academic labs use zebrafish as a screening platform to discover new drugs that could stimulate tissue repair.

Zebrafish also play a role in toxicology and safety pharmacology. Before drugs are given to humans, it's important to know whether they cause harm to organs. Zebrafish allow researchers to assess how certain chemicals affect tissue integrity and regeneration, helping to eliminate harmful compounds early in the drug development process.

In the future, zebrafish could aid in the customization of regenerative therapies, particularly with the advancement of personalized medicine. By studying patient-specific genetic mutations in zebrafish models, researchers may identify individual differences in regenerative responses and drug efficacy, paving the way for tailored treatment strategies.

Is Zebrafish Regeneration Infinite?

Zebrafish are known for their extraordinary ability to regenerate lost or damaged body parts, and in many cases, this regeneration seems almost unlimited. For instance, even after several rounds of fin or barbel amputation, zebrafish can regrow these structures over and over again. Studies have shown that repeated injuries do not stop the regrowth process, although small differences may appear in the newly formed structures. These changes might include slight shifts in pigmentation patterns on the fin or in the positioning of bone branches, suggesting that while regrowth is impressive, it may not always be exactly the same as the original. Interestingly, the age of the zebrafish does not appear to limit its regenerative ability, at least in the case of heart tissue. Older zebrafish are still capable of regrowing heart muscle after injury, which is quite different from most other vertebrates, including humans, where aging usually reduces healing capacity.

However, even in zebrafish, regeneration is not always completely perfect. Although the external appearance of an organ may look fully restored after injury—for example, the heart may show no visible scar—its internal function might not be entirely normal.

Organ/Tissue	**Regenerative Ability**	**Medical Relevance**	**Key Genes / Pathways Involved**
Heart	Regenerates up to 20% of ventricle tissue	Model for heart attack recovery, cardiac repair	**gata4, fgf, notch, retinoic acid, mps1**
Spinal Cord	Regrows neurons and reconnects spinal tissue	Insights into spinal injury repair and paralysis treatment	**stat3, sox2, wnt/β-catenin, shh**
Fin (Limb-like)	Regenerates bone, muscle, blood vessels, and skin	Model for limb regeneration and orthopedic recovery	**fgf20a, msxb, shh, wnt, bmp**
Brain	Neurogenesis in specific brain regions post-injury	Helps understand stroke recovery, neurodegeneration	**ascl1a, notch, stat3, sox2, wnt/β-catenin**
Retina	Regenerates all major retinal neurons	Key for therapies for blindness, retinal degeneration	**mmp9, ascl1a, lin28, shh, stat3, notch**
Liver	Compensatory liver regrowth post-damage	Applicable in liver failure and regeneration therapies	**hhex, wnt, notch, stat3**
Kidney	Regenerates nephrons and tubule cells	Chronic kidney disease and acute kidney injury models	**wt1b, pax2a, notch, retinoic acid**
Skin & Scales	Quick re-epithelialization and regrowth of scales	Helps develop burn and wound healing therapies	**tgfb, wnt, fgf, mmp9**

In some studies, the area of the heart that was regenerated did not move in perfect rhythm with the rest of the heart muscle, showing delayed or uneven contractions. This suggests that the newly formed tissue, while structurally similar, may not always perform exactly like the origin. These findings highlight an important point: regeneration should not be judged solely by how an organ looks after healing. There is a difference between morphological regeneration (restoring the shape and structure) and functional regeneration (restoring full performance and activity). Zebrafish may be champions of regeneration, but even in them, the process is not always 100% flawless. Understanding these subtle differences is crucial for scientists who hope to apply lessons from zebrafish to improving human healing and regenerative therapies.

Conclusion

Zebrafish have emerged as a powerful model for studying tissue and organ regeneration. Their ability to regrow complex structures like the heart, spinal cord, and fins without scarring provides valuable insights into natural healing processes that are absent or limited in humans. Through advanced imaging, genetic tools, and a wide range of injury models, scientists are uncovering the steps involved in zebrafish regeneration — from immune response and cell dedifferentiation to tissue regrowth and remodeling. These discoveries are laying the groundwork for innovative regenerative therapies, which could one day revolutionize the way we treat injuries and chronic diseases in humans. However, challenges like interspecies differences, ethical constraints, and incomplete understanding of molecular signals still exist. Overcoming these will require continued research and interdisciplinary collaboration. As we move forward, zebrafish will continue to serve as a tiny yet mighty ally in our quest to unlock the full potential of regenerative medicine.

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UFRA DISEASE OF RICE & THEIR MANAGEMENT

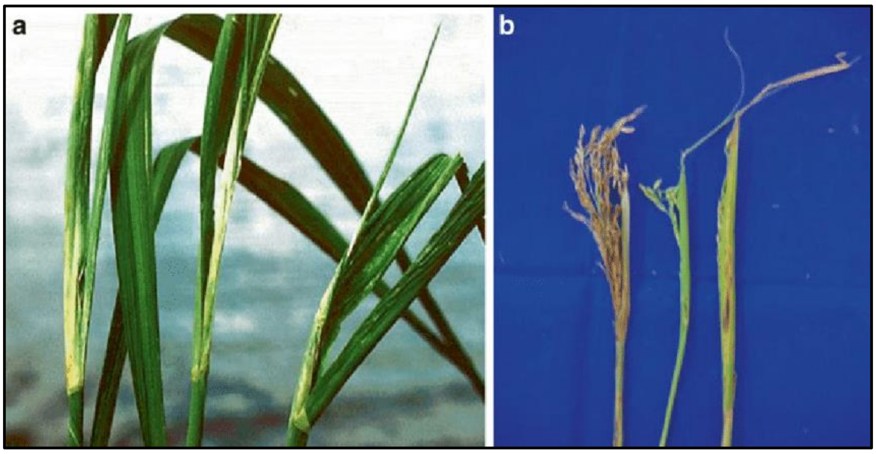
ABSTRACT: Many of the plant parasitic nematodes are reported in association with rice culture in India. The potential of a few plant-parasitic nematodes as pest of rice has been investigated. Among which, the stem or ufra nematode (***Ditylenchus angustus***) is widely prevalent & is restricted to the Northeastern states, Assam & West Bengal, inflicting upto 30% yield loss. In this article, mainly the symptoms, distribution, host ranges, biology and management of this nematodes are discussed.

KEYWORDS: Rice, ***Ditylenchus angustus***, alternate host, yield loss, management.

INTRODUCTION: Plant Parasitic nematodes cause serious damage to rice crop. They have diverse parasitic habits, but mainly cause mechanical damage and/or malfunctions of the physiological processes that involved in plant development, resulting in poor growth and yield loss. About 32 species belonging to 13 genera were observed in association with the crop, among which few are economically important. Based on their parasitic habit, nematodes are mainly divided into two groups- a) Foliar parasites that mainly feeds on stem, leaves & panicles; & b) Root parasites. Some of the most important foliar parasitic nematodes are- 1) white-tip nematode **(*Aphelenchoides besseyi*)**; 2) rice stem nematode **(*Ditylenchus angustus*)** & some of the important root parasitic nematodes that are associated with the rice crop are- 1) rice root nematode **(*Hirschmaniella spp.*)**; 2) rice root-knot nematode **(*Meloidogyne spp.*)**; 3) rice cyst nematode **(*Heterodera spp.*)**; 4) rice root lesion nematode **(*Pratylenchus spp.*)**: 5) rice lance nematode **(*Hoplolaimus spp.*)**. Here the rice stem nematode which is most destructive in rice field is discussed.

1) RICE STEM NEMATODE (*Ditylenchus angustus*):

a) DISTRIBUTION: The rice stem nematode has been reported in Bangladesh, India, Burma, Malaya, Thailand, Phillipines & Madagascar. The yield losses due to this nematode are about 10 to 30% (**ASSAM & WEST BENGAL**).



b) <u>SYMPTOMS</u>: The nematode causes **Ufra** disease in rice. Initial chlorosis or streaks appear on the leaves. There are mainly 2 types of symptoms are found, a) **Swollen Ufra**; b) **Ripe Ufra.**

In **Swollen Ufra**, the panicle remains enclosed within the leaf sheath & branching occurs in the infested portions. In **Ripe Ufra**, the panicle emerge & produces normal grain only near the tip region.

Dark brown patches of ufra infected plants can be observed in the field after the panicle initiation. Panicles remain completely enclosed within a swollen sheath or only partially emerge.

c) <u>BIOLOGY</u>: It is an ectoparasitic nematode & can feed on young, foliar tissues. In deep water rice seedlings, nematodes are found around the growing point. During the humid periods, nematodes are migrated upwards to feed on newly forming tissues enclosed in rolled leaf sheaths. They accumulate and feed on the primordia of the developing panicles and at harvest, they are coiled in a quiescent stage mainly within the dried glumes of the lower spikelets on each panicle, but not within the grains. Activity and infectivity are resumed when water returns for the next rice crop.

The pre adult fourth stage juvenile (J_4) forms cottony like masses known as **Nematode Wool** in the infested plants. The optimum temperature for the greater infestation in rice ranges in between 27 to 30 ^oC.

d) <u>HOST RANGES</u>: ***Leersia hexandra*** (Swamp rice grass), ***Echinochloa colona*** (Jungle rice) & ***Sacciolepsis interrupta*** (Interrupted Cudweed) are found as an alternate host for this nematode.

e) <u>MANAGEMENT</u>: 1) Crop rotation with non-host crop like Jute, avoid water logged conditions by providing proper drainage system is highly recommended for the management purpose.

2) Removal of infested stubble after harvest.

3) Use of nematode free seeds.

4) Khao Tah Oo is the resistant rice variety against this nematode which is also resistant against blast disease of rice.

5) Spray Diazinon 100 ppm within 72 hours on the soil to control the nematode.

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VEGETABLES' NUTRITIONAL VALUE AND HEALTH ADVANTAGES

Introduction:-

The vegetables include a large amount of the human diet and are important for human nutrition, particularly as sources of phytonutriceuticals, which include minerals, dietary fiber, Vitamins C, A, B_1, B_6, B_9, E, and phytochemicals. Strong antioxidants found in some vegetable phytochemicals may lower the risk of chronic disease by preventing damage from free radicals, altering the metabolic activation and detoxification of carcinogens, or even influencing processes that change the trajectory of tumor cells. Consuming vegetables on a daily basis has been closely linked to improved gastrointestinal health and vision, lower risk of heart disease, stroke, diabetes, anemia, stomach ulcers, rheumatoid arthritis, and some types of cancer, as well as other chronic illnesses (**Dias J. S. 2012).** All the vegetables may offer protection to humans against chronic diseases. Nutrition is both a quantity and a quality issue, and vegetables in all their many forms ensure an adequate intake of most vitamins and nutrients, dietary fibers, and phytochemicals which can bring a much-needed measure of balance back to diets contributing to solve many of these nutrition problems.

