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PRECISION AGRICULTURE: A NEW ERA IN FARMING PRACTICES

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Abstract

Precision agriculture (PA), also known as smart farming, strongly emphasizes the application of sophisticated technologies, ranging from Artificial Intelligence (AI) and the Internet of Things (IoT) to data analytics, for increased agricultural productivity and sustainability in the face of increasing food demands and environmental pressures. Article outlined the historical progression from manual farming to modern data-driven approaches through contributions of technologies such as GPS, robotics, remote sensing, and big data analytics. These innovations optimize crop production with efficient resource management and targeted interventions, thus leading to higher yields and lower environmental impacts. Article aims to focus on the key technology of agriculture 4.0 with benefits and challenges.

Keywords : Agriculture 4.0, Block chain, Precision farming, Robotics, Smart Farming

Introduction

Precision Agriculture (PA) is a farming management approach that uses technology and data analysis, satellite imagery, and robust machinery to optimize field-level management regarding crop farming. This reflects emerging with all the rising demands for food production amidst climate changes, resource depletion, and more population.

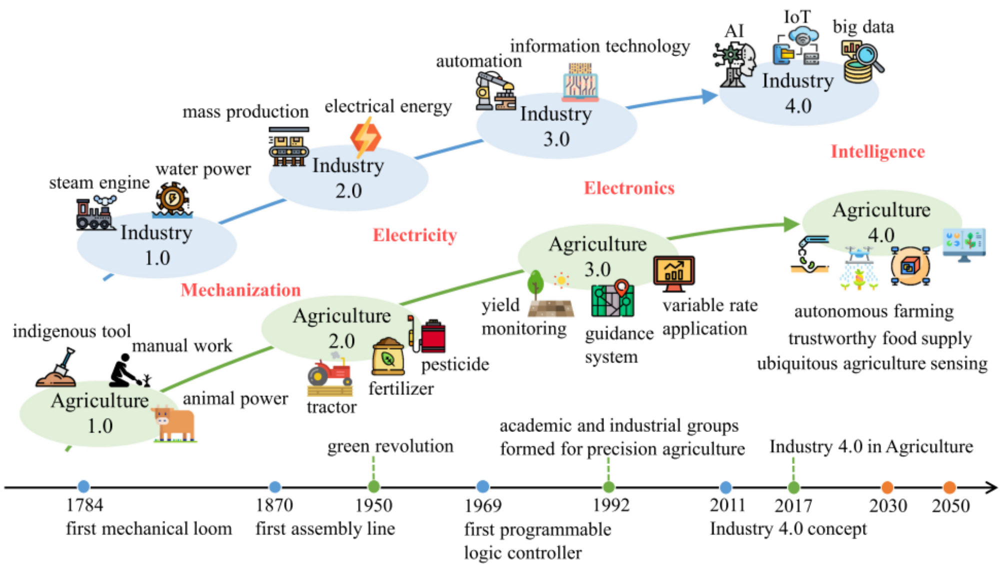

Fig.1 Agricultural revolutions (Liu et al., 2020)

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AI and IoT are some of the core tech drivers applied in precision farming. For instance, IoT sensors collect real-time data on soil, weather, and crops while AI performs analysis to optimize irrigation, pest control, and operation of machinery (Parmar et al., 2024). It has developed in steps; Agriculture 1.0 was manual labour using manual tools up to Agriculture 2.0, which used early 20th century mechanized equipment, which improved yield. Mass production and new energy sources that the 2nd industrial revolution brought changed the tide of farming. Agriculture 3.0 emphasized PA via technology but has yet to address ecological issues. The 4th industrial revolution is advancing Agriculture 4.0 through IoT and AI for improved productivity, efficiency, and sustainability (Fig. 1).

The evolution of precision agriculture

Origins of precision agriculture trace their roots back to the late 20th century with the discovery of GPS technology. Recent innovations in technology with the support of decisions through data provide a greater improvement over the years about collecting and analyzing data from sensors and IoT through drones. The PA cycle (Fig. 2) includes soil and crop data collection; data analysis in search for patterns; input planning based on resource requirement; resource application in the aim of giving an optimal distribution; crop mapping so to visualize crop health; and intervention efficiency.

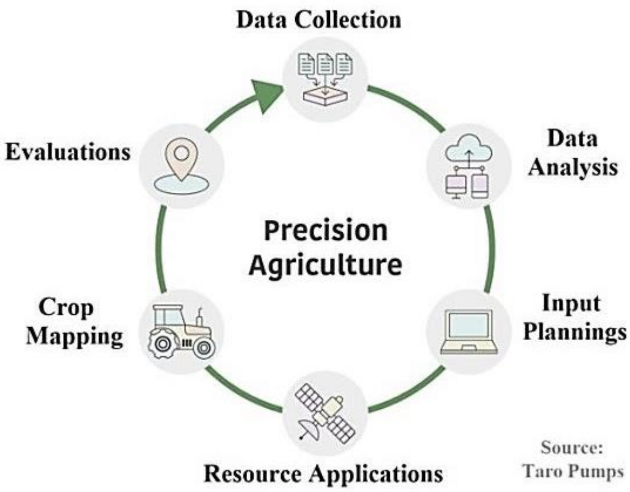


Fig.2 Precision Agriculture cycle

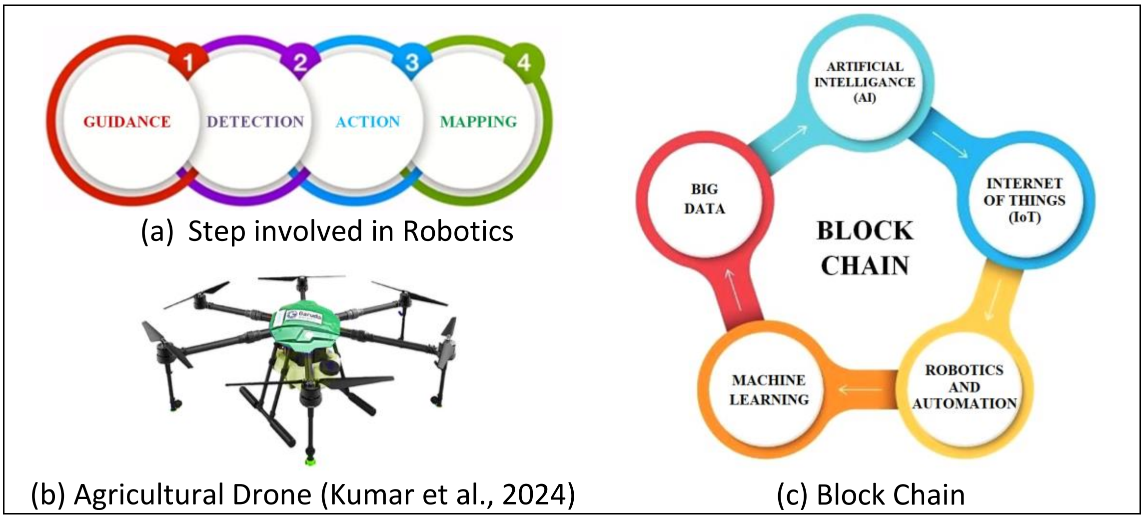
Key technologies driving precision agriculture

PA is driven by data collection by following technologies to enhance farming efficiency and decision-making.

- **GPS and GIS:** Using GPS, location in the field can also be precise for farmers, which helps in very accurate mapping and monitoring of variability. Then, the GIS tool analyzes that information to help them manage the fields based on variations.
- **Robotics and Automation:** Automated machineries are used in PA for task such as planting, weeding, and harvesting; this reduces labour costs and improving efficiency. This free autonomous robotic control system (Fig. 3a) contains four elements which include guidance, detection, action, and mapping (Fernando *et.al.*, 2013).
- **Remote Sensing and Drones:** Remote sensing, particularly with drones, has completely transformed farm monitoring. The multispectral camera attached to a drone captures clear

images of the health condition of crops and level of moisture in the soil as well as the deficiencies of nutrients. This information allows the farmer to reduce fertilizers and pesticides, and increase yields (Fig 3b).

- **Sensors:** Soil and Crop Sensors in the soil are able to measure moisture, temperature, pH, and nutrients. All of this would optimize inputs such as fertilizers and water use, thus minimizing waste and maximizing efficiency.
- **Internet of Things (IoT):** IoT in agriculture involves deploying sensors, devices, and software to obtain real-time data on crops, soil, and weather conditions. It enables farmers to make informed decisions, improve resource management, and enhancing productivity.
- **AI and Machine Learning (ML):** AI helps analyze large data in agriculture to spot trends and predict outcomes like irrigation optimization, yield projection, early pest detection etc. helps farmers boost productivity and reduce chemical use for more sustainable practice. ML models can integrate with IoT to develop smart sensors for generating of big data.
- **Big Data and Analytics:** Big data analytics helps farmers analyze the long tail information relating to sources including weather, historical yields, and market trends. This approach makes for predictive modelling and, therefore, informs planting, harvesting, and resource allocation decisions made by a farmer.



(a) Step involved in Robotics

(b) Agricultural Drone (Kumar et al., 2024)

(c) Block Chain

Fig. 3 Precision Agriculture Technologies

- **Block chain Technology:** Block chain revolutionizes the agricultural supply chain with traceability and accountability. The amalgamation of AI, IoT, ML, robotics, and big data enhances efficiency with improved transparency. The IoT will collect data on the block chain for the sake of tracing, and AI and ML can also analyze the data for better decisions and improvement in crop management. Robotics automates tasks, while big data analytics gives insights so that agriculture will be more productive and sustainable (Fig 3c).

Benefits of precision agriculture

The benefits of PA are manifold and have significant implications for the agricultural sector.

- **Increased Yields and Profitability:** By utilizing data-driven insights, farmers can make precise applications of fertilizers, pesticides, and water, leading to healthier crops and increased yields. This optimization not only enhances productivity but also contributes to greater profitability.

- **Resource Efficiency and Sustainability:** PA allows for efficient use of inputs, minimizing waste and reducing costs. For instance, variable rate technology (VRT) enables farmers to apply only required fertilizers, significantly lowering input costs and mitigating environmental impacts. It controls fertilizer application rate with variation of 11.7-15% (Parmar et al., 2024).
- **Risk Management:** PA equips with the tools to manage risks associated with climate variability, pest infestations, and price fluctuations. By analysing data trends and using predictive analytics enables proactive decisions for crops and financial investments.
- **Data-Driven Decision:** PA enables data-driven decision-making, empowering farmers to make informed choices. With access to real-time data and analytics, farmers can adapt their practices based on current conditions, leading to more effective resource management and outcomes.

Challenges and limitations

The adoption of PA is associated with following challenges:

- **High Initial Costs:** As PA technology is capital-intensive, it prohibits many small-scale farmers from accessing such technologies. This creates ethical questions based on equity and equality, arguing that there is a need to develop solutions where everybody can benefit from these enhanced agricultural technologies.
- **Data Management and Integration:** Merging vast data from various sources raises concerns about data quality, security, and accessibility. Agricultural data analysis is primarily statistical, while AI techniques focus on discovering potential relationships between variables directly from the data, without relying on pre-established hypotheses (Peters et al., 2014).
- **Technological Dependence:** Reliance on technology raises concerns about system failures, cybersecurity, and the need for constant updates and maintenance. The adoption of new agricultural technologies can demand for skilled labour, therefore, training is vital for successful implementation.
- **Limited Awareness and Education:** The lack of awareness and understanding of PA among many farmers. Education and training programs are essential to empower farmers to leverage these technologies effectively and maximize their benefits.

Conclusion

PA is a visionary approach to farming, integrating productivity with sustainability in response to global food security challenges. By adopting current technology, it would be possible to create data-informed decisions by farmers for the optimization of inputs to minimize the ecological footprint associated with such agricultural systems. However, the barriers are still very significant-majorly to smallholder farmers in developing regions. In general, only through investment in education, technology accessibility, and data management solutions can the challenges be addressed to create a fair growth path in agriculture. Ultimately, embracing precision agriculture would raise a more resilient and sustainable food system that could respond to the growing population's demands while preserving environmental integrity.

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REIMAGINING AGRIBUSINESS IN INDIA: CHALLENGES AND FUTURE SCOPE

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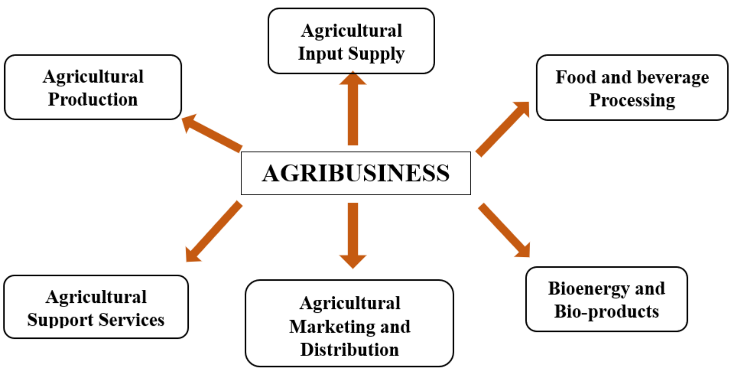
Introduction

Agribusiness refers to the business sector encompassing farming and farming-related commercial activities. Today's food and agribusiness managers navigate a fast-paced, highly volatile environment that is global, technology-driven, and centered on consumer demands. Agribusiness is a broad term that encompasses all the activities involved in the production, processing, and distribution of agricultural products. Agribusiness covers a wide range of activities such as crop cultivation, livestock farming, agricultural machinery manufacturing, agrochemicals, food processing, and distribution networks. It represents the integration of various industries within the agricultural supply chain, starting from farm inputs like seeds and fertilizers to food processing and retail distribution. It ensures the efficient production and delivery of food and other agricultural goods. The concept of agribusiness extends beyond mere farming; it includes a wide range of services and goods essential for modern agriculture, such as machinery, finance, marketing, and technology.

At its core, agribusiness aims to increase efficiency and productivity in agriculture. This is achieved through the use of advanced technologies, such as genetically modified seeds, precision farming tools, and automated equipment, which enhance crop yields and reduce labor costs. Agribusiness also involves the development and application of agrochemicals, including pesticides and fertilizers, to protect crops and improve soil fertility. The processing and distribution aspects of agribusiness are crucial in transforming raw agricultural products into consumable goods and delivering them to markets. This includes activities like packaging, transportation, and storage, which ensure that food products remain fresh and safe for consumption. Large agribusiness firms often operate globally, leveraging economies of scale to lower costs and increase market reach. Moreover, agribusiness plays a significant role in economic development, particularly in rural areas. It creates employment opportunities, supports local economies, and contributes to national GDP.

Classification of Agribusiness



Agribusiness includes various enterprises in the agricultural value chain, from production to distribution, and can be categorized into several sectors, including:

Agricultural Support Services

- **Financial Services**: Banks, credit unions, and microfinance institutions providing different financial products to farmers and agribusinesses..
- **Consulting and Advisory Services**: Firms offering agricultural consulting, farm management, and extension services
- **Research and Development**: Organizations focused on developing new agricultural technologies, crop varieties, and farming practices

Agricultural Marketing and Distribution

- **Wholesalers and Distributors**: Businesses that buy agricultural products in bulk from producers and sell them to retailers or other businesses
- **Retailers**: Supermarkets, farmers' markets, and specialty stores that sell agricultural products directly to consumers
- **Exporters and Importers**: Companies involved in the international trade of agricultural goods.

Bioenergy and Bio products

- **Biofuel Production**: Businesses that convert agricultural biomass into biofuels like ethanol and biodiesel.
- **Bio products**: Companies producing bioplastics, bio-based chemicals, and other products derived from agricultural materials.

Agricultural Production

- **Crop Farming:** Cultivation of grains, vegetables, fruits, and fibre plants.
- **Livestock Farming**: Raising animals for meat, dairy, eggs etc.
- **Aquaculture**: Farming of fish, shellfish, and other aquatic organisms
- **Horticulture**: Cultivation of fruits, vegetables, flower, medicinal and aromatic plants for food, medicinal purposes, and ornamental uses

Agricultural Input Supply

- **Seed, Sapling and Planting Material Production**: Companies that produce and sell seeds, seedlings, and plant materials
- **Fertilizers and Pesticides**: Manufacturers and distributors of chemical and organic fertilizers, pesticides etc.
- **Agricultural Machinery and Equipment**: Producers and suppliers of farming machinery, tools, and equipment like tractors, plows, harvesters, and irrigation systems.

Food and Beverage Processing

- **Food Processing:** Businesses that transform raw agricultural products into consumable food items.
- **Beverage Production**: Companies involved in producing alcoholic and non-alcoholic beverages from agricultural products

Constraints and Challenges

Agribusiness faces a variety of challenges and constraints that can impact its efficiency, productivity, and sustainability. These challenges can be broadly categorized into environmental, economic, social, and regulatory factors:

1. **Environmental Challenges**: Environmental challenges in agriculture are significant and multifaceted. Climate change, with its unpredictable weather patterns, frequent extreme events, and altered growing seasons, poses a major threat to crop yields and livestock health. Additionally, the overuse of natural resources like water, soil, and minerals leads to resource depletion, undermining long-term sustainability. Agricultural practices, such as habitat destruction and reliance on monocultures, contribute to biodiversity loss, weakening ecosystems. Moreover, the rising resistance to pesticides and the emergence of new pests and diseases further jeopardize crop and livestock productivity. Together, these challenges demand urgent attention and sustainable solutions.
2. **Economic Challenges**: Economic challenges in agriculture include market volatility, where fluctuations in commodity prices affect profitability. High input costs, such as for seeds, fertilizers, and machinery, further strain profit margins. Many small and medium-sized agribusinesses face difficulties in accessing finance for growth and innovation, often due to lack of collateral and high-interest rates. Additionally, local agribusinesses struggle to compete with large multinational corporations in the global market.
3. **Social Challenges**: Labor shortages, driven by rural-to-urban migration and aging farming populations, present a major challenge for both skilled and unskilled labor in agriculture. Additionally, limited access to modern agricultural education and training hinders farmers and workers from adopting innovative practices. Land ownership and tenure issues, where unclear or insecure land rights prevail, further discourage investment and can lead to conflicts, complicating agricultural development.
4. **Regulatory and Policy Challenges**: Trade policies and tariffs, along with import/export restrictions, can disrupt markets and supply chains, creating challenges for agribusiness. Navigating complex regulatory frameworks related to food safety, environmental standards, and labor laws adds to the burden, especially for small businesses. Additionally, inconsistent or unequal distribution of government subsidies and support can disadvantage certain groups within the sector, making it harder for them to compete.
5. **Technological Challenges**: Limited access to advanced technologies, particularly in developing regions, hinders productivity improvements in agriculture. Additionally, poor infrastructure—such as inadequate transportation, storage, and communication networks—further impedes the efficient operation and growth of agribusinesses.
6. **Sustainability and Ethical Challenges**: Agribusiness faces the challenge of balancing productivity with sustainable practices to minimize environmental impact and ensure long-term viability. Additionally, ethical treatment of livestock and adherence to animal welfare standards are becoming increasingly important. Meeting evolving consumer preferences, particularly the demand for organic, non-GMO, and sustainably produced food, often requires significant adjustments to traditional farming practices.

Addressing these challenges requires a multi-faceted approach involving government policy, technological innovation, sustainable practices, and effective management strategies to ensure the resilience and growth of the agribusiness sector.

Future Prospects

The future scope of agribusiness is vast and promising, driven by advancements in technology, changing consumer preferences, and the need for sustainable agricultural practices. Several key trends and developments are likely to shape the future of agribusiness:

1) **Technological Innovations:** Precision agriculture leverages data analytics, GPS, and IoT devices to optimize farming practices, reduce waste, and boost productivity. Technologies like drones, sensors, and satellite imagery provide real-time data for better crop management. Automation and robotics, including autonomous machinery for planting and harvesting, help reduce labor costs and enhance efficiency. Meanwhile, biotechnology, through advances in genetic engineering and CRISPR technology, enables the development of crops with higher yields, pest resistance, and improved nutritional content.
2) **Sustainability and Climate Resilience**: The adoption of sustainable practices, such as no-till farming, agroforestry, and organic farming, helps reduce environmental impact and maintain soil health. Climate-smart agriculture focuses on strategies to mitigate the effects of climate change, including the use of drought-resistant crops, efficient water management systems, and carbon sequestration techniques.
3) **Digital Transformation**: Digital platforms, including online marketplaces, connect farmers with consumers, suppliers, and financial services, streamlining supply chains and improving market access. Meanwhile, block-chain technology enhances transparency and traceability in the food supply chain, ensuring food safety and reducing fraud.
4) **Consumer Trends**: The rising demand for organic, non-GMO, and nutritionally enhanced foods is driving innovation in product development and marketing. Additionally, increasing consumer interest in plant-based diets and alternative protein sources, such as lab-grown meat, is creating new market opportunities in the agribusiness sector.
5) **Global Market Expansion**: The expansion of agribusiness into emerging markets with growing populations and rising incomes can significantly drive demand for agricultural products and technologies. Additionally, global trade agreements and the removal of trade barriers create new opportunities for agricultural exports, enhancing market access for producers.
6) **Financial Innovations**: Agri-fintech encompasses the development of financial technologies specifically designed for the agricultural sector, including digital lending platforms, insurance products, and mobile banking services for farmers. Additionally, there is a growing interest from venture capital and private equity in agribusiness start-ups and innovations, fuelling investment in this sector.
7) **Policy and Institutional Support**: Government initiatives that support research and development, infrastructure development, and sustainable farming practices create a favourable environment for agribusiness growth. Additionally, international cooperation among countries is essential to tackle global challenges such as food security, climate change, and sustainable development, fostering collaborative solutions in the agricultural sector.
8) **Urban Agriculture**: Vertical farming, which involves growing crops in stacked layers within urban environments, minimizes the land footprint and brings fresh produce closer to consumers. Similarly, urban gardens, including community gardens and rooftop farming initiatives, enhance local food security and promote urban sustainability.

The future of agribusiness will be shaped by these trends and innovations, leading to a more efficient, sustainable, and resilient agricultural sector capable of meeting the global demand for food and agricultural products.

Conclusion

The agricultural landscape is evolving, with agribusiness diversifying into various sectors, including crop cultivation, livestock farming, and food processing. Despite facing challenges such as climate change, resource depletion, and market volatility, the sector remains resilient and adaptable. Technological innovations like precision agriculture and biotechnology, coupled with consumer trends favoring health and sustainability, are shaping its future. Supportive government policies and financial innovations further open new avenues for growth. As agribusiness continues to adapt to these dynamics, it will play a vital role in ensuring food security, promoting economic development, and fostering sustainable practices. By leveraging collaboration, innovation, and resilience, the agribusiness sector can effectively meet the global demand for food and agricultural products, ultimately driving progress and prosperity in both rural and urban communities worldwide. Embracing these opportunities will be key to transforming agribusiness into a cornerstone of sustainable development.

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LATEST DEVELOPMENT IN CARCASS EVALUATION AND FUTURE DIRECTION

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Abstract

Carcass evaluation is crucial in the meat industry, influencing quality assessment, pricing, and consumer satisfaction. Recent advancements in technology and methodology have significantly improved the accuracy and efficiency of carcass evaluation. This article reviews the latest developments, including imaging techniques, machine learning applications, and the integration of sensor technology, while discussing their implications for meat quality assessment and industry practices.

Introduction

Carcass evaluation is a key process to ascertain the value and the quality characteristics of the animal at slaughter. This evaluation also helps to determine the market allocation of cuts. Carcasses are now rarely sold to retailers whole; the carcassesare broken down into different cuts and sorted to meet the demands of various markets and retailers. Better knowledge of carcass quality and composition can lead to better allocation of cuts to markets according to their specific demands. Carcass evaluation has traditionally relied on visual inspection and subjective measurements to determine meat quality traits such as marbling, fat cover, and muscle development. However, with the increasing demand for high-quality meat and the need for efficient processing, the industry has seen a shift toward more objectives i.e. move towards advanced value-based systems which are precise evaluation methods. Recent advancements in technology offer new tools that enhance the assessment process, promising better outcomes for producers, processors, and consumers.Some countries have introduced objective carcass measurement (OCM). OCM technologies for meat: Dual x-ray absorptiometry (DEXA), computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US) can be found in Further provide an overview of broader applications of nondestructive methods for carcass and meat evaluation.

Latest developments in non-invasive methods for the determination of body and carcass evaluation are given below-

X-ray based technologies
X-ray technologies are based on the different degrees of attenuation of the x-rays as a consequence of the different densities of the body/carcass tissues (lean muscle, bone, fat).

1. Computed tomography: The x-ray source rotates and the attenuation, after passing through the object, is measured by stationary ring detectors, thus enabling the generation of 3D images after data processing by a computer. The tissues of interest: fat, muscle and bone, all have different mass attenuation coefficients .The HU increases with increasing density such that fat, water and bone have average HU units of − 50 to− 100, 0 and >250, respectively, whereas average muscle values usually range between 0 to 100 CT is recognized as the 'Gold Standard' in determining the LMY of carcasses. CT has been applied for the determination of carcass composition intramuscular fat (IMF).CT scanning include the prediction of fat and lean weights from primal cuts of pigs. CT was a suitable technology for determining pig carcass composition before slaughter.

2. Dual energy x-ray absorptiometry: Dual energy x-ray absorptiometry (DEXA) couples the x-ray information acquired at two energy levels (high and low) difference (ratio) between the attenuation from the high- and low-intensity x-ray, the so called R-value. The R-value is used to determine the fat content from the former and the bone content from the latter, whereas the lean content is estimated as a difference between the two. Bone mineral content and bone mineral density can also be obtained.

3. Transmission radiography: The simplest x-ray approach, has been used to estimate total fat and salt content in hams

4. micro-CT: For the rapid estimation of IMF in five different commercial cuts obtaining high correlations (R2 > 0.92) with chemical fat content.

5. Robotics (rotating x-ray)

6. Enabling phase contrast x-ray imaging (PCI)

Nuclear magnetic resonance based technologies
1. Magnetic resonance imaging: Magnetic resonance imaging (MRI) is based on nuclear magnetic resonance (NMR) and involves transforming the signal information into 3D grey scale images. The tissue structures present in meat — muscle, fat, and connective tissue — can be exceptionally well differentiated using MRI in a volumetric way (Baulain, 1997). The vast majority of the literature using MRI in animal science is focused on live pigs, scanning the live animal at selected points (loin, thorax region, ham) and obtaining the correlations with body components. Due to these size constraints, beef carcasses cannot be analysed if they have not been previously cut to smaller piece.

2. Magnetic resonance spectroscopy and quantitative magnetic: Successfully applied to small samples (~15g) of meat for fast prediction of quality characteristics.

3. Quantitative magnetic resonance (QMR) : is a relatively new noninvasive and non-imaging method that is still in the evaluation phase for farm animals. QMR has been successfully applied for assessing changes in body composition of piglets.

Bioelectromagnetic methods
Bioelectrical impedance analysis, total body electrical conductivity and magnetic induction. The electromagnetic properties of the animal, carcass and meat are highly correlated with the fat

tissue content and therefore bioelectromagnetic technologies could be applied to understand the animal or carcass composition.BIA has been used to predict free-fat mass in buffalo calves obtaining high accuracy and obtained good prediction of carcass composition in young goats using BIA.TOBEC accurately predicted the lean meat percentage in beef leg primal and pork carcasses. Despite the high accuracy and relative safety (electromagnetic field is really low), the use of these technologies by the meat industry was scarce and mainly focused on ham grading and the estimation of chemical lean in boxed manufactured meat.

Ultrasound

Used for on-line grading of pig carcasses by LMY predicted from hundreds of backfat thickness and muscle thickness measurements. Even though this technology is very advanced in pigs (suitable online due to wet skin after the scalding process ensuring good acoustic contact), the same technology cannot be implemented on beef or sheep carcass due to air pockets following de-hiding which would impedeaccess of the sound energy.

Video image analysis

Video image analysis (VIA) systems is based on the differences in light intensity received by a video camera (e.g. fat versus lean meat).VIA system which can be used for quality grading (typically IMF, rib-eye area, colour and fat thickness measured at the quartering site of the carcass) and whole-carcass VIA systems which can assess carcass attributes related to yield or composition (fat cover, conformation).Whole carcass VIA instruments have also been developed specifically for sheep carcasses.VIA systems are, therefore, useful tools to predict carcass conformation in a consistent way and can be successfully applied under harsh environments such as abattoirs. It can be installed on-line, the speed is adequate for the meat industry's requirements and it is non-intrusive such that measurements can be done without contact with the carcass. The main drawback is that the information provided only comes from the external (visible) surface of the carcass or side.so Fat content determination is especially difficult for VIA.VIA only determining the subcutaneous fat cover, it loses accuracy as the fat depth increases.

Optical probes

New probe model based on fibre optical sensors and near infrared was tested on pig carcasses obtaining accurate predictions of lean meat ratio. All methods based on predicting carcass composition from subcutaneous fat depths, they are less accurate on beef and sheep than on pig carcasses.

Near-infrared (NIR) and Raman spectroscopy probes

NIR spectroscopy has also been used as a research tool to predict sensory traits with better accuracy.

Future Direction For Carcass Evaluation Method

An emerging biomedical imaging methodology based on the microwave spectrum and the dielectric properties of soft tissue is being developed; this technique is called microwave tomography (MWT). Camera based systems could also offer direction. Incorporation of 'time of flight' (TOF) technology has led to improved accuracy and resolution of the cameras.

Conclusion

The landscape of carcass evaluation is rapidly evolving, driven by technological advancements that offer greater accuracy, efficiency, and economic benefits. The integration of imaging techniques, machine learning, and sensor technology not only improves quality assessments but also addresses consumer demands for transparency and ethical production practices. As these technologies continue to develop, the meat industry is poised for significant transformation, ultimately leading to better products for consumers and improved outcomes for producers.