2. The health benefits of the most consumed vegetables:-

2.1 Crucifers

uciferous vegetables (Brassicacea or Cruciferae family) which include, cabbage, brocolli, cauliflower, Brussels sprouts, kales, chinese cabbage, turnip, rutabaga, radish, mustards, among other vegetables, provide the richest sources of glucosenolates in the human diet. Most consumers associate cruciferous vegetable consumption with health. Crucifers rich in glucosenolates. Analysis indicated that 79% of β-carotene, 82% of α-tocopherol, and 55% of vitamin C variability in broccoli were associated with genetic factors **(A. Kurilich 1999).** Crucifers are also excellent source of folate. Brussels sprouts and broccoli were ranked among the highest vegetable sources for folate, contributing about 110 to 135 and 70 to 90 µg/100 g, respectively **(J. Scott *et al.*, 2000).**They have reasons for that because based on one of the largest and most detailed reviews of diet and cancer **(The World Cancer Research Fund in USA, 1997).** Dietary fiber content of cauliflower was estimated to be about 5% of the total fresh weight or about 50% of the total dry weight, consisting of about 40% nonstarch polysaccharides.

2.2. Alliaceae

Alliaceae family vegetables include, garlic, onion, leek, chive, Welsh onion, among other vegetables. They are rich in a wide variety of thiosulfides, which have been linked to reducing various chronic diseases. Similar to glucosinolates in crucifers, the types and amounts of thiosulfides in alliums vary significantly. Onion and garlic are an excellent source of calcium, potassium and manganese providing up to 10% of the human daily requirements of these elements. High fructan diets have also been shown to lower concentration of colesterol, tryacylglycerol, phospholipids, glucose and insulin in the blood of middle-aged men and women **(K. G. Jackson 1999).** A reduced cancer risk has been widely documented also for colorectal and prostate cancers.

2.3. Solanaceous Vegetables

The use of solanaceous vegetables in traditional medicine is ancient. Tomato is popular fresh and in many processed forms (e.g. ketchup, canned whole or in pieces, puree, sauce, soup, juice, or sundried). Compositionally, the tomato has a unique nutritional and phytochemical profile. The major phytochemicals in tomato are the carotenoids consisting of 60% to 64% lycopene, 10% to 12% phytoene, 7% to 9% neurosporene, and 10% to 15% carotenes **(S. Clinton 1998).**The increased recommendation was based on evidence indicating that 4700 mg potassium should help lower blood pressure, reduce the adverse effect of excess sodium intake on blood pressure, reduce the risk of kidney stones, and possibly reduce age-related bone loss. Tomato fruits are also an excellent source of ascorbic acid, about 200 mg/kg and are the major source of vitamin C next to citrus **(A. V. Rao and L. G. Rao, 2007).** For skin protection, tomato intake (40 g tomato paste corresponding to a lycopene dose of approximately 16 mg) for more than 8 weeks reduced ultraviolet light-induced erythema.

All fresh peppers are excellent sources of vitamins C, K, carotenoids, and flavonoids **(L. R. Howard *et al.*, 2000).** Antioxidant vitamins A and C help to prevent cell damage, cancer, and diseases related to aging, and they support immune function. They also reduce inflammation like that found in arthritis and asthma. Vitamin K promotes proper blood clotting, strengthens bones, and helps protect cells from oxidative damage. The capsaicin in hot peppers has been shown to decrease blood cholesterol and triglycerides, boost immunity, and reduce the risk of stomach ulcers. It used to be thought that hot peppers aggravated ulcers. Instead, they may help kill bacteria in the stomach that can lead to ulcers. Capsaicin has also analgesic, anti-bacterial, and antidiabetic properties.

The eggplant also contains important phytochemicals which have antioxidant activity. Phytochemicals contained in eggplant include phenolic compounds, such caffeic and chlorogenic acid, and flavonoids, such as nasunin. Nasusin or delphinidin- 3-(coumaroylrutinoside)-5-glucoside is the major phytochemical in eggplant. Eggplant is an excellent source of digestion-supportive dietary fiber and bone-building manganese. It is very good source of enzyme-catalyzing molybdenum and heart-healthy potassium. Eggplant is also a good source of bone-building vitamin K and magnesium as well as heart-healthy copper, vitamin C, vitamin B6, folate, and niacin **(A. H. Ensminger *et al.*, 1986).**

2.4 Cucurbitaceous

Commonly consumed plants including pumpkin, watermelon, melon, horned melon, and cucumber belong to the Cucurbitaceae family and are prized for their high nutritional content and health-promoting qualities. The vital macronutrients, minerals, and bioactive substances that these plants offer add to their nutritional and medicinal value. The antidiabetic, hypolipidemic, antioxidant, and anticancer qualities of Cucurbitaceae plants in particular make them useful for treating metabolic diseases and reducing the health hazards brought on by oxidative stress **(Boreck, M. & Karaś M. 2025).** Additionally, it looks at their glycemic load, glycemic index, and caloric value, providing information about how they may be used in dietary plans for those with diabetes, obesity, or insulin resistance. This review also examines frequently disregarded by-products, such as seeds, leaves, and flowers, which are abundant in bioactive substances that may have health advantages. This review emphasizes the nutritional and functional potential of Cucurbitaceae plants by gathering and evaluating the available evidence, so reaffirming their importance in a diet that promotes health and prevents disease.

3. Conclusions

Consuming a diet high in vegetables on a regular basis has unquestionably beneficial benefits on health since the phytonutriceuticals in vegetables can shield the body from a number of chronic illnesses. Vegetables reduce the risk of disease through a complicated and mostly unidentified method. The overall health benefit of the food is probably influenced by a number of its components. Numerous phytonutriceuticals with antioxidant qualities can either directly or indirectly affect redox-sensitive cell signaling pathways by squelching free radicals. Blood pressure is regulated in part by nutrients like potassium. A large number of minerals and phytochemicals associated with the fiber matrix are transported through the human gut by the dietary fiber content and type of various vegetables, which may also help to improve bowel transit, lower cholesterol, and help control blood glucose levels. Lastly, consuming more veggies may mean consuming fewer items high in calories, trans fats, and saturated fats, all of which may contribute to a healthy diet. Consumer-perceived nutritional quality that is reasonably priced may promote increased consumption, giving plant breeding a significant marketing advantage.

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VERMICOMPOST AND ITS EFFECT ON CROP YIELD AND SOIL HEALTH

Introduction

Vermicompost is the type of organic manure, which is used as source of nutrient for plant growth. It contains all the essential nutrients required by plants i.e. N, P, K, Ca, Mg etc. The regular addition of vermicompost improves the soil organic matter and humus substances which help to build up the soil structure. It increase the quality of products on long term basis and it give better yield of products. It promote the sustainable agriculture, i.e. the use of natural resources in that way it fullfill the needs of present generation without endangering the resource base of the future generation. Earthworms convert farm waste and organic residue into high quality compost. For the preparation of vermicompost four species of earthworms are *Eisenia foetida, Perionyx excavates, Eudrillus euginiae* and *Lumbrius rubellus* are important. For an estimate about 1000 adult earthworms can convert 5 kg waste into compost per day. Vermicompost is fine granural organic matter, when added to soil it loosen the soil and improves the aeration into soil. It improves the physical, chemical and biological properties of soil.


Definition of vermicompost: Vermicompost is a method of making compost, with the use of earthworms, which generally live in soil, eat biomass and excrete it in digested form. The compost obtained by this method is called as vermicompost.

Definition of vermiwash: Vermiwash is a liquid, a foliar spray, collected by passing water in a regulated way through a column of active live local earthworms being cultured in a cultured in a container.

Definition of vermiculture : Vermiculture means the scientific method of breeding and raising earthworms in controlled conditions.

Vermitechnology : Vermitechnology is the combination of vermiculture and vermicomposting. In other words, the raising of earthworms for the for the preparation of vermicompost is called as vermitechnology.

Materials required for the preparation of vermicompost :

- Basic raw material : organic farm material like straw, leaf fall etc. Marigold, pine needles, horse dung are not advisable to be used as feeding material for vermicompost.
- Starter: Cow dung, biogas slurry , urine of cattle etc.
- Soil animal : Earthworms species like *Eisenia foetida* is most commonly used for vermicomposting .
- Thatched roof or vermished.

Physical conditions of soil required by earthworms in compost material :

- pH range between 6.5 to 7.5 .
- Moisture : 60-70% moisture content is required.
- Aeration : 50% aeration from the total pore space.
- Temperature range between 18^0 C to 35^0C.

Types of vermicomposting :

Small scale vermicomposting :

The name indicates the vermicomposting is for small scale and the main aim of this is to meet the personal requirement. It produce 5-10 tonnes of vermicompost annualy.

Large scale vermicomposting :

The name indicated the vermicomposting is for large scale and the main aim of this is to meet the requirements at commercial level. It produce 50-100 tonnes of vermicompost annually.

Vermicompost preparation methods :

Mainly two methods are used for the preparation of vermicompost are bed method and pit method.

Bed method : composting is done on the pucca/ kachcha floor by making bed. The dimensions are 6*2*2 feet size for organic mixture. This method is easy to maintain and to practice.

Pit method : It is mostly prepared in pit method in a shady area in in the farm. The dimensions are 10*4*2 feet size for organic mixture.

Procedure for vermicomposting :

- 1^{st} layer – bedding material of 1 inch thick with soft leaves
- 2^{nd} layer – organic residue layer with 9 inch thickness finely chopped material.
- 3^{rd} layer – equal mixture of dung and water of 2 inch layer
- Continue the layer up to ground level and regular watering should be done.
- Protect the worms against natural enemies like ants, lizards, snakes, frogs etc.
- Maintain the proper moisture and temperature by turning and subsequent staking.
- At the day of 24^{th} , 4000 earthworms are introduced into the pit (1metre square= 2000 worms)
- Without disturbing the pit by regular watering the entire raw material will be turned into the vermicompost in the form of worm excreta.
- The temperature at the beginning may reach up to 66 degree C. Hence the earthworms should be added after 2-3 week.

Harvesting of the vermicompost from the pit :

- Stop watering before1 week of harvest.
- All the earthworms are spread across the pit come in closer and form the balls in 2 to 3 locations inside the pit.
- Heap the compost by removing the balls and place them in bucket.
- Earthworms moves downward and compost is separated by disturbing the top layer manually.
- Then the material is sieved in 2mm sieve, the material that passed through the sieve is called vermicompost.

- Store the vermicompost in polythene bags.
- Recomposting is done in the same pit or bed, vermicompost can be prepared in wooden box or brick column in similar way.

Nutrient composition of vermicompost :

SN	Nutrient	Content
1	Organic carbon	9.15 to 17.98 %
2	Total nitrogen	1.5 to 2.10 %
3	Total phosphorus	1.0 to 150 %
4	Total potassium	0.60 %
5	Ca and Mg	22.00 to 70.00 m.e / 100 g
6	Sulphur	128 to 548 ppm
7	Copper	100 ppm
8	Iron	1800 ppm
9	Zinc	50 ppm

Application rate :

The application rate for field crops 5-6 t/ha; vegetable 10-12 t/ha; flower plants 100-200 g/sq ft; fruit trees 5-10 kg/tree.

It can be applied in any crop at any stage, but it would be more beneficial if mixed if mixed in soil after broadcasting.

Advantages of vermicompost :

- Its application enhance nodulation in legumes. It improves the physical properties of soil like soil aeration, porosity etc.
- Nutrient content of vermicompost is higher than traditional compost.
- Vermicompost is rich source of nutrients, vitamins, enzymes, antibiotics and growth hormones.
- It is valuable soil amendment.
- It has immobilized enzymes like protease, lipase, amylase, cellulase and chitinase which keep on their functions of biodegradation of agricultural residue in the soil so that further microbial attack is speeded up.
- It does not odour as is associated with manures and decaying organic wastes.
- It increase the long term fertility of soil.
- It can be used as rooting medium and for establishment of saplings in nurseries.
- It improves the keeping quality and taste of produce.
- It gives disease resistance to plants.
- It increase the soil productivity per unit area.
- It promotes the sustainable agriculture.

Disadvantages of vermicompost :

- Vermicompost require high maintenance.
- It is a time consuming process it takes six to seven months for the preparation of vermicompost.
- The feed has to be added periodically and care should be taken that the worms are not flooded with too much to eat.
- They nurture the growth of pest and pathogen such as fruit flies.
- The bin should not be too dry or too wet and the moisture level to be monitored periodically.
- It release a very foul odour.

Effect of vermicompost on crop yield :

- Vermicompost accerlerates the germination of seeds.
- It increase the plant growth .
- It increase the no of fruits per plant and per branch, tiller, pod etc.
- Production of humic acid or growth hormones.
- Nutrient released slowly (as needed) in small but efficient quantities.
- It also accelerates the flowering.

- Improve the plant adaptation to abiotic stress.
- Suppresses the diseases and insect's attacks.
- Vermicompost enriched with auxins, cytokinin, humic acid, vitamins etc.

Effect of vermicompost on the growth of brinjal plant (Solanum melongena) under field conditions :

Plant characteristics	Without vermicompost	With vermicompost
Height of plant	1-1.5 ft	2-2.8 ft
No. of leaves	22-29	37-42
Length of leaves	6-7.2 cm	13-15 cm
Width of leaves	2.5-3.2 cm	5-7.6 cm
No. of fruits to each plant	2-3	6-12
Weight of brinjal	19.1-27.1 gms	296.1- 343.7 gms

Effect of vermicompost on soil health :

- Vermicompost improve the physical properties of soil such as soil aeration, soil structure, good porosity, bulk density and water retention.
- It improves the chemical properties such as pH, electrical conductivity and organic matter content of soil.
- It improves the biological properties of soil such as microbial activity in soil.
- It improves the root growth in soil.
- Enriches the soil with micro-organisms.
- Develops good soil structure for better root alteration.
- Fresh vermicompost increase worm population and ensures longer sustenance of soil fertility.
- Enriches the soil with plant hormones such as auxins and gibberellic acid.
- Attracts deep-burrowing earthworms already present in the soil which indirectly improves the fertility of soil.
- Enhance the soil biodiversity by promoting the beneficial microbes.

Conclusion :

Application of vermicompost + vermiwash has long term effect on physiological as well as on the biochemical properties of soil. When vermicompost is integrated with other chemical fertilizers it produce maximum yield than the sole application of vermicompost and other chemical fertilizers. Vermicompost is a process based on earthworms whose joint action provides degradation of organic waste. Vermicompost application not only improve the physical properties of soil but also enhance the nutrient status, organic matter, microbial activities and enzyme activities. Earthworms and microorganism show symbiotic relationship. The effect of vermicompost on plants are not solely attribute to the quality of mineral nutrition, it also provides the growth promoting substances.

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WEATHERING OF ROCKS- CHEMICAL, PHYSICAL AND BIOLOGICAL

Abstract

The process of rock weathering is a fundamental geomorphic activity that alters rock surfaces through physical, chemical, and biological mechanisms. Weathering weakens rock structures and works in conjunction with erosion to shape landscapes in both natural and built environments. Chemical weathering dissolves minerals through interactions with water, acids, and atmospheric gases, leading to the formation of clays, oxides, and salts. Physical weathering includes processes such as frost wedging, root expansion, salt crystallization, and exfoliation, which mechanically fragment rocks. Biological weathering results from the actions of plant roots, microorganisms, and animals, which contribute to rock disintegration through both physical and biochemical means. Recent technological advances have enabled high-resolution, remote monitoring of weathering processes, supporting applications in conservation, materials science, and the study of climate impacts. A multidisciplinary understanding of these processes is essential for ensuring the durability of materials and preserving both geological formations and architectural structures.

Keywords: Rock Disintegration, Stone Conservation, Weathering, Erosion

Introduction

One of the most basic geomorphic processes is the change of rock surfaces exposed to atmospheric conditions, which is sometimes referred to as "weathering." Rock deterioration, decay, crumbling, decomposition, rotting, disintegration, disaggregation, or breakdown are some of the terms used to describe the changes that occur because of physical, chemical, and biological processes. These changes typically weaken the rock surface and cause erosion. Weathering, however, can occasionally cause the rock's surface layers to become momentarily harder. While this type of hardening can temporarily prevent erosion on a rock surface, it might eventually cause the rock to deteriorate. For instance, a solid crust may react to environmental stresses somewhat differently from the underlying rock, which could cause the surface layer to deteriorate. Both urban and natural settings frequently experience this.

In order to further interact with atmospheric conditions, rock weathering processes work in tandem with erosion processes, which remove weathered elements to expose the new rock surface. Measuring and tracking the effects of weathering and erosion processes is essential to comprehending how these processes interact to affect rock surfaces.

The variety of techniques created to accomplish this has changed significantly in the last several years. This is partially due to weathering experts using their expertise of how rocks behave naturally to save buildings and comprehend how climate change can affect rock surfaces. Architects, designers, manufacturers, test laboratory staff, materials engineers, failure and forensic specialists, and others who need to know how weather affects materials and products will therefore find the methods useful in the larger field of materials degradation and stone conservation. Technological advancements have made it possible to investigate rock weathering remotely and at much higher spatial resolutions than previously possible, which has benefited in the development of methodologies. (Moses et al.,2014)

Chemical weathering

Chemical weathering typically takes place in soil where minerals and water are constantly in touch. Water, carbonic acid, oxygen, air pollution, and strong acids are all weathering agents. The end products of chemical weathering are clays, iron oxides, and salts, which are created when they mix with the minerals in rocks.

A broken rock surface's differential weathering is visible in this fig. 1. The massive fissures that run from top left to lower right have been preferred by water, which has caused them to deteriorate more quickly than the rock face. A severely cracked area of the rock that was subsequently filled with silica is shown by the pockmarked surface. Because silica is harder than the original rock, it stands out in sharp relief when the rock weathers away, indicating the fracture lines.

Three distinct approaches exist in which water is crucial to chemical weathering.

- First it forms carbonic acid, a weak acid, in the soil by reacting with carbon dioxide. Soil carbon dioxide is produced in large quantities by microbe respiration, and the water comes from rainwater that seeps through the earth and contains carbon dioxide from the atmosphere. Minerals in rock, particularly the carbonate minerals that comprise marble and limestone, are gradually dissolved by carbonic acid. The insoluble rock is broken down by the weak acid into water-soluble byproducts that enter the groundwater. These dissolved minerals have the potential to make water hard at large quantities.
- Second, by adhering to the mineral lattice, water can hydrate minerals. One example is the transformation of anhydrite into gypsum.

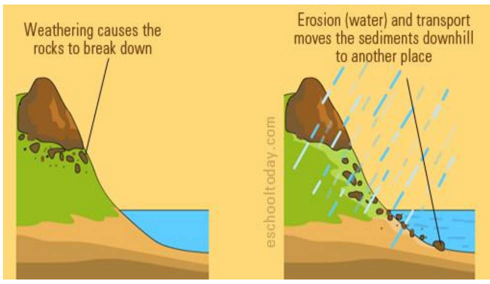

Fig 1: (Source: quizlet.com)

Lastly, minerals can hydrolyse and be broken apart by the water. This process breaks down the silicates, the most prevalent class of minerals. The mineral breaks down, reactive hydrogen ions released from the water attack the crystal lattice, and gases and acids are further agents of chemical weathering. Oxides like hematite, limonite, and goethite are created when oxygen reacts with the metals in minerals. They resemble the rust that develops on metal that is exposed to moisture or rain. Strong acids like sulfuric and nitric acid are typically found in trace amounts in air pollution that aids in the weathering of rock. Increased weathering of neighbouring rocks can also be caused by strong acids emanating from steam vents near volcanoes and former mine sites. (Lutgens,2002)

Physical weathering

Physical weathering is any process that stresses a rock to the point where it eventually fractures into smaller pieces. One of the most significant types of physical weathering is most likely the freezing of water in rocks. Water expands about 9% as it freezes. It will cause a crack to widen if it fills it entirely. Water-containing rocks will break up into tiny pieces if they experience repeated cycles of freezing and thawing. We refer to this as frost wedging. The absorption of water by swelling clays, called smectites, causes rocks to split. Additionally, plant roots can push themselves into rock fissures and fracture them. Rock exteriors expand, fracture parallel to the surface, and finally "spall" off as a result of forest fires. When sea mist evaporates, salt crystals may form in rock pores, causing the pores to disintegrate. When the overburden is removed via erosion, the rocks that were under pressure from the sediment and rock overburden may expand, causing fractures to emerge parallel to the surface. We refer to these joints as exfoliation cracks. (Birkeland,1999)

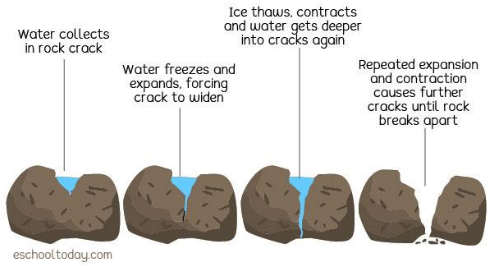

Fig. 2 (Source: https://eschooltoday.com/)

Biological weathering

The weakening and eventual disintegration of rock caused by microorganisms, plants, and animals is known as biological weathering. Rock may experience strain or stress from expanding plant roots. Even though the action is physical, a biological activity—growing roots, for example—is applying the pressure given in Fig. 3. Chemical weathering can also result from biological processes; for instance, organic acids produced by bacteria or plant roots aid in the dissolution of minerals. By changing the chemical makeup of the rock, microbial activity degrades its minerals and increases its susceptibility to weathering. Lichen, which is a symbiotic interaction between fungi and algae, is an example of microbial activity. The minerals in rock are broken down by the chemicals generated by fungi, and the algae then eat the minerals. As this process continues, holes and gaps continue to grow on the rock, exposing the rock more to physical and chemical degradation. Rock weathering can be indirectly accelerated by burrowing animals because they can carry rock pieces to the surface, where they are subjected to more severe chemical, physical, and biological processes. (University of Nebraska–Lincoln, n.d.)