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AQUAVOLTAICS: INTEGRATING FLOATING SOLAR PHOTOVOLTAICS SYSTEM WITH AQUACULTURE FOR SUSTAINABLE FOOD AND ENERGY PRODUCTION

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Abstract

"Aquavoltaics" refers to integrating floating solar photovoltaic (FPV) systems with aquaculture operations as a potentially viable approach to sustainable food and energy production. Aquavoltaics optimizes water resource use while offering several environmental and economic benefits by integrating solar power generation with fish farming. The potential benefits of floating solar and aquaculture are explained in this article, which aims to improve energy efficiency, promote resilience to climate change, lower operating costs, and improve water quality. The future of aquaculture is directly related to the use of renewable energy, and floating solar is a unique example of innovative technology that ensures a more abundant and environmentally friendly future for food and energy production.

Introduction

The need for sustainable food and energy sources has grown as the world's population continues to grow. Aquaculture or farming of aquatic species, including fish, crustaceans, and mollusks, plays a vital role in meeting this demand. Conventional aquaculture methods frequently face issues with energy consumption, environmental effects, and a need for significant land and water resources.

A floating solar photovoltaic (FPV) system offers a promising solution to the challenges faced by the aquaculture industry. Integrating floating solar technology into aquaculture operations creates a symbiotic relationship that addresses energy needs and enhances fishery practices' overall ecological sustainability (Leadvent, 2024). This innovative approach of "Aquavoltaics" optimizes the use of water resources and provides numerous benefits to both the aquaculture industry and the environment.

Components of Aquavoltaic Floating Solar Systems

i. **Solar Panels (PV Modules) :** These main parts absorb sunlight and transform it into electrical energy. They come in polycrystalline and monocrystalline types, which have higher efficiency.
ii. **Floaters :** The buoyant structures known as floaters, often composed of polyethylene, hold the solar panels above the water's surface. They are designed to withstand environmental conditions and provide stability.

iii. **Mooring System :** The mooring lines and anchors are used to fix the floating solar panels to the waterbed. Suction, drag-embedded, and vertical load anchors are commonly used anchor types.

iv. **Central Inverter :** The electricity produced by the solar panels is transformed into alternating current (AC) by the inverter, enabling it to be used for aquaculture activities (Clark, 2023).

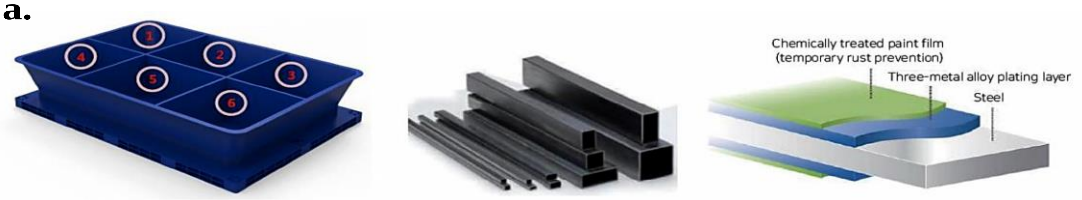
v. **Cabling :** The solar panels, transformer, inverter, and combiner box are all connected by a network of wires that provides effective electrical transmission throughout the system.

vi. **Transmission System :** This process transports the generated electricity from the floating arrays to its target location by connecting it to the nearby electrical grid.

Installation of Floating Solar Photovoltaic (FPV) system in Aquaculture

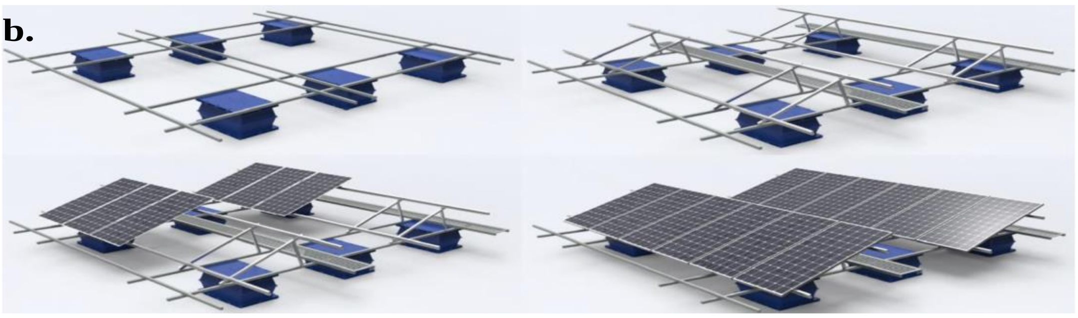
Aquaculture floating solar photovoltaic (FPV) system installation involves site selection that ensures the stability of the floating structure. It includes finding a suitable area of water that is sufficient in-depth and has low wave action. Depending on the site's characteristics, the mooring system can be installed by fixing anchors into the waterbed. After the installation of the mooring system, the floating structure assembly is carried out. Here, floaters are put together to provide a sturdy platform for the solar panels, and it is ensured that they are tightly attached and strong enough to withstand the weight of the panels (**Fig 1a**). After that, the solar panels are installed by mounting them onto the floaters using corrosion-resistant mounts, ensuring that the panels are positioned for the best possible exposure to sunlight, as shown in **Fig 1b**.

a.



a. Buoyancy body and Floating material

b.



b. Floating PV Buoyancy, Assembly

Source: Korea Water Resources Corporation (K-water)

Fig. 1. Components of Floating Solar Photovoltaic (FPV) system.

The central inverter and transformer are installed either on the floating structure or onshore during the electrical installation phase, which also involves connecting the solar panels to the combiner box via waterproof cabling. After that, underwater cables are installed to connect the floating array to the onshore transmission system, providing safe connections to the transformer and inverter. This process is known as cabling and transmission setup. The system undergoes extensive testing to ensure all parts are operating as intended after installation, and energy generation is monitored to make any required modifications during commissioning and testing. The maintenance planning procedure develops a strategy for periodic inspection of the mooring systems, electrical components, and solar panels to ensure long-term performance and reliability.

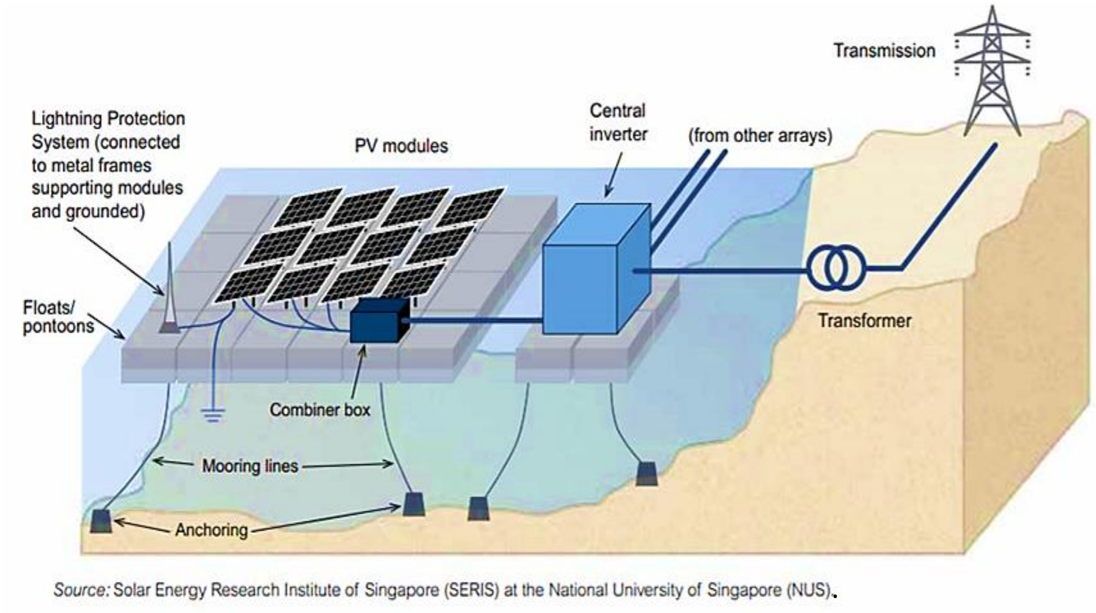


Fig. 2. Floating Solar Photovoltaic (FPV) system in Aquaculture.

The Advantages of Floating Solar and Aquaculture

a) **Enhancing Energy Efficiency :** A significant benefit of combining floating solar and aquaculture is the potential of increasing energy efficiency. Floating solar installations act as a protective layer by covering the water below and reducing algae growth. In addition to maintaining ideal water temperatures, this natural shade creates an environment that promotes healthy aquatic life. The dual-use approach of Aquavoltaics increases the overall efficiency and sustainability of the combined system. Aquaculture operations may reduce operational costs by reducing their reliance on traditional power sources by producing renewable energy on-site ((Leadvent, 2024).

b) **Improving Water Quality and Ecosystem Benefits :** Floating solar installations also play a crucial role in maintaining water quality and promoting a healthy ecosystem in aquaculture ponds. The panels prevent excessive sunlight penetration, reducing the risk of algal blooms and improving the ecological balance. Furthermore, floating solar systems in aquaculture ponds serve as a shield, lowering evaporation and maintaining water quality. It promotes aquatic organisms' overall health and growth by establishing a more stable and sustainable environment (Leadvent, 2024).

c) **Maximizing Land and Water Use :** The ability of Aquavoltaics to maximize the utilization of limited land and water resources is one of its main benefits. Fish farming in aquaculture frequently requires large areas; however, aquaculturists can obtain solar energy by utilizing floating solar technology without losing the surface area needed for their operations.

   This approach not only increases the system's overall efficiency but also helps to address the growing demand for food and energy production. Aquavoltaics optimizes resource utilization using the same water surface for aquaculture and solar power generation.

d) **Operational Cost Reduction :** Significant operational cost reductions can result from incorporating floating solar technology into aquaculture operations. Aquaculture facilities might reduce their need for traditional power sources like diesel generators or grid electricity by producing renewable energy on-site. Sustainable aquaculture practices are more competitive and viable due to this economic advantage. The financial advantages of Aquavoltaics will draw aquaculture operators in as solar technology's cost continues to decline and its efficiency rises.

e) **Resilience to Climate Change :** Aquaculture's development is inextricably linked to the problems caused by climate change. Floating solar integration provides a reliable alternative by offering aquaculture operations a more controlled environment. Maintaining stable water conditions and protecting aquatic life became more crucial when catastrophic weather events and irregular climate patterns became more common. Aquavoltaics offers a way to overcome these challenges and assure the long-term viability of aquaculture operations.

Challenges and Considerations

While the integration of floating solar and aquaculture presents numerous benefits, some challenges and considerations must be addressed:

Cost and Financing

The higher building expenses of floating solar power plants compared to ground-mounted systems is one of the main challenges. The initial investment may be more costly due to the additional costs related to the underwater cables, anchoring system, and floating structure (Pouran et al., 2022).

Innovative financing methods and legislative support may be required to address this issue and encourage using Aquavoltaics. Governments and financial institutions might contribute to providing this technology to farmers by offering subsidies, low-interest loans, or other monetary incentives.

Environmental Impacts

Floating solar systems have the potential to benefit the environment by reducing water evaporation and improving water quality, but certain drawbacks need to be taken into account as well. These can impact aquatic ecosystems, including variations in water temperature, light penetration, and dissolved oxygen levels (Vo et al., 2021; Pouran et al., 2022).

Technical Challenges

Floating solar systems face technical challenges related to the harsh marine environment, such as corrosion, biofouling, and the impact of waves and currents. These factors can affect the durability and performance of the solar panels and supporting structures (Pouran et al., 2022). Developing specialized materials and engineering solutions is necessary to address these challenges. Continuous research and development in floating solar technology will help improve the reliability and longevity of these systems, making them more suitable for integration with aquaculture operations (Patil et al., 2024).

Conclusion

Integrating floating solar photovoltaic systems with aquaculture offers a promising solution for sustainable food and energy production. Aquavoltaics optimizes the use of water resources by solar power generation with fish farming while providing numerous environmental and economic benefits. Aquaculture industries may benefit from floating solar systems' higher energy efficiency, better water quality, lower operating costs, and promotion of climate resilience. The combination of floating solar and aquaculture has the potential to revolutionize the way we produce food and energy, leaving future generations with a more economical and sustainable future.

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TOMATO CROP AND LEAF CURL DISEASE IN BIHAR

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Abstract

Tomato production in Bihar is constrained by Tomato Leaf Curl Disease (TLCD), and it is badly impacting the tomato productivity in districts of Bihar. The extent of occurrence and intensity of TLCD in different tomato growing districts is assessed through the field surveys and laboratory analysis. The socio-economic implications on local farmers, focusing on crop management practices and potential loss of income, is also explored. Findings indicate that early detection and integrated pest management strategies are crucial for mitigating TLCD's effects, but it is defacing sustainable environment goals. We aim to support farmers in adopting sustainable practices, ultimately enhancing tomato production and food security in Bihar. The study underscores the need for ongoing surveillance and education to combat TLCD effectively.

Introduction

Tomato Leaf Curl Virus (TLCV) is a significant phytopathogen that affects tomato crops across India, leading to substantial economic losses for farmers. This virus, transmitted primarily by whiteflies, causes a range of symptoms including leaf curling, yellowing, and stunted growth, severely compromising crop yields. In India, where tomatoes are a staple vegetable and a crucial source of income for many farmers, the impact of TLCV can be particularly devastating. TLCV belongs to the begomovirus group and is characterized by its ability to cause systemic infection in tomato plants. The virus has multiple strains, and its prevalence varies geographically. Different states like Punjab, Haryana, Maharashtra, and Karnataka have reported high incidence rates of TLCV, particularly during warmer months when whitefly populations thrive. The rapid spread of the virus can lead to a total crop failure if not managed properly. The impact of TLCV on tomato productivity is severe. Infected plants often show a significant reduction in fruit set, resulting in smaller and fewer fruits. Reports indicate that TLCV can reduce tomato yields by as much as 50% to 80% in heavily infested fields. Farmers face not only reduced quantity but also lower quality of produce, leading to decreased market prices. Additionally, the cost of managing the disease through increased pesticide applications and crop management strategies places a financial burden on farmers already facing economic challenges.

Tomato as a crop

Tomato is an adornment for vegetable seller; from an indispensable one to a bash item. As a crop, tomato is significant for farmers due to short growing cycle and high market-demand providing for quick and profitable returns. Tomato is also important because various products like sauces and pastes made from tomato expand its market opportunities for growers. Tomato is rich in Vitamins A, C, antioxidants like lycopene, and essential minerals, making them highly nutritious and beneficial for health. However, tomato production in Bihar is facing several challenges, one of the most important ones is the disease called as ‘leaf curl’, which is severely affecting yield and quality. Insect infestations, notably whiteflies that transmit Leaf curl Virus (a Begomovirus), posing real threats to the crop.

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Current status of cultivation of tomato

The region's fertile soil and favorable climate support the cultivation of a variety of vegetables, including potatoes, onions, tomatoes, and green leafy vegetables. Bihar has three major vegetable production belts where tomato is being cultivated on a large scale. Tomato production in Bihar is concentrated in several key districts known for their high yield and quality. The districts of Muzaffarpur and East-Champaran are known for their innovative farming practices and substantial outputs. These districts play a vital role in supplying tomatoes to local markets and neighbouring states, bolstering Bihar's agricultural economy. Samastipur, Darbhanga and Vaishali are prominent in tomato production due to its fertile soil and favourable climatic conditions. Lakhisarai (Badhaiyaa) and Rohtas (Dehri-on-Son) are notable regions in Bihar for tomato production. Nalanda districts, (including Biharsharif, Noorsarai, Soosarai) has extensive tomato farming contributing significantly to the state's overall production. The most popular verities of tomato in Bihar, developed by government agencies include Pusa Ruby, Arka Vikas, Swarna Sampada, and Swarna Lalima. During growing season, the leaf curl disease does not spare any of these varieties. On the other hand, private seed companies like VNR, Syngenta, and Seminis are also quite popular among farmers due to their high yield and fruit quality, though the cultivar resistance status to leaf curl disease is unclear. Due to unclear resistance status, farmers are totally reliant on chemical pest management strategies, which is heavily promoted by seed companies. Interaction with farmers in Bihar during field survey in 2022-2023 and 2023-2024, revealed that most of the farmers use insecticide overdose and misunderstood it as a growth promoter for high crop production. The government appointed district agricultural co-ordinators and kissan salahkaar at several districts across vegetable growing zones of the state, were interacted, to locate the infected fields for analysing the current scenario of this disease. During the field survey, the leaf curl disease incident is recorded at Lakhisarai, Vaishali, Siwan, Darbhanga, Patna, Nalanda, Rohtas and West Champaran. (Fig. 1)

Fig 1: Tomato field survey

Ways to combat the constraints on tomato production

However, the 'leaf curl' disease is greatly affecting the productivity of this crop, the research and breeding efforts by agricultural scientists are continuously aiming at enhancing the disease resistance of tomato varieties, ensuring better performance and reliability for farmers. Extended collaboration between the seed companies, agricultural institutions, and local farmers is vital to develop and disseminate varieties that not only promise high yields but also possess robust disease resistance. Continuous research and development in breeding disease-resistant varieties and improving farming practices are essential to sustain and boost tomato production in Bihar. Educating farmers about early detection, using insect-resistant crop varieties, and implementing proper crop rotation can mitigate the impact of these diseases. Moreover, enhancing surveillance for viral infections can help in timely interventions, potentially reducing the spread and severity of outbreaks. Thus, the collaboration between the agricultural institutions, the government agencies, and the farmers is crucial to address these constraints and ensure the long-term success of tomato production in the state.

Conclusion

Tomato Leaf Curl Virus significantly threatens tomato productivity not only in Bihar but most of the regions of India, exemplifying broader challenges posed by viral diseases across various crops. Moreover, the increased need for chemical controls to manage these viral infections can lead to environmental degradation and long-term soil health issues. The economic implications for farmers and the agricultural sector are profound, underscoring the need for effective management strategies and research into resistant crop varieties. As climate change continues to alter pest dynamics, addressing viral infections will be crucial for ensuring food security and sustaining agricultural livelihoods in India.

Acknowledgement

At present, a research project focussing on the status of constraints imposed by Begomovirus on tomato production in Bihar, is funded by Scientific and Engineering Research Board, Department of Science and Technology, Government of India (now Anusandhan National Research Foundation; ANRF), to Dr. Punam Ranjan, Project Investigator (PI), Assistant Professor at Department of Botany, Patna Science College, Patna University.

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UAV: AN EMERGING TECHNOLOGY IN AGRICULTURE SECTOR

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Abstract

India's economy is primarily agriculture-based, but it lags in technological advancements. Farmers still rely heavily on monsoon rains and traditional methods, which affect the quality and quantity of agricultural output. Unmanned Aerial Vehicles (UAVs) or drones are utilized for surveillance in a variety of sectors including agricultural areas. Although drone technology is in its early stages and still in its infancy in India, e government has launched several initiatives to integrate drones into agriculture. Drones offer benefits like soil analysis, crop monitoring, livestock management, crop spraying, and weather forecasting. However, limitations include connectivity issues, weather dependence, and the need for skilled operators. Drones are predicted to revolutionize Indian agriculture in the next few years.

Keywords: UAV, agriculture, technologies, advancements, government, initiatives.

Introduction

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, remotely piloted aircraft (RPA), or unpiloted aerial vehicles, are rapidly gaining traction in the agricultural sector. The growing popularity of UAVs stems from their ability to provide numerous advantages to farmers, including enhanced production efficiency, higher crop yields, and cost savings. These technological tools have revolutionized various agricultural operations, with their primary role being to optimize crop yields and monitor the growth and health of crops throughout the cultivation process. One of the primary reasons UAVs have become essential in modern agriculture is their capability to gather valuable data that aids farmers in making informed decisions. Drones are equipped with advanced sensors that collect crucial information on soil conditions, crop health, and the stages of crop growth. By utilizing multispectral sensors, UAVs can capture electromagnetic radiation, including near-infrared and short-wave infrared light, which are not visible to the human eye. This enables drones to assess plant and soil health with greater accuracy and detail than traditional methods. As a result, farmers can detect issues like nutrient deficiencies, water stress, and pest infestations early on, allowing for timely interventions that improve crop health and yield. Additionally, UAVs in agriculture come with sophisticated features such as GPS navigation systems, high-resolution cameras, programmable controllers, and autonomous flying capabilities. These technological advancements make data collection more precise and efficient, allowing farmers to gather real-time insights about their fields with minimal manual effort. By automating tasks like crop monitoring and data collection, UAVs free up time for farmers to focus on other essential aspects of their operations. The global agricultural drone market is expected to experience significant growth, with a compound annual growth rate (CAGR) of 35.9%. By 2025, it is projected to reach $5.7 billion. This rapid expansion is fueling interest from businesses in India, where companies are increasingly looking to invest in cost-effective drones tailored to the needs of farmers. Such investments are not only expected to help farmers improve productivity but also create new job opportunities for rural youth, fostering skill development and enhancing technological expertise in the agricultural sector. As drones continue to evolve and become more affordable, their impact on agriculture will likely be profound. From improving crop yields to reducing resource waste, UAV technology is poised to transform farming practices and usher in a new era of precision agriculture.

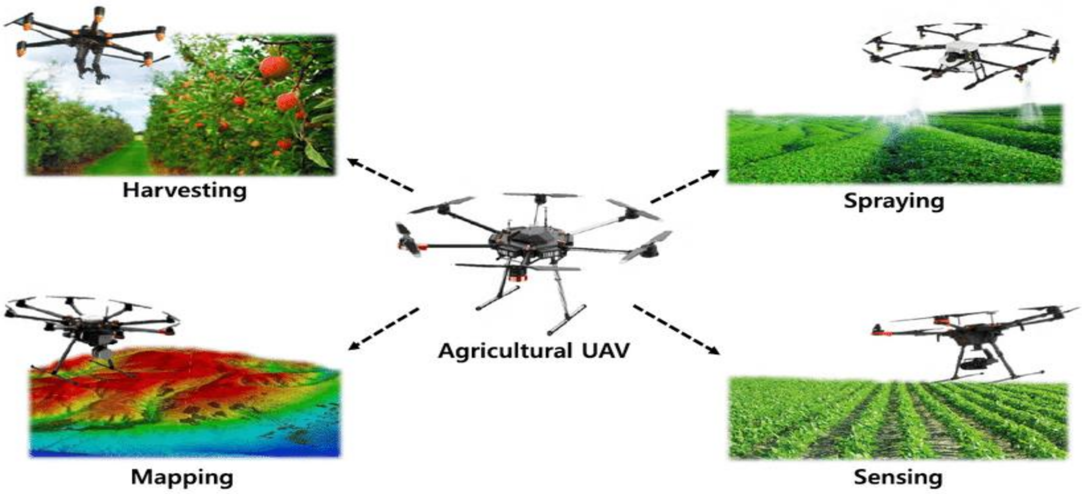

Fig., Various uses of UAVs in agriculture sector

The evolving agriculture drones market

The drone manufacturing business in India is expected to increase from Rs 60 crore in 2020-21 to Rs 900 crore in 2024-25. According to Bluewave Consulting, India's agricultural drones industry is predicted to triple throughout the timeframe. According to Frost and Sullivan, drone adoption in India's agriculture sector is expected to grow at a CAGR of 38.5% and reach US$ 121.43 million by 2030, accounting for 2% of all expenditures on agricultural machinery. Gradually becoming an integral part of the farming process, drones offer solutions for precision agriculture, crop monitoring and input management. In April 2023, the Ministry of Agriculture unveiled standard operating procedures (SOP) for pesticide application using drones across 10 crops, including rice, wheat, cotton, and maize. The government sanctioned a central sector scheme, known as **'Drone Didi',** allocating 15,000 drones to women self-help groups (SHGs) in specified clusters, last year. The scheme, spanning from 2024-25 to 2025-26, has a budget of Rs.1261 crore. The Centre will offer 80% assistance, capped at Rs.8 lakh per SHG, to cover the drones' costs and accessories. Farmer Producer Organisations (*FPOs*) are provided a grant-in-aid equivalent to 75% of the drone purchase cost for conducting demonstrations in farmers' fields.

Types of drones used in agriculture

In agriculture, various types of drones are utilized for specific applications. **Multirotor drones** are maneuverable, ideal for crop monitoring and spraying. **Fixed-wing drones** cover large areas for mapping and surveying. **Hybrid drones** combine both types for versatility. **Single-rotor drones** excel in carrying heavy payloads for spraying. Agricultural drones with sensors capture detailed data on crop health and soil conditions. **Spray drones** efficiently apply fertilizers and pesticides. **Surveying drones** provide high-resolution mapping, while monitoring drones assess crop health through imagery. Lastly, **delivery drones** transport supplies directly to remote fields, improving logistical efficiency.

Benefits of drones in the agriculture sector

Drones can be used for a wide range of tasks in the agriculture sector, including crop mapping, crop health monitoring & surveillance, soil analysis, irrigation monitoring, crop damages and pest management. Here are some of the key benefits of using drones in agriculture:

1. **Precision Agriculture**: Drones enable farmers to gather accurate data on soil health, crop conditions, and overall field variability, allowing for targeted interventions that optimize inputs like water, fertilizers, and pesticides.
2. **Crop Monitoring**: Drones provide real-time aerial imagery and data analytics, helping farmers monitor crop growth, detect diseases, and assess overall plant health throughout the growing season.
3. **Increased Efficiency**: By automating tasks such as crop spraying and field mapping, drones can significantly reduce the time and labor required for these operations, leading to cost savings and increased productivity.
4. **Early Disease and Pest Detection**: Drones equipped with multispectral sensors can identify stress in crops and detect diseases or pest infestations early, enabling timely interventions that can save crops and reduce losses.
5. **Irrigation Management**: Drones can help identify areas in fields that require more or less water, allowing farmers to manage irrigation more effectively and conserve water resources.
6. **Soil Analysis**: Drones can collect data on soil health & composition, helping farmers understand their fields better & make informed decisions regarding soil management & crop selection.
7. **Improved Yield Predictions**: By analyzing aerial imagery and data, drones can provide farmers with insights into crop yields, helping them plan better for harvests and market demands.
8. **Livestock Monitoring**: Drones can be used to monitor livestock health and movement, ensuring better management of animal welfare and grazing patterns.
9. **Reduced Chemical Usage**: Drones allow for precise application of pesticides and fertilizers, minimizing the quantity needed and reducing environmental impact while improving crop health.
10. **Cost Savings**: Although the initial investment may be high, the long-term benefits of increased efficiency, reduced labor costs, and optimized resource use can lead to substantial savings for farmers.
11. **Enhanced Mapping and Planning**: Drones can create detailed maps of farmland, aiding in planning and decision-making processes regarding land use, crop rotation, and other farming strategies.
12. **Environmental Monitoring**: Drones can help farmers monitor environmental conditions and assess the impact of farming practices on ecosystems, supporting sustainable agriculture.

Impediments of adopting Agro-UAVs:

Although farmers may gain a lot from using drones, there are certain obstacles that could prevent them from doing so. Here are a few of the main difficulties:

1. **Fear of job loss:** Farmers fear that the adoption of drone technology in agriculture could lead to job losses by reducing the need for manual labor in tasks like planting, monitoring, and

harvesting. In rural areas where agriculture provides essential employment, this fear of displacement may create resistance to embracing drones, despite their efficiency and potential benefits.

2. **Lack of expertise and training:** Many farmers lack the technical expertise to operate drones effectively, which reduces their confidence in adopting the technology. Drones require knowledge of programming, data analysis, and equipment maintenance. The lack of accessible training programs, especially in rural areas, exacerbates this issue, creating a significant barrier to the widespread adoption of drone technology in agriculture.
3. **Price:** The high cost of purchasing and maintaining drones, especially for small-scale farmers, limits adoption. Advanced drones with sensors are expensive, and ongoing expenses like repairs and updates add to the financial burden. Many farmers prioritize essential equipment over drones, uncertain about the return on investment, making the technology less accessible.
4. **Regulatory obstacles:** The use of drones in agriculture faces legal and regulatory challenges that vary by region. Farmers may need licenses, comply with airspace restrictions, and ensure drones don't interfere with airports or residential areas. These regulations can be costly and time-consuming, deterring adoption. Changing laws or added restrictions may further limit drones' agricultural impact.
5. **Connectivity and Weather Limitations:** Drones in agriculture depend on stable connectivity and favorable weather. In rural areas, poor connectivity hampers real-time data analysis and decision-making, while adverse weather conditions like heavy rain or strong winds reduce their effectiveness, limiting their overall utility in unpredictable climates.

Drone technology in India’s rural agriculture is nascent, offering potential but facing concerns over job loss, expertise, and training deficits. However, initiatives are being made to overcome these issues and promote the use of drone technology. The **Digital India Programme** (DIP), one of the major efforts, strives to give rural regions access to digital infrastructure and connectivity. The initiative's emphasis on education and training may assist to overcome farmers' lack of training and expertise. **The use of drone technology in agriculture is also being promoted by a number of organisations and projects. A Centre for Precision and Farming technology, for instance, was founded by the Indian Council of Agricultural Research (ICAR) with the goal of developing precision agricultural technology, such as drones.**

Integrating drones with other technologies

Integrating agricultural drones with technologies such as GIS, GPS, IoT, and AI may dramatically improve farming methods, increasing efficiency, production, and overall sustainability. Drones accumulate high-resolution data for mapping and real-time monitoring, enabling more accurate resource management. They also enable predictive analytics using big data, machine learning, and remote sensing. Furthermore, integrating with farm management software and autonomous vehicles simplifies operations, while blockchain improves supply chain transparency by assuring accuracy of information and product traceability. Overall, this technological synergy enables farmers to make more informed decisions, promote resource usage, and adapt to changing conditions, resulting in improved agricultural outcomes.

Conclusion and Future Outlook

In nutshell, the use of drone technology in agriculture has the potential to change how farmers manage their crops and increase yields. Farmers in the agricultural industry may profit from drones in a variety of ways, including higher productivity, better yields, and lower expenses. Farmers may be hesitant to accept this technology due to worries about job loss, a lack of expertise, and inadequate training. While drone technology acceptance in rural India is still in its infancy, initiatives are being made to overcome these issues and advance drone use in agriculture. It is crucial that farmers comprehend the potential advantages of this technology and get the assistance and training they need to use it successfully. To guarantee that the advantages of drone technology in agriculture are realized while also addressing any worries or issues that may arise, it is crucial that farmers and policymakers collaborate. By doing this, we can contribute to the development of a more productive and sustainable agricultural industry that will benefit both farmers and consumers.