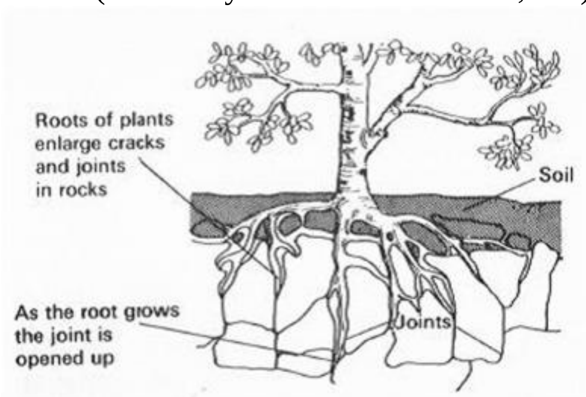

Fig. 3 (Source: https://www.sciencedirect.com/)

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Whispers of Change: RNAi's Role in Shaping Sustainable Insect Management

Introduction: A New Era in Pest Control

Agricultural productivity faces relentless pressure from different areas of biotic and abiotic factors such as climate change, habitat alteration, and an expanding global population. Among the many threats to food security, insect pests continue to inflict devastating losses up to 20–40% of total crop yield globally despite decades of chemical pesticide use. However, chemical control methods have reached a point of diminishing returns, as injudicious usage of pesticides has resulted in creating issues like resistance, resurgence and secondary pest outbreak with mounting of environmental concerns with an increase demand of consumer for pesticide free produce. This has created a vacuum for novel, sustainable, and species-specific pest control methods. RNA interference (RNAi) has emerged as one of the most promising solutions. Harnessing a natural gene-silencing mechanism, RNAi offers precision control over pest species with minimal environmental footprint. As a next-generation molecular tool, RNAi aligns with integrated pest management (IPM) goals and offers an opportunity to revolutionize modern agriculture. However, challenges such as dsRNA stability, delivery methods, and variable RNAi efficiency across insect orders must be addressed for successful field applications. This article explores the mechanisms, advancements, and future prospects of RNAi technology in revolutionizing insect pest control in agriculture.

The Discovery of RNA Interference: A Scientific Milestone

From Petunias to Gene Silencing

RNA interference (RNAi) has dramatically transformed the landscape of genetic research, allowing scientists to precisely silence genes and study their functions. But its discovery was anything but straightforward—it began with an unexpected twist in a garden plant. In 1990, scientists Rich Jorgensen and Carolyn Napoli aimed to intensify the purple pigmentation of petunia flowers by overexpressing the chalcone synthase (CHS) gene. To their surprise, the modified plants produced white or variegated flowers instead of deeper hues. This mysterious loss of pigmentation was one of the first observed instances of what we now recognize as RNA interference, a process where the introduction of extra genetic material silences a gene instead of enhancing it. Two years later, in 1992, a similar silencing effect was observed in the fungus *Neurospora crassa* by Romano and Macino. When they introduced RNA sequences matching an existing gene, it suppressed the expression of both the introduced and the native gene. This process was dubbed "quelling"**,** and it pointed to a conserved gene-silencing mechanism guided by RNA molecules. Evidence for RNA-based gene silencing in animals emerged when Guo and Kemphues conducted experiments in the nematode *Caenorhabditis elegans*.

What Is RNA Interference? A Primer

RNA interference is an evolutionary conserved process by which double-stranded RNA (dsRNA) suppresses the expression of specific genes.

RNA interference (RNAi) is a naturally occurring biological mechanism that regulates gene expression by silencing specific target genes. RNAi involves the introduction of double-stranded RNA (dsRNA) into a cell, leading to the degradation of complementary messenger RNA (mRNA) and subsequent inhibition of protein synthesis. This process not only serves as a vital defense mechanism against viruses and transposable elements in eukaryotes but has also been harnessed as a powerful tool for genetic research and biotechnology.The RNAi pathway begins when long dsRNA is processed by the enzyme Dicer into small interfering RNAs (siRNAs), typically 21–23 nucleotides in length. These siRNAs are then incorporated into the RNA-induced silencing complex (RISC), where the guide strand directs RISC to bind and cleave complementary mRNA, preventing its translation. In insects, systemic RNAi—where the silencing effect spreads beyond the initial site of dsRNA delivery—varies among species, influencing the feasibility of RNAi-based pest control strategies. Unlike mammals, many insects exhibit a robust systemic RNAi response, where introduced double-stranded RNA (dsRNA) can spread throughout the body, enhancing its effectiveness in gene silencing. However, the efficiency of RNAi varies significantly among insect species, with beetles (Coleoptera) showing high sensitivity, while others, such as moths (Lepidoptera) many, exhibit weaker responses due to differences in their RNAi machinery.

Mechanism of Action in Insect Pests

The RNAi pathway in insects follows a sequence of key steps:

1. Uptake of dsRNA: Insects can uptake dsRNA through oral feeding, injection and topical application sometimes. The uptake varies among different orders. Coleopterans (e.g., beetles) show high systemic uptake, while Lepidopterans (e.g., moths) are relatively resistant due to midgut nucleases that degrade dsRNA
2. Processing by Dicer – The enzyme Dicer-2 cleaves long dsRNA into small interfering RNAs (siRNAs) (21–23 nucleotides)
3. RISC Assembly – The siRNA is loaded into the RNA-induced silencing complex (RISC), where the passenger strand is discarded, and the guide strand directs RISC to the target mRNA
4. Target gene selection: Genes involved in core metabolic or cellular processes like V-ATPase, chitin synthase, or Snf7are preferred for maximizing lethality

In some insects, a phenomenon called systemic RNAi allows the silencing signal to spread to distant tissues, amplifying the effect. This is facilitated by proteins like Sid-1 (Systemic RNA interference defective-1), which transport dsRNA across cells.

Laboratory and Field Applications

Extensive research has demonstrated the effectiveness of RNA interference (RNAi) in controlling economically important insect pests, with successful applications ranging from controlled laboratory experiments to field trials. Below are key examples highlighting RNAi's potential:

1. Western Corn Rootworm (*Diabrotica virgifera virgifera*)

One of the most successful applications of RNAi in agriculture involves targeting the Western corn rootworm, a major pest of maize. Researchers developed transgenic corn plants expressing dsRNA targeting the Snf7 gene, which is essential for larval survival. Field trials showed up to 95% larval mortality, significantly reducing root damage (Baum et al., 2007). This breakthrough led to the commercialization of SmartStax® PRO maize, combining RNAi with Bt toxins for enhanced pest resistance.

2. Colorado Potato Beetle (*Leptinotarsa decemlineata*)

The Colorado potato beetle, a notorious pest of potatoes and other solanaceous crops, has been effectively controlled using RNAi. Studies have shown that feeding beetles dsRNA targeting the V-ATPase gene (critical for nutrient absorption and pH regulation) leads to reduced fecundity and enhanced mortality

3. Cotton Bollworm

Unlike beetles, many lepidopteran pests (like the cotton bollworm) exhibit limited systemic RNAi, making oral delivery challenging. However, recent advances in nanocarrier-based delivery systems (e.g., chitosan nanoparticles, lipid coatings) have improved dsRNA stability in the insect gut. Experiments with dsRNA targeting growth-related genes (e.g., chitin synthase) have shown delayed larval development, Increased mortality and Reduced pupation percentage

4. Aphids and Whiteflies (Sap-Sucking Pests)

Sap-feeding pests like aphids and whiteflies present unique challenges due to their piercing-sucking mouthparts and rapid reproduction. However, foliar sprays containing dsRNA targeting essential genes (e.g., salivary proteins or detoxification enzymes) have shown reduced feeding efficiency

Commercial Products and Platforms

The successful transition of RNAi technology from laboratory research to real-world agricultural applications is evidenced by several pioneering commercial products and platforms

Key Commercial Products and Platforms

1. SmartStax® PRO (Bayer)

- Target Pest: Western corn rootworm (*Diabrotica virgifera virgifera*)
- Technology: Genetically engineered maize expressing Snf7 dsRNA, designed to disrupt larval development
- Regulatory Status: First RNAi-based crop approved by the U.S. EPA (2017)
- Advantage: Provides season-long protection by integrating RNAi with Bt toxins, reducing the need for chemical insecticides

2. GreenLight Biosciences

- Target Pests: Colorado potato beetle (*Leptinortarsa decemlineata*) and Varroa mite (Varroa destructor)
- Technology: Sprayable, non-transgenic RNAi formulations compatible with conventional sprayers
- Advantage: Eliminates GMO concerns while offering flexible, on-demand pest control.

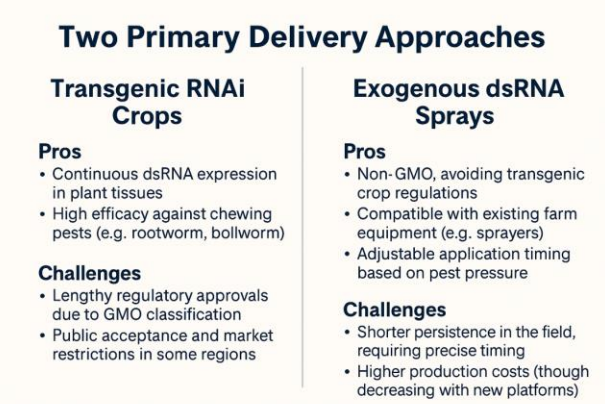
3. Syngenta &RNAgri Collaboration

- Focus: Microbial fermentation-based dsRNA production for cost-effective, field-stable sprays
- Targets: Soil-dwelling and foliar pests (e.g., corn rootworm, aphids)
- Innovation: Scalable production platform to lower dsRNA costs for broad-acre crops

4. BioDirect™ (Monsanto, now Bayer)

- Scope: dsRNA sprays targeting insect pests (e.g., soybean aphid) and plant pathogens
    - Goal: Non-transgenic, foliar-applied RNAi solutions to complement existing crop protection tools

Comparison among delivery approaches



Public Perception and Farmer Adoption Considerations

RNAi-based biopesticides, which work by targeting specific genes, have raised important questions about their safety, impact on crops, and how they will be received by both farmers and the general public. A key concern is the potential for misunderstanding many people may mistakenly equate RNAi biopesticides with genetically modified organisms (GMOs).

Research shows that consumers are generally more receptive to RNAi sprays than to GMO-based pest control strategies. Between 50% and 70% of surveyed individuals indicated they would consider buying products produced using either method, though a subset preferred those derived solely from topical RNAi or Bt applications. These findings suggest that while public opinion on RNAi technologies is mixed, many people are aware of and influenced by the agricultural technologies behind their food choices.

Despite their potential benefits in terms of safety and sustainability, RNAi-based biopesticides still face several hurdles to widespread adoption. Gaining broad public and farmer acceptance will depend on demonstrating their safety, minimizing ecological and health risks, keeping costs manageable, and aligning with ethical and cultural values.

Regulatory Landscape: Challenges and Progress in RNAi Adoption

Bringing RNAi-based pest control products to market is a promising yet complex journey, largely due to the absence of a consistent global regulatory framework.

Current Regulatory Outlook by Region

1. United States (EPA Oversight)
In the U.S., the Environmental Protection Agency (EPA) treats RNAi-expressing crops, such as *SmartStax® PRO* maize, as Plant-Incorporated Protectants (PIPs). These products must undergo comprehensive environmental risk assessments, with particular attention to potential effects on non-target organisms.

2. European Union (EFSA Guidelines)
In the EU, RNAi products are regulated under existing pesticide laws, but specific guidance on RNA-based biocontrol agents is still evolving. The European Food Safety Authority (EFSA) has raised concerns about off-target effects on pollinators like honeybees and beneficial soil organisms.

3. India and China (Developing but Active)
Though no RNAi-based pesticides are yet commercially approved in either India or China, both countries are investing heavily in research. China, in particular, is ahead in conducting field trials targeting pests in major crops like cotton and rice. India is showing growing interest in developing non-GMO topical RNAi sprays.

Key Regulatory Hurdles

- **Fragmented global standards:** Without harmonized regulations, companies must navigate separate, often redundant, approval processes in each country, driving up costs and time
- **Ambiguity around topical RNAi sprays:** A central question remains—should sprayed dsRNA be regulated like traditional pesticides or treated as advanced biotech? This lack of clarity causes delays and uncertainty
- **Demanding data requirements:** Regulators often call for extensive long-term studies on environmental safety, especially for impacts on non-target species. While important, these requirements can significantly slow down innovation

Barriers to Implementation: Scientific and Technical Hurdles

While RNAi technology holds great promise for sustainable pest control, several scientific and technical challenges need to be addressed before it can be widely adopted in agricultural systems:

1. Uneven Effectiveness across Insect Orders

Not all insect pests respond equally to RNAi treatments:

- **Beetles (Coleopterans)** respond well, making them ideal initial targets.
- **Moths and butterflies (Lepidopterans)** tend to be less responsive and often require enhanced delivery systems.
- **Aphids and other Hemipterans** show inconsistent responses, partly due to rapid dsRNA breakdown in their guts or saliva.

2. Limited Field Stability and Delivery Efficiency

One of the biggest technical barriers is that unprotected (naked) dsRNA degrades quickly when exposed to sunlight, rain, or digestive enzymes. To address this:

- **Clay nanosheets (e.g., BioClay)** help shield dsRNA from environmental degradation, prolonging its activity.
- **Lipid and polymer nanoparticles** improve dsRNA uptake by insect cells, increasing its effectiveness.

3. Risk of Off-Target Effects

There's a concern that dsRNA could unintentionally silence genes in non-target organisms, such as beneficial insects or soil microbes. However:

AI-based design tools can help improve precision by predicting and avoiding gene sequences shared with non-target species.

4. High Production Costs

Producing large amounts of dsRNA through chemical synthesis remains expensive. However:

Newer methods, such as **bacterial fermentation** and **cell-free production systems**, are making dsRNA manufacturing more affordable and scalable.

Future Outlook: Advancing RNAi in Agriculture

To fully harness RNAi's potential as a next-generation pest management tool, the following strategies are key:

1. Smarter Delivery Technologies

- **Nanoparticles** like layered double hydroxide (LDH) clays and biopolymers like **chitosan** can protect dsRNA and boost its delivery into pest cells.
- **Virus-like particles (VLPs)** offer another promising route, mimicking natural viruses to deliver dsRNA with high efficiency.

2. Multi-Gene Silencing Approaches

By targeting multiple essential genes (e.g., **V-ATPase and chitin synthase**), RNAi strategies can increase mortality and delayed the resistance evolution

3. Integration into IPM Programs

RNAi works best when used alongside other pest control strategies, such as:

- **Biological control agents** like predatory insects or nematodes.
- **Cultural practices** such as crop rotation and using pest-resistant plant varieties.
- **Eco-friendly chemicals**, including low-toxicity or biorational insecticides.

4. Policy Support and Public Engagement

- **Clear, science-based regulatory frameworks** are essential to encourage safe innovation.
- **Educational outreach** to farmers and consumers can help build trust in RNAi's safety, precision, and environmental benefits.

Conclusion: RNAi as a Game-Changer in Sustainable Agriculture

RNAi is not just another pest control tool—it represents a paradigm shift toward precision, sustainability, and reduced chemical reliance. While challenges remain in regulation, delivery, and cost, rapid advancements in biotechnology are paving the way for broader adoption.

The next decade will determine whether RNAi transitions from promising innovation to mainstream agriculture. With smart policies, technological refinements, and stakeholder collaboration, RNAi could become a cornerstone of next-generation integrated pest management (IPM)—ushering in a new era of eco-friendly, productive farming.

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FUELING THE FUTURE: INDIA'S JOURNEY TOWARD BIOFUEL SUSTAINABILITY

Introduction

India's growing dependence on fossil fuels for transportation has significant economic and environmental implications, prompting the need for sustainable energy alternatives. Biofuels have emerged as a strategic solution to reduce crude oil imports, lower greenhouse gas emissions, and enhance energy security. Recognizing this, the Government of India has implemented a series of policies and initiatives to promote the production and blending of ethanol, biodiesel, and compressed biogas (CBG). These efforts are supported by feedstock diversification, pricing reforms, and financial incentives aimed at increasing domestic biofuel capacity. This paper explores the evolution of biofuel policy in India, highlights key initiatives such as the Ethanol Blended Petrol (EBP) programme, and examines the role of feedstock availability, water consumption, and market dynamics in shaping the country's biofuel landscape.

Boifuels: Sustainable Alternatives to Traditional Fuels

About 98 per cent of the fuel requirement in the road transportation sector is currently met by fossil fuels and the remaining 2 per cent by biofuels. Domestic biofuels provide a strategic opportunity to the country, as they reduce the nation's dependence on imported fossil fuels. In addition, when utilized with appropriate care, biofuels can be environmentally friendly, sustainable energy sources. They can also help generate employment, promote Make in India, Swachh Bharat, doubling of farmers' incomes and promote Waste to Wealth generation.

Biofuels are classified into four generations based on the type of the feedstock that is used.

1. **First generation biofuels** utilize edible biomass which sparked controversy because it competes with global food needs.
2. **Second generation biofuels** use non-edible biomass but there are still some limitations related to the cost- effectiveness involved in scaling the production to a commercial level.
3. **Third generation biofuels** use microorganisms as feedstock.
4. **Fourth generation biofuel** focuses on modifying these microorganisms genetically to achieve a preferable hydrogen to carbon (HC) yield along with creating an artificial carbon sink to eliminate or minimize carbon emissions.

Steps Taken to Promote Biofuels in India

1. First-Generation (1G) Ethanol: Produced from sugarcane-based materials (molasses, juice, syrup) and damaged food grains like wheat and rice. Surplus rice from FCI and maize are also allowed as feedstocks.

2. Second-Generation (2G) Ethanol: Derived from non-food biomass such as lignocellulosic materials. The government launched the PM JI-VAN Yojana (2018–24) to support 12 integrated bio-ethanol projects with a financial outlay of ₹1969.5 crore. Oil PSUs are setting up 2G ethanol refineries.

3. Biodiesel: Initially supported through a Biodiesel Purchase Policy (2006), later expanded to allow sales to all consumers. Production grew from 11.9 million litres (2015–16) to 105.5 million litres (2019–20). Used Cooking Oil (UCO) is promoted as feedstock under the National Policy on Biofuels-2018, aiming for a 5 per cent biodiesel blending target by 2030.

4. Compressed Biogas (CBG): Promoted under the SATAT initiative using agricultural and municipal waste. CBG is intended as a clean transportation fuel to reduce emissions.

5. Ethanol Blended Petrol (EBP): Launched in 2003 with a 5 per cent blending mandate, the EBP Programme initially faced challenges but has since expanded. Key policy measures include reducing GST on ethanol from 18 per cent to 5 per cent and introducing interest subvention in 2018 to boost production. An administered pricing mechanism was reintroduced in December 2014. The National Policy on Biofuels (2018) set a target of 20 per cent blending by 2025, with blending rising from 1.53 per cent in ESY 2013–14 to 10% in ESY 2021–22. The government also approved the use of damaged and surplus food grains for ethanol. The programme has helped reduce CO_2 emissions by over 318 lakh tons and saved foreign exchange worth ₹53,894 crore.

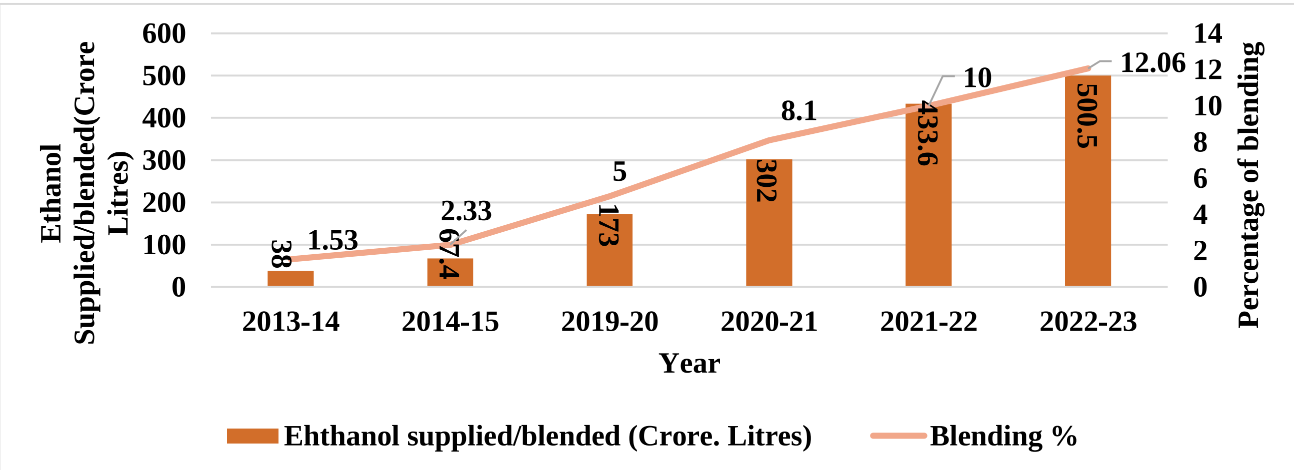

Fig 1: Ethanol Blending Percentage Source: Ministry of Petroleum and Natural Gas

Under the **Ethanol Blended Petrol (EBP) Programme**, ethanol blending in petrol has increased over sixfold in the last eight years. Blending rose from 1.5 per cent during 2005–14 to 10 per cent by 2022, while petrol consumption grew by around 64 per cent. Fuel-grade ethanol supply to Oil Marketing Companies (OMCs) increased more than seven times between ESY 2013–14 and 2020–21. Encouraged by this progress, the government advanced the 20 per cent blending target from 2030 to ESY 2025–26. The 10 per cent blending milestone was achieved in June 2022, ahead of schedule, with blending rising to **12.06 per cent** in ESY 2022–23 and crossing **13 per cent** in ESY 2023–24.

Although sugarcane can contribute more ethanol from the next season, it is capped at **5 billion litres**, as the government prioritizes domestic sugar needs.Since **2014**, ethanol has had a government-notified price. A **differential pricing policy** based on feedstock was introduced in **2018-19**, with higher prices for all types of ethanol continuing through **ESY 2022–23**.

India's increased push for **corn-based ethanol**—supported by a price hike in January—has led the country to shift from being a net corn exporter to an **importer**, affecting poultry producers and global corn supply chains.With the government promoting ethanol in gasoline to reduce carbon emissions and trying to ensure ample supply of cheap sugar in the world's biggest market for the sweetener, Indian corn exports dip, imports seen rising to record 1 million tonnes, Poultry industry seeks duty-free imports, GM corn, Importers tap Myanmar, Ukraine for non-GM corn. Last year, however, ethanol distilleries started using corn, and their demand grew this year after the government abruptly curbed the use of sugarcane for fuel following a drought. That led to a shortfall of 5 million tons.