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THE ROLE OF SOFT SKILLS FOR FARMERS: CULTIVATING SUCCESS BEYOND THE FIELDS

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Introduction

Traditionally, farming has been seen as a profession rooted in physical labor and technical expertise. However, there is growing recognition of the critical role soft skills play in ensuring a farmer's success and sustainability. As agriculture rapidly evolves due to technological advancements, climate change, and shifting market dynamics, farmers need more than just practical skills to succeed. They must develop and leverage soft skills to thrive in this changing landscape.

Farming involves the cultivation of crops and the raising of livestock, often for commercial purposes. Enhancing your farming skills can improve your day-to-day operations and provide an edge in job interviews and career advancement. Understanding the essential skills farmers need and how these skills apply to their work can deepen your appreciation of farming as a career.

What Are Farmer Skills?

Farmer skills encompass the abilities necessary to carry out daily farming tasks effectively. These skills include problem-solving, interpersonal communication, farm management, and organizational capabilities—all of which are crucial for successful farming. These skills are applied in various aspects of farming, such as managing farmlands, cultivating crops, and repairing machinery. Mastering and highlighting these abilities can enhance your growth in the farming industry and set you apart from other candidates during job applications. Farmers require a diverse skill set to perform their tasks successfully. Here are ten key skills every farmer should have:

1. **Farm Operations:** Farmers need a comprehensive understanding of agricultural processes and the farming industry. This knowledge allows them to perform their daily tasks, such as raising animals or cultivating the soil, with expertise and efficiency.
2. **Technological Awareness:** While farmers don't need to adopt every new piece of equipment, staying informed about technological advancements is crucial. Understanding developments in pesticide use, irrigation techniques, and strategies for improving cultivation, harvest, storage, and transportation can make farmers more efficient. This awareness also helps in selecting the right equipment to meet specific needs.
3. **Problem-Solving:** Farming often involves solving complex problems through trial and error. For instance, farmers continually seek ways to increase crop yields or respond to unexpected weather conditions. Strong problem-solving skills enable farmers to make smart decisions, ensuring the best possible harvest despite challenges.
4. **Mechanical and Repair Skills:** Farmers work with a variety of equipment and tools, making mechanical skills essential for maintaining and repairing machinery. Being able to handle

routine repairs independently can save time and money, reducing reliance on external repair specialists.

5. **Interpersonal Skills:** Effective communication is a key in farming, whether it's managing farmlands, negotiating with buyers, or building community networks. Farmers with strong interpersonal skills can motivate their teams, negotiate better prices, and create supportive networks for sharing resources and knowledge.
6. **Time Management:** Farmers often work long hours, especially during peak seasons. Effective time management is crucial for completing tasks efficiently and seizing new opportunities as they arise. Successful farmers consistently manage their time to meet market demands and ensure productivity.
7. **Physical Health and Stamina:** Farming is physically demanding, requiring tasks like lifting, hauling, and operating machinery, often in challenging weather conditions. Good physical health and stamina are essential for handling these strenuous activities and maintaining productivity throughout the day.
8. **Organizational Skills:** Farmers need strong organizational skills to manage records related to various activities, such as invoices, equipment manuals, warranties, and contracts. These skills are particularly important for tracking certifications and other critical documents, especially for organic farmers or those running their own businesses.
9. **Management Skills:** Even on small farms, strong management skills are essential. Effective management enables farmers to coordinate harvests, supervise team productivity, and manage the commercial aspects of farming, such as buying supplies and selling crops.
10. **Adaptability:** The farming industry is unpredictable, with challenges such as fluctuating demand, weather variations, and economic shifts. Adaptability allows farmers to adjust to these changes, adopt new techniques, and anticipate future challenges, ensuring long-term success.

What Are Soft Skills?

Soft skills refer to personal attributes and interpersonal abilities that influence how effectively individuals interact with others, manage their work, and navigate challenges. These skills include communication, problem-solving, leadership, teamwork, adaptability, and time management, among others. While traditionally associated with corporate environments, these skills are equally crucial for farmers.

1. Communication Skills

Effective communication is vital for farmers, whether it's negotiating prices with buyers, discussing best practices with fellow farmers, or explaining agricultural needs to government officials. Good communication skills help farmers articulate their ideas, share knowledge, and build relationships with stakeholders in the agricultural value chain. Moreover, as farming communities become more interconnected through digital platforms and social media, the ability to communicate clearly and persuasively is becoming increasingly important.

2. Problem-Solving and Critical Thinking

Farming is fraught with uncertainties, from unpredictable weather patterns to fluctuating market prices. Farmers must be adept at problem-solving and critical thinking to make informed decisions quickly. Whether it's finding alternative solutions to crop failures or adapting to new agricultural practices, these skills enable farmers to stay resilient in the face of challenges.

3. Leadership and Teamwork

Farming often requires collaboration, whether within a family, a community, or a cooperative. Leadership skills empower farmers to take charge, motivate others, and drive collective efforts toward common goals, such as community-based farming projects or cooperative marketing. Meanwhile, teamwork fosters a sense of unity and shared responsibility, leading to better resource management and mutual support during tough times.

4. Adaptability and Learning

The agricultural sector is undergoing rapid transformation, with new technologies, practices, and market demands emerging regularly. Farmers who are adaptable and willing to learn new skills are better positioned to capitalize on these changes. This could involve embracing precision farming techniques, learning about sustainable agriculture practices, or staying informed about market trends to diversify crops or products.

5. Time Management

Farmers often juggle multiple tasks simultaneously, from planting and harvesting to marketing and financial management. Effective time management is crucial to ensuring that all these tasks are completed efficiently. Farmers who can prioritize their work, plan ahead, and manage their time well are more likely to achieve higher productivity and profitability.

6. Emotional Intelligence

Farming can be emotionally demanding, with stressors ranging from economic pressures to environmental challenges. Emotional intelligence— the ability to recognize, understand, and manage emotions—helps farmers cope with stress, build strong relationships, and maintain a positive outlook even during difficult times. It also fosters better relationships with customers, suppliers, and the community, essential for long-term success.

Conclusion

In today's dynamic agricultural environment, soft skills are not just a complement to technical expertise—they are essential for the overall success of farmers. By developing strong communication, problem-solving, leadership, adaptability, time management, and emotional intelligence, farmers can better navigate the complexities of modern agriculture, build stronger communities, and ensure a more sustainable and prosperous future. As the agricultural sector continues to evolve, the importance of soft skills will only grow, making them indispensable.

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POTENTIAL OF ENTOMOPATHOGENIC NEMATODE AS BIOCONTROL AGENT AGAINST *Spodoptera frugiperda* (J. E. SMITH) IN MAIZE, *Zea mays* L.

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Abstract
Due to its extensive host range, fast rate of reproduction and dispersal, and propensity to seriously harm crops anywhere in the world, *Spodoptera frugiperda* is a highly recognized pest. The most popular host plant for *S. frugiperda* larvae is maize, which can be attacked at any stage of the life cycle, including vegetative, reproductive, and blooming. In order to become more hidden and difficult to detect in time, the larvae can also drill into the ears, stems, and cobs of maize. Chemical control remains the most widely used and successful method of managing *S. frugiperda* to date. Biological options against *S. frugiperda* are continuously being investigated in an effort to reduce the negative effects of chemical pesticide overuse or misuse. Consequently, entomopathogenic nematodes (EPNs) have attracted a lot of interest as a biocontrol agent for pest management that is environmentally sustainable. EPNs have been widely used to reduce soil-dwelling insect pests by using their gut associated bacteria. Due to its high virulency, it is found effective against *S. frugiperda* in maize.

Key words: Biocontrol agent, Entomopathogenic nematodes, *Spodoptera frugiperda*, Virulency

Introduction
The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is native to tropical and subtropical regions of America and has rapidly spread to over 70 countries in Africa, Asia, Australia and Europe since 2016. It causes severe damage to the leaves and stems of at least 353 species in 76 plant families (Silva *et al.,* 2017). According to the differences in host preference, *S. frugiperda* has been categorized into two sub-populations, the "rice-strain" (R-strain) and the "maize-strain" (C-strain). The maize-strain haplotype mainly feeds on maize, cotton and sorghum, while the rice-strain haplotype invades rice and pastures. Due to its high capacity of long-distance migration and adaptation, it continues spreading into new territory and is widely regarded as the most damaging pest of global economic importance. Due to the rapid global invasion capacity and devastating damages to agricultural crops (Plate 1A), there is a pressing need for the effective management of *S. frugiperda*. Chemical insecticides are widely used and function as the most effective weapon for its management. However, the misuse or overuse of chemical insecticides have resulted in evolved resistance in the *S. frugiperda* population (Chen *et al.,* 2022).

It was reported that it showed resistance to many of the active ingredients. As resistance to insecticides is the main challenge in pest control, cultural and biological strategies must also be adopted to fight *S. frugiperda*. For its management, the applications of extracts and metabolites from plants, such as limonoids and azadirachtin, is considered to be effective, cost-efficient, environmentally friendly and without negative effect to consumers. Biological controls using microbials, including entomopathogenic nematodes, fungi, viruses and bacterium, are now important components in integrative *S. frugiperda* management, all of which represent sustainable and promising strategies.

Table 1. The grading criteria of maize for *Spodoptera frugiperda* infection

Grade	Grading Standard
0	Healthy
1	Leaves of the whole plant were infected by 0–5% (excluding 0%). The heart leaf, tassel and maize ears were not infected.
2	Leaves of the whole plant were infected by 5–15% (excluding 5%), or the heart leaf, tassel and maize ears were infected by 0–5% (excluding 0%).
3	Leaves over the whole plant were infected by 15–25% (excluding 15%), or the heart leaf, tassel and maize ears were infected by 5–15% (excluding 5%).
4	Leaves over the whole plant were infected by 25–50% (excluding 25%), or the heart leaf, tassel and maize ears were infected by 15–25% (excluding 15%).
5	Leaves over the whole plant were infected over 50%, or the heart leaf, tassel and maize ears were infected over 25%.

Entomopathogenic nematodes (EPNs)

Nematodes that parasitize insects, known as entomopathogenic nematodes (EPN), have been considered as one of the most effective biological agents against *Spodoptera frugiperda*. EPNs are lethal parasites of insect hosts which release symbiont bacteria, such as *Xenorhabdus* and *Photorhabdus*, after invading the body cavity of host insects. Of all the EPNs, Steinernematidae and Heterorhabditidae families draw the most attention, and about 100 species of Steinernema and 21 species of Heterorhabditis had been identified on different continents of the world prior to 2020. Due to their attributes of having a broad host range, a rapid speed of kill, compatibility with chemical pesticides and being ecologically friendly, EPNs are employed as an alternative strategy for insect pest control (Plate 1 A). In general, most of the applications of EPNs were aimed at soil containing pest insects (Kumar *et al.,* 2022). For foliar insects, promising results were found in laboratory and glasshouse trials, including against Coleoptera, Diptera, Hemiptera, Hymenopera, Lepidoptera and Thysanoptera. Considering the high application potential to suppress larval populations, Steinernema and Heterorhabditis species have been commercialized.

Mode of action

EPNs are minute soil-dwelling roundworms found worldwide, except in Antarctica. They exclusively parasitize insects, which they locate with the help of chemical cues and enter via natural orifices, or in some cases through the cuticle. EPNs carry symbiotic bacteria in their guts that are released inside their host. These bacteria, as well as the EPN, exude toxins that rapidly kill their insect host. EPNs can kill a large variety of insects and can be easily mass-produced inside the insect cadaver. They are safe for humans and the environment and have been successfully used as biocontrol agents against insect pests. Although EPNs are sensitive to ultraviolet (UV) radiation and desiccation, the protective location of the feeding *Spodoptera frugiperda* caterpillars, mostly deep within the maize whorl, makes the maize– *S. frugiperda* system a suitable candidate for EPN application. Moreover, EPNs exhibit exceptional virulence against *S. frugiperda* with the ability to kill young caterpillars within 24 h (Plate 2 B;C), which is considerably faster than entomopathogenic fungi, viruses, or parasitoids. Furthermore, the isolation of highly virulent EPN strains from local soils eliminates the need for introducing nonnative organisms, thereby avoiding potential regulatory barriers.

Plate 1. A). *Spodoptera frugiperda* infection in maize B) & C). *S. frigiperda* inoculated with *Heterorhabditis* spp. under laboratory bioassay

Plate 2. Cadavers of *Spodoptera frugiperda* due to infection of *Heterorhabditis* spp.

Constraints

EPNs are considered to be one of the most promising biocontrol agents in insect pest control, while its application for broader utilization in the field still faces great challenges. Indeed, there are many obstacles in the translation of the good efficacy in laboratory experiments into success in field. As shown in some studies, the larval and adult of *Heteronychus arator* were susceptible to *Steinernema carpocapsae* in laboratory assays, while field tests using *S. carpocapsae* against adults were unsuccessful. Similar results were obtained from *Heterorhabditis bacteriophora* where attempting to control *S. frugiperda* in field trial, the control efficacy was low and was unqualified to be an effective biocontrol inoculant due to factors affecting EPN survival and infection. The control efficacy of each treatment ranged from 25–51%, after 5 days of treatment while it decreased to 9 to 20 per cent after 20 days of treatment. It can be concluded that the success of EPN application for foliar pests depends on abiotic conditions, such as moisture and temperature and biotic conditions, for instance the pathogenicity and foraging strategy of nematode species. Compared with treating soil-dwelling pests, EPN application on foliar environments is more vulnerable to unfavorable conditions and less successful than soil-based applications. After being sprayed on maize leaves, IJs of EPNs were exposed to adverse environmental conditions, including temperature, ultraviolet radiation and the risk of desiccation.

Solution over constraints

- ✓ EPNs are usually applied in high numbers, up to billions of nematodes, to increase the chances of finding host insects.
- ✓ To increase the survival time of EPNs after aboveground application, mixing with a surfactant and polymer can successfully improve control efficacy *via* increased leaf coverage.
- ✓ The time of EPN application is also crucial for the effective control of *S. frugiperda*. It is likely that if the application time coincides with the susceptible pest life stages, the control effects will increase.
- ✓ Application technology is another key point to improve EPNs efficacy in field. The efficiency of equipment used for spray EPN formulations is determined by nozzle/dripper type, volume, agitation, pressure and recycling time.

Conclusions

Spodoptera frugiperda is notorious for its wide host range, high reproductive and dispersal capacity and ability to cause severe damage to crop worldwide. Among the host plants, maize is the most favored by *S. frugiperda* larvae and can be struck during the vegetative and reproductive or flowering phase. The larvae are also able bore into maize ears, stems and cobs, which make them more concealed and harder to spot in time. To date, the management of *S. frugiperda* by chemical control is the most effective and prevalent strategy. To minimize the adverse effects of the misuse or overuse of chemical insecticides, biological alternatives against *S. frugiperda* are constantly being explored. Thus, EPN species have garnered significant attention as an environmentally sustainable biocontrol agent in pest control. As EPNs are predominantly isolated from soil habitats, they have been extensively exploited to suppress soil-dwelling insect pests. To better exploit EPNs as a biological agent, more efforts are needed to improve future field work, including the optimization of production, the formulation and application of technology and other diverse factors.

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PLANT LECTINS AND THEIR ROLE IN PEST MANAGEMENT

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Abstract

Plant lectins are carbohydrate-binding proteins that have emerged as valuable tools in pest management due to their specific binding affinity for sugars present on the surface of insect cells. This article reviews the role of plant lectins in pest management, focusing on their mechanisms of action, applications, benefits, and the challenges associated with their use. We highlight recent advances in research and development that are paving the way for the effective integration of lectins into sustainable pest management strategies.

Introduction

Pest management is a critical aspect of agriculture, with the goal of minimizing crop damage and improving yield while minimizing environmental impact. Traditional chemical pesticides have been effective but often pose risks to non-target organisms and the environment. In recent years, plant lectins have emerged as a promising alternative due to their specificity and potential for reduced environmental impact. Lectins are proteins that bind to specific carbohydrates and play various roles in plant defense against pathogens and herbivores.

Mechanisms of Action

Plant lectins can exert their pesticidal effects through several mechanisms:

1. **Inhibition of Digestion**: Lectins can bind to carbohydrates on the gut epithelial cells of insects, disrupting digestive enzyme function and leading to reduced nutrient absorption. This interference impairs growth and development, ultimately causing mortality.
2. **Immune Response Modulation**: By binding to specific carbohydrate structures on immune cells, lectins can alter the immune response of pests. This can lead to increased susceptibility to other pathogens or stress, reducing the insect's fitness.
3. **Disruption of Cellular Processes**: Lectins can interfere with cellular processes by binding to glycoproteins on cell membranes, affecting cell signaling and function. This can disrupt various physiological processes critical for insect survival.

Plant lectins

Lectins are a group of proteins that are found in plants and they discourage predation by being harmful to various types of insects and animals that eat plants.

Lectin (plant source)	Insect	Reference
Mannose specific:		
ASA (*Allium sativum*)	*Nilaparvata lugens* *Myzus persicae* *Dysdercus cingulatus*	Powell *et al*., 1995 Sauvion et al., 1996

Lectin (plant source)	Insect	Reference
ASA I, II	*Dysdercus cingulatus* *D. Koenigii*	Roy *et al.*, 2002
ASAL (*Allium sativum* leaf)	*D. Cingulatus* *Liphaphis erysimi*	Bandyopadhyay *et al.*,2001
GNA (*Galanthus nivalis*)	*N. lugens* *Callosobruchus maculatus* *Acyrthosiphon pisum* *M. Persiacae*	Loc *et al.*, 2002 Gatehouse *et al.*, 1991 Down *et al.,* 1996
LOA (*Listera ovata)*	*Maruca vitrata*	Machuka *et al*., 1999
Mannose/ glucose specific		
ConA (*Canavalia ensiformis*)	*Acyrthosipum pisum* *Aphis gossypii* *M. persiacae*	Rahbe´ *et al*., 1995
LCA (*Lens culinaris*)	*A. pisum*	Rahbe´ *et al.,* 1995
PSA (*Pisum sativum*)	*A. Pisum*	Rahbe´ *et al.,* 1995
N-acetyl-D-glucosamine specific		
ACA (*Amaranthus caudatus*)	*A. Pisum*	Rahbe´ *et al*., 1995
WGA (*Triticum aestivum*)	*Diabroticus undecimpuctata* *L. Erysimi*	Czapla and Lang, 1990 Elden, 2000
PAA *(Phytolacca* americana)	*D. undecimpunctata;* *O. nubilaris*	Czapla and Lang, 1990
Galactose specific		
AHA (*Artocarpus hirsuta)*	*Tribolium castaneum*	Gurjar *et al*., 2000
AIA (*Artocarpus integrifolia)*	*D. undecimpunctata;* *O. nubilaris*	Czapla and Lang, 1990
RCA120 (*Ricinus communis)*	*D. undecimpunctata;* *O. nubilaris*	Czapla and Lang, 1990
N-acetyl-D-galactosamine specific		
ACA (*Amaranthus caudatus)*	*A. pisum*	Rahbe´ *et al.,* 1995
SNA-II (*Sambucus nigra)*	A. pisum	Rahbe´ *et al*., 1995
BFA (*Brassica fructiculosa)*	*Brevicoryne brassicae*	Cole, 1994

Applications in Pest Management

Plant lectins have been investigated for use in various pest management strategies:

1. **Bioinsecticides**: Lectins can be applied directly to crops or incorporated into formulations to target specific pests. For example, lectins from beans and other legumes have been tested for their ability to control pests such as aphids, beetles, and caterpillars.
2. **Genetically Modified Crops**: Genetic engineering has enabled the incorporation of lectin genes into crops, providing built-in pest resistance. This approach aims to create crops that produce their own pest-deterrent proteins, reducing the need for external applications.
3. **Integrated Pest Management (IPM)**: Lectins can be used as part of an IPM strategy, combining them with other biological control agents, cultural practices, and physical controls to achieve more comprehensive pest management.

Benefits

1. **Target Specificity**: Plant lectins often have specific binding targets, reducing the risk of affecting non-target organisms and beneficial insects.
2. **Reduced Environmental Impact**: As natural proteins, lectins typically decompose more readily than synthetic chemicals, potentially leading to less environmental contamination.
3. **Compatibility with Other Controls**: Lectins can be integrated with other pest management strategies, enhancing overall effectiveness and sustainability.

Challenges

1. **Stability and Longevity**: Lectins can be sensitive to environmental conditions such as temperature and humidity, which may limit their effectiveness over time.
2. **Pest Resistance**: Like other pest control methods, there is a potential for pests to develop resistance to lectins. Continuous monitoring and management strategies are required to mitigate this risk.
3. **Production Costs**: Producing and purifying plant lectins for commercial use can be costly, which may impact their widespread adoption.

Recent Advances

Research is ongoing to address the challenges associated with lectin use. Advances include:

1. **Genetic Engineering**: Improved techniques for incorporating lectin genes into crops are being developed to enhance pest resistance and stability.
2. **Formulation Improvements**: New formulations and delivery systems are being explored to increase the stability and efficacy of lectin-based products.
3. **Combination Strategies**: Researchers are investigating the synergistic effects of combining lectins with other biopesticides and control methods to enhance overall pest management strategies.

Conclusion

Plant lectins offer a promising alternative to traditional chemical pesticides in pest management. Their specificity and potential environmental benefits make them an attractive option for sustainable agriculture. However, challenges such as stability, resistance, and production costs must be addressed to fully realize their potential. Continued research and innovation are crucial for integrating lectins effectively into pest management strategies, contributing to more sustainable and environmentally friendly agricultural practices.

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BETA DISTRIBUTIONS: THEORETICAL PROPERTIES & BRIEF REVIEW

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Abstract

The generalized beta is a flexible probability distribution, which generalizes the classical beta distribution. Its applications vary from finance and engineering to natural sciences. The paper discusses properties, types, applications, assumptions, and calculations involving the generalized beta distribution. In addition, it presents precautions for its use and concludes with practical implications of such a distribution.

Keywords: Generalized beta distribution, probability distribution, shape parameters, statistical modeling, non-central moments, and applications.

Introduction

The beta distribution is one of the most established probability distributions defined on the interval [0,1], and it is used in many practical fields to model variables that lie within the range. However, in practice, many situations cannot strictly follow the assumptions made for the classical beta distribution. Hence, the most general beta distribution with additional shape and scale parameters can be a generalization. These parameters enable the distribution to model an even wider range of behaviors; thus, applications across diverse fields include risk management, quality control, and ecological modelling.

The generalized beta distribution is primarily useful when the data exhibit complicated patterns of skewness and kurtosis that a simpler distribution cannot grasp. Its flexibility makes it a very potent tool in the hands of statisticians and researchers who need to model data that often come far from standard assumptions.

Types of beta distribution

There are many forms of generalized beta distributions, each suited for a particular application. The common ones include:

Generalized Beta Type I (GB1): This is an extension of the beta distribution to include a scaling parameter, allowing this distribution to model data over any interval [a, b]. The GB1 is very useful in empirical data modeling, where the shape of the distribution has to be more flexible.

Generalized Beta Type II Distribution-GB2: It is similar to GB1 with an additional parameter controlling the tail characteristics of the distribution. It makes GB2 particularly suitable to model heavy-tailed data-for instance, financial returns-whose extreme values pop up considerably more often than predicted by a normal distribution.

Kumaraswamy's Generalized Beta Distribution: This is an alternative to GB1 and GB2, which yields a much simpler mathematical form than that of the generalized beta distributions, with much of the flexibility of the former. This is easier to estimate and more readily interpretable, hence suitable for applications where simplicity is key.

Each of these generalized beta distributions has relative advantages; hence, based on particular data and application, one can choose an appropriate model accordingly.

Assumptions

As with all statistical models, the generalized beta distribution is based upon some assumptions, briefly described below.

Parameter assumptions: The shape parameters-usually denoted as α and β which must be positive in order for the distribution to be well defined. The parameters control the skewness and kurtosis of the distribution; therefore, their values must be chosen with due attention to capturing the essential features of the data.

Range Assumption: The variable of interest must be in some specified range, say from [a, b], where 'a' is the lower and 'b' is the upper limit. Generalized beta distribution is particularly well-suited for modeling data that are naturally bounded, such as proportions or percentages.

Independence: The observations should be independent; the value of one observation does not determine or in any way set a pattern for the value of another. Many times, this is one of the main assumptions in calculating a probability distribution because, if the data is true, it will help ensure that the model appropriately captures the data that underlies it.

Properties of generalized beta distribution

This distribution has several important properties that have turned it into one of the most powerful in statistical modeling. Some key properties of the generalized beta distribution include flexibility; the generalized beta distribution, with its additional shape parameters, can model data exhibiting quite different measures of skewness and kurtosis. Such flexibility enables one to obtain a wide variety of data distributions, which may be symmetrically bell-shaped or very highly-skewed or heavy-tailed.

MGF: The MGF of the generalized beta can be derived, which contains information on its mean and variance and higher-order moments. In fact, we will see that this is a very useful representation from which other key statistical properties can be derived.

Non-central moments: The non-central moments of the generalized beta distribution are functions of the shape parameters and give in-depth insight into the characteristics of the distribution. With the help of these moments, one can work out such distribution quantities as mean, variance, skewness, and kurtosis-all helpful in describing the shape of this distribution.

Distribution Function: The distribution function of the generalized beta distribution is more complicated than in the case of the classical beta distribution. It reflects the added flexibility afforded by the generalized form. The CDF is useful for calculating probabilities and quantiles and hence enables one to find out how likely it will be to observe certain values within the distribution.

Calculation
An example is provided below:
Parameters:
Shape parameters: α=2.5 β=3
Scale parameters: a0 (lower bound), b=1 (upper bound)
Random variable: X=0.6
B(α,β) is the Beta function, which can be defined as:
B(α,β)= ∫01tα−1(1−t)β−1dt

For α=2.5 and β=3, the Beta function B(2.5,3) can be computed using standard tables or numerical integration, yielding:
B(2.5,3)= 0.113
f(0.6;2.5,3,0,1)= ((0.6−0)2.5−1·(1−0.6)3−1)/ 0.113
Thus f= 0.658

Interpretation
For the given parameters, the probability density function value at X=0.6X = 0.6X=0.6 is approximately 0.6580.6580.658. This value indicates the relative likelihood of the random variable XXX taking the value 0.6 within the range [0, 1] for this specific GB1 distribution.

Generalized beta distribution: Applications
Due to its flexibility, the generalized beta distribution has a broad range of applications:

Finance: In finance, generalized beta distribution is used in modeling asset returns. Skewness and kurtosis are handled with greater flexibility in this distribution than any other, which hence can capture the asymmetric behavior of returns and will be useful in risk management and portfolio optimization.

Engineering: The generalized beta distribution in engineering can be applied to modeling time-to-failure data, particularly in reliability analysis. It is of great use in the evaluation of components and systems for their reliability by representation of data with diversified tail behaviors.

Natural Sciences: Applications in the natural sciences include ecology and hydrology, where a generalized beta distribution is considered. It describes naturally bounded phenomena closer to reality.

Conclusion
In some sense, the generalized beta distribution could be considered as one of the most convenient and flexible means of statistical modeling. It possesses a number of considerable advantages within a wide range of applications. This is a distribution that can even model very complex distributions, hence, of largest importance for finance, engineering, and natural sciences. Another critical issue is that care should be taken against the assumptions made, and extra efforts in computations may be expected. By understanding and addressing such factors, researchers and practitioners could apply the generalized beta distribution in an effective way to learn more about their data for better decision-making.

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BONSAI: AN ANCIENT ART FORM WITH MODERN APPEAL

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Abstract

Bonsai, the ancient art of cultivating miniature trees, has evolved from its roots in Chinese "penjing" to a globally practiced form of artistic horticulture. This article explores the historical development of bonsai, its techniques, and styles, emphasizing the intricate processes of pruning, wiring, defoliation, grafting, and root management that shape these miniature trees. It delves into popular bonsai styles such as formal upright, informal upright, slanting, and cascade, each reflecting different natural conditions. The article also highlights bonsai's modern appeal as a blend of mindfulness, art, and nature, resonating with contemporary themes of sustainability and environmental consciousness. Through an understanding of its techniques and styles, bonsai continues to offer a profound connection to nature and creativity.

Keywords: Bonsai, Horticulture, Miniature plant, artistic horticultural skill, Japanese art

The art of bonsai, involves cultivating miniature trees, has captivated people around the world for centuries. Originating in China over a thousand years ago as "penjing," the art migrated to Japan, where it developed into the more refined practice known as bonsai. Today, bonsai has evolved into a global phenomenon, blending tradition, artistry, and horticultural skill.

Origins and Evolution of Bonsai

The word "bonsai" is a Japanese term that translates to "planted in a container." The earliest records of bonsai can be traced back to the Chinese Tang Dynasty (618-907 AD). However, it wasn't until it reached Japan during the Heian period (794-1185 AD) that bonsai began to take on its distinctive characteristics. In Japan, bonsai became not only a form of artistic expression but also a reflection of Zen Buddhism's values, such as patience, discipline, and harmony with nature. Over time, different styles of bonsai developed, such as the formal upright (chokkan), slanting (shakan), and cascading (kengai) forms, all of which reflect natural trees found in the wild.

Techniques and Styles

The art of bonsai is built on a foundation of specialized techniques and an array of styles, each reflecting different interpretations of natural forms. Mastering these techniques allows bonsai practitioners to create miniature versions of fully-grown trees that are not only healthy but also aesthetically pleasing. Below is a detailed exploration of the core techniques and styles that define bonsai culture.

Key Techniques in Bonsai

1. **Pruning**
   Pruning is perhaps the most fundamental technique in bonsai cultivation. It involves cutting

back branches and roots to shape the tree, control its growth, and maintain its miniature size. Pruning is also critical for ensuring the tree's health. Removing excess branches and leaves allows sunlight and air to penetrate all parts of the tree, reducing the risk of disease and promoting even growth.