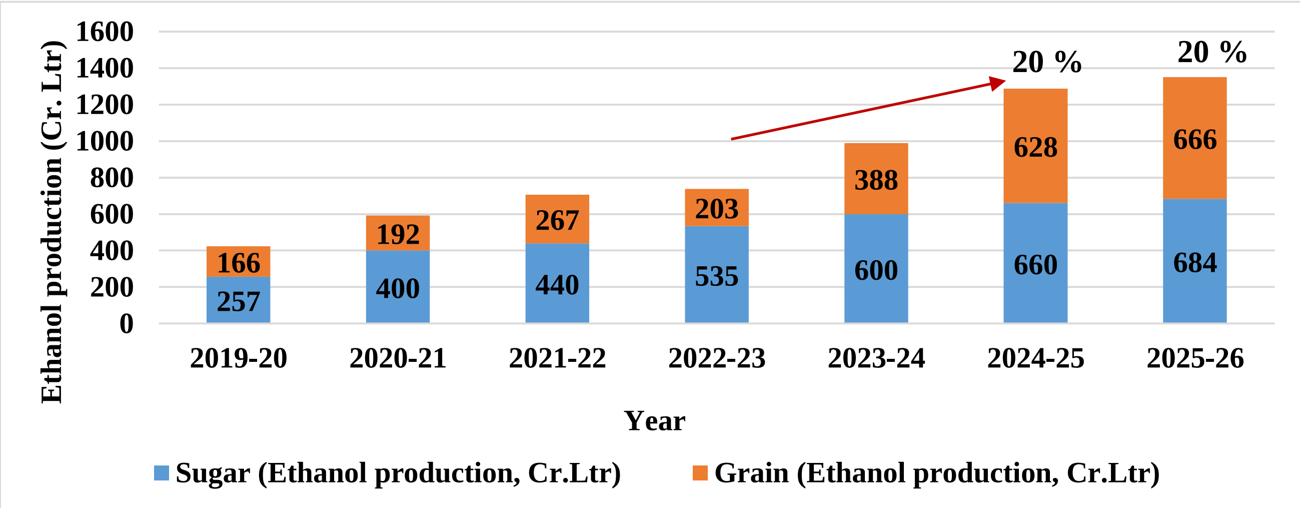

Fig 2: The Ethanol Roll-out plan

Source: Ministry of Petroleum and Natural Gas

Ethanol Production and Water Use: NITI Aayog Study and Policy Measures

An in-house **NITI Aayog study** found that while sugarcane is the most water-intensive crop, it remains the most profitable for ethanol production. Among grains, **maize** is less water-intensive but has a lower ethanol conversion rate than rice. The study suggests promoting maize and other low-water-use feedstocks for ethanol.

Remunerative prices of ethanol to suppliers have more than doubled in last 8 years-a major boost to farmers' income.

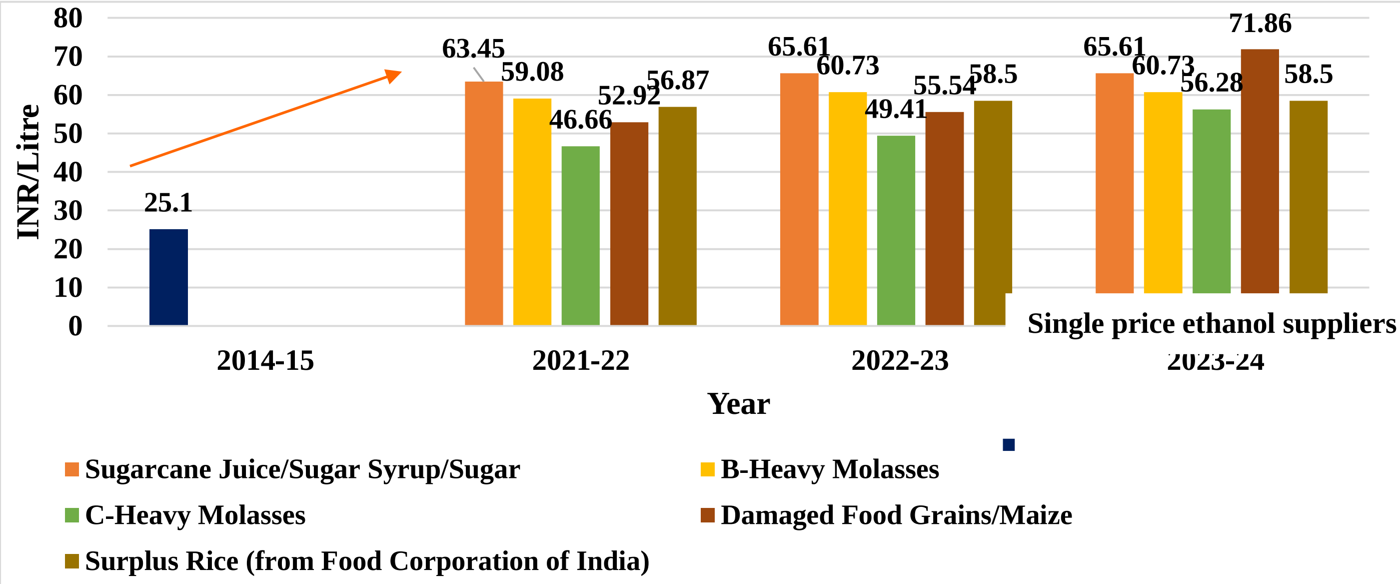

Fig 3: Prices of Ethanol to Suppliers

Source: Ministry of Petroleum and Natural Gas

Note: B-heavy molasses, sugarcane juice and damaged food grainswere allowed only from ESY 2018-2019 onward. Surplus rice by FCI and maize as feed stocks were allowed beginning ESY 2020-2021.

The Future Landscape of Opportunities:

- Ethanol Industry is expected to grow by 500 per cent. By 2025, at 20 per cent blending level, ethanol demand will increase to 1016 crore litres. Therefore, the worth of the ethanol industry will jump by over 500 per cent from around 9,000 crore to over 50,000 crore. Ethanol distillation capacity to double to 1,500 crore litres annually.
- Financial assistance scheme introduced by DFPD during 2018-2022 to increase ethanol production capacity.
- Long term off-take agreement signed to establish 431 crore litres per annum of dedicated ethanol capacity.clean transportation fuel to reduce emissions.

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ENVIRONMENT IMPACT OF GOLD MINE TAILINGS AND ITS POSSIBLE USE IN AGRICULTURE

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Summary: India is blessed with abundant mineral deposits and the country's mining sector forms an important segment of the economy contributing around 2.6% to the country's GDP (2022-23). India is the largest producer of mica (90%), the fourth largest producer of iron ore and the fifth largest producer of bauxite in the world. Minerals are valuable natural resources being finite and non-renewable. They constitute the vital raw materials for many basic industries and are a major resource for development. Mining in India dates back to ancient times, with archaeological evidence suggesting that it is an integral part of ancient civilization right from Harappans civilization. Mining is defined as extraction valuable minerals from an ore. Gold mine tailings, the residual materials left after gold extraction, pose significant environmental challenges due to their potential to contaminate soil and water with heavy metals and toxic chemicals such as cyanide and arsenic. These tailings often lead to long-term ecological degradation, including loss of biodiversity, soil infertility and water pollution. However, recent studies have explored the potential reuse of gold mine tailings in agriculture. When properly treated and stabilized, tailings may be amended with organic matter and other nutrients to support plant growth, offering a sustainable approach to land reclamation. Utilizing tailings in agriculture not only helps mitigate their environmental impact but also contributes to soil restoration and circular economy practices. Nonetheless, careful risk assessment and monitoring are essential to ensure food safety and ecological balance.

Introduction

Mining is Extraction of valuable minerals or other geological materials from the earth from an ore body, lode, vein which forms the mineralized package of economic interest to the miner. Mine Tailings are left over material after the process of separating the valuable fraction from the uneconomic fraction of an ore. Tailings are the result of mineral beneficiation/milling process. Tailings are ground rock, process effluents and the by-products generated during that process. Mine tailings are inevitably generated during the extraction, processing and refinement of valuable fraction from the uneconomic fraction of an ore (Kossoff *et al.*, 2014). Many minerals cannot be used for metal extraction directly as the concentration of the basic ore is less and has to be concentrated before it can be used. During the process of concentration, which involves grinding and milling, tailings are generated which is in a form of slurry. Available in powder/liquid/slurry form. The characteristic of tailings depends on the type of ore and hence varies from mineral to mineral. It also depends on the ore physical and chemical processes used to extract the economic product. However, there are certain common contents of tailings such as arsenic, barite, calcite, cyanide, fluorite, mercury, pyrite and quartz. They are rich source of nutrients especially micronutrients.

Gold mine tailing: Tailings are a by-product of a gold mining process. Rocks that contained both gold and arsenic were crushed and then spread over liquid mercury to remove the gold. The mercury was then evaporated, leaving the gold. The remaining sand-like substance is known as tailings including arsenic and mercury.

Gold deposits are formed usually during the late stages of the chilling of the magma, which along fissures to the upper layers of the earth`s crust from great depths. The gold is transported together with the magma from the depths of the earth in hot aqueous solution and vapors. These solutions get solidified with the falling of temperature, giving rise to ore bodies mostly in the form of veins in rocks. These veins generally consist of quartz with a small admixture of other minerals. The particles of gold in the form of fine grains, platelets and flaks and sometimes crystals wires, filaments etc. In the course of time these rocks and veins under the action of geological agents, undergo mechanical disintegration and chemical decomposition. The weathered products while being carried down to the depositional site undergo the process give rise to placer gold deposits.

TYPES OF GOLD MINING

Surface mining: This mining is adopted when the ore is located on the surface of soil. By opening pit on the surface ore minerals will be extracted.

Types

1) Placer mining: Involves any type of mining where raw materials are deposited in sand or gravel or on the surface and are picked up without having to drive, use dynamite or any other significant means. This technique involves separating gold from gravel, sand and other sediments using water, gravity and simple tools like pans, sluicing box to capture gold.

2) Hydraulic mining: Involves high pressure water. The water is sprayed at an area of rock and/or gravel and the water breaks the rock, dislodging ore and placer deposits. The ore mixture is then milled.

3) Open pit mining: Involve digging large open holes/burrow in the ground as opposed to a small shaft in hard rock mining. Blasting and excavation creating a large terraced pit from which ore is removed in successive layer. This method of mining is most often used with minerals like copper and molybdenum.

4) Dredging: It is a method often used to bring up underwater mineral deposits using dredges. These machines suck up sediments from bottom of bodies of water like rivers, oceans.

Underground mining: Adopted when the ore is located on the beneath the surface of earth.

Types

1) Drift mining: Is a method of accessing valuable geological material such as coal by cutting into the sides of the earth.

2) Slope mining: Is a method of accessing valuable geological material such as coal by tunnelling downwards at an incline.

3) Shaft mining: Shafts are pushed from top to bottom to extract the minerals. It is best suited for concentrated minerals like coal and Iron.

4) Hard rock mining: Used to extract hard minerals by creating underground rooms supported by surrounding pillars of standing rocks. Example: gold

Mineral extraction : From mining to metal

The process begins with blasting which breaks up the ore containing rock. The broken ore is then crushed into smaller pieces. These pieces are then subjected to crushing to reduce their size further. The crushed material then processed through grinding which pulverizes the rock into fine particles. This stage involves the separation of valuable minerals from the waste rock. The fine particles undergo floatation where minerals are separated from waste rock based on their different surface properties. The separated material is then subjected to thickening to remove excess water. Finally, the material is filtered and dried to obtain a concentrated form of the mineral.

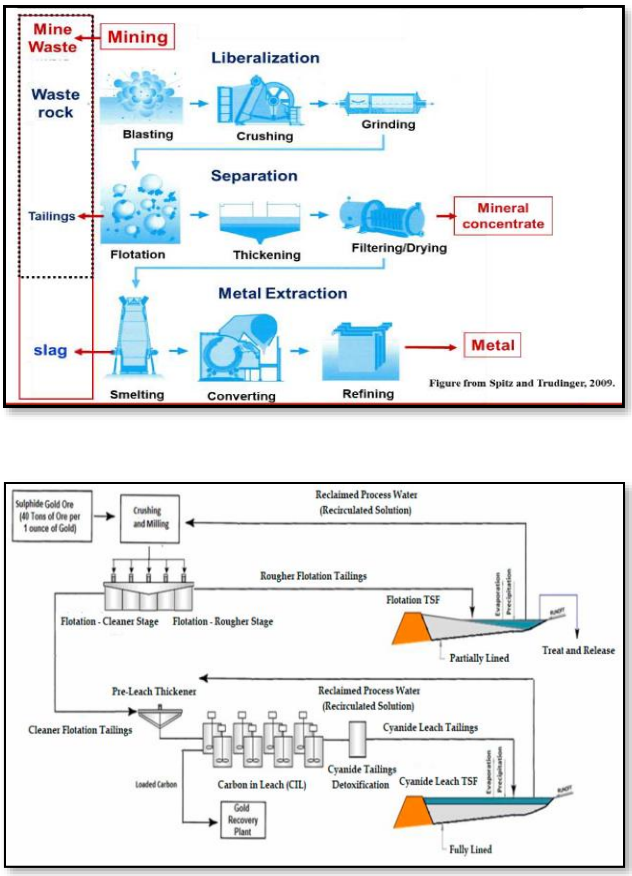


Fig 1. Typical sulphide gold ore flowsheet process of gold mine tailings

This flowsheet illustrates the typical process for extracting gold from sulphide gold ore, focusing on the various stages involved in treating mine tailings. Initially, sulphide gold ore is crushed and milled to liberate the gold particles from the surrounding ore. The milled ore then undergoes flotation in two stages. The first stage, known as the rougher stage, separates valuable minerals from waste material, while the cleaner stage further purifies the concentrate from the rougher stage.

The waste material from the rougher flotation, known as rougher flotation tailings, is directed to the Flotation Tailings Storage Facility (TSF), which is partially lined to control runoff and allow for water treatment and release. Waste from the cleaner stage, referred to as cleaner flotation tailings, is thickened in a pre-leach thickener before being directed to cyanide leaching. The cyanide process involves dissolving gold (and silver present in soluble form) from ground ore in a dilute cyanide solution (usually NaCN or KCN) in the presence of lime and oxygen. The typical method is to use the counter-current decantation (CCD) thickening and carbon-in-leach (CIL) settling processes.

Carbon is added to the ore along with cyanide, air, and lime, and the gold is recovered in the carbon as it is leached by the cyanide The concentrate from the flotation process is then subjected to cyanide leaching in Carbon in Leach (CIL) tanks, where activated carbon adsorbs the dissolved gold. The loaded carbon is subsequently transferred to a gold recovery plant to extract the gold. Throughout the process, reclaimed process water is recirculated to minimize water consumption and manage waste. This integrated approach ensures efficient gold recovery while managing environmental impacts through careful handling and treatment of tailings and process water.

Properties of Tailings

❖ Physical properties

Tailings particles commonly are angular to very angular and this morphology imposes a high friction angle on dry tailings. Tailings grain size is highly variable and difficult to generalize, as it is delineated by specific process requirements. Hard rock tailings particle sizes as largely gravel-free (<2 mm) and clay-free (<3.9 µm), with sand (625 µm to 2 mm) being more common than silt (3.9-625 µm). Density varies according to the parent rock type. A generalized range for tailings bulk density is given as 1.8-1.9 t m^3 with a specific gravity of 2.6-2.8.

❖ **Chemical properties**

The chemical composition of tailings depends on the mineralogy of the ore body, the nature of the processing fluids used to extract the economic metals, the efficiency of the extraction process and the degree of weathering during storage in the dammed impoundment. Silica and Fe presence, however, are almost universal and together with oxygen, are usually the most abundant elements, with Al, Ca, K, Mg, Mn, Na, P, Ti and S also major components.

Chemical Composition	Gold Tailings (%)
Silicon dioxide (SiO_2)	50.82
Ferric oxide (Fe_2O_3)	28.97
Aluminium oxide (Al_2O_3)	8.87
Magnesium oxide (MgO)	3.39
Calcium oxide (CaO)	3.19
Potassium oxide (K_2O)	0.84
Titanium dioxide (TiO_2)	0.45
Magnesium oxide (MnO)	0.36
Phosphorus pentoxide (P_2O_5)	0.15
Sodium oxide (Na_2O)	0.02
Chromium oxide (Cr_2O_3)	0.02
Sulphur trioxide (SO_3)	0.05

DISPOSAL METHOD OF TAILINGS

1) Pond storage: Large earthen dams may be constructed and then filled with the tailings. Tailings may be deposited into natural topographical depressions. Exhausted open pit mines may be refilled with tailings. Dewatering is an important part of pond storage, as the tailings are added to the storage facility the water is removed, usually by draining into decant tower structures. The water removed can thus be reused in the processing cycle. Once a storage facility is filled and completed, the surface can be covered with topsoil and revegetation commenced. However, unless a non-permeable capping method is used, water that infiltrates into the storage facility will have to be continually pumped out into the future.

2) Dry stacking: Tailings do not have to be stored in ponds or sent as slurries into oceans, rivers or streams. There is a growing use of the practice of dewatering tailings using vacuum or pressure filters so the tailings can then be stacked. This saves water, reduces the impacts on the environment in terms of space used, leaves the tailings in a dense and stable arrangement and eliminates the long-term liability that ponds leave after mining is finished (Darron *et al.*, 2007).

3) Disposal into the rivers and oceans: Commonly referred to as Submarine Tailings Disposal or Deep-Sea Tailings Disposal. If a mine is located in close proximity to the coast, and the coast itself is not an excessive distance from a continental shelf, STD is conceptually an excellent method for the disposal of tailings. Tailings can be conveyed using a pipeline then discharged so as to eventually descend into the depths

4) Phytostabilisation: Itis a form of phytoremediation that uses plants for long-term stabilization and containment of tailings, by sequestering pollutants in soil near the roots. The plant's presence can reduce wind erosion, or the plant's roots can prevent water erosion, immobilize metals by adsorption or accumulation, and provide a zone around the roots where the metals can precipitate and stabilize. Pollutants become less bioavailable and livestock, wildlife, and human exposure is reduced. This approach can be especially useful in dry environments, which are subject to wind and water dispersion.

ENVIRONMENT IMPACT OF GOLD MINING

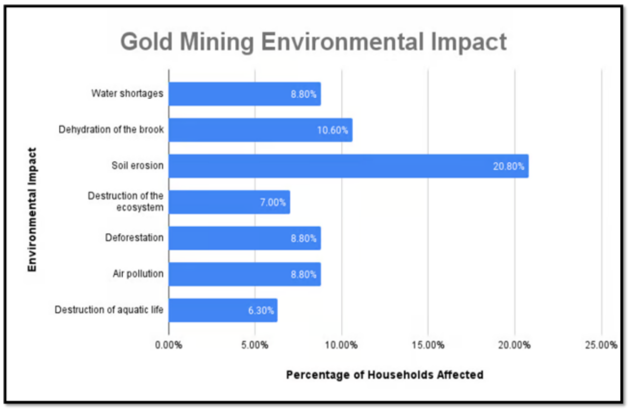
Environmental impact of mining can occur at local, regional and global scales through direct and indirect mining practices. Mining can cause erosion, sinkholes, loss of biodiversity, or the contamination of soil, groundwater, and surface water by chemicals emitted from mining processes. These processes also affect the atmosphere through carbon emissions which contributes to climate change.

In either open-pit or underground mine sites, both mining methods pose the risk of water contamination through contact with surface water or groundwater. Contamination of groundwater may cut off or limit the supply to nearby areas. For surface water, dissolved metals like sulfates, radio-nuclides, and nitrates may travel through streams, or through erosion be carried to local groundwater. In reference to mining, the chemicals used in processing the ores are a source of contamination. This affects the quality of water sources in nearby communities and will affect aquatic life.

Acid mine drainage (AMD) is the outflow of acidic water that is generated in the oxidation of pyrite or iron ores rich in sulfur. It is also commonly referred to as Acid Rock Drainage (ARD). Acid is produced when mined materials such as excavated host rocks with metal sulfide minerals are exposed to air and water. Acid drainage sites may contain dissolved metals like lead, copper, silver, iron, and zinc. High concentrations of these dissolved metals affect aquatic life and the quality of water in streams.

Heavy Metal Contamination: Heavy metal pollution is caused when such metals as cobalt, arsenic, copper, zinc, lead, cadmium, and silver exposed in an underground mine or contained in an excavated rock come in contact with water. Mainly, non-essential heavy metals like gold and mercury are of no biological significance to living organisms. However, they are highly toxic when digested. A trace amount of heavy metals may be found in sources of water and could still be a potential threat and impose serious health problems both on humans and other aquatic life. Humans are more prone to serious health problems because the concentrations of heavy metals increase in the food chain.

Sedimentation and Erosion: Mining that involves removing earth and scraping away rocks to get the coal buried near the surface leads to the destruction of agricultural lands and erosion of soil. Plants, trees, and topsoil are scraped away from the mining area and destroys wildlife habitats and landscapes. When these mining sites experience heavy rain, the loosened topsoil is washed away, carrying sediments that may pollute the streams, lakes, and rivers. Excessive residue can harm aquatic organisms and watershed vegetation downstream. Moreover, it can also cause disfiguration of streams and river channels, which results in flooding.



Processing chemicals pollution: Mining companies generally use chemical compounds such as sulphuric acid or cyanide to separate their respective target minerals from the ore. Contamination occurs when these chemicals are leached, leaked, or spilled from the mining area into the nearby bodies of water. These chemicals are highly toxic and could lead to loss of life on wildlife species and severe health concerns on the human body.

The mining releases heavy metals and cyanide into the environment containing soil and water. These pollutants are absorbed by plants and livestock, leading to bioaccumulation in the food chain. When humans are exposed through ingestion, skin contact and inhalation resulting in various health problems such as lung cancer, neurological disorder, reproductive problems etc due to accumulation of toxic substances in the body.

CONCLUSION

The residual waste from gold mining operation poses significant environment risks, primarily due to their content of toxic heavy metals and chemical residues. However, the innovative reuse of gold mine tailings in agriculture presents a promising avenue for mitigating these environment impacts and their potential repurposing for agricultural use offers a dual benefit of mitigating environment pollution and enhancing soil productivity. As there is a saying that waste is not a waste until we waste it. So, we can transform a waste product into a valuable agriculture resource contributing to sustainable agriculture, sustainable development in mining areas and demonstrating that environment stewardship and economic growth can go hand in hand.

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Strengthening Fodder Systems in India: A Blueprint for Effective Management and Food Security

Introduction

India's livestock sector forms the backbone of its agricultural economy, contributing significantly to food security, rural livelihoods, and GDP. The sector supports about 20% of the world's livestock population and 17.5% of the human population, within only 2.3% of the world's land area. However, despite its scale and importance, India faces a persistent fodder deficit-estimated at 35.6% for green fodder, 10.5% for dry crop residues, and 44% for concentrate feeds. This shortage severely impacts livestock productivity, leading to reduced milk and meat output and threatening millions of rural livelihoods.