2. **Wiring**
   Wiring is another essential technique used to shape bonsai trees. Thin, flexible wire (usually copper or aluminum) is wrapped around branches and sometimes the trunk, allowing the practitioner to bend and position them as desired. Wiring helps create the elegant curves and twists often seen in bonsai trees, mimicking the appearance of trees shaped by natural forces like wind and gravity. Wires must be carefully monitored and removed before they cut into the bark, which could cause permanent scarring. Typically, wires are left in place for a few months, until the branches "set" into their new positions.
3. **Defoliation**
   Defoliation is the process of removing all or some leaves from a bonsai tree, usually during the growing season. This technique encourages the growth of smaller leaves and promotes finer branch structure. By reducing the number of leaves, the tree directs its energy to producing new buds, which leads to a denser canopy and enhances the overall aesthetic. Defoliation also allows more light to penetrate the inner branches, promoting healthy growth throughout the tree. However, this technique is used selectively, as it can be stressful for the tree if overdone, especially for younger or weaker trees.
4. **Grafting**
   Grafting is an advanced bonsai technique used to add new branches or roots to a tree. It involves attaching a piece of plant tissue (called a scion) from one plant to another, where it will eventually grow as part of the host tree. Grafting is often used to repair damaged trees or to introduce specific aesthetic elements, such as adding a new branch in a desired location or creating a more intricate root structure. This technique can also be employed to incorporate different species of trees into a single bonsai, creating unique combinations of foliage, flowers, or fruit.
5. **Deadwood Techniques (Jin and Shari)**
   Deadwood techniques like **jin** and **shari** are used to simulate the natural aging process of trees. These methods involve stripping bark from parts of the tree to create the appearance of weathered, exposed wood, as often seen in old trees affected by lightning, wind, or disease.
   - **Jin**: Refers to stripping bark from a branch to make it look like a dead, weathered limb.
   - **Shari**: Involves removing bark from the trunk to create a long strip of exposed wood, simulating natural scarring and adding character to the tree.

These techniques, while aesthetic, are delicate and must be done carefully to avoid weakening the tree or exposing it to disease.

6. **Root Pruning and Potting**
   Unlike regular trees, bonsai are grown in shallow pots, which restrict root growth. To maintain the health and balance of the tree, root pruning is essential. Root pruning involves cutting back the roots periodically to prevent the tree from becoming root-bound and to promote new, healthy root growth. Repotting, which is typically done every two to five years depending on the species, is when root pruning occurs. During this process, the tree is lifted from its pot, the roots are trimmed, and the tree is placed back into fresh soil. This allows the tree to remain

healthy and ensures that the roots have enough space to grow without overwhelming the limited soil volume.

Popular Bonsai Styles

Bonsai styles have evolved to reflect different natural forms and conditions that trees experience in the wild. These styles are not rigid rules but serve as guidelines for artistic expression, allowing the practitioner to interpret the natural world through miniature trees. Some of the most common bonsai styles include:

1. **Formal Upright (Chokkan)**
   The formal upright style is one of the most classic and symmetrical bonsai forms. The tree's trunk grows straight and upright, tapering gradually from the base to the tip, with branches evenly spaced and balanced on both sides. This style mimics tall trees found in nature, such as pines or redwoods, that grow in open spaces with plenty of sunlight.
2. **Informal Upright (Moyogi)**
   The informal upright style is more relaxed and naturalistic than the formal upright style. In this form, the trunk has gentle curves or bends as it grows upward, while maintaining an overall upright structure. This style is inspired by trees that grow in less ideal conditions, bending and curving to reach light or adapt to their environment.
3. **Slanting (Shakan)**
   In the slanting style, the tree grows at a pronounced angle, as if pushed by strong winds or growing on a slope. The trunk leans to one side, but the roots and branches are arranged to create balance and stability. This style evokes a sense of dynamism, as if the tree is actively growing in response to external forces.
4. **Cascade (Kengai)**
   Cascade-style bonsai mimic trees that grow on cliffs or near waterfalls, where branches naturally cascade downward. The trunk grows upright for a short distance before bending and cascading below the level of the pot. Cascade bonsai often have long, elegant branches that hang down gracefully, evoking a dramatic, natural scene.
5. **Windswept (Fukinagashi)**
   The windswept style depicts a tree growing in harsh, windy conditions, with all branches and foliage growing in one direction, as if perpetually pushed by strong winds. This style creates a dynamic, dramatic effect and conveys the idea of resilience and survival against the elements.
6. **Forest (Yose-ue)**
   The forest style involves planting multiple trees of the same species in a single container to create a miniature forest scene. The trees are arranged with a main, dominant tree in the center, surrounded by smaller, secondary trees. This style mimics the natural growth patterns of trees in a forest, with varying heights and sizes.

Bonsai in Modern Times

Today, bonsai culture has expanded beyond its Asian roots, becoming a global hobby practiced by enthusiasts from all walks of life. In the West, bonsai's appeal lies in its blend of nature, art, and mindfulness. The cultivation process requires patience, attention to detail, and a long-term commitment, which makes it a soothing hobby for many. The modern world has also embraced technological advancements that aid in bonsai care. For instance, specialized apps help beginners track watering schedules, monitor plant health, and provide detailed care instructions based on the species of tree. Social media platforms like Instagram and Pinterest have contributed to the growing popularity of bonsai. Stunning images of miniature trees attract new generations of enthusiasts, who seek to share their creations with a global audience. The practice has become a symbol of mindfulness and slow living, offering a counterpoint to the fast pace of modern life.

Sustainability and Environmental Impact

The resurgence of interest in bonsai is also tied to the broader trend of sustainability and environmental consciousness. Bonsai can serve as a reminder of the importance of nature conservation, and many bonsai practitioners are also involved in environmental causes. By cultivating trees, even in miniature form, bonsai artists contribute to fostering a deeper connection with nature. Additionally, bonsai trees, when well-maintained, can live for hundreds of years, with some specimens passed down through generations. These ancient trees often symbolize endurance, wisdom, and continuity, making them cherished family heirlooms.

Conclusion

Bonsai is much more than just a horticultural practice; it is a way of life that embodies patience, artistry, and respect for nature. As the world becomes more urbanized and fast-paced, the ancient art of bonsai offers a way to slow down, connect with nature, and find beauty in simplicity. With its deep historical roots and modern appeal, bonsai culture is poised to continue growing, captivating both seasoned practitioners and newcomers alike.

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DESCRIPTION OF TRADITIONAL FISH MARKETS OF SEEMANCHAL REGION, BIHAR

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Introduction

Market is simply defined as the place where buying and Selling takes place However term 'marketing' describes about the movement of goods from the area of production/surplus to the area of consumption/demand. Marketing of involves many complex processes like fish production, assembly, sorting, reassembly, and distribution.

The domestic fish marketing system in India is mainly traditional type which is not very efficient and is mainly carried out by private traders with the help of a large number of intermediaries between producer and consumer. It decreases the fish producer's share in consumer's rupees and also increases the price of fishes. Infrastructure facilities in all types of fish markets are generally poor (FAO, 2001).

Traditional fish market of Bihar is very important because it fulfil the high demand for fish in Bihar. Supply of local fish used to fluctuate according to catch of fish from natural water bodies, inefficient storage and transportation facilities, highly perishable nature of product etc. These supply and demand gap of fish is filled by fishes coming from outside the state in the market. Present study focuses on the description of famous traditional fish market of Seemanchal Region of Bihar.

Description of study locale:

The Seemanchal region consist four districts: - Araria, Purnea, Kishanganj and Katihar. Seemanchal region is considered as backward region of Bihar. Agriculture and allied activities are main source of income in this region. Seemanchal region is gifted with a number of natural water bodies namely- Ganga, Koshi, Mahananda, Righa, Suwara, Kali parma, Kankai, Mechi, Donk, Ratua & Ramzan Sudhani etc. A large number of populations of this region depends upon fisheries resources for their livelihood.

Description of important fish markets of Seemanchal region:

There are many traditional fish markets in Seemanchal region where a lot of variety of fishes are being sold. Modern facilities are not present in this market but attract the large number of fish producers or traders even from outside the state because of high demand of fishes in the market. Some of the important fish markets of Seemanchal region are described here:

Wholesale Fish Market, Khuskibagh, Purnia

This market is situated in Khuskibagh near NH-31. This is the biggest fish market of Seemanchal region where 3000 to 4000 kg fishes are sold daily. There are 52 wholesalers present in the market. The major fish species present in this market are: Rohu, Catla, Mrigal, Kabai, Singhi, Pangas, Pabda, Roopchand. According to wholesalers of the market, contribution of local fish in the market is about 50 % and rest 50 % fishes come from other states mostly from Andhra Pradesh and West Bengal. Frozen fish coming from Andhra Pradesh plays an important role when supply of local fish is not able to meet the high demand of fish in the market. Live and fresh fish are available here at wholesale rate. This market starts at early morning. This is a very big market where wholesalers from many districts like- Purnia, Katihar, Araria, Madhepura etc. come to buy the fish.

Wholesale Fish Market, New Market, Katihar

Wholesale fish market of Katihar is situated in New Market, Katihar. This place belongs to Nagar Nigam, Katihar. Market is famous for fresh fish as well as for frozen fish.

Source of fresh and live fishes in the market are local fishers as well as fish farmers however frozen fish come from Andhra Pradesh and Jharkhand. Local fishes from riverine system are also seen in good amount. The common fish species present in the market are: Rohu, Catla, Mrigal, Pangas, Reba, Cheetal, Roopchand, Jhinga etc. Retail fish market is also present in same place in the back side of the wholesale fish market. Overall condition of the market is good. Fish price is highly dependent on supply of local fish. Frozen fish is relatively cheaper than fresh fish.

Fishes from the wholesale fish market of Katihar are sold in all the parts of Katihar District. About 800 kg to 1000 kg fishes are sold daily in this market. Proportion of frozen fish has been increased because of low availability and high price of fresh fish. Price may be compared in following table:

Fish Species	Fresh fish price (Rupees/Kg)	Frozen fish price (Rupees/Kg)
Rohu	200- 250	140-150
Catla	200-270	140-160
Pangas	140-150	110-120

However fresh fish specially fishes cought from reverine systems are highly demanded and fatching high price in the market.

Wholesale Fish Market, Khagra, Kishanganj

Wholesale fish market in Kishanganj is located near Khagra Mela gate functioning under Municipal Corporation. This market is famous for low-cost frozen fish as well as fresh fish from West Bengal and Bihar. High priced fishes like Singhi, Magur and Jhinga are also available in small quantity. There are eight wholesalers in the market. Market starts at 7 am. Most of the retailers of

Kishanganj district used to buy their fishes from this market. Price of the fishes are determined by auctioning of particular fish basket.

Common fish species available in the market are: Rohu, Catla, Marigal, Pangas, Singhi (live), Roopchand, Common carp etc. The condition of fish market during rainy season becomes worst. Municipal Corporation should take some initiative so that this market becomes more attractive for the consumers.

Fish Market, Forbesganj

This is the retail fish market situated in Forbesganj near Forbesganj railway station. About 25 retailers are present in the market. The market is dominated with live as well as fresh fishes. Fishes from Riverine system is also available in good quantity.

Frozen fishes are also sold by some retailers. Besides IMCs other fishes available in the market are: Singhi, Kabai, Common carp, Reba, Tengra, Pabda, Puntius, Cheetal etc. Some of the fishers catch the fish from river and directly sell the fish in this market. So, you will get fresh riverine fishes here.

Conclusion

There are three traditional Wholesale fish markets and many retail fish markets present in Seemanchal Region of Bihar. These markets are famous for fresh riverine fish at fair prices. These Local riverine fishes are well known for its taste. Frozen fishes are also available in the market at cheaper price.

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DISCOVER THE FASCINATING WORLD OF REPRODUCTIVE ECOLOGY IN INSECTS

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Abstract

Reproductive ecology studies how an organism's physiology, behavior, and abiotic and biotic environments influence reproductive success. Sexual selection, sexual conflict, mating systems, parent-offspring interactions, and environmental influences are critical areas of focus in understanding insect reproductive ecology. These interactions contribute to the evolving dynamics of sexual conflict and mating systems, providing insights into how organisms reproduce and adapt to their environments.

Introduction

A reproductive ecology study explores how an organism's physiology, behavior, and environmental factors interact to affect its reproductive success . The study provides insights into how various aspects of an organism's life, including its physical traits, behavioral strategies, and interactions with non-living (abiotic) and living (biotic) components of the surrounding environment, influence reproductive outcomes. The essential aspects of reproductive ecology include understanding how certain traits and behaviors are favored through sexual selection, influencing reproductive success, and shaping evolutionary strategies, investigating conflicts between males and females over resource allocation and mating strategies, leading to the evolution of antagonistic traits, studying different mating systems (Anonymous, 2024), such as monogamy, polygamy, and promiscuity, and how these systems affect reproductive strategies and success, analyzing the dynamics between parents and their progeny, including conflicts for resource division and parental investment and understanding how environmental factors, such as habitat quality and resource availability, impact reproductive strategies and outcomes. By integrating these aspects, reproductive ecology provides valuable insights into how organisms reproduce and adapt to their environments, revealing the complex interplay between biological systems and their surroundings (Anonymous, 2024).

Sexual selection: Alcock (2001) defined sexual selection as "A form of natural selection that occurs when individuals differ in their ability to compete with others for mates or to attract members of the opposite sex (Belanger, 2003)." A widespread competition is observed among siblings for limited resources in the animal kingdom and some plants. Hamilton (1964) and Trivers (1974) highlighted that natural selection can result in varying levels of competition among offspring, influenced by genes expressed in the parents or the offspring. This results in conflict between parents and offspring over the division of resources among siblings and the intensity of the competition for these resources (Anonymous, 2024).

Sexual selection can be classified into two main categories: intersexual selection and intrasexual selection. The intrasexual selection showcases competition among individuals of the same sex, often males, with the winners obtaining the opportunity to mate with females. In contrast, the defeated males frequently struggle to find mates. Involvement in territorial competition and locking horns are critical examples of intrasexual selection. Intersexual selection is characterized by active female choice, as males display their morphological, physiological, and behavioral traits to attract females. Females engaging in intersexual selection typically evaluate males and choose the best fit (Anonymous, 2024). Intrasexual and intersexual selection can occur before or after mating. Sexual selection arises as individuals compete for limited resources to find a suitable mate, resulting in increased direct and indirect fitness.

Pre-copulatory sexual selection is typically associated with assessing phenotypic traits before mating (Pizzari & Parker, 2009). Physical traits that help with mate selection include (1) size, essential for competing in fights, endurance, and productivity; (2) color, which indicates health and immunity through appearance; (3) age, shows reproductive status and health; (4) mating history, reflects the viability of a mate in terms of sperm and egg quantity and quality, paternity determination, and offspring viability; (5) nutritional adaptability, indicates the ability to adapt to different nutritional conditions; and (6) chemical signals, act as honest indicators of an individual's health and mating status.

Postcopulatory sexual selection involves sperm competition and cryptic female choice, influencing paternity share (Eberhard, 2009; Manier et al., 2010; Aquiloni & Gherardi, 2008).

Sperm competition occurs when the sperm of different males compete to fertilize (Maraqa, 2015) the female's eggs, exhibiting nature's way of passing on the most robust genes.

Cryptic female choice is a type of female selection that occurs in a less overt manner. Females have developed ways to avoid the energy-intensive process of choosing a mate before mating. Females may mate with multiple males and select the best sperm without the males being aware instead of actively choosing and evaluating potential male partners.

Mating systems in insects: These systems are generally species-specific, although individuals within a species may exhibit alternative strategies and describe the patterns of pairings between males and females. The study of mating systems provides deeper insights into behavioral, physiological, and ecological factors determining predictable interactions between males and females during reproduction (Anonymous, 2024) . A mating system showcases the number of mates obtained, the mate acquisition method, the presence and traits of any pair bonds, and the pattern of parental care by each sex. Much of the research on mating systems focuses on male-male competition and its impact on male morphology and behavior.

Monogamy: Monogamy, an ancestral characteristic for bees, wasps, ants, and other eusocial insects, involves one male and one female, often forming a pair bond through behaviors such as mate guarding, the use of copulatory plugs, prolonged copulation, and aggressive actions. For instance, Nicrophorus beetles (Silphidae) construct a nest beneath a buried carcass where both males and females nourish their offspring (Anonymous, 2024).

Polygyny involves one male mating with multiple females and is characterized by scramble competition (a term introduced by Thornhill and Alcock in 1983) (Anonymous, 2024). Examples include territorial Hilltoppers such as tarantula hawk wasps, certain butterflies, and lekking species like *Drosophila heteroneura*.

Polygynandry: A male mates with several females but cannot guard them while foraging for prey, as observed in some scorpion flies and water striders. This situation allows females to obtain additional nuptial gifts and sperm from other males.

Polygamy: Males and females mate multiple times, with males unable to protect females from other males long-term. This can lead to conflicts among males striving for access to females and intersexual conflicts where females may reject males. e.g., Drosophila and damselflies.

Polyandrogyny: Males provide parental care, limiting their ability to mate, as their primary focus is protecting the young. This often leads to females having a variable number of mates. In contrast, females are free to mate with multiple males. This phenomenon is commonly observed in insects, as seen in examples like the giant water bugs Belostoma, Abedus, and Lethocerus.

Polyandry highlights monogamous behavior where males mate with a single female for life. Females may outlive males or become dedicated to parental care after mating, e.g., praying mantids (Order: Mantodea) and certain spiders.

Promiscuity: In a social setting, individuals of any gender can form relationships with members of the opposite gender. This is commonly associated with group compositions involving multiple males and multiple females.

Reproductive strategies: semelparity and iteroparity are the two reproductive strategies insects adopt.

Semelparity involves an organism reproducing only once during its lifetime, and after a single reproductive event, the organism typically dies. The reproductive strategy is characteristic of species that heavily invest in a single reproductive event. This includes salmon and certain insect species, such as some forest Lepidoptera such as tent caterpillars (*Malacosoma* spp.: Lasiocampidae), bagworms (*Thyridopteryx ephemeraeformis*: Psychidae), gypsy moths (*Lymantria dispar*: Lymantriidae), fall cankerworms (*Alsophila pometaria*), and winter moths (*Operophtera brumata*: Geometridae).

Iteroparity refers to organisms that reproduce multiple times throughout their lives. These organisms spread their reproductive efforts over several events, which can help increase their overall reproductive success. Examples include many mammals, birds, and perennial plants, along with invertebrates like most mollusks and insects, such as mosquitoes and cockroaches.

Drifting behavior is an alternative reproductive strategy observed in social insect workers. It involves workers leaving their original colonies to join other colonies, usually of the same species. This behavior helps spread genetic material and reduce competition within the original colony (Anonymous, 2024). As a result, it can increase an individual worker's chances of indirectly reproducing through the success of other colonies.

In the bumblebee, *Bombus terrestris*, drifting is an alternative reproductive strategy fertile workers use. During the early stages of colony development, workers with activated ovaries cooperate while waiting for chances to reproduce. As the colony cycle progresses and closely related future queens (gynes) are produced, fertile workers have less incentive to limit their reproduction and begin competing to produce males. Some workers can reproduce within their nest due to their dominant status, while many fertile workers reproduce with individuals from other colonies. Two main factors likely support the evolution of drifting as a reproductive strategy in *B. terrestris* (Blacher et al., 2013).:

- Their kin-selected interests drive the intense competition for reproduction among fertile workers.
- Colonies show high tolerance towards intruders, possibly due to the contribution of infertile foreign workers to the colony's workforce (Blacher et al., 2013).

Egg size: The size of an egg is a critical factor that impacts the reproductive success of animals that lay eggs (Adomako et al., 2022). Generally, an animal can either increase the number of eggs it lays while decreasing the size of each egg or increase the size of each egg while laying fewer eggs. This depends on the resources available for reproduction. The egg's initial size affects the offspring's survival and the time it takes for them to develop from egg to adult. Therefore, natural selection optimizes egg size based on the current environmental conditions. The optimal egg size is the one that maximizes the reproductive success of the female parent (Wiklund et al., 1987).

Reproductive effort is an organism's investment in current reproductive activities and forms a key concept in understanding reproductive tactics. Fisher (1930) differentiated between physiological mechanisms (proximate factors) and circumstances in life history and environment (ultimate factors) that influence the allocation of resources (O'Brien, 2011) to reproductive and non-reproductive tissues and activities. The concept of reproductive effort is valuable, but it can be challenging to quantify precisely. An ideal measure of reproductive effort would consider the direct material and energetic costs of reproduction and the risks associated with a specific level of current reproductive investment.

Sibling-sibling conflict/Sibling rivalry

Lifetime parental investment involves the total resources a parent can allocate to all of their offspring, representing a crucial aspect of parenting and ensuring the well-being of future generations. Each offspring aims to secure the maximum possible of these available resources (Anonymous, 2024). Siblings in a family often strive to outdo each other when it comes to getting their fair share of the resources their parents provide. In some cases, sibling rivalry escalates to an extreme extent, and one sibling attempts to eliminate its siblings to increase its share of parental investment. For example, in the Galapagos fur seal, the second pup is often born while the first is still nursing. During food shortages, competition for the mother's milk intensifies, leading to the older pup attacking and killing the younger one(Anonymous, 2024).

Asynchronous hatching in certain bird species exacerbates sibling rivalry. The blue-footed booby's first egg hatches four days before the second one, which gives the older chick a significant growth advantage (Anonymous, 2024). If the older chick falls 20–25% below its expected weight, it may attack and drive the younger sibling from the nest. Additionally, the connection between siblings impacts the extent of disagreement; for example, studies on perching birds suggest that offspring in species with increased levels of extra-pair paternity tend to make louder begging sounds.

Exploring Sibling Rivalry and Brood Sex Ratios in Polyembryonic Species

In species with multiple embryos, more females tend to be due to local mating competition, where offspring from one or a few females mate within isolated subpopulations. Parasitic wasps can control their sex ratios by manipulating fertilization, thanks to their haplodiploid sex determination. However, parental influence is not the only factor affecting the composition of offspring in these wasps. These parasites produce many offspring from a single egg, typically resulting in two types of larvae: precocious larvae that die without pupating and reproductive larvae that mature into adults (Anonymous, 2024). For instance, *Copidosoma floridanum*

(Hymenoptera: Encyrtidae) can produce 1,000-1,400 offspring per host, with most broods containing both sexes. Mixed broods typically have more females; mating occurs before the wasps leave. During these situations, the female wasp lays one male and one female egg, and adult males probably seek other mating opportunities away from the host. This situation implies that the sexes may be conflicted regarding the most advantageous number of offspring to produce per host (Anonymous, 2024).

Understanding the Complexities of Parent-Offspring Conflict and Its Resolution

The concept of parent-offspring conflict has been a critical idea in behavioral ecology since it was introduced by Trivers in 1974. Before Trivers, evolutionary biologists commonly believed that parents and offspring had the same evolutionary interests when allocating resources. However, Trivers proposed that due to differences in relatedness, each offspring tends to demand more resources than its siblings because it is more closely related to itself. On the other hand, parents allocate resources equally among their offspring since they are equally related to all of them. Trivers' research has led behavioral ecologists to use game-theoretic modeling and behavioral experiments to examine how parent-offspring conflict influences the evolution of their interactions.

Game-theoretic models/ Competitive modeling: The models are based on specific assumptions about the behavioral strategies of family members. They effectively demonstrate how complex interactions between parents and children can be understood in conflict resolution. The primary goal of these models is to identify the most effective combinations of parental resource allocation and offspring-begging strategies that have proven successful over time in evolution. These models fall into two main categories:

1. Honest Signalling Models - These models propose that parents regulate the distribution of resources (Godfray 1991, 1995).
2. Scramble Competition Models - These models propose that offspring regulate the distribution of resources (Parker & Macnair, 1979; Parker *et al*., 2002).

Both types predict that begging reflects offspring's needs, informing parents about nutritional requirements.

There is a conflict between parents and offspring in eusocial species due to haplodiploidy and sterile workers. Sisters are more closely related to each other than their mothers or brothers, which leads female workers to seek a 3:1 female-to-male sex ratio within the colony. On the other hand, queens prefer a 1:1 sex ratio because they are equally related to sons and daughters. The conflict in social insects pertains to how much the queen should invest in each sex for current and future offspring. Workers are commonly believed to prevail in this conflict, but there are exceptions, such as in Bombus terrestris, where the queen exerts significant control to maintain a 1:1 ratio.

Parent-offspring conflict resolution

Adults need an accurate signal from their young about their hunger or resource requirements to distribute resources efficiently. However, the young want to receive more than their fair share and might overstate their need for more parental support. This conflict is usually resolved through the negative consequences of excessive begging. Begging excessively can attract predators and hinder development if it does not result in more resources. As a result, the drawbacks of excessive begging encourage the young to be truthful in their signaling.

An alternative way to resolve parent-offspring conflict involves simultaneously evolving parental provisioning and offspring demand, potentially reducing perceived conflict (Anonymous, 2024). Studies involving cross-fostering with great tits (Parus major) have shown that offspring exhibit more begging behavior when their biological mothers are more generous. This suggests that parental willingness to invest in offspring is adjusted to match offspring demand.

Conclusion

The reproductive ecology of insects is a rich and diverse field that provides a deeper understanding of the adaptive strategies and evolutionary processes shaping insect behavior and physiology. Insects utilize a wide range of reproductive strategies, from intricate mating rituals and parental care to sophisticated mechanisms of sperm competition and mate selection . Various factors influence these strategies, including environmental conditions, resource availability, and inter- and intra-species interactions. Understanding reproductive ecology in insects is crucial for applications in pest management, conservation biology, and the study of evolutionary biology. As we continue to explore and uncover the complexities of insect reproduction, we gain a deeper appreciation for the intricate ecological and evolutionary processes that sustain biodiversity and ecosystem health.

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FIGHTING FIRE WITH FIRE: STRATEGIES FOR ADAPTING FOREST MANAGEMENT TO A CHANGING CLIMATE

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Introduction

The global phenomenon of climate change has been a key driver in the rising frequency and intensity of forest fires, dramatically altering ecosystems and affecting human communities. Rising temperatures and erratic precipitation patterns have amplified the vulnerability of forests, increased fuel loads and creating conditions that foster the proliferation of large-scale, intense fires. These trends have led to a cascade of adverse impacts, including loss of biodiversity, disruption of ecosystem services, economic damage, and displacement of communities. In response, forest management strategies must evolve, incorporating adaptive techniques that mitigate fire risks while enhancing ecological resilience. This article explores the main factors contributing to increased forest fires, the ecological and socio-economic impacts of these fires, and strategies for adaptive forest management in the context of climate change. Prescribed burning, fuel reduction techniques, early detection, and rapid response systems are analyzed, as are broader climate change adaptation strategies designed to create fire-resilient landscapes and communities.

Causes of Increased Forest Fires in a Changing Climate

A. Changes in Temperature and Precipitation Patterns

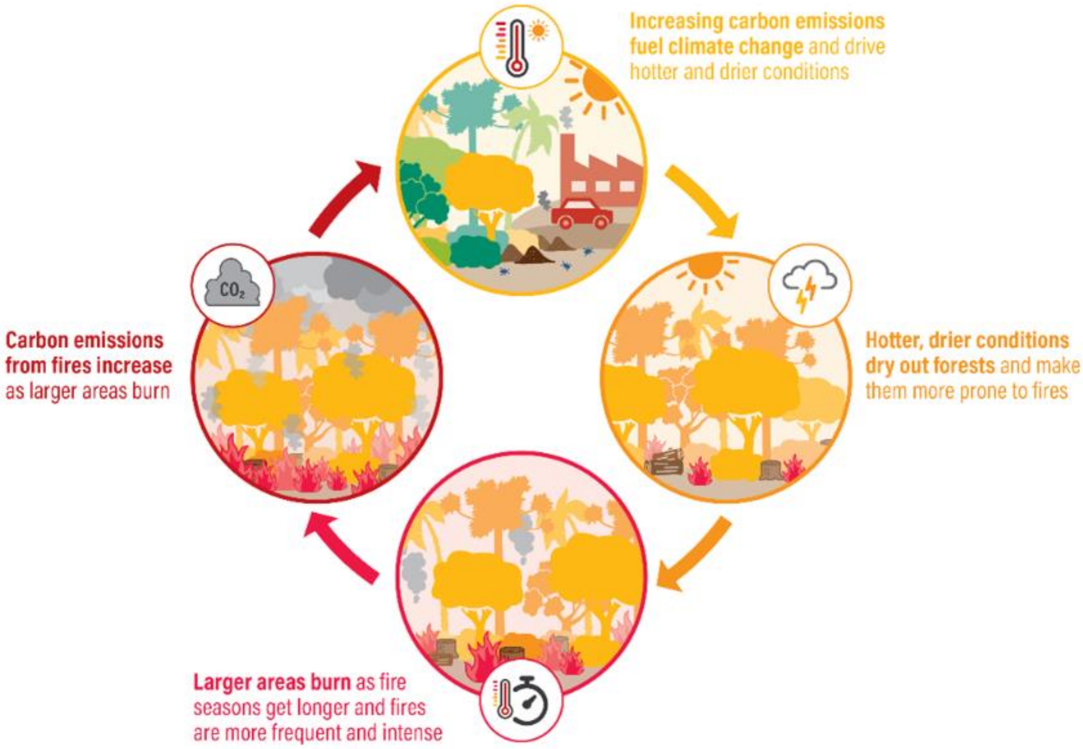
Climate change has disrupted traditional weather patterns, leading to prolonged periods of higher temperatures and altered precipitation regimes. These shifts contribute to increased evaporation rates, leaving vegetation more susceptible to drought and desiccation. As moisture levels in soils decline, the vegetation that forms the forest underlayer becomes drier, increasing its combustibility (Heidary *et al.*, 2021). This dynamic is exacerbated by erratic rainfall, which can either promote excessive growth of flammable species in wet years or fail to sufficiently dampen the fuel load in dry years. The cumulative effect of these climate-driven processes has been the creation of tinderbox conditions that amplify both the likelihood and intensity of forest fires.

B. Increase in Fuel Loads

Rising temperatures and altered rainfall patterns have led to the proliferation of invasive species and denser underbrush in many forested areas. Invasive plant species often grow unchecked, accumulating biomass that adds to the available fuel for fires. The increase in fire activity itself contributes to the problem, as fires leave behind dead trees, fallen branches, and other debris, which accumulate on the forest floor (Singh, 2022). This creates a vicious cycle in which each successive fire event leaves behind more fuel, thereby increasing the risk and intensity of future fires. As such, the combined effects of climate change and unchecked fuel accumulation present a significant challenge for forest management.

C. Changes in Fire Weather

In addition to increasing the amount of combustible material, climate change is also creating conditions conducive to more extreme fire weather. Prolonged heatwaves, stronger winds, and lower humidity levels are combining to create ideal conditions for large, uncontrollable fires. Moreover, there has been an increase in the frequency of lightning strikes, which are a natural ignition source for wildfires. The interplay between these changing climatic factors and increased fuel loads means that fire seasons are starting earlier, lasting longer, and burning more intensely than ever before.



Source: *Global Forest Watch Report 2021*

Impacts of Increased Forest Fires on Forests and Communities

A. Ecological Impacts

1. **Biodiversity Loss :** Forests are critical habitats for countless species of plants and animals. When forest fires occur, they often destroy large tracts of habitat, displacing wildlife and leading to species loss. The frequency and severity of these fires can prevent forests from recovering fully between events, leading to long-term declines in biodiversity.
2. **Carbon Sequestration** : Forests serve as vital carbon sinks, helping to mitigate the effects of climate change by absorbing carbon dioxide from the atmosphere. However, when forests burn, the carbon stored in trees and other vegetation is released back into the atmosphere, contributing to global warming. The loss of carbon-sequestration capacity following a fire further compounds the environmental damage.

B. Economic Impacts

1. **Timber Resources** : Forest fires can severely damage timber resources, leading to financial losses for logging companies and local economies that depend on forest products. Burnt timber is often of reduced value, and the cost of rehabilitating affected areas can be prohibitive.
2. **Recreational Activities** : Forests are popular destinations for recreational activities such as hiking, camping, and hunting. Fires can damage infrastructure such as trails and facilities, while also rendering areas unsafe for visitors, resulting in a loss of revenue for local communities and businesses reliant on eco-tourism.
3. **Human Displacement and Infrastructure Damage** : Fires often lead to the evacuation of people living in affected areas, and in some cases, result in long-term displacement if homes and infrastructure are destroyed. Roads, bridges, and utility lines are also frequently damaged by fires, leading to long-term economic and logistical challenges for recovery efforts.

Adaptive Forest Fire Management Strategies

A. Prescribed Burning

Prescribed burning is a technique in which small, controlled fires are intentionally set under safe conditions to reduce fuel loads and restore ecosystem balance. By mimicking the natural fire regimes to which many ecosystems are adapted, prescribed burns can clear out accumulated dead material, promote the growth of fire-adapted species, and reduce the intensity of future wildfires. Despite its success in reducing the likelihood of severe wildfires, prescribed burning faces significant challenges. Weather conditions must be closely monitored to ensure that fires remain controlled, and concerns about air quality and public safety can limit the use of this technique (Attri *et al*., 2020). Additionally, the specialized skills and experience required for effective prescribed burning limit its widespread application in many regions.

B. Fuel Reduction

Fuel reduction strategies, such as mechanical thinning and grazing management, are aimed at removing excess vegetation that can fuel large fires. Mechanical thinning involves the selective removal of small trees, shrubs, and other flammable materials using tools like chainsaws or skidders. Grazing management, on the other hand, uses livestock to reduce grass and brush that could otherwise serve as fire fuel. In India, mechanical thinning has been employed in the Chir Pine forests of Himachal Pradesh to reduce fuel loads and prevent large fires. Grazing management has been implemented in the Nilgiri Biosphere Reserve of Tamil Nadu to control the overgrowth of grasses and shrubs, reducing fire risk. However, both techniques must be applied carefully, as improper implementation can lead to soil erosion, habitat destruction, and damage to water resources.

C. Early Detection and Rapid Response

Early detection and rapid response systems rely on advanced technologies such as satellite imagery, thermal imaging, and remote sensing to identify and respond to wildfires before they spread out of control (Dhar *et al*., 2023). Tools like NASA’s Fire Information for Resource Management System (FIRMS) provide near real-time data on fire outbreaks, enabling quicker and more effective responses. The use of drones equipped with thermal cameras has further enhanced fire detection capabilities. Drones can quickly cover large areas, providing critical information on fire behavior, spread, and containment opportunities, helping firefighters focus their efforts more efficiently.

D. Climate Change Adaptation Strategies

1. **Integrated Fire Management :** This comprehensive approach combines prescribed burns, fuel reduction, and rapid response strategies to manage fire risk while promoting ecosystem health. Integrated fire management helps ensure that fire is used as a tool to maintain healthy forests rather than as a destructive force.
2. **Land Use Planning and Zoning :** Zoning restrictions can prevent the development of residential areas in high-risk fire zones, reducing the potential for human casualties and property damage. Additionally, promoting the planting of fire-resistant vegetation in these zones can further mitigate fire risk.
3. **Community Engagement :** Successful fire management depends on the involvement of local communities. Programs such as the Firewise Communities initiative in the United States and the Van Panchayats program in India empower communities to take proactive steps to protect their homes and livelihoods from wildfire risks.
4. **Fire-Adapted Communities and Landscapes :** Fire-adapted communities are educated and equipped to coexist with fire. In these communities, fire-resilient infrastructure and proactive measures, such as defensible space around homes, help minimize fire damage. Similarly, fire-resilient landscapes incorporate vegetation and land management practices designed to withstand and recover from fire.
5. **Firefighting Capacity Building :** Investments in training, equipment, and personnel are essential to ensure that firefighting agencies can effectively combat the increased fire risk associated with climate change. This includes providing the necessary resources for fire prevention, suppression, and recovery efforts.

Conclusion

The escalating threat of forest fires due to climate change demands adaptive and multi-faceted forest management strategies. Techniques such as prescribed burning, fuel reduction, early detection systems, and community engagement must be integrated into a broader framework of climate change adaptation. By fostering fire-resilient landscapes and empowering communities to manage fire risk, we can mitigate the devastating ecological, economic, and social impacts of forest fires in the context of a changing climate. Effective forest fire management is not only essential for protecting human lives and property but also for preserving the ecological integrity of forests worldwide.

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ENHANCING SOIL HEALTH AND FERTILITY WITH MUCUNA: A GREEN MANURE REVOLUTION

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Consequences of Neglecting Green Manuring

Green manuring is a traditional agricultural practice that boosts soil fertility, enhances soil structure, and helps control weeds. Without it, soils can lose essential nutrients, leading to lower crop yields. Continuous cropping without replenishing the soil can cause compaction, poor water retention, and greater susceptibility to pests and diseases. This reliance on synthetic fertilizers and pesticides can increase costs and undermine sustainable farming practices. Furthermore, intensive cultivation without regular nutrient input can deplete organic carbon and reduce the biological diversity of the soil, negatively impacting its quality. Incorporating green manure biomass into intensive vegetable cropping systems promotes organic carbon accumulation, nutrient recycling, improved soil structure, and increased microbial activity and enzyme function.

Fig. 1. Mucuna crop cultivated in field and its nodule development

Mucuna: a Green Manure Crop

Mucuna (Mucuna pruriens), also known as velvet bean, is a leguminous cover crop celebrated for its green manuring benefits. This tropical legume is valued for its rapid growth and serves multiple purposes: as forage, a fallow crop, soil cover, and green manure. Native to tropical regions, Mucuna is increasingly acknowledged for its role in enhancing soil health through root nodule which fixes atmospheric nitrogen (Fig.1). The plant produces dense foliage that decomposes quickly when incorporated into the soil, releasing vital nutrients. Mucuna is especially prized in organic farming and sustainable agriculture/horticulture for its natural soil fertility enhancement.

It can be grown in various soil types, with sandy loam offering the best conditions, characterized by good drainage and a pH between 5.5 and 7.5. The plant starts producing mature pods approximately 140 days after planting, with pods maturing in 2 to 3 harvests every 20 days. Pods should be harvested when they turn brown and begin to dry. During the dry season, it is recommended to irrigate every two weeks, while in winter, monthly irrigation is adequate during pod harvesting.

Mucuna has become increasingly popular as a green manuring crop in tropical and subtropical regions around the world, including Brazil, India, and parts of Africa where agriculture is vital to the economy. Its deep-rooted system enhances nutrient recycling and fixes atmospheric nitrogen. The plant's roots and foliage help prevent soil erosion, improve soil fertility, and boost soil health. Additionally, Mucuna reduces weed growth and associated costs while moderating soil moisture and temperature extremes.

Despite these advantages, Mucuna is still underutilized in many areas due to limited awareness and access to seeds. However, with growing interest in sustainable farming practices, Mucuna's role as a valuable green manuring crop is gaining recognition, supported by agricultural extension services and research institutions.

Mucuna Cultivation Practices

Mucuna is extensively used in tropical regions of India as an intercrop, cover crop, or catch crop, and is sometimes cultivated as a sole crop. This versatile plant offers dual benefits: it functions as green manure for soil enrichment and as fodder for livestock. It thrives in sub-tropical to tropical climates, requiring a minimum winter temperature of 15ºC and a maximum summer temperature of 38ºC. Mature seeds have a viability of over 90% and can be stored for 2 to 3 years.

Fig. 2. Mucuna crop growth stages

In porous natured soil, Mucuna germinates and sprouts within 7 to 10 days. During land preparation, it is recommended to apply 10 to 20 tonnes of farmyard manure (FYM) per hectare.

For optimal seed yield, the fertilizer application should include 75 kg of nitrogen (N), 50 kg of phosphorus (P_2O_5), and 50 kg of potassium (K_2O) per hectare, divided into 2 to 3 doses. Phosphorus and potassium should be applied with FYM at sowing time. Irrigation is needed every two weeks during the dry season and once a month during winter, especially during pod picking. A key pest to manage is the leaf-eating hairy caterpillar, which affects the crop during the pre-flowering stage. Neem soap, applied at 5 grams per liter, is recommended for pest control. Collar rot can be a problem during the initial stages of seedling growth. This disease can be managed by applying 2 kg of Trichorich (a Trichoderma formulation mixed with neem cake) and 2 kg of Pseudomonas fluorescens, combined with 500 kg of FYM, to the root zone.

The crop duration for seed production ranges from 180 to 200 days. For green manure, Mucuna can be used at the flowering stage. Short-duration varieties (120–130 days) yield about 2.31 tonnes per hectare, medium-duration varieties (155–165 days) yield 3.0 to 3.5 tonnes per hectare, and long-duration varieties (180–190 days) produce 2.25 to 5.5 tonnes per hectare, depending on whether they are grown with support or through surface cultivation. Mucuna offers a range of cultural and agronomic advantages. As a legume, it enhances soil fertility by fixing atmospheric nitrogen with the aid of rhizobia bacteria (Rhizobium meliloti), boosting both organic carbon and nitrogen levels. Additionally, Mucuna is effective in suppressing weeds and conserving soil. Its benefits make it increasingly valued in vegetable-based cropping systems and long-term horticultural practices, where it plays a significant role in restoring soil organic carbon, improving soil fertility, and enhancing overall soil health.

Mucuna is a fast-growing, robust plant that can reach heights of up to 15 feet and generates a substantial biomass, making it well-suited for green manuring (Fig. 2). Its deep-rooted system effectively breaks up compacted soils, improving soil aeration and water infiltration. Mucuna is also rich in nitrogen, which is crucial for replenishing soil fertility. Its dense foliage offers excellent ground cover, suppresses weeds and protects the soil from erosion. Additionally, Mucuna's resistance to many pests and diseases further enhances its reliability as a green manuring option.

Mucuna is relatively straightforward to cultivate and manage, making it a viable option for farmers of all scales. It thrives in warm climates with well-drained soils and demands minimal inputs once established. The practice of using Mucuna as green manure involves sowing the seeds, allowing the crop to mature up to flowering, and then incorporating the biomass into the soil. Timing of this total process in align with the planting of main crops can maximize the benefits of green manuring. For the best results, careful attention to the timing and method of incorporation is essential.

Advantages and Disadvantages of Mucuna as a Green Manure Crop

The major advantages are as follow:

Soil Improvement: The plant's deep roots and substantial biomass enhance soil structure and increase organic matter.

Weed Suppression: Mucuna's dense canopy effectively suppresses weed growth, reducing the need for herbicides.

Erosion Control: Its extensive root system and ground cover help prevent soil erosion.

Pest and Disease Resistance: Mucuna has naturally resistance against many common pests and diseases, minimizes the need for chemical treatments.

The main disadvantages of Mucuna cultivation are:

Seed Availability: In certain areas, Mucuna seeds availability and identifying the source can be challenging task, which may restrict its broader use.

Allelopathy: Mucuna may release allelopathic compounds that could inhibit the growth of subsequent crops if not managed correctly.

Biomass Production Capacity of Mucuna and Other Green Manure Crops

A study was conducted to evaluate the biomass production with in various Mucuna varieties compared to Sunnhemp and Dhaincha. The total dry biomass of the selected Mucuna varieties was as follows: Arka Aswini (3.6 to 3.9 t ha^{-1}), Arka Daksha (1.0 to 1.2 t ha^{-1}), Arka Shubra (3.4 to 3.6 t ha^{-1}), and Arka Dhanavantri (1.5 to 1.7 t ha^{-1}). Among the Mucuna varieties, Arka Aswini produced the most biomass evaluated at flowering stage (50-60 DAS).

Impact on Soil Health and Fertility

The effects of different green manures on soil organic carbon (SOC) and nitrogen (N) stocks and sequestration were investigated. The results indicate that green manures, particularly Mucuna varieties, significantly enhance SOC and carbon sequestration. Among the Mucuna varieties, Arka Aswini and Arka Dhanavantri recorded the highest SOC and N stocks, although the differences were not statistically significant. Over three years, SOC stock ranged from 15.2 to 16.7 t ha^{-1}, with SOC sequestration between 2.24 and 3.71 t ha^{-1}, resulting in a sequestration rate of 0.75 to 1.24 t ha^{-1} y^{-}. Additionally, nitrogen levels increased to between 2.0 and 2.44 t ha^{-1}, with N sequestration rate of 0.93 to 1.34 t ha^{-1} over the same period, achieving an annual sequestration rate of 445 kg ha^{-1} compared to the control and other Mucuna varieties. These findings suggest that incorporating Mucuna green manure, especially the Arka Aswini and Arka Dhanavantri varieties, into horticultural practices can significantly enhance soil fertility, reduce reliance on synthetic inputs, and promote sustainable farming practices in the long.

Summary

Mucuna, when used as a green manuring crop, provides a range of benefits, including enhanced soil fertility, effective weed suppression, and erosion control. Although challenges such as seed availability and the need for careful management exist, the benefits generally outweigh these drawbacks. With the increasing focus on sustainable agriculture/horticulture, Mucuna is expected to become more significant in farming systems worldwide, contributing to healthier soils and more resilient agricultural practices.

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LOW COST AND EFFECTIVE TECHNOLOGY FOR FRUIT FLY TRAP OF MANGO FRUIT FLY (*Bactrocera dorsalis*) UNDER VALLEY CONDITION OF MANIPUR

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Abstract
Mango fruit fly is an important pest in mango growing belt of India and its lay egg during unripe bowl stage during May month under Manipur condition. Once the eggs hatch, the maggots consume the pulp of the fruit causing it to decay and rot. As the larvae feed on the fruit, it become mushy and black sunken spots / patches which hamper the production of the fruit. To control this pest, an innovative low cost eco-friendly way by using methyl eugenol (2ml) in bottle cap or styrofoam having hole. It is put in floating water in 1liter plastic bottle having 2 numbers of windows and about 400 ml of water at the bottom of the bottle was found effective in control of mango fruit fly. It can capture an average about 310 numbers of fruit flies/ bottle/week. It is very effective in the management of this serious pest of mango if we place in time as a trap during the unripe bowl stage of mango during May month under Manipur condition.

Key words: Mango fruit fly, bowl stage, fruit fly trap

Introduction
Mango (*Mangifera indica*) is the leading fruit crop of India and considered to be the king of fruits. Besides delicious taste, excellent flavour and attractive fragrance, it is rich in vitamin A & C. The tree is hardy in nature and requires comparatively low maintenance costs. Indian mangoes come in various shape, size and color with a wide variety of flavor, aroma and taste. The Indian mango is a special product that substantiates the high standards of quality and bountiful nutrients packed in it. A single mango can provide up to 40 percent of the daily dietary fiber needs - a potent protector against heart disease, cancer and cholesterol build-up. In addition, this luscious fruit is a warehouse of potassium, beta- carotene and antioxidants. In India, mangoes are mainly grown in tropical and subtropical regions from sea level to an altitude of 1,500m. Mangoes grow best in temperatures around 27°C. In India, Uttar Pradesh and Andhra Pradesh are having the largest area under mango each with around 25% of the total area followed by Bihar, Karnataka, Kerala and Tamil Nadu. Mango fruit is utilized at all stages of its development both in its immature and mature state. Raw fruits are used for making chutney, pickles and juices. The ripe fruits besides being used for desert are also utilized for preparing several products like squashes, syrups, nectars, jams and jellies. Besides, it is the richest source of vitamin A among the fruit. The mango kernel also contains 8-10 percent good quality fat which can be used for soap and also as a substitute for cola in confectionery (Chadha, 2013). In Manipur also it is popular fruit crop but mainly growing in the homestead garden both valley and hill regions of Manipur. There is lots of genetic diversity is observed due to its center of origin in the Indo-Myanmar region Yadav and Singh, (2017). However, this important fruit crop in Manipur is facing the problem of mango fruit fly which lays egg during unripe bowl stage size of the fruit during May month resulting unfit for marketing as well as consumption.

Construction of methyl eugenol pheromone trap using ½ L water bottle : This technique is simple, cheap and effective for the management of this serious pest in mango under Manipur condition. The mango fruit fly species found under Manipur condition is (*Bactrocera dorsalis*). In this technology, ½ L bottles are convenient having length 22cm and diameter of 6cm having a door height from the bottle: 10-15 cm from the bottom. The size of the door is about 5m length and 8m width (2 No. opposite each other) and filled with water about 200ml. After filling the water, float the ½ L bottle cap. 2 ml of methyl eugenol are added in bottle cap floating in the water. Every week 200 ml water/bottle and 2 ml methyl eugenol need to be replace it until the complete of fruiting season of mango depending on the variety (late or early season variety). About 20 number are sufficient for the management of this pest for I ha area (100 number of plants/1ha area)

Precaution measures: It should be kept in time during the bowl stage of mango under Manipur condition during May month for effective capturing of this serious pest in mango. For every week it needs to replace the water as well as methyl eugenol which are kept inside the bottle for the effective management of it.

Merits of this technology: a) It is low cost, eco-friendly and not harmful to the environment b) It is effective technology for the capturing of this pest during fruiting season

Conclusion: The novelty of this model is uniquely designed for the capturing of mango fruit fly pests which is eco-friendly as well as cost effective in sustainable ways for mango growers in Manipur.

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Fig 1: Fruit fly trap under field condition

Fig 2: Fruit fly important pest for mango

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FUNCTIONAL FEED ADDITIVES IN AQUACULTURE FEEDS

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Introduction

Nowadays, a wide range of feed additives are using to extend beyond the satisfying basic nutritional requirements of the target species to improve growth and feed utilization, but also to support the health and stress resistance of the aquatic animals. The nature and characteristics of these feed additives is quite diverse, and their application into diet formulations targets a specific purpose. Some additives, such as acidifiers, exogenous enzymes, are used to improve the animals' performance by providing enhanced digestibility of the feed materials, or counteracting the negative effects of antinutrients. Other additives, such as probiotics, prebiotics, phytogenics, and immune-stimulants target the improvement of intestinal health, stress, and disease resistance.

The Role of Functional Feed Additives in Enhancing Aquaculture Sustainability

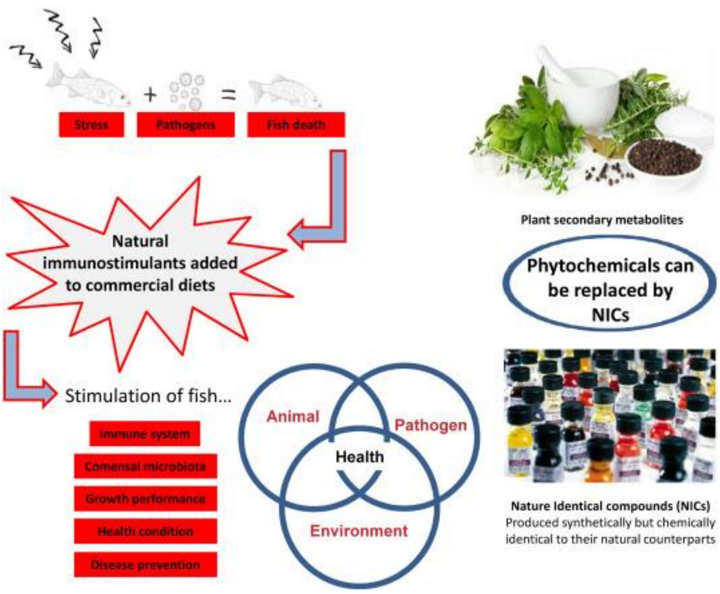
One such effort is using functional feed additives in feed formulation. Functional feed additives are dietary ingredients incorporated in feed formulations, not only for the usual provision of basic nutritional requirements as offered by traditional feed but also for growth and health enhancement; environmental and economic gain. Aquaculture is of huge benefit to society. However, there are concerns regarding its sustainability. Functional feed additives are a catalyst for sustainable aquaculture. Their use in aqua feed formulation results in improved gut health and beneficial gut bacteria, the elimination of opportunist bacteria, increased enzyme production, and appetite stimulation, resulting in improved growth and immunity in their host (Gatesoupe F.J.,1999). They also ameliorate the use of alternative proteins in aquafeed and improve water quality, thereby reducing the footprint of aquaculture on the environment. The use of functional feed additives (FFA) in aquaculture is promising in addressing some sustainability challenges linked to aquaculture. Therefore, functional feed additives are of great benefit in aquaculture, and their use should be encouraged by governments and stakeholders.

Some Common Functional Feed Additives in Aquaculture

Probiotics: Probiotics can be administered either via food or in the rearing water. Probiotic organisms used as food additives should not be pathogenic, should possess the ability to survive transit via the gut, and should withstand exposure to gastric juices and bile.

Prebiotics: The benefits obtained from using prebiotics as feed additives emanate from the byproducts obtained during fermentation by bacteria in the gut. For prebiotics to promote the growth of gut microbiota, the particular microbiota needs to possess enzymes capable of fermenting the prebiotic; therefore, not all gut microbiota can be promoted by a particular prebiotic; hence, a mixture of prebiotics is encouraged.

Phytogenics: Phytogenics are a vast class of feed additives obtained from leaves, stems, roots, seeds, tubers, fruits, shrubs, and spices. They can be used in dried, solid, or ground states or as extracts or essential oils. Phytogenics stimulate the appetite, enhance beneficial gut bacteria, and provide antioxidant, antimicrobial, anti-carcinogenic, analgesic, and antiparasitic effects in farmed aquatic animals.

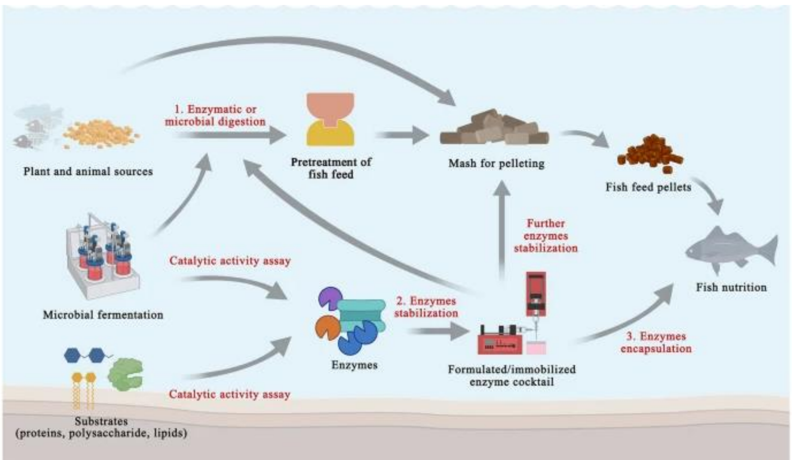


Functional feeds are regarded as the future of the aquaculture by embracing nutrition strategies to address specific stresses, environmental situation, life stage requirements and pathologies, the industry can optimize animal performance as well as operational efficiency.

By preventing health management through feed, aquatic animals can divert more energy to tissue growth and reduce biological energy reserves needed to fight disease.

Functional Feeds, provide benefits other than just nutritional, support health and reduce the risk of disease

- ✓ Certain Nutrients (e.g. PHs, SDP, Nucleotides)
- ✓ Chemicals (e.g. Levamisole)
- ✓ Exogenous enzyme (e.g Phytase)
- ✓ Immunostimulants (e.g Beta-glucan, LPS)
- ✓ Organic acids (e.g formic, sorbic, butyric acids)
- ✓ Pigments (e.g carotenoids)
- ✓ Prebiotics
- ✓ Probiotics
- ✓ Vegetable extract
- ✓ Vitamin C&V



Types of aquaculture feed additives

There are several types of aquaculture feed additives, including:

- **Phytogenic compounds:** Phytogenic compounds are plant derivatives from leaves, roots, fruits and other plant parts. They have a range of beneficial characteristics, including antioxidant, antimicrobial, insecticidal and more.
- **Microalgae:** Microalgae are photosynthetic microorganisms that support nutrition and growth performance. They are an excellent source of protein, fat, vitamins and antioxidants.
- **Yeast:** Certain yeast species are used in aquaculture to enhance fish growth and help boost their immune systems. Yeast provides a high amount of vitamin B, fatty acids and amino acids.
- **Enzymes:** Enzymes can increase growth, feed conversion ratios and energy levels in various fish species. Common aquaculture feed enzymes include phytase, pepsin and lipase.
- **Organic acids:** Organic acids enhance nutrient use, disease resistance and growth in fish. They decrease pH levels in the stomach and intestine while increasing digestive enzyme activity. Examples include citric acid, lactic acid, sorbic acid and benzoic acid.
- **Probiotics:** Probiotics are live microbes that can support intestinal microbial balance in fish. They can also enhance water quality in aquaculture systems.
- **Prebiotics:** Prebiotics are indigestible ingredients that stimulate the growth and activity of certain bacteria species to help support fish health. Common aquaculture prebiotics include inulin, oligofructose and b-glucan.
- **Seaweeds:** Seaweed has minerals and polysaccharides that can improve fish growth and immune system performance.
- **Mushrooms:** Mushrooms have polysaccharides that promote weight gain and bolster immune systems in numerous fish species.

Challenges Associated with Functional Feed Additives

Functional feed additive is beneficial to improving the growth performance, health, and overall immunity of the target species, it is not void of limitations. Functional feed additives contain specialized additives that may increase the feed cost and cost of production, making functional feeds more expensive than traditional feeds. Formulating an effective functional feed requires a thorough understanding of the nutritional requirements of the target species. Hence, incorporating functional additives, such as probiotics and prebiotics, may require fish nutrition and feed formulation expertise. Ironically, the application of phytogenics, which seems less technical than other additives, may also require expertise (Dawood et al., 2016). Moreover, the use of certain feed additives in aquaculture feeds may depend on regulatory approval; obtaining the approval for novel additives may be prolonged and complicated, delaying the commercialization of the feed. One of the reasons that such innovativeness is checked is to ascertain that the consumption of animals from such innovativeness is not detrimental to humans/consumers. Certain functional additives may be susceptible to environmental factors like temperature and humidity, thus impacting their stability and shelf life.

Conclusion

The application of functional feed additives in aquaculture reduces stress, aids digestion, improves growth and water quality, increases the chances of survival of aquatic animals after exposure to infections, reduces parasitic infestation, and reduces the footprint of aquaculture on the environment. Feed additives, which provide all these benefits, are a plus to the farmer as they increase profitability, reduce reliance on antibiotics, and mitigate the cost of purchasing antibiotics, together with other effects associated with their use. All these benefits derived from functional feed additives make them superfoods. The initiative of functional feed additives remains a significant breakthrough for aquaculture.

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APPLICATION OF HEDONIC PRICE METHOD IN AGRICULTURAL ECONOMICS RESEARCH

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Introduction

The hedonic pricing method is a statistical tool that estimates the economic value of a non-market effect by observing how people behave in property markets. It's also known as hedonic regression or hedonic demand theory. The word ‘Hedonic’ is derived from the Greek word “hedonikos” which means utility or satisfaction derived through the consumption of goods and services. Hedonic pricing models are used to infer demand for the quality attributes through the analysis of marketed goods whose value depends in part on these attributes.

Hedonic price function is a regression of the observed price of a commodity against its quality attributes. Hedonic pricing involves implicit prices of attributes or characteristics of a commodity rather than the price of the commodity itself. Hedonic price models are used to infer the demand for quality attributes through the analysis of marketed goods whose value depends in part on these attributes. The hedonic price model, derived mostly from Lancaster’s consumer theory and Rosen’s model, posits that a good possesses a myriad of attributes that combine to form bundles of utility-affecting attributes that the consumer values (Pearce and Turner, 1990).

Hedonic price approach looks for a market in which goods or factors of production are bought and sold, and observes that factors frequently attributes of those goods or factors. The classical goal of price statistics is quantification of the true price change. Hedonic prices are calculated by regressing price of a product/commodity on the levels of its characteristics. Hedonic method is simple statistical regression technique which can help to measure inflation more precisely, by taking account of quality change of products, by correctly adjusting their prices.

Hedonic theory recognizes heterogeneity in goods. A commodity’s price(s) may be conceptualized as simultaneously affected by the commodity’s quantitative and qualitative dimensions. The quantitative dimensions consist of supply and demand forces affecting the price of homogenous good. The qualitative dimension is the effect on price as quality characteristics change.

Advantages of the hedonic pricing method:

- This method can be used to estimate values based on the actual choices.
- Data on sales and characteristics are readily available through many sources, and can be related to other secondary data sources to obtain descriptive variables for the analysis.
- The method is versatile, and can be adapted to consider several possible interactions between market goods and its quality.
- It is straight forward approach, because only the co-efficient of the estimated hedonic regression are needed to indicate the preference structure.

Application of hedonic price model in Agriculture:

Hedonic pricing method can be applied to various fields and are mentioned as below:

- Valuation of public goods
- Valuation of environmental goods
- House hold production
- Real estate valuation
- Job satisfaction
- Estimation of price index
- Estimation of resource cost or user value
- Credit market and *etc*.

Functional form of Hedonic price model:

There are three stages in estimation of hedonic model, they are

- Hedonic price function
- Willingness to pay function
- Welfare function

Hedonic price function:

The functional form of hedonic pricing is regression model. The data can be analysing using regression, which relates price of the good to its characteristics. Thus, the effects of different characteristics on price can be estimated. The regression results indicate how much property values will change for a small change in each characteristics, holding all other characteristics constant.

Assume that each individual's utility function has arguments for X, a composite commodity. The market is assumed to be in equilibrium, which requires that individuals have optimized their product/good choice based on the prices of alternative goods. The prices are assumed to be market clearing prices given the existing good/product choices and their characteristics. With these assumptions, the price of any good can be described as a function of the quality characteristics of the good.

$$P_{gi} = P_g (z_{i1}, z_{i2}, \ldots., z_{ij}, \ldots, z_{in}) \text{ ------------ } (1)$$

Where, P_{hi} is the price of the i^{th} good,

$z_{1, \ldots} z_j, \ldots, z_n$ are the characteristics of the good

Now consider the individual who buys the good i. Assume that preference are weakly separable in good and its characteristics, which allows the demand for characteristics to be independent from the prices of other goods.

The partial derivative of the hedonic price function with respect to any characteristic yields its marginal implicit price. The first partial derivative represents the additional amount that must be paid (received) to be located an additional unit quality attribute. For a linear specification, the first partial derivative is the coefficient on the variable of interest.

Willingness-to-Pay Function:

The hedonic technique's second stage is an effort to identify the marginal willingness-to-pay function by combining the quality and price information obtained from the first stage. Whether or not the marginal willingness-to-pay function can be identified depends on the conditions under which it was estimated. Individual i's marginal willingness-to-pay function or uncompensated inverse demand function for z_j can be obtained by solving the choice problem:

$$b_{ij} = b_{ij}(z_j, u^*) \text{ ------------- } (2)$$

Where, b_{ij} is individual i's willingness to pay for z_j, and u* is the error term.
The intersection of the individual's inverse demand function and the marginal implicit price function for z_j, Pz_j (opportunity locus to purchase z_j, where Pz_j is the price of z_j) is the utility maximizing equilibrium for individual i. Thus, it measures the individual's equilibrium marginal willingness to pay for z_j.

As long as the willingness to pay (as defined by individuals' inverse demand curves) exceeds the marginal implicit price, individuals will move out along Pz_j. Therefore, Pz_j, represents a locus of individuals' equilibrium willingness to pay.

Measuring changes in Welfare:
An important application of both the hedonic price function and the willingness-to-pay function is the ability to measure welfare effects. The value of marginal change in a characteristic is the sum of the marginal willingness to pay for each of the individuals affected by the change evaluated at the existing housing market equilibrium. That is, for the characteristic, z_j

$$W_z = \sum_{i=1}^{n} b_{ij} = \sum_{i=1}^{n} \frac{\partial Pg_i}{\partial z_i} \text{ ------------ } (3)$$

Where W_z is the aggregate marginal welfare change

For non marginal changes, in the partial equilibrium or short run case where other prices and characteristics are held constant, the welfare change is the area under the willingness-to-pay function.

$$W_z = \sum_{i=1}^{n} \int_{z0j}^{zij} b_{ij}(z_{ij}, P, u_j^*) \text{ ----------- } (4)$$

Where, W_z is the aggregate benefit. This measure also represents the lower bound of the long-run welfare change. The upper bound of the long run welfare change can be directly estimated by the hedonic price function.

The hedonic price function and the willingness-to-pay function are relatively straightforward while defining in a theoretical way while, the practical applications have numerous challenges and are:

a. The dependent variable
The issues relates to the source of the good values. Good values can come from aggregated market data, expert opinion such as professional appraisers, and actual individual market transactions. The preference for actual sales data over other sources is based on the presumption that such transactions come closest to reflecting true market values. "True" market values result when all buyers and sellers have perfect information and have exhausted all opportunities for further gains from additional trades. While both market and no market data may be biased and will tend to cloud the relationship between true good values and their characteristics, they will not result in biased parameter estimates unless the error terms are correlated with other regressors in the model.

b. The explanatory variables
There are a number of practical and conceptual issues in selecting variables which make up the hedonic price function and explain the transaction price of a good. To delineate clearly the effects

of a quality characteristic on good price, the analysis must control for the effects of other characteristics. This challenge is made more troublesome by the introduction of Multicollinearity. If some of the variables in the hedonic price function are correlated, the variance or imprecision of the coefficient estimates are increased. On the other hand, if relevant variables are left out of the regression to reduce collinearity problems, the coefficient estimates will be biased. Unfortunately, theory provides little help in addressing the bias/variance tradeoff and its resolution is left to the art of econometrics.

c. Hedonic functional form

From the statistical or econometric point of view, there is nothing very complicated about estimating hedonic functions. The economics that lie behind hedonic functions are not necessarily simple, but the economics of hedonic functions do not imply complex econometric methods. Most hedonic functions have been estimated by ordinary least squares (OLS) regression, which is the most straightforward statistical technique employed by economists.

Many functional forms have been proposed and used for hedonic models including linear, quadratic, log-log (double log), semi-log, inverse semi-log, exponential and Box-Cox transformation. Theory only suggests that the first derivative of the hedonic price function with respect to the characteristic in question be positive (negative) if the characteristic is desirable (undesirable). Properties of the second derivative cannot be deduced from the general features of the model. Popular methods to select the functional form include using a linear relationship and altering any variable which are believed a priori to be nonlinear and using flexible forms to determine the best fit. Goodness of fit has traditionally been the basis for selecting functional form (Triplett, 2004).

Linear functional Form

The linear functional form uses no logarithms at all. Both price and the explanatory (right hand side) variables appear in their own, or native, values.

$$P = \alpha + \sum_{j=1}^{J} \beta_j z_j + u \quad \text{--------- (5)}$$

With the hedonic price,

$$\frac{\partial P}{\partial z_j} = \beta_j \quad \text{------------ (6)}$$

Where, P =Price of the commodity

Z_j =Characteristics of the product (j=1…….J)

u =Error term

Choosing among functional form:

The theory of hedonic functions shows that the form of the hedonic function is entirely an empirical matter. Accordingly, one should choose the functional form that best fits the data, Sometimes researchers have used measures of "goodness of fit", including examination of values of R^2, the standard error of the regression, and so forth, for choosing among functional forms. However, the normal econometric test for choosing functional forms has come to be the "Box-Cox" test. The test involves adding nonlinear parameters on both sides of the hedonic function equation, so that, depending on these estimated parameters, the function collapses to either logarithmic or linear (on either side). The Box-Cox function thus "nests" the three popular functional forms for hedonic studies, and depending on its estimated nonlinear parameters, it yields linear, semi-log or double log functions (or, actually, none of them, if all are rejected statistically). The test is an option in standard statistical packages (Triplet, 2004).

Limitations of the Hedonic Price model

- The method will only capture people's willingness to pay for perceived differences in attributes, and their direct consequences. Thus, if people aren't aware of the linkages between the attributes and benefits to them, the value will not be reflected in prices.
- The method assumes that people have the opportunity to select the combination of features they, prefer, given their income.
- The method is relatively complex to implement and interpret; requiring a high degree of statistical expertise and large amounts of data must be gathered and manipulated.

Conclusion

The hedonic price technique is used to estimate the value of quality attributes that affect prices of marketed goods. The method is based on the assumption that people value the characteristics of a good, or the services it provides, rather than the good itself. Thus, prices will reflect the value of a set of characteristics, including quality that people consider important when purchasing a good. The hedonic pricing method is relatively straight forward and uncontroversial to apply, because it is based on actual market prices and fairly measured data.

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IMPORTANCE OF RURAL YOUTH TOWARDS AGRICULTURE

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Abstract

The agricultural sector is crucial for socio-economic development, especially in countries like India, where a significant portion of the population is youthful. With 70% of its population under 35, India has a vast potential demographic dividend. However, despite high literacy rates, youth unemployment remains a challenge. Engaging rural youth (ages 15-34) in agriculture is essential for sustainability, economic growth, food security, social stability, environmental stewardship, and cultural preservation. Their capacity for innovation and adaptability can drive advancements in agricultural practices, create job opportunities, and reduce rural-urban migration. By empowering rural youth, societies can enhance agricultural productivity and resilience, ensuring a vibrant future for both agriculture and rural communities.

Key words: Agriculture, Rural youth, Unemployment, Productivity.

Introduction

The importance of agriculture to the socio-economic development of the country cannot be overemphasized. Agriculture sector is potentially the largest employment providing sector in the country. Despite this, unemployment is high among rural youth, who prefer to migrate to urban areas to take up low paying jobs. The youth population growth rate is generally higher in the poor countries and their number has tripled since 1950s. By the year 2025, the number of youth living in developing countries is likely to reach 89.5 %. In India, about 70 % population is below the age of 35 years, making it the youngest nation in the World. According to some estimates, the proportion of population under 25 years in India is 51 %. Some experts refer to this large proportion of youth as “demographic dividend” because greater proportion of the population is young and in the working age group which can lead to economic growth. However, out of the youth population of 460 million, only 333 million youth in India are literate and unemployment rate is highest (10.6 %) among youth. This high percentage of youth can be utilized for taking Indian agriculture to new heights by channelizing the creative energies of the youth through development of appropriate skills, knowledge and attitude. This predominance of youth in the population is expected to last until 2050. Hence, the National Youth Policy (2012) emphasizes youth empowerment in different spheres of national life. There are several advantages of involvement of youth in agriculture as they have the latent energy, capacity and ability to produce, propensity to learn and grasp new ideas or technologies faster and they are excellent source of ideas and innovations.

Rural youth:

Electoral Support Programme defines rural youth as people aged 18 to 29 who live in rural settlements, while the United Nations defines youth as people aged 15 to 24. The National Youth Policy (NYP) of 2014 defines youth as people aged 15 to 29, and the 2017 report Youth in India defines youth as people aged 15 to 34.

Importance of rural youth in agriculture:

The importance of rural youth in agriculture is critical for the sustainability and development of the agricultural sector. Here are several key points that highlight their significance:

i. Sustainability of Agriculture:

- **Generational Continuity:** Rural youth are essential for ensuring the continuation of farming practices as older generations retire. Their involvement is crucial for maintaining the knowledge and skills needed for effective agricultural production.
- **Innovation and Technology Adoption:** Young people tend to be more open to adopting new technologies and innovative farming practices. Their engagement can lead to increased productivity, efficiency, and sustainability in agriculture.

ii. Economic Growth:

- **Job Creation:** Agriculture provides significant employment opportunities for rural youth. Their involvement in farming, agribusiness, and value-added activities can stimulate economic growth and reduce rural poverty.
- **Entrepreneurship:** Rural youth can drive the development of new agricultural enterprises, creating jobs for themselves and others in their communities. This entrepreneurial spirit can help diversify rural economies.

iii. Food Security:

- **Increased Production:** Engaging rural youth in agriculture helps ensure that food production keeps pace with population growth. Their participation is vital for meeting local and global food security needs.
- **Innovation in Food Systems:** Youth can introduce innovative approaches to food production, processing, and distribution, helping to create more resilient and sustainable food systems.

iv. Social Stability:

- **Reducing Rural-Urban Migration:** Providing opportunities for rural youth in agriculture can reduce the migration of young people to urban areas in search of better livelihoods. This helps to maintain social stability in rural regions and prevents the depopulation of these areas.
- **Community Development:** Youth engagement in agriculture contributes to the overall development of rural communities. They can play a role in improving infrastructure, education, and healthcare services, leading to a better quality of life.

v. Environmental Stewardship:

- **Sustainable Practices:** Rural youth can be instrumental in promoting sustainable farming practices that protect natural resources and reduce the environmental impact of agriculture. They are more likely to embrace practices like organic farming, agroforestry, and conservation agriculture.

- **Climate Change Mitigation:** With the right training and resources, rural youth can lead efforts to adapt to and mitigate the effects of climate change on agriculture. They can implement strategies that increase resilience to climate-related challenges.

vi. Cultural Preservation:

- **Maintaining Traditions:** Rural youth play a key role in preserving traditional agricultural knowledge and practices that have been passed down through generations. This cultural heritage is valuable for maintaining biodiversity and sustainable farming systems.
- **Innovation in Tradition:** While preserving cultural practices, rural youth can also innovate within these traditions, finding new ways to make traditional agriculture more efficient and economically viable.

Conclusion

The involvement of rural youth in agriculture is vital for the long-term viability of the agricultural sector. By supporting and empowering rural youth, societies can ensure that agriculture remains a vibrant and dynamic field, capable of meeting the challenges of the future while providing livelihoods for millions of people.

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MAXIMIZING AGRICULTURAL PRESERVATION OUTCOMES THROUGH STRATEGIC DRYING TECHNOLOGIES

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Abstract

Sustainable drying technologies, particularly solar dryers with integrated heat storage, present a promising solution to global food security challenges and post-harvest losses. These systems offer multiple advantages over conventional preservation methods, including reduced spoilage, cost-effectiveness, and environmental sustainability. The integration of heat storage capabilities enhances drying efficiency and consistency, enabling continuous operation during non-sunlight hours and improving overall system performance. Adoption of these technologies has far-reaching implications for agricultural sustainability, potentially catalyzing economic growth in rural communities, expanding market access for farmers, and bolstering climate resilience in food production systems. By extending product shelf life and maintaining nutritional quality, solar drying technologies can significantly reduce food waste and improve resource utilization. The ability to scale-up these systems, from small-scale farmers to larger operations, underscores their versatility and broad applicability. As global food demand increases and climate change threatens agricultural productivity, the widespread implementation of advanced solar drying technologies emerges as a critical strategy for ensuring long-term food security and sustainable agricultural practices.

Keywords: drying techniques, food security, post-harvest management, storage preservation method

Introduction

Agricultural preservation plays a crucial role in maintaining food security and addressing post-harvest losses which are critical challenges faced globally (Bertodo, 2002). As the world population continues to grow, efficient methods of preserving agricultural products become increasingly important (FAO, 2019). Sustainable drying technologies, particularly solar dryers, offer an efficient and cost-effective solution to this challenge (Kumar *et al*., 2016). Solar dryers harness renewable energy to preserve agricultural products, reducing spoilage and extending shelf life. The use of renewable energy sources makes these methods cost-effective and environmentally friendly. (Olunloyo *et al*., 2022). These systems can be further optimized by integrating heat storage capabilities, allowing for continuous drying even during periods without direct sunlight (Sharma *et al.,* 2009). This innovation has the potential to significantly contribute to poverty alleviation and economic growth in agricultural communities (Tiwari *et al*., 2016).

Promoting the adoption of sustainable drying technologies is crucial for long-term agricultural sustainability (Ajala *et al*., 2020). Maximizing agricultural preservation outcomes through the use of these technologies can have a profound impact on food security globally. They can lead to increased food security, reduced post-harvest losses, poverty alleviation, and economic growth. (Olunloyo *et al*., 2022) (Chaudhari *et al.,* 2021) (Akinjiola & Balachandran, 2012).

Benefits of Sustainable Drying Technologies
Sustainable drying technologies, such as solar dryers, offer numerous advantages in preserving agricultural products:

a. Reduced spoilage: Solar dryers effectively remove moisture from produce, inhibiting the growth of mold and bacteria that cause spoilage. This process extends the shelf life of agricultural products, reducing waste and improving food security (Vijayan *et al.,* 2020).
b. Cost-effectiveness: By utilizing renewable solar energy, these drying systems minimize operational costs compared to conventional electric or fuel-powered dryers. This makes them particularly suitable for small-scale farmers and rural communities with limited access to electricity (Mustayen *et al.,* 2014).
c. Environmental friendliness: Solar dryers have a minimal carbon footprint, contributing to sustainable agricultural practices and reducing the environmental impact of food preservation (Bennamoun, 2013).
d. Enhanced product quality: Controlled drying conditions in solar dryers help maintain the nutritional value and quality of dried products, ensuring better market value and consumer acceptance (Prakash and Kumar, 2014).

The integration of heat storage into solar drying systems further enhances these benefits:

a. Extended drying periods: Heat storage allows for continued drying during cloudy periods or at night, maximizing the system's efficiency and reducing overall drying time (Ayyappan *et al.,* 2015).
b. Improved consistency: Stored heat provides a more stable drying temperature, resulting in more uniform product quality (Shalaby *et al*., 2014).
c. Increased capacity: The ability to dry products continuously allows for higher throughput, benefiting larger-scale operations (Bal *et al*., 2011).

Importance of Adoption for Sustainable Agricultural Practices
Promoting the adoption of sustainable drying technologies is crucial for long-term agricultural sustainability:

a. Food security: By reducing post-harvest losses and extending the shelf life of agricultural products, these technologies contribute significantly to improved food security, especially in regions prone to shortages (Gustavsson *et al.,* 2011).
b. Economic growth: Farmers can increase their income by preserving surplus produce for sale during off-seasons when prices are higher. This economic benefit can lead to poverty alleviation in agricultural communities (Tiwari *et al.,* 2016).
c. Market access: Improved preservation methods allow farmers to reach broader markets, including export opportunities for high-quality dried products (Kader, 2005).
d. Resource efficiency: Sustainable drying technologies help conserve resources by reducing waste and maximizing the utilization of harvested crops (Gustavsson *et al.,* 2011).
e. Climate resilience: As climate change impacts agricultural production, efficient preservation methods become increasingly important in maintaining food supply stability (Wheeler and von Braun, 2013).

In conclusion, the adoption of sustainable drying technologies, particularly solar dryers with integrated heat storage, is a critical step towards achieving long-term agricultural sustainability. By maximizing preservation outcomes, these technologies address food security challenges, reduce post-harvest losses, and contribute to economic growth. As we face increasing pressure on global food systems, embracing these innovative solutions becomes not just beneficial, but essential for a sustainable agricultural future.

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MICROBIAL FERTILIZERS: A PATH TO REDUCED CHEMICAL USE

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Abstract

Microbial fertilizers, also known as biofertilizers, have emerged as a sustainable alternative to conventional chemical fertilizers. These products rely on naturally occurring microorganisms to enhance plant growth by improving nutrient availability, fixing atmospheric nitrogen, and decomposing organic matter. With growing environmental concerns related to synthetic fertilizer use, microbial fertilizers offer a path to reduced chemical input while maintaining or improving crop yields. This article explores the different types of microbial fertilizers, their mechanisms, and the latest research on their benefits. It also examines the challenges of widespread adoption and potential solutions.

Introduction

The use of synthetic chemical fertilizers in modern agriculture has led to significant environmental degradation, including soil degradation, water pollution, and a decline in biodiversity. Additionally, the long-term overuse of these fertilizers can reduce soil fertility, leading to dependency on external inputs. Consequently, the agricultural sector is increasingly exploring more sustainable practices, including the use of microbial fertilizers to reduce reliance on chemicals while maintaining productivity.

Microbial fertilizers contain beneficial microorganisms that naturally promote plant growth by fixing atmospheric nitrogen, decomposing organic material, improving nutrient absorption, and fostering better soil structure. These organisms contribute to the natural nutrient cycles in the soil, providing a more environmentally friendly alternative to chemical fertilizers. This review delves into the current state of microbial fertilizers, their types, how they function to reduce chemical use, and the challenges and opportunities in their adoption.

Types of Microbial Fertilizers

1. Nitrogen-Fixing Bacteria

Nitrogen is an essential nutrient for plant growth, but most plants cannot utilize nitrogen directly from the atmosphere. Nitrogen-fixing bacteria, such as *Rhizobium, Azotobacter*, and *Azospirillum*, help convert atmospheric nitrogen into forms that plants can readily absorb. These bacteria form symbiotic relationships with leguminous plants, facilitating natural nitrogen fertilization and reducing the need for synthetic nitrogen fertilizers.

A recent study by Alori *et. al.,* (2022) demonstrated that nitrogen-fixing bacteria could enhance nitrogen availability in soils, increasing crop yields by up to 20%. This shows the potential of these microorganisms to replace chemical nitrogen fertilizers while maintaining productivity.

2. Phosphate-Solubilizing Microorganisms

Phosphorus is another vital nutrient, but much of the phosphorus in soils is present in forms that plants cannot use. Phosphate-solubilizing microorganisms (PSMs), such as ***Bacillus,*** *Pseudomonas*, and certain fungi like *Aspergillus,* convert insoluble phosphorus into bioavailable forms. These microorganisms excrete organic acids that help solubilize phosphorus compounds, allowing plants to absorb this critical nutrient.

According to Zhang *et. al.,* (2023), the application of phosphate-solubilizing bacteria increased available phosphorus in soil by 40%, thereby reducing the need for chemical phosphorus fertilizers. This improvement in nutrient availability also translates into enhanced crop growth and higher yields.

3. Mycorrhizal Fungi

Mycorrhizal fungi form a mutualistic association with plant roots, effectively extending the root surface area and improving the plant's ability to absorb nutrients, particularly phosphorus and micronutrients. Arbuscular mycorrhizal fungi (AMF) are the most common type, benefiting crops by enhancing nutrient uptake, improving soil structure, and increasing plant resistance to drought.

A study by Verbruggen *et. al.,* (2021) found that AMF increased phosphorus uptake by 30% and improved plant growth under nutrient-limited conditions. The application of mycorrhizal fungi reduces the need for chemical fertilizers and promotes long-term soil health by fostering a robust microbial ecosystem.

4. Plant Growth-Promoting Rhizobacteria (PGPR)

Plant growth-promoting rhizobacteria (PGPR) are a group of bacteria that colonize plant roots and stimulate plant growth by producing phytohormones, improving nutrient availability, and protecting plants from pathogens. PGPR, such as *Bacillus subtilis* and *Pseudomonas fluorescens,* enhance root growth, increase nutrient uptake, and induce plant defense mechanisms.

Recent research by Ali *et. al.,* (2022) demonstrated that PGPR-treated crops showed a 15-25% increase in yield compared to untreated crops. The ability of PGPR to improve nutrient efficiency reduces the need for synthetic inputs, contributing to more sustainable agricultural practices.

Mechanisms of Microbial Fertilizers in Reducing Chemical Use

1. Nutrient Cycling and Availability

Microbial fertilizers facilitate the cycling of essential nutrients, such as nitrogen, phosphorus, and potassium, by converting them into forms that plants can easily absorb. Nitrogen-fixing bacteria convert atmospheric nitrogen into ammonia, phosphate-solubilizing microbes release phosphorus from soil-bound compounds, and other microorganisms enhance the availability of micronutrients.

A study by Hassan *et. al.,* (2021) reported that microbial fertilizers increased nutrient availability by 25%, reducing the need for chemical fertilizers. These microorganisms work with natural soil processes to provide plants with a balanced supply of nutrients, enhancing plant growth while minimizing external chemical inputs.

2. Soil Structure and Organic Matter

The application of microbial fertilizers can improve soil structure and organic matter content. Mycorrhizal fungi and bacteria produce exopolysaccharides that help aggregate soil particles, increasing soil porosity and water retention. Improved soil structure enhances root growth and nutrient absorption, reducing the need for chemical soil conditioners.

In a study by Xia *et. al.,* (2022), microbial fertilizers increased organic matter content by 20%, which helped restore soil fertility in degraded agricultural fields. This improvement in soil health reduces the reliance on chemical inputs and promotes long-term agricultural sustainability.

3. Enhanced Plant Stress Resistance

Microbial fertilizers also help plants resist environmental stresses, such as drought, salinity, and disease. Certain PGPRs and mycorrhizal fungi increase plant tolerance to abiotic and biotic stresses by inducing plant defense mechanisms and improving water and nutrient uptake.

According to a study by Patel *et. al.,* (2023), crops treated with microbial fertilizers exhibited a 30% higher tolerance to drought stress compared to untreated crops. This increased resilience reduces the need for chemical pesticides and herbicides, contributing to reduced chemical input in agriculture.

Benefits of Microbial Fertilizers

1. Environmental Sustainability

The reduced use of chemical fertilizers through the application of microbial fertilizers leads to lower environmental pollution. Excessive chemical fertilizer use contributes to water contamination, eutrophication, and greenhouse gas emissions. Microbial fertilizers provide a natural alternative that minimizes these environmental impacts.

Research by Johnson *et. al.,* (2022) showed that fields treated with microbial fertilizers had 50% lower nitrogen runoff and 30% lower greenhouse gas emissions compared to fields treated with synthetic fertilizers. This significant reduction highlights the potential of microbial fertilizers to mitigate the environmental damage caused by conventional agriculture.

2. Long-term Soil Fertility

Chemical fertilizers can degrade soil health over time by disrupting soil microbial communities and causing nutrient imbalances. In contrast, microbial fertilizers improve soil fertility by enhancing microbial diversity, organic matter content, and nutrient cycling. This leads to better long-term soil productivity without the need for excessive chemical inputs.

A study by Delgado *et. al.,* (2023) reported that the continuous use of microbial fertilizers increased soil organic carbon levels and microbial biomass, contributing to the restoration of degraded soils.

3. Economic Benefits for Farmers

Although microbial fertilizers may have a higher initial cost, they provide long-term economic benefits by reducing the need for chemical fertilizers and pesticides. Enhanced crop yields and soil health result in more consistent production, leading to lower input costs and higher profits for farmers.

A cost-benefit analysis by Kumar *et. al.,* (2023) found that farmers using microbial fertilizers saw a 15-20% reduction in fertilizer costs and a 10-15% increase in crop yields over five years, highlighting the economic viability of these products.

Challenges in Adoption

1. Inconsistent Results

One of the primary challenges in adopting microbial fertilizers is the variability in their effectiveness. The performance of these products can depend on factors such as soil type, climate, and crop species. In some cases, microbial fertilizers may not provide the same immediate results as chemical fertilizers, leading to inconsistent outcomes for farmers.

A study by Jones *et. al.,* (2021) noted that while microbial fertilizers performed well in controlled experiments, their efficacy varied significantly under different field conditions. Further research is needed to optimize their application for diverse agricultural environments.

2. Lack of Awareness and Education

Many farmers are unfamiliar with the benefits of microbial fertilizers, and there is a lack of training on how to use them effectively. Widespread adoption of microbial fertilizers will require greater education and outreach efforts to ensure farmers understand their long-term benefits and how to integrate them into their existing farming practices.

Conclusion

Microbial fertilizers offer a promising path toward reducing the use of chemical fertilizers in agriculture. By improving nutrient availability, enhancing soil health, and increasing crop resilience to stress, microbial fertilizers contribute to more sustainable farming practices that protect the environment and ensure long-term productivity. While challenges remain, including inconsistent performance and a lack of awareness, continued research and education can help overcome these barriers. Microbial fertilizers represent a key component in the transition to sustainable agriculture, reducing chemical inputs and fostering healthier ecosystems.

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MINI TRACTOR OPERATED BUSH CUTTING MACHINE

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Introduction

Generally, grasses are found to survive in a variety of conditions and thus the need to curb their growth in order to enhance the beauty of our environment. The aesthetic value of environment is as important as food and shelter to the modern man (Okafor, 2013). As man evolved intellectually, brush cutting Mowing and cleaning of lawns and walkways have become a critical part of aesthetic design in building management and have invariably developed to an art. The earliest brush cutters were invented as early as 1830s by Edwin Beard Budding (Mandloi et al, 2011) who was said to have obtained the idea after watching a machine in a local cloth mill which used a cutting cylinder mounted on a bench to trim clothes for a smooth finish after weaving (Fossett, 2007). As technology advanced, grass cutting devices developed giving birth lawn mower and brush cutter, away from use of machetes, hoes and cutlasses to motorized grass cutters. This technology had continued to advance and better techniques of grass cutting are being invented and constantly improved upon; many designs are available on commercial scale, each suited to specific purposes such as shrub cutting, lawn mowing and hedge trimmings which are comparatively very much thicker than grass and other common weeds. Among the types available in market, is the one sold under the commercial name of brush cutter. In operation, brush cutters navigate through weeds, heavy brush and overgrown vegetation with ease. The welded steel frame design and engine positioning provide excellent balance regardless of the terrain. Existing engine trimmers suffer from high initial cost, high levels of engine noise, high fuel consumption rate and high operator fatigue on the long run (Cobb and Cooney, 2006; Reddy et al., 2010; Sujendran and Vanitha, 2014) Manual mowing or slashing which is the most common and cheapest way of keeping the lawn clean involves a lot stress and inefficiency. Commercial brush cutters equally have certain inherent drawbacks, which can be eliminated by locally fabricated shrub cutter machine with some special features. They are expensive, generates a lot of noise, vibrations and has ergonomic effects on operator' hand, ears and waist (Muggleton et al., 1999). This paper intends to eliminate some of these drawbacks by developing, fabricating and evaluating the performance of an tractor operated bush cutting machine.

Development of bush cutting machine

A mini tractor operated bush cutting machine has been developed in the department of Farm Machinery & Power Engineering, Agricultural Engineering College and Research Institute, Coimbatore for cutting grass and clearing bushes. The bush cutting machine is an attachment to the mini tractor which requires an operator to perform the operation of cutting grass and bushes. The main frame is of size (1000 x 680 mm) fabricated with square tube of size (40 x 40 mm) with the thickness of 3mm. The three point hitch frame was developed in such a way that it can be adjusted from minimum 300 mm to maximum of 900mm to suit any tractor.

The power from the mini tractor engine of 15- 25 hp and 540 rev/min rotational speed from PTO is transmitted with PTO shaft to the gear box with the speed ratio of 1:2. From the gear box power is transmitted to the bush cutting unit through "V" belt pulley arrangement. The shaft speed is increased by using a driving pulley of 300 mm diameter and a driven pulley of 50 mm diameter. The rotational speed available for the cutting the grasses and bush clearing is around 4200 rev/min and 8000 rev/min in standard PTO speeds of 540 & 1000 rev/min respectively.

In this machine two cutting shafts of diameter 20mm and length 370 mm are placed in main frame in vertical position and supported by the UCP bearings. In each cutting shaft, one end is fixed with circular plate of 6 mm thickness and diameter 150 mm. In each circular plate, two numbers of chains of size 12.5 mm and length of 240 mm is riveted to the circular plate attached. The cutting is carried out by impact force at high speed. The machine can be used on rough ground also for cutting the bushes. As the cutting shaft rotates, centrifugal force pushes the chains outward in tight position so as to cut the bushes uniformly. In addition, an adjustable two supporting wheels are provided at the rear corner of the bush cutting machine so as to adjust the height of the bush cutting.

Conclusion

The field capacity of bush cutting machine is 0.12 ha/h with the filed efficiency of 88 per cent. The cost of mini tractor operated bush cutting machine is around Rs. 18,000/- (excluding mini tractor). The cost of operation of mini tractor operated bush cutting machine is Rs. 1200/ha whereas the cost of operation with manual cutting of bushes is Rs.4000/ha. The mini tractor bush cutting machine resulted in 70 per cent saving in cost and 95 per cent savings in time when compared to manual cutting with scythe besides increasing the annual usage of mini tractor.

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View of the bush cutting machine in the actual field condition

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BIG DATA ANALYTICS: A WAY FORWARD IN TRANSFORMING AGRICULTURE

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Abstract
The popularity of big data analytics is increasing as farmers are slowly shifting from traditional methods to adopting new technologies. Big data analytics is the application of statistical and analytical tools for processing high volumes of data from a large database for extracting information and processing to get meaningful insights. In agriculture, big data are available from many sources such as IoT Devices, Remote sensing sensors, satellite images, social media, data repositories, government organizations etc. The success of big data in the future is possible as its adoption becomes popular gradually as we overcome technological, financial, and privacy challenges. Sustainability under the umbrella of big data analytics is a promising aspect towards a secure future in the field of agriculture.

Introduction

Big data refers to the collection, analysis, and application of large and complex datasets which is generated at high velocity. The volume of the datasets is so high that they cannot be easily processed, stored, or analyzed using traditional data processing tools or methods. Big data typically involves advanced techniques such as machine learning, artificial intelligence, and data analytics to extract meaningful insights, trends, and patterns from the data. Big data is characterised by five V's: Volume, velocity, variety, value and veracity (Chi et al. 2016). Big data has a high Volume of data which can range from terabytes to petabytes or more generated by sources like sensors, social media, or business transactions. Velocity refers to the speed at which data is generated and processed, usually in real time. Variety includes a wide range of data types, including structured (databases), semi-structured (XML, JSON), and unstructured (videos, images, social media posts) data. Big data often comes with inaccuracies, inconsistencies, or noise. There is uncertainty and variability in data quality which is called veracity. By value, we mean the potential insights, information and benefits of big data that create business or societal value. To build a strong support system in agriculture, the application of big data enhances decision-making and improves agricultural practices. Big data analytics in agriculture deals with the application of advanced analytical tools to process and extract valuable insights from a huge database.

Sources of Big Data

Data are stored in different types and formats viz., web services, live feeds, archives, static repositories and files (Kamilaris et al., 2017). Big data in agriculture comes from a variety of sources which include:

1. Sensors and IoT Devices

- Soil Sensors: These measure soil moisture, temperature, pH, and nutrient levels.
- Weather Stations: IoT weather stations collect localized data on weather parameters such as temperature, humidity, rainfall, wind speed, etc.

- Livestock Wearables: Devices attached to livestock collect data on the health, movement, and behaviour of animals.

2. Drones and Satellite Imagery

- Remote Sensing: Drones and satellites capture high-resolution images of agricultural fields. These images can be processed to assess crop health, track outbreaks of pests and diseases across regions, estimate biomass and monitor land use changes. Data from smart irrigation systems is used to track and control water usage based on real-time weather and soil data.
- Precision Mapping: Data from satellites, Unmanned Aerial Vehicles, and airplanes is used to create detailed maps of fields that show soil variability, crop health, and water distribution.

3. Farm Machinery and Equipment

- Smart Tractors and Harvesters: Modern agricultural machinery is equipped with GPS, sensors, and data analytics systems that collect data on field conditions, yields, and machine performance during operations.
- Variable Rate Technology (VRT): VRT-enabled equipment uses big data to apply seeds, fertilizers, or pesticides in precise quantities based on field conditions.

4. Agricultural Management Software

- Farm Management Systems (FMS): These platforms integrate various data sources (e.g., weather data, market data, sensor data) to help farmers plan and manage their operations, providing insights into productivity, input use, and profitability.
- Supply Chain Data: Farm management software also tracks data from the entire supply chain, including logistics, storage, and sales.

5. Weather Data Providers

- Government Agencies: National weather services and climate monitoring agencies (e.g., NOAA, UK Met Office) provide real-time and historical weather data that is critical for agricultural decision-making.
- Private Weather Services: Companies like IBM's The Weather Company offer detailed weather data and predictive models tailored specifically to the needs of agriculture.

6. Genomic and Biological Data

- Plant and Animal Genomics: Genetic data from crops and livestock is used for selecting traits like disease resistance, drought tolerance, or higher yields.
- Microbial Data: Soil and plant microbiome studies generate data on the role of microbes in plant health and soil fertility.

7. Market Data and Economic Reports

- Commodity Prices: Data from agricultural commodity markets provides information on price trends, demand, and international trade.
- Supply Chain Data: Data from distributors, retailers, and consumers can provide insights into demand fluctuations, transportation efficiency, and storage conditions.

8. Social Media and Consumer Feedback

- Customer Reviews and Surveys: Online reviews and surveys provide data on consumer sentiment and satisfaction, food preferences, and emerging market trends.

- Social Media Analytics: Data from social media platforms like Twitter or Facebook provide local information on natural hazards and disease pest outbreak.

9. Government and Public Databases

- Census and Surveys: National agricultural censuses, surveys, and statistical agencies (e.g., USDA, FAO) collects data on farm sizes, crop production, labor use, and other relevant metrics, providing a macro-level view of agricultural trends.
- Research Institutions: Public research bodies often publish data on crop performance, agricultural technologies, and economic trends.

10. Satellite Data Providers

- Agencies such as NASA provide valuable data on land use, weather patterns, and climate changes through platforms like Landsat and MODIS (Moderate Resolution Imaging Spectroradiometer).

11. Mobile Apps and Crowdsourced Data

- Agricultural Apps: Many mobile apps allow farmers to collect and input data directly from the field, such as planting dates, crop conditions, or pest sightings. This data can be aggregated to provide regional insights.
- Crowdsourcing Platforms: Platforms like Open Ag Data Alliance (OADA) enable farmers to contribute data, which can then be used for broader agricultural research.

12. Blockchain and Food Traceability Systems

- Blockchain Platforms: Blockchain technology is increasingly being used for food traceability. By recording every step of the supply chain, creates transparent and tamper-proof records of where and how food products are grown, processed, and distributed.
- Certification and Compliance Data: Certification data related to organic farming, fair trade, or other standards can be integrated into big data systems to ensure compliance and transparency in the agricultural sector.

Challenges in Big Data Analytics for Agriculture

1. **Data Integration and Quality**

Data from multiple sources must be integrated and harmonized to provide useful insights. Ensuring compatibility between different data formats and systems is a significant challenge. Inconsistent, incomplete, or inaccurate data can lead to misleading results. Cleaning and validating data is a crucial step in big data analytics.

2. **Privacy and Data Ownership**

Data generated by farms may involve sensitive information, leading to concerns about privacy and ownership. Ensuring that farmers retain control over their data while allowing it to be analyzed is essential.

3. **Technological Barriers**

Technologically challenged farmers lack access to the technologies required to collect and analyze big data. Bridging the digital divide and ensuring access to modern technologies is vital for widespread adoption.

4. **High Cost and Complexity**

The cost of implementing big data analytics solutions, such as installing sensors and purchasing advanced software, can be prohibitive for small-scale farmers. Simplifying tools and making them more affordable is key to increasing adoption.

The Way Foreward

The usage of big data in the recent 8-10 years has been relatively low in the field of agriculture. Although it is at an early developmental stage, it is predicted to be of utmost use in the days to come. The scope of applying big data in agriculture is as follows (Bose, 2020; Kamliaris et al., 2017):

- Coordinating the global supply chain with the field of agriculture would uplift the agriculture sector due to its access to high-quality products (Syngenta Foundation for Sustainable Agriculture, 2016).
- Utilization of better optimization techniques such as metaheuristics, and genetic algorithms (Wari and Zhu, 2016), and neural networks (Erenturk and Erenturk, 2007) to develop better food processing techniques can reduce losses and improve food quality.
- Improved simulation techniques provide better models so that policymakers, farmers and agriculturists can make better decisions (Song et al., 2016).
- Involving self-operating robots for activities such as distinguishing weeds and pests, removing them, and harvesting crops using better screening technologies increases agricultural efficiency.
- The accessibility of software, hardware and big data analytical techniques, and the openness of sources support research, business and public sector initiatives.
- Genome editing changes a crop or animal's genome which is an imitation of the process of mutation (González-Recio et al., 2015) and it is not indicative of the generation of transgenic plants or animals. This technology would supplement existing research in epigenetics

Big data could be used by policymakers to balance need and demand, raise food safety and security, and increase productivity.

Conclusion

Big data analytics is transforming agriculture by enabling more precise, efficient, and sustainable practices. Challenges posed by traditional farming can be overcome with the help of big data (Bose, 2020). The adoption of big data analytics will take time for implementation in agriculture even when infrastructure and technological facilities are available due to certain challenges (Osinga et al., 2022). Through advanced analytical techniques, farmers can improve yields, reduce costs, and make data-driven decisions to address the challenges of food security, climate change, and resource management. Big data analytics favours the growth of research and development towards smart agriculture. Addressing the challenges of data integration, quality, and accessibility is critical for realizing the full potential of big data in agriculture.

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MARINE OTTER: DISTRIBUTION, CONSERVATION AND THREATS

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The marine otter (*Lontra felina*) is a rare and relatively unknown South American mammal of the weasel family (Mustelidae). The scientific name means "feline otter", and in Spanish, the marine otter is also often referred to as gato marino: "marine cat" (Schiaffini, 2022). The marine otter (while spending much of its time out of the water) only lives in saltwater, coastal environments and rarely ventures into fresh water or estuarine habitats. This saltwater exclusivity is unlike most other otter species, except for the almost fully aquatic sea otter (*Enhydra lutris*) of the North Pacific (DeNeve Weeks, 2020).

The marine otter is one of the smallest otters and the smallest marine mammal, measuring 87 to 115 cm (34 to 45 in) from the nose to the tip of the tail and weighs 3 to 5 kg (6.6 to 11.0 lb). The tail measures 30 to 36 cm (12 to 14 in). Its fur is coarse, with guard hairs measuring up to 2 cm (0.79 in) in length covering dense, insulating under fur (Manzuetti, et al., 2023). The marine otter is dark brown above and, on the sides, and fawn on the throat and underside.

The marine otter has webbed paws and strong claws. The ventral side (underside) of the paws are partially covered in fur. It has 36 teeth. The teeth are developed for slicing instead of crushing. The marine otter does not display sexual dimorphism (Macdonald et al., 2017).

***Luntra felina* – Marine otters**

Distinctive Characteristics

- Marine otters are very similar in appearance to freshwater otters.
- The snout is blunt at the tip and the nose pad is naked and relatively flat.
- The tail tapers to a point, typical of freshwater otters
- Marine otters are dark brown above, a lighter fawn colour below

Fig. 582 *Lutra felina*

Size

- Marine otters attain total lengths (including the tail) of slightly over 1 m, and weights up to 4.5 kg

Food and feed

- Marine otters feed on crabs, shrimps, mollusks, and fish.
- They sometimes enter rivers to feed on freshwater prawns.

Behaviour

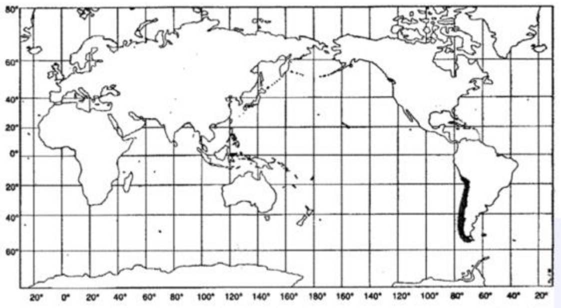
- Very little is known of the biology of the marine otter.
- They are found mostly singly or in pairs, but groups of 3 or more are sometimes seen.

Life cycle

- The reproductive season in not well-known, but much of the breeding may occur in December and January.
- The usual litter of 2 pups is born after a gestation period of 60 to 70 days.

Geographical Distribution

- These coastal otters are found on exposed rocky shores from the southern tip of Chile to southern Peru.
- They have been extirpated from Argentina.



Threat

- This species has been hunted in Chile for fur and because of perceived competition with shellfish fisheries.
- Although legally protected, there is still some poaching.

Conservation

- IUCN Status – Endangered

  Scientific classification

  Kingdom – Animalia
  Phylum – Chordata
  Class – Mammalia
  Sub-class – Eutheria
  Order – Carnivora
  Sub-order – Fissipedia
  Family – Ursidae (polar bears)

Family – Ursidae (polar bear)

- There are 7 species of bears in the world and 6 are wholly terrestrial.
- Grizzly, brown, and black bears of the Northern Hemisphere are often exhibited in zoos and are well-known.
- The single marine species, the polar bear, qualifies as the least aquatic of all marine mammals
- Found in North America, South America, Europe and Asia

Characteristics of Ursidae

- Bears are found on all continents except Antarctica and Australia

- Bears occur in nearly all terrestrial habitats throughout their range, from Arctic tundra and polar ice floes to tropical and temperate forests, mountains, grasslands, and deserts.
- Bears are large, robustly built animals.
- The smallest species, *Helarctos malayanu s*ranges in size from 25 to 65 kg, the largest individuals can weigh up to 800 kg - *Ursus maritimus*.
- Males are larger than females
- Bears have small, rounded ears, small eyes, and very short tails.
- Most species have long, rough fur, and the hairs that make it up are generally unicolored
- Bears give birth to 1 to 4 young, usually 2, at intervals of 1 to 4 years.
- Gestation lengths - 60 to 70 days.
- Births in temperate species occur during the winter when the female is dormant.
- Sexual maturity occurs at from to 3 to 6.5 years old, usually occurring later in males.
- Cubs grow rapidly, polar bears go from 600 grams at birth to 10 to 15 kg within 4 months.
- Young stay with their mother for up to 3 years
- Bears - solitary, with the exception of mothers with their young.
- Polar bears - primarily diurnal

Bears (1 marine species in 1 genus) p. 302

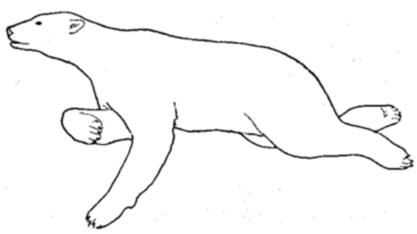
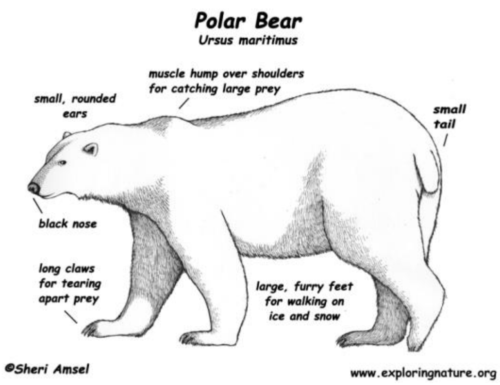


Fig. 578 Ursidae

Ursus maritimus – Polar bear sow

Distinctive Characteristics

- It is not substantially different from other bears in body form.
- Similar in size to brown and grizzly bears (*Ursus arctos*), but is slenderer, and has a long neck and elongated head.
- The ears are small, an adaptation to the cold.
- Polar bears - white, but (depending on lighting and condition) it can appear yellow, light brown, or light grey.
- The nose and skin are black.



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Size

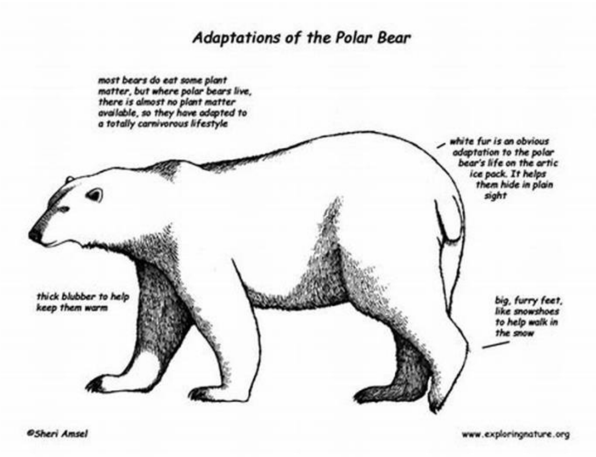
- Males may be up to 250 cm long and weigh 800 kg.
- Females reach lengths and weights of 200 cm and 300 kg, respectively.
- At birth, the tiny cubs weigh only about 0.6 kg

Food and feed

- The primary diet of polar bears consists of ringed seals, but they also take bearded, harp, and hooded seals, and rarely walruses and white whales.
- These bears sometimes eat arctic cod and other forms of animal and vegetable matter

Behaviour

- They also aggregate in areas of great food concentrations.
- These bears can swim rather well, using their large webbed paws.
- They sometimes spend significant periods of time on land.

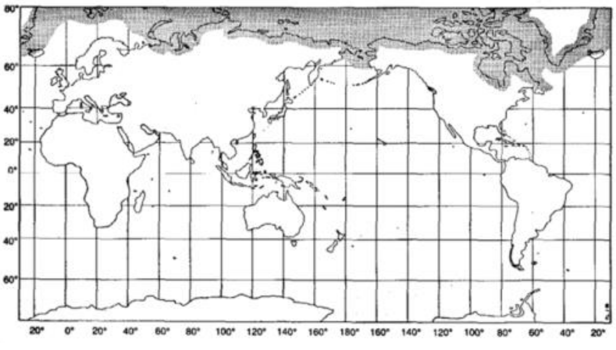


Life cycle

- Polar bears tend to be solitary, but breeding pairs and females with up to 3 cubs may be seen together.
- Mating occurs from April to June.
- Each male may mate with 1 or several females.
- In November to December, the pregnant female excavates a den, where the 1 to 3 cubs are born in December and January.

Geographical Distribution

- Polar bears have a circumpolar distribution in the Northern Hemisphere
- Polar bears are generally associated with sea ice, but they have been seen swimming at sea many kilometers away from the nearest land.



Threat

- There is a long history of hunting, both commercial and subsistence, of the polar bear, mostly for meat and hides.
- There is active management in several areas, and most stocks are stable or increasing.

Conservation -IUCN Status – Vulnerable

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INNOVATIVE POST-HARVEST TECHNOLOGIES: A KEY TO SECURING THE GLOBAL FOOD SUPPLY

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In a world where hunger continues to affect millions, addressing food security remains a pressing concern. While agricultural productivity is crucial in increasing food supply, a significant amount of the harvest is lost before it even reaches consumers. Post-harvest losses—caused by poor handling, inadequate storage, transportation inefficiencies, and pest infestations—are a major roadblock to global food security. It is here that post-harvest technologies play a critical role. These technologies not only minimize losses but also improve food quality, ensuring that the produce is safe, nutritious, and available to those who need it the most.

The Global Challenge of Post-Harvest Losses

According to the Food and Agriculture Organization (FAO), nearly one-third of all food produced globally is wasted or lost. This staggering figure highlights the need for interventions that ensure harvested crops make it from farms to consumers in an optimal condition. Post-harvest losses are particularly severe in developing countries, where lack of infrastructure and limited access to modern technologies exacerbate the problem. Fresh fruits, vegetables, and grains are especially vulnerable, with post-harvest losses often reaching up to 40% in certain regions.

Enhancing Food Security through Post-Harvest Technologies

Post-harvest technologies focus on preserving the quality and extending the shelf life of harvested crops. From innovative storage solutions to advanced processing techniques, these technologies are indispensable in bridging the gap between food production and consumption.

1. Improved Storage Solutions

One of the primary reasons for post-harvest losses is inadequate storage facilities. Traditional storage methods often expose produce to environmental factors such as moisture, pests, and mold, leading to significant spoilage. The development of modern storage technologies—such as controlled atmosphere storage, cold chains, and hermetically sealed bags—has revolutionized the preservation of food. These solutions maintain optimal temperature and humidity levels, significantly reducing spoilage and extending the shelf life of perishables.

2. Innovations in Packaging

Packaging plays a pivotal role in maintaining food quality post-harvest. Advances in smart packaging technologies, which can monitor and respond to changes in the environment (such as temperature and humidity), are helping reduce spoilage. Biodegradable packaging materials are also gaining popularity, offering an eco-friendly alternative to traditional plastics while ensuring food remains fresh during transportation and storage.

3. Processing and Value Addition

Post-harvest technologies also include food processing and value addition. Processing methods such as drying, canning, and freezing transform perishable products into more stable forms, reducing the risk of spoilage. Value-added products not only last longer but can also open up new market opportunities for farmers, contributing to economic development while ensuring food security.

4. Cold Chain Management

A cold chain is a temperature-controlled supply chain that is essential for preserving the quality of perishable food items like fruits, vegetables, dairy, and meat. The integration of cold chain systems—from harvest to consumer—ensures that food remains fresh, minimizing spoilage during transport and storage. Investments in cold chain infrastructure have proven especially beneficial in tropical regions, where high temperatures accelerate food degradation.

Addressing the Challenges

Despite the clear benefits of post-harvest technologies, several challenges remain in their widespread adoption. High upfront costs, lack of technical know-how, and limited access to energy in rural areas are significant barriers, particularly in developing countries. Furthermore, while technology plays a crucial role, it must be paired with improved agricultural policies, farmer education, and infrastructure development to have a lasting impact.

The Way Forward

As the global population continues to rise, securing enough food to meet demand will become even more challenging. Post-harvest technologies offer a viable solution by reducing losses and ensuring the safe distribution of food. By minimizing waste and improving food quality, these technologies contribute directly to global food security.

Collaboration between governments, private companies, and international organizations is essential in scaling up these innovations. Investment in research and development, coupled with farmer training and education, can help bridge the gap between production and consumption. By embracing these solutions, we can ensure that the food grown to feed the world actually reaches the plates of those who need it.

Conclusion

As the global population continues to grow, the pressure on agricultural systems to feed billions of people will only intensify. Post-harvest technologies offer a critical solution to this challenge, reducing losses and ensuring that more food reaches consumers. By minimizing waste, improving the quality of produce, and enhancing the efficiency of supply chains, these technologies contribute directly to global food security.

However, widespread adoption of these technologies requires a concerted effort from all stakeholders, including governments, private enterprises, and international organizations. Investment in research, infrastructure, and education will be essential to overcoming the barriers to implementation and unlocking the full potential of post-harvest innovations. Only by addressing food losses at the post-harvest level can we ensure a future where food is abundant, accessible, and secure for all.

This version expands on the previous sections and provides a broader global perspective on post-harvest technology adoption, while also emphasizing the need for collaborative efforts in addressing food security challenges.

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THE ROLE OF *Tecomella undulata* IN COMBATING DESERTIFICATION

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Abstract

Desertification, a critical environmental issue, threatens ecosystems, agriculture and livelihoods worldwide. Among the strategies to combat desertification, reforestation and the use of drought-resistant plants like *Tecomella undulata* (Indian trumpet tree) have proven effective. Native to the arid regions of India, particularly Rajasthan, *Tecomella undulata* plays a vital role in ecological restoration due to its resilience and ability to thrive in harsh environments (Jat et al., 2020). Its deep root system stabilizes soil, reduces erosion and improves soil fertility through nitrogen fixation, enhancing agricultural productivity (Soni and Bhati, 2021). The tree also supports water conservation by accessing underground water and creating microclimates that promote biodiversity (Kumar and Choudhary, 2018). Economically, it provides high-quality timber, medicinal extracts and income opportunities for local communities (Sharma et al., 2019). Integrating *Tecomella undulata* into agroforestry systems can further boost livelihoods and agricultural output. However, challenges such as proper management, seedling availability and potential invasiveness must be addressed (Venkateswarlu, 1993). Successful reforestation projects, such as those in the Thar Desert, demonstrate the tree's potential in combating desertification (Aggarwal et al., 1994). With its numerous ecological and economic benefits, *Tecomella undulata* stands as a promising solution to enhance environmental resilience and support sustainable development in arid regions.

Introduction

Tecomella undulata is a deciduous tree native to the arid regions of India, particularly Rajasthan. Known for its striking yellow flowers and robust nature, this tree is well adapted to harsh environments. Its deep root system enables it to access groundwater, making it an ideal candidate for reforestation efforts in dry areas.

*Tecomella undulata (*Rohida)

Status	Endangered (EN) on India's National Red List
Other names	Rohida, desert teak, Marwar teak
Description	Medium-sized tree that produces quality timber
Habitat	Arid regions, desert or dry shrubland biome, gentle hill slopes, ravines,

	stabilized sand dunes
Range	Oman, southwest Iran to northwest India
Uses	Timber, medicinal tree, anti-obesity formulation, blood purifier

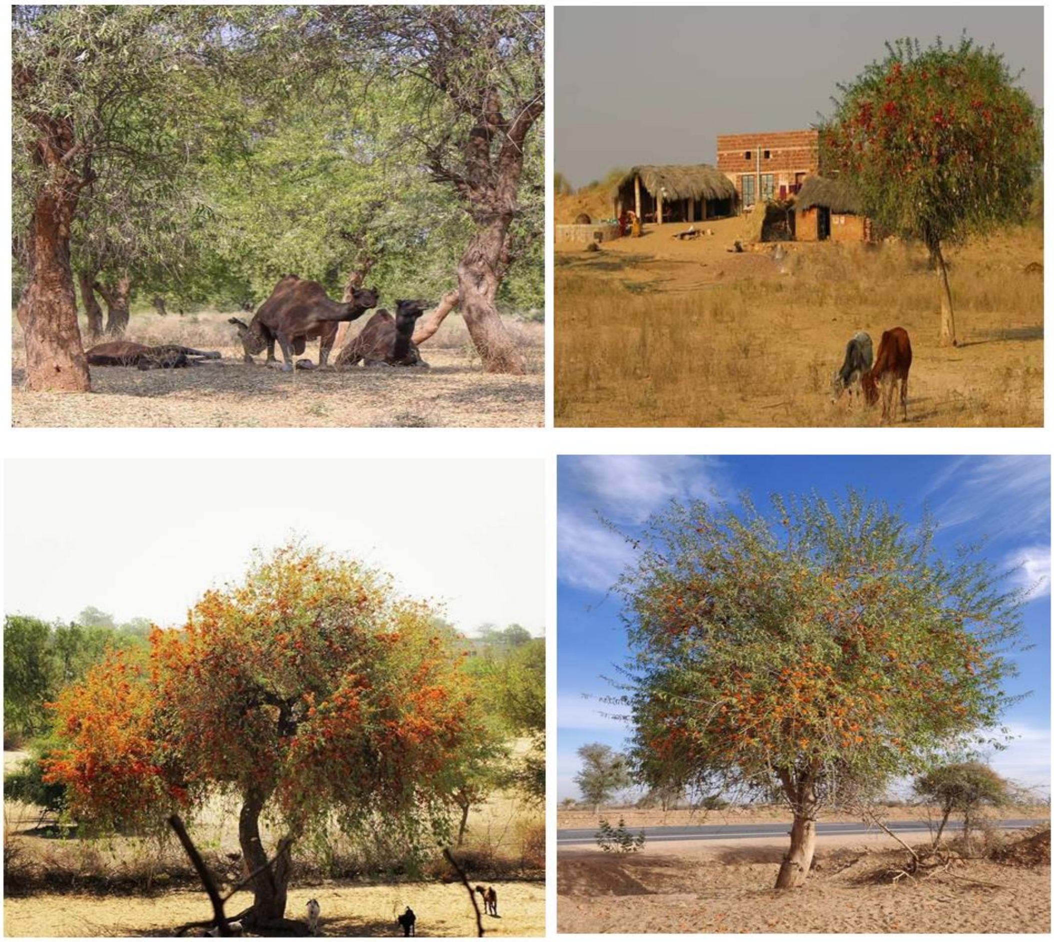

Figure: 1. Close-ups of the tree's roots, illustrating their role in soil stabilization

Figure: 2. Tecomella undulata (Rohida) Timber Products

Ecological Benefits

1. **Soil Stabilization**: *Tecomella undulata* has an extensive root system that helps bind the soil, preventing erosion and reducing the risk of sandstorms. By stabilizing the soil, it contributes to the retention of moisture, essential for other plant species and overall ecosystem health.
2. **Improving Soil Fertility**: This tree species is known to enhance soil fertility through its leaf litter, which decomposes to enrich the soil with organic matter. Additionally, its roots host nitrogen-fixing bacteria, which can improve soil nutrient content, benefiting neighboring plants and crops.
3. **Microclimate Regulation**: By providing shade and reducing wind speed, *Tecomella undulata* can create a more favorable microclimate for other vegetation. This promotes biodiversity and can help restore degraded landscapes by facilitating the growth of additional flora.
4. **Water Conservation**: The deep root systems of *Tecomella undulata* allow it to access underground water sources, which can be crucial in arid regions. Its presence can also help retain moisture in the soil, benefiting other plants in the vicinity.

Economic Importance

1. **Timber and Non-Timber Products**: *Tecomella undulata* is highly valued for its durable timber, used in construction and furniture making. Its wood is resistant to decay and pests, making it a sustainable choice for various applications. Moreover, the tree produces non-timber products like medicinal extracts, which have economic potential for local communities.
2. **Livelihoods for Local Communities**: By promoting the cultivation of *Tecomella undulata*, local communities can benefit from both timber and non-timber resources. This diversification of income can enhance community resilience against economic shocks and environmental changes.
3. **Agroforestry Potential**: Integrating *Tecomella undulata* into agroforestry systems can enhance agricultural productivity. The tree can be planted alongside crops to provide shade, improve soil quality and offer additional income streams through timber and other products.

Challenges and Considerations

While *Tecomella undulata* presents numerous benefits, there are challenges to its widespread adoption. These include the need for proper management practices, ensuring the availability of quality seedlings and addressing the potential for invasive behavior in non-native regions. Education and awareness among local communities are essential for fostering a sustainable approach to planting and managing this species.

Successful Reforestation Projects

Numerous initiatives across India have successfully incorporated *Tecomella undulata* into their reforestation efforts. In the Thar Desert, for example, local NGOs have collaborated with communities to plant this tree, leading to improved soil quality and increased agricultural yields. Such projects illustrate how traditional knowledge, combined with modern ecological practices, can provide sustainable solutions to combat desertification.

Table: Plant species suitable for sand dune Stabilization in the Thar Desert, India

Annual rainfall Zone (mm)	Trees	Shrubs	Grasses
150-300	*Prosopis juliflora, Acacia tortilis, Acacia senerged*	*Calligonum polygonoides, Ziziphus nummularia,*	*Lasiurus sindivus*
300-400	*Acacia tortilis, Acacia senegal, Prosopis juliflora, Prosopis cineraria, Tecomella undulata, Parkinsonia aculeata, Acacia nubica, Dichrostachys glomerata,*	*Ziziphus mauritiana, Z. nummularia, C. polygonoides, C. colosynthis*	*Cenchrus ciliaris, C. setigerus, L. sindicus, Saccharum munja*
400-550	*Acacia tortilis, Acacia senegal, Ailanthus excelsa, Albizia lebbek, Prosopis cineraria, Prosopis juliflora, Dalbergia sissoo,*	*Z. mauritiana, Cassia auriculata*	*C. ciliaris, C. setigerus, S. munja, Panicum antidotale*

Venkateswarlu, J. (1993)

Conclusion

Tecomella undulata emerges as a powerful ally in the fight against desertification. Its ecological benefits-ranging from soil stabilization and fertility improvement to microclimate regulation-make it a valuable asset in arid landscapes. Coupled with its economic advantages, this tree has the potential to support sustainable development while addressing one of the most critical environmental challenges of our time. As we explore innovative solutions to desertification, the role of resilient plant species like *Tecomella undulata* is increasingly vital. By leveraging its capabilities, we can foster healthier ecosystems and stronger communities in the face of an uncertain future.

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ROLE OF AZOSPIRILLUM IN THE GROWTH OF CEREAL CROPS

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Introduction

Cereal crops, including maize, rice, wheat, and sorghum, are essential staples that support global food security. These crops, members of the Poaceae family, have been cultivated for thousands of years to utilize the edible grains they produce. However, the production of these cereals is often limited by nitrogen availability, a critical nutrient for plant growth. Overusing chemical fertilizers has raised concerns about their sustainability and environmental impact, prompting researchers to seek alternative nitrogen sources. Biological Nitrogen Fixation (BNF) by diazotrophic bacteria presents a promising solution. These bacteria, which convert atmospheric nitrogen into a form usable by plants, contribute substantially to the nitrogen economy of agricultural soils. Despite their potential, diazotrophs are typically present in low quantities in plant environments. Recent advancements suggest that enhancing BNF through either plant-bacteria interactions or genetic engineering could offer a more sustainable approach to nitrogen management. By increasing the efficiency of nitrogen fixation or introducing nitrogen-fixing capabilities directly into cereal crops, it may be possible to reduce reliance on chemical fertilizers and mitigate environmental impacts.

Azospirillum and its BNF ability

Azospirillum spp., a type of nitrogen-fixing bacteria, promotes plant growth primarily through biological nitrogen fixation, which enhances nitrogen content in plant shoots and grains and reduces the need for synthetic nitrogen fertilizers. However, it contributes less than 20% of the overall nitrogen uptake in plants. Recent studies suggest that its role in agriculture might be less significant.

Beyond nitrogen fixation, *Azospirillum spp*. also supports plant growth through several other mechanisms. These include the production of phytohormones like indole-3-acetic acid (IAA), phosphate solubilization, biocontrol of phytopathogens, and mitigation of stress from soil salinity and pollutants. The additive hypothesis explains that multiple mechanisms, rather than a single one, contribute to the beneficial effects of *Azospirillum spp.* on plants. Over decades of research, it has been established that these bacteria produce a range of plant growth regulators, including auxins, gibberellins, ethylene, abscisic acid, nitric oxide, and polyamines.

Azospirillum bacteria can fix atmospheric nitrogen (N_2) into ammonia (NH_3), which plants can use. This process, known as biological nitrogen fixation (BNF), is facilitated by the enzyme nitrogenase. Azospirillum efficiently contributes up to 18% of the nitrogen needed by plants, with strains like *Azospirillum lipoferum* N-4 providing about 66% of the nitrogen for crops like rice. Some mutants of *Azospirillum lipoferum* can fix nitrogen at high temperatures, though not all are effective. Inoculating plants with Azospirillum promotes early growth, higher yields, and better nitrogen uptake, aided by phytohormones and enhanced nutrition.

Azospirillum as PGPR

1. Nitrogen Fixation

Azospirillum species can fix atmospheric nitrogen (N_2) through a process mediated by nitrogenase, an enzyme complex that reduces nitrogen gas to ammonia (NH_3). This conversion enriches the soil with bioavailable nitrogen, vital for plant growth and development.

Benefits

The application of Azospirillum has been shown to significantly increase nitrogen content in plants, leading to improved growth rates and yields. For example, studies indicate that Azospirillum inoculation can enhance wheat yields by 15-30%, particularly in nitrogen-deficient soils (Graham & Vance, 2000; Bashan et al., 2013). This biological nitrogen fixation helps reduce reliance on chemical fertilizers, promoting sustainable agricultural practices.

2. Phytohormone Production

Types of Hormones

Azospirillum synthesizes various phytohormones that influence plant growth positively:

- **Auxins**: These hormones stimulate root elongation and lateral root formation, resulting in a more extensive root system capable of better nutrient and water absorption.
- **Cytokinins**: By promoting cell division and differentiation, cytokinins enhance shoot growth and leaf expansion.
- **Gibberellins**: These hormones facilitate stem elongation and flowering, which can lead to increased crop yields.

Effects on Growth

The production of these hormones leads to enhanced root and shoot growth, resulting in more vigorous plants. For instance, rice plants inoculated with Azospirillum have shown significantly greater root biomass, which correlates with improved nutrient and moisture uptake (Khan et al., 2009).

3. Enhanced Nutrient Uptake

- **Nutrient Solubilization**
  Azospirillum plays a critical role in the solubilization of essential nutrients, particularly phosphorus. By producing organic acids and enzymes, Azospirillum can convert insoluble forms of phosphorus into bioavailable forms, making them accessible to plants.
- **Iron Mobilization**
  In addition to phosphorus, Azospirillum enhances the availability of iron, a micronutrient that is often limited in alkaline or calcareous soils. Increased iron availability is crucial for chlorophyll synthesis and overall plant health, leading to improved growth and development (Gonzalez *et al*., 2012).
- **Impact on Yield**
  Field studies consistently demonstrate that improved nutrient uptake due to Azospirillum inoculation correlates with increased cereal crop yields. For instance, a study on maize showed a 20% yield increase with Azospirillum application, attributed to enhanced phosphorus and nitrogen availability (Zhang *et al*., 2015).

4. Soil Health and Structure

- **Microbial Diversity**
  Azospirillum contributes to improved soil health by increasing microbial diversity. A diverse soil microbial community is essential for nutrient cycling, organic matter decomposition, and overall soil fertility.
- **Organic Matter Decomposition**
  Azospirillum promotes the breakdown of organic matter, enriching the soil and enhancing its physical properties. Healthy soils with good structure facilitate better water retention and aeration, which are beneficial for root development (Lynch & Whipps, 1990).

5. Stress Resistance

- **Drought Tolerance**
  Cereal crops frequently encounter drought conditions, which can severely impact yields. Azospirillum enhances root architecture, enabling plants to access deeper water sources. Research shows that inoculated plants maintain turgor pressure more effectively during drought, resulting in improved survival and growth rates (Zahir *et al*., 2009).
- **Salinity Tolerance**
  Salinity is a significant challenge for agriculture, particularly in arid and semi-arid regions. Azospirillum helps mitigate the adverse effects of salinity by improving nutrient uptake and physiological responses in plants, enabling them to tolerate saline conditions better.

6. Plant-Microbe Interactions

- **Root Colonization**
  Azospirillum effectively colonizes the rhizosphere, forming biofilms around plant roots. This colonization provides a protective environment and facilitates the exchange of nutrients and growth-promoting signals between the bacteria and the plant.
- **Induced Systemic Resistance (ISR)**
  The presence of Azospirillum can induce systemic resistance in plants, enhancing their defenses against pathogens. This ISR mechanism contributes to healthier plants and

reduces the need for chemical pesticides, promoting an environmentally friendly approach to agriculture (Bashan & Holguin, 1998).

Field Studies and Applications

Numerous field trials have demonstrated the effectiveness of Azospirillum as a biofertilizer for various cereal crops. Research indicates that Azospirillum inoculation leads to significant increases in yield, improved crop quality, and enhanced resilience to environmental stresses. A comprehensive meta-analysis of several studies indicated yield increases of 10-25% in Azospirillum-treated crops compared to untreated controls (Zhang *et al*., 2015).

Application Methods

Azospirillum can be applied using various methods, including:

- **Seed Inoculation**: Coating seeds with a suspension of Azospirillum before planting to ensure root contact upon germination.
- **Soil Application**: Mixing Azospirillum with the soil during planting or as a side-dressing to improve root colonization.
- **Incorporation into Compost**: Adding Azospirillum to compost can enhance the microbial content and effectiveness of organic fertilizers.

These application methods are relatively straightforward and can be integrated into existing agricultural practices.

Azospirillum biofertilizer

Conclusion

Azospirillum serves as a multifaceted agent in promoting the growth and productivity of cereal crops. Its mechanisms of action, including nitrogen fixation, hormone production, enhanced nutrient uptake, and improved stress resistance, offer a sustainable alternative to chemical fertilizers. The integration of Azospirillum into agricultural practices not only boosts crop yields but also promotes soil health and environmental sustainability.

Future research should focus on optimizing the use of Azospirillum across different soil types and climatic conditions, as well as exploring its potential synergistic effects in combination with other beneficial microbes. By advancing our understanding of Azospirillum's interactions with cereal crops, we can further enhance the productivity and sustainability of global food systems.

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SEAWEED-BASED SKINCARE PRODUCTS: WHAT'S BEHIND THE HYPE ?

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Introduction

Seaweed-based skincare products have gained significant popularity in recent years due to their wide range of beneficial properties for skin health. The "hype" around these products is supported by the unique combination of vitamins, minerals, antioxidants, and bioactive compounds found in seaweed, which can nourish, protect, and rejuvenate the skin. Here's a closer look at what makes seaweed-based skincare so appealing:

1. Rich Nutrient Profile

- **Vitamins and Minerals**: Seaweeds are packed with essential nutrients like vitamins A, C, E, and K, as well as minerals such as calcium, magnesium, potassium, and iodine. These nutrients help strengthen the skin barrier, promote healing, and provide overall nourishment.
- **Amino Acids**: Seaweed contains amino acids that can help improve skin elasticity and hydration. Amino acids also play a key role in repairing damaged skin tissues (Pereira, 2018).

2. Hydration and Moisturization

- **Natural Humectants**: Seaweed is a natural humectant, meaning it helps the skin retain moisture by attracting water from the environment. This makes seaweed-based products particularly effective in hydrating dry or dehydrated skin.
- **Polysaccharides**: Seaweeds contain polysaccharides like alginates and carrageenan, which form a protective layer on the skin's surface, preventing moisture loss and improving skin texture.

3. Antioxidant Properties

- **Fighting Free Radicals**: Seaweeds are rich in antioxidants like vitamins C and E, as well as compounds like phlorotannins and fucoidan, which help neutralize free radicals. Free radicals contribute to skin aging by breaking down collagen and causing oxidative stress. Seaweed-based products help protect the skin from environmental damage, pollution, and UV exposure (Kalasariya etal.,2021).
- **Anti-Aging Effects**: The antioxidants in seaweed help reduce the appearance of fine lines, wrinkles, and dark spots by promoting collagen production and protecting skin cells from oxidative damage.

4. Anti-Inflammatory and Soothing Effects

- **Reducing Redness and Irritation**: Seaweed has natural anti-inflammatory properties, which can help calm and soothe irritated or sensitive skin. Compounds like fucoidan and polyphenols reduce inflammation and redness, making seaweed-based products ideal for conditions like eczema, rosacea, and acne-prone skin.
- **Soothing Sunburn and Damage**: Seaweed extracts can also help soothe sunburned skin and repair UV-damaged cells, making them beneficial for post-sun exposure treatments.

5. Detoxification and Cleansing

- **Drawing Out Toxins**: Seaweeds, particularly brown seaweeds, are known for their detoxifying properties. They contain compounds like alginic acid that help draw out impurities, heavy metals, and pollutants from the skin. This makes seaweed-based masks and cleansers highly effective for deep cleansing.
- **Oil Regulation**: Seaweed helps balance oil production in the skin, making it a good ingredient for people with oily or combination skin types. It cleanses pores without stripping the skin of its natural oils.

6. Brightening and Even Skin Tone

- **Reducing Hyperpigmentation**: Seaweed extracts have been shown to reduce the appearance of dark spots, hyperpigmentation, and uneven skin tone. This is due to compounds like phlorotannins, which inhibit the production of melanin, helping to brighten the skin and promote a more even complexion.
- **Promoting Cell Turnover**: Seaweed stimulates cell regeneration, which can lead to smoother, more radiant skin. This is particularly useful for people dealing with dull or tired-looking skin.

7. Natural Exfoliation

- **Mild Exfoliants**: Seaweeds like red algae contain natural exfoliating agents that gently remove dead skin cells, unclog pores, and encourage new cell growth. Unlike harsh chemical exfoliants, seaweed-based scrubs provide a gentle exfoliation, making them suitable for sensitive skin.

8. Protection Against Environmental Stressors

- **UV Protection**: While seaweed-based skincare should not replace sunscreen, certain compounds in seaweed, such as mycosporine-like amino acids (MAAs), provide some degree of protection against UV radiation. These compounds help shield the skin from UV damage and photoaging.
- **Pollution Defense**: Seaweeds act as a barrier against environmental pollutants, which can cause premature aging, inflammation, and other skin issues. Seaweed's ability to detoxify and neutralize harmful particles can help reduce the effects of pollution on the skin.

9. Sustainability

- **Eco-Friendly Ingredient**: One of the reasons for the growing popularity of seaweed-based skincare is its sustainability. Seaweed is a renewable resource that grows quickly in oceans, without the need for freshwater, fertilizers, or pesticides. This makes it an eco-friendly ingredient, aligning with the increasing consumer demand for sustainable and ethical beauty products.

10. Variety of Seaweeds and Their Benefits

Different types of seaweed offer specific benefits:

- **Brown Seaweed (Kelp, Wakame)**: Rich in antioxidants, minerals, and polysaccharides, brown seaweed is excellent for anti-aging, hydration, and detoxification.
- **Red Seaweed (Nori, Dulse)**: Known for its high levels of amino acids and polysaccharides, red seaweed is great for soothing inflammation, boosting collagen production, and promoting skin healing.
- **Green Seaweed (Ulva, Sea Lettuce)**: High in chlorophyll and vitamins, green seaweed has brightening and detoxifying properties, helping to revitalize dull or tired skin.

Conclusion

Seaweed-based skincare products are more than just a trend—they offer a combination of nourishing, hydrating, and protective benefits for the skin. With their rich blend of vitamins, minerals, antioxidants, and anti-inflammatory properties, seaweeds can address a range of skin concerns from aging and dryness to irritation and hyperpigmentation. Moreover, their eco-friendly and sustainable nature makes them an attractive option for conscious consumers looking for effective, natural skincare solutions.

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THE ART OF FLOWER PRESERVATION: TRADITIONAL AND MODERN TECHNIQUES

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Abstract

The preservation of flowers is a practice that dates many years which has changed over the years with integrating both old and new methods of keeping the flowers in their beauty and spirit. For ages, older approaches such as air drying, pressing, and using silica gel have been applied to keep flowers for display and even sentimental reasons. Such methods tend to focus more on the ease of use and availability while ensuring that the natural colours and textures are retained. The last few years have however seen the introduction of modern techniques such as freeze-drying, resin treatment, and microwave ovens which aim at increasing the shelf life and colour plus shape retention of flowers put under preservation. The new methods enhance process time and the shape retention of vertical elements to higher levels compared to the old methods where applicable. Given the growing worries over the effects of climate change, the concept of 'Green' has also encouraged practices which have low levels of flower preservation and distribution cost. This paper examines the history, practices, and uses of traditional flower preservation and contemporary flower preservation considering their place in culture, art, and business in the floral market today.

Keywords : Flower preservation, drying, Longevity of flowers, Eco-friendly

Introduction

Flowers have long been admired for their beauty, symbolism, and emotional significance, but their fleeting nature often limits their enjoyment to just a few days. The art of flower preservation, which dates back centuries, offers a solution by capturing the essence of blooms and extending their lifespan. From the simplicity of air drying to the precision of modern freeze-drying, flower preservation has evolved significantly, blending traditional and contemporary techniques. These methods not only serve to retain the aesthetic appeal of flowers but also preserve memories attached to special events, create lasting decorative pieces, and support the floriculture industry. As more people seek sustainable ways to enjoy nature's beauty, the demand for preserved flowers has grown, giving rise to innovative techniques that maintain the integrity of the flowers in their most vibrant and lifelike forms. This article delves into the fascinating world of flower preservation, exploring both time-honoured practices and cutting-edge advancements.

Traditional Techniques of Flower Preservation

Traditional flower preservation methods date back centuries and are still widely practiced today due to their simplicity and the low cost involved. These techniques often rely on natural drying processes or manual pressing, which help retain the flowers' structure and color while slowing down their natural decomposition. Let's explore the most common traditional methods:

1. Air Drying

One of the oldest and most commonly used methods, air drying involves hanging flowers upside down in a dry, dark, and well-ventilated area. This allows the moisture in the flower to evaporate slowly while maintaining most of its natural form. The drying process can take anywhere from a few days to weeks, depending on the type of flower. This method works particularly well for robust flowers such as roses, lavender, and hydrangeas. While air-dried flowers lose some vibrancy and become more fragile, they are often used in rustic floral arrangements or as home décor.

2. Pressing

Pressing flowers is another age-old technique, often used to create floral art, bookmarks, or cards. In this method, flowers are placed between sheets of paper or in a flower press and weighted down to flatten them. As the moisture escapes, the flowers dry in their pressed state. Pressing is ideal for flowers with a naturally flat structure like pansies, daisies, and violets. It preserves the colour fairly well, though the flowers lose their three-dimensional shape. Pressed flowers are highly valued in art and scrapbooking.

3. Silica Gel Embedding

Silica gel is a desiccant, a substance that absorbs moisture from flowers. By embedding flowers in silica gel and sealing them in an airtight container, moisture is drawn out of the petals, leaving them preserved. Silica gel is particularly effective for delicate flowers like lilies or tulips, and it helps retain the bloom's shape and colour. The drying process typically takes a few days, resulting in flowers that look more lifelike than those air-dried.

4. Glycerin Preservation

In this method, flowers are soaked in a mixture of glycerin and water. The glycerin replaces the water content within the flower, making the petals flexible and preventing them from becoming brittle. The flowers retain their shape, although the colours may darken. This method is commonly used for foliage like eucalyptus, as it keeps the leaves supple and long-lasting.

Modern Flower Preservation Techniques

With advances in technology, modern flower preservation techniques have emerged, offering more control over the preservation process, faster results, and a higher degree of precision. These methods are now commonly used in the floral industry for crafting high-quality, long-lasting floral arrangements.

1. Freeze-Drying

Freeze-drying is a cutting-edge method that produces remarkably realistic preserved flowers. The flowers are first frozen at very low temperatures, and then a vacuum is applied to remove the moisture through sublimation-where ice turns directly into vapor. This process leaves the flower's structure intact, preserving not only its shape but also its colour and texture. Freeze-dried flowers can last for years and are commonly used in wedding bouquets, memorials, and high-end floral arrangements.

2. Resin Encapsulation

Resin preservation is a modern technique that involves encasing flowers in clear resin, often in the form of blocks or jewellery. This method creates a permanent, three-dimensional display of the flower, ideal for preserving sentimental blooms like wedding or anniversary flowers. The resin not only preserves the flower but also enhances its visual appeal, giving it a glossy, glass-like finish. While the process can be intricate and requires curing time, resin-preserved flowers are durable and long-lasting.

3. Microwave Drying

Microwave drying is a faster alternative to traditional air drying. Flowers are placed between absorbent material (like paper towels) and microwaved in short intervals to draw out moisture quickly. This method retains the flower’s colour better than air drying but may not preserve the structure as effectively. It is often used for quickly preserving flowers for crafts or temporary arrangements.

4. Wax Dipping

In wax dipping, flowers are coated with a layer of paraffin wax to preserve their form and colour. The wax helps seal in moisture and protect the petals from damage. This technique is often used for short-term preservation, such as floral displays for events. While wax-dipped flowers eventually deteriorate, they can last several months and maintain a fresh appearance for extended periods.

Applications and Benefits of Flower Preservation

Flower preservation is not just an artistic or sentimental practice but also has practical applications in various industries.

1. Artistic and Crafting

Preserved flowers are frequently used in art projects, scrapbooking, and home décor. Pressed flowers can be framed or embedded in handmade paper, while resin flowers are turned into stunning jewellery or keepsakes. These crafts allow individuals to preserve flowers from special occasions such as weddings, birthdays, or anniversaries.

2. Floriculture and Commercial Use

In the floral industry, preservation has expanded the range of products available to consumers. Preserved flowers are often used in arrangements where fresh flowers would not last, such as in environments with little water or sunlight. Freeze-dried and glycerin-preserved flowers are popular in floral boutiques, allowing customers to enjoy the appearance of fresh flowers without the need for maintenance.

3. Environmental and Sustainable Practices

As sustainability becomes more important in all industries, flower preservation is being explored as an eco-friendlier alternative to constantly sourcing fresh flowers. Preserved flowers reduce the need for constant harvesting and transportation, lowering the carbon footprint associated with fresh blooms. They also minimize waste, as preserved flowers can last much longer than fresh ones.

Challenges and Future Innovations

While flower preservation offers many benefits, there are challenges to consider. Traditional methods often result in brittle flowers with reduced vibrancy, while modern techniques can be costly and require specialized equipment. Additionally, preserving flowers can sometimes lead to chemical exposure, depending on the method used. As the floral industry continues to evolve, new innovations are likely to emerge that focus on improving preservation techniques while minimizing environmental impact.

Conclusion

Flower preservation is an art form that has gracefully evolved over centuries, offering both traditional charm and modern efficiency. Whether used for sentimental reasons, artistic expression, or commercial purposes, the preservation of flowers allows us to hold on to the beauty of nature long after its initial bloom. With a range of techniques available-from simple air drying to advanced freeze-drying flower preservation continues to thrive as both a craft and a science, keeping memories alive and flowers beautiful for years to come.

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THE IMPORTANCE OF POLLINATOR DIVERSITY: A DEEP DIVE INTO THE IMPACT OF HONEY BEE SPECIES ON ECOSYSTEMS

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Abstract
Pollination is a critical function of honey bees (*Apis mellifera*, *Apis dorsata*, and *Apis cerana indica*) in preserving the health of ecosystems and food security. However, several dangers exist for these species, such as illnesses, pesticide use, habitat loss, and climate change. The significance of diversity in honey bee populations and the effects of their decrease on ecosystems and food supply are discussed in this article. To safeguard these essential pollinators, we emphasise the necessity for conservation efforts while discussing each species' distinctive traits and contributions. By investigating the intricate connections between honey bees, their surroundings, and the effects of different threats, we may create practical plans that will guarantee these important species' long-term survival and adaptability.

Keywords: Honey bees, Pollination, Biodiversity, Conservation, Apis mellifera, Apis dorsata, Apis cerana indica, Ecosystem health, Food security

Introduction

The unsung heroes of our planet, pollinators are essential to preserving the delicate balance of ecosystems. Honey bees (*Apis* spp.) are among the most well-known and significant of these pollinators. They are frequently referred to as the poster children of pollination because of their busy buzzing and honey production. But the value of a diverse range of pollinators goes far beyond bees. In actuality, our wide variety of crops and wildflowers require more than one species of honey bee to adequately pollinate them. The importance of pollinator diversity in preserving ecosystem health and food


Pic credit: Anderson Magazine

security has been emphasised by recent studies. The influence of various honey bee species on ecosystems must be understood in light of the global decline in pollinator populations.

This article delves into the world of *Apis mellifera*, *Apis dorsata*, and *Apis cerana indica*, exploring their unique characteristics, habits, and habitats. We can comprehend the necessity of conserving pollinator variety and the far-reaching effects of inaction by looking at the significance of these species.

Honey Bee Species

The highly social species of bees known as honey bees (*Apis* spp.) are well-known for their intricate communication, intricate social structure, and ability to produce honey. Three of the most prevalent species among the seven identified are *A. mellifera, A. dorsata*, and *A. cerana indica. A. mellifera*, also referred to as the Western honey bee, is a highly adaptive species that is kept extensively for agricultural pollination and honey production. It originated in Africa, Europe, and Western Asia. This species is prized for its gentle nature and abundant honey output.

On the other hand, *A. dorsata*, sometimes known as the giant honey bee, is the largest species of honey bee found in South and Southeast Asia; its workers can grow up to 2 cm in length. This species is renowned for its hostile demeanour and high honey production. The Indian honey bee, *A. cerana indica*, is a native of Southeast Asia and the Indian subcontinent. It is well suited to tropical and subtropical regions. This species is well renowned for both its great brood output and illness resilience.

These species are distinguished from one another by distinctive traits, lifestyles, and environments. Comprehending these distinctions is essential for the proficient preservation and administration of honey bee populations. We can better adapt our strategies to match the unique requirements of each species and support robust, healthy populations if we are aware of their distinctive characteristics.

Foraging Behaviour and Pollination Efficiency

There are notable differences in the foraging habits and pollination effectiveness of *A. mellifera, A. dorsata,* and *A. cerana indica*. Because of its quick foraging, *A. mellifera* can visit a large number of blooms in a short period of time. Because of this, it is a useful pollinator for crops that need a lot of pollination, such as apples and almonds. *A. dorsata*, on the other hand, forages more slowly but can transport more pollen and nectar due to its bigger body size, which makes it an important pollinator for tropical crops like bananas and mangoes. Because of their unusual foraging habits, *A. cerana indica* frequently visits a variety of blooms in a single trip. Because of this, it is crucial for pollinating crops like cardamom and coffee, which require pollination from multiple sources. Furthermore, it has been noted that *A. cerana indica* is more effective at gathering pollen than *A. mellifera*, which makes it a useful tool for pollination. These species' feeding habits also affect how well they pollinate crops; in some cases, *A. mellifera* and *A. cerana indica* are more effective than others.

These species differ in how they forage and how well they pollinate, which emphasises how crucial it is to preserve and manage a variety of pollinator populations. We can maximise each species' use in pollination and maintain the long-term health of food systems and ecosystems by knowing their distinct advantages.

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Ecosystem Services and Biodiversity

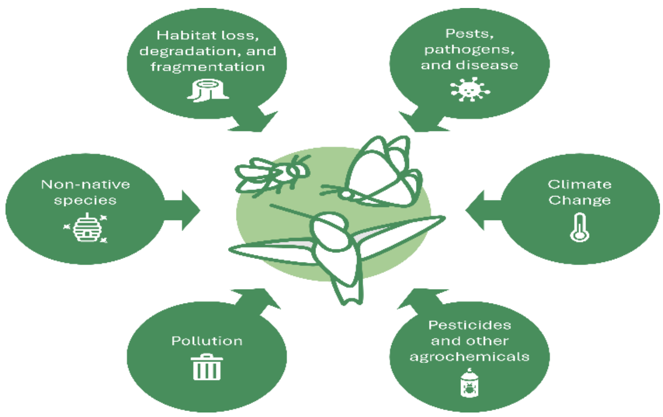
Certain species of honey bee are essential to the preservation of biodiversity and ecosystem services. Among other ecological services, *A. mellifera, A. dorsata*, and *A. cerana indica* provide pollination, pest management, and nutrient cycling. They aid in the reproduction of innumerable plant species, many of which are vital to the stability of ecosystems and the availability of food. For instance, *A. dorsata* pollinates tropical crops like cashew and coconut, whereas *A. mellifera* is essential for pollinating crops like alfalfa, sunflowers and pumpkins.

By feeding on pests that damage crops, honey bees help with pest management in addition to pollination. Particularly *A. cerana indica* has been shown to consume pests including whiteflies and aphids, offering a natural method of pest control. Additionally, by gathering and processing pollen and nectar, which serves to transfer nutrients throughout ecosystems, honey bees contribute to the cycle of nutrients. Other creatures that depend on the same plant species for food, such as butterflies and birds, can reproduce more easily thanks to this mechanism.

The health and biodiversity of ecosystems could be significantly impacted by the extinction of honey bee species. Many plant species would not be able to reproduce without these pollinators, which would result in lower crop yields and weakened ecosystem resilience. Moreover, the disappearance of honey bees would upset the delicate ecosystem balance, which could have a domino impact on other species and ecosystem functions. Consequently, biodiversity and ecosystem services depend on honey bee population management and conservation.

Threats to Pollinator Diversity

It's crucial to remember that the populations and diversity of all three honey bee species are seriously threatened. The loss and fragmentation of habitat, primarily brought about by urbanisation and intensive agriculture, has decreased the number of places where honey bees may nest and forage. For instance, *A. mellifera* is frequently raised in monoculture farms, which may result in a lack of genetic diversity and a higher risk of illness.



Pic credit: Alberta Wilderness Association

A further connection between pesticide use and honey bee decreases is the use of neonicotinoids. These substances may hinder bees' ability to navigate and communicate, which may make it more difficult for them to locate food and return to their colonies. Even though Apis dorsata has a larger