Several intertwined factors drive this deficit: limited land devoted to fodder cultivation, over-dependence on nutritionally poor crop residues, shrinking grazing lands, and the worsening effects of climate change. In an era of growing demand for dairy and meat products, addressing these challenges through a transformative approach is essential. This article examines the current hurdles, sustainable fodder management practices, and a roadmap to achieve long-term fodder security in India. Through policy reforms, technology adoption, and community-based initiatives, India can strengthen its livestock sector and secure rural prosperity.

Key Barriers to Fodder Availability in India

Fodder production in India faces multiple interlinked challenges that threaten the sustainability of the livestock sector. One major issue is the limited land allocation for fodder cultivation, with only about 4% of cultivable land devoted to it. The dominance of food grains and cash crops, incentivized by procurement policies and market demand, further restricts year-round availability of green fodder. Additionally, there is an over-reliance on low-nutrient crop residues such as wheat straw and paddy stubble, which are poor in protein and digestible energy. The widespread practice of stubble burning not only reduces potential feed sources but also contributes to environmental pollution. Compounding the problem is the shrinking of common grazing lands due to rapid urbanization, infrastructure expansion, and land encroachments, which disproportionately affect small and landless livestock holders.

The adverse effects of climate change including erratic rainfall, prolonged droughts, and rising temperatures have significantly disrupted the growth and nutritional value of important fodder crops like maize, sorghum, and berseem.

Furthermore, the lack of awareness and access to modern technologies among farmers hinders the adoption of improved fodder management practices such as silage making, hydroponics, and use of high-yielding varieties. Weak agricultural extension services and cost barriers further exacerbate this issue. Soil degradation and water scarcity, particularly in semi-arid regions, also pose a serious threat to fodder productivity. Depleted soil nutrients, falling groundwater levels, and poor irrigation infrastructure limit the success of fodder crops.

Moreover, the high cost of inputs including seeds, fertilizers, and mechanization discourages farmers from growing fodder. Without strong market linkages or pricing mechanisms, fodder cultivation remains economically unappealing. Finally, weak logistics, poor supply chains, and inadequate storage infrastructure result in significant post-harvest losses. Seasonal surpluses of fodder often go to waste due to the lack of efficient transportation, warehousing, and organized markets. Together, these challenges highlight the urgent need for integrated policy support, farmer education, and infrastructure investment to strengthen India's fodder economy.

Innovative Strategies for Strengthening Fodder Security in India

Sustainable fodder management in India requires a multifaceted approach that enhances productivity while conserving resources. One effective strategy is **integrating fodder crops into existing farming systems**. For instance, intercropping legumes such as cowpea with cereals not only boosts soil fertility through nitrogen fixation but also optimizes land utilization, ensuring consistent fodder availability throughout the year. Additionally, **utilizing degraded and wastelands** by cultivating salt-tolerant and drought-resistant fodder species helps in expanding the fodder base without competing with prime agricultural land, making use of otherwise underutilized resources. **Agroforestry systems** also present a viable solution by integrating trees like *Terminalia chebula* and *Morus alba* alongside fodder crops, which enhances biodiversity, improves soil structure, and contributes to carbon sequestration. Equally important is the **promotion of high-yielding and nutritious fodder varieties** such as hybrid Napier grass (*Pennisetum purpureum* × *P. americanum*), known for their superior biomass and nutritional quality, supporting the needs of intensive livestock operations.

To ensure availability during off-seasons, **fodder preservation techniques** like silage making and hay production at the community level play a critical role in stabilizing supply. At the same time, **leveraging technological innovations** such as hydroponic fodder systems and azolla cultivation allows for the production of nutrient-rich green fodder with minimal land and water, particularly beneficial in resource-constrained settings. Sustainable productivity is further enhanced through **integrated nutrient management**, where the use of organic manure, compost, and biofertilizers rejuvenates soil health and boosts long-term yields. Lastly, **efficient water management** practices, including rainwater harvesting, drip irrigation, and precision watering, are essential to ensure the viability of fodder crops amidst changing climatic conditions and erratic rainfall. Collectively, these strategies form a holistic framework for strengthening India's fodder economy while promoting environmental sustainability and resilience in the livestock sector.

Enhancing Fodder Security Through Post-Harvest Processing Techniques

Post-harvest processing offers a powerful means to address the growing fodder deficit by converting agricultural residues into valuable livestock feed and preserving surplus green fodder for future use. A major opportunity lies in the conversion of crop residues such as straw, husks, stovers, and sugarcane tops into usable feed forms. Traditionally, these by-products are either wasted or burned, contributing to environmental degradation. However, with appropriate processing, they can be transformed into nutritive feed blocks, silage, or pellets, significantly increasing the volume of usable fodder and narrowing the gap between supply and demand. Another crucial intervention is silage and haymaking, which involves preserving surplus green fodder during peak production periods. Through controlled fermentation (silage) or drying (hay), fodder can be stored for extended periods, ensuring a stable supply during lean or drought-prone seasons. This helps in stabilizing fodder availability and supports consistent livestock productivity throughout the year.

Densification and storage technologies such as baling and pelleting further enhance the efficiency of fodder systems. These methods compress the volume of fodder, making it easier to store, handle, and transport. As a result, surplus fodder from one region can be transported economically to fodder-deficit areas, effectively bridging regional imbalances in availability. Moreover, nutrient enrichment techniques are critical for improving the feed value of low-quality residues like paddy straw. Treatments using urea, molasses, or microbial cultures increase the digestibility, protein content, and energy value of the feed. This reduces the reliance on green fodder and optimizes the nutritional intake of livestock. Lastly, minimizing post-harvest losses is essential to reduce wastage. A significant amount of green fodder is lost due to poor handling, improper storage, and exposure to moisture. By adopting improved post-harvest practices—such as using covered sheds, ventilated storage, and controlled fermentation chambers—fodder losses can be reduced by 15% to 25%. Collectively, these post-harvest interventions not only improve fodder availability but also contribute to environmental sustainability, economic efficiency, and enhanced livestock productivity.

Unlocking the Power of Artificial Intelligence for the Future of Fodder Management

Artificial Intelligence (AI) is redefining the future of agriculture, and its integration into fodder management systems marks a transformative leap forward, especially in regions like Punjab and broader India. Traditionally, fodder production has been reliant on conventional methods, making it vulnerable to climatic uncertainties, inefficient resource use, and supply chain disruptions. AI-driven technologies now offer smart, data-backed solutions that can significantly enhance the efficiency, productivity, and sustainability of fodder systems.

Through precision agriculture tools such as satellite imagery, soil sensors, and unmanned aerial vehicles (drones), farmers can monitor field conditions in real time, enabling them to optimize sowing times, fertilizer application, and irrigation schedules for maximum fodder yield. Predictive analytics based on historical weather data and machine learning models allow for early forecasting of droughts, floods, or pest outbreaks, helping farmers take proactive steps to protect their crops.

In the supply chain domain, AI supports intelligent inventory management, storage optimization, and market linkage development. Algorithms can predict fodder demand across seasons, reducing post-harvest losses and minimizing wastage through better distribution planning. Furthermore, AI-enabled mobile platforms offer decision-support systems, providing farmers especially smallholders with personalized recommendations on crop selection, harvesting schedules, and preservation techniques like silage-making.

By harnessing the power of AI, India can bridge the gap between fodder demand and supply, build climate-resilient fodder production systems, ensure continuous feed availability for livestock, and uplift rural livelihoods. Embracing AI-driven fodder management not only boosts farm profitability but also plays a pivotal role in achieving national food and nutritional security goals.

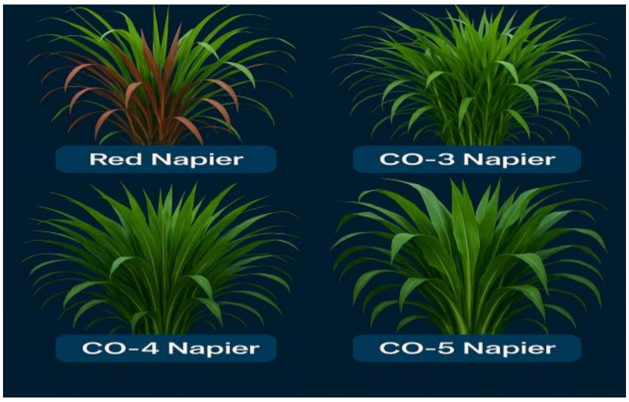
The Rise of Napier Grass: A New Era of Resilient Fodder Solutions

Among the various fodder crops cultivated in India, Napier grass (*Pennisetum purpureum*) stands out as a revolutionary species for meeting the future fodder demands of the livestock sector. Its rapid growth rate, exceptional biomass yield, and superior nutritional profile make it a cornerstone for sustainable fodder production, especially in a country grappling with feed shortages.

Napier grass shows remarkable adaptability to a wide range of soils, including marginal, degraded, and drought-prone lands and areas traditionally unsuitable for conventional crops. This adaptability enhances its significance in climate-affected regions, where water scarcity and soil degradation limit agricultural options.

The evolution of Napier varieties further exemplifies scientific innovation in fodder management. The traditional Red Napier offered hardiness and drought tolerance but had moderate productivity. Modern hybrids like CO-3 improved palatability and regrowth capabilities, while CO-4 focused on enhanced biomass and digestibility. CO-5, a cross between Napier and Bajra (pearl millet), provided extremely high green fodder yield but slightly lower palatability. The latest CO-6 variety brings superior crude protein content, softer stems, and better digestibility, offering an ideal solution for both high milk yield and sustainable livestock health.

Napier grass not only supports high-frequency cutting for year-round green fodder availability but also contributes to soil conservation, biodiversity enhancement, and carbon sequestration. Given its multiple agronomic and environmental benefits, Napier grass is poised to become the backbone of future fodder systems across India, ensuring resilience, sustainability, and economic viability for livestock farmers.



Conclusion

India's livestock sector stands at a critical juncture, facing mounting challenges of fodder scarcity, environmental degradation, and climate vulnerability. The persistent gap between the demand and supply of quality fodder directly threatens livestock productivity, farmer incomes, and national food security. Bridging this gap requires a holistic and strategic approach that reimagines fodder not as a secondary crop but as a strategic agricultural commodity essential for sustainable rural economies. Harnessing Artificial Intelligence offers a game-changing opportunity to modernize fodder management from production optimization to supply chain streamlining and farmer empowerment through real-time data insights. Simultaneously, promoting climate-resilient crops like Napier grass, with its wide adaptability and high nutritional value, provides a scalable, sustainable fodder solution for India's diverse agro - ecological zones.

Future progress hinges on synergizing multiple efforts: integrating digital technologies, adopting high-yielding and drought-resilient varieties, promoting agroforestry and multi-tier farming systems, and strengthening farmer institutions like FPOs and cooperatives. Policy interventions must prioritize fodder research, incentivize fodder cultivation, establish fodder banks, and embed fodder planning into national agricultural strategies. Ultimately, a well-coordinated effort involving farmers, researchers, policymakers, private stakeholders, and technology innovators is essential. Through such collective action, India can build a resilient, sustainable, and future-ready fodder ecosystem that supports livestock productivity, rural prosperity, and national food and nutritional security for generations to come.

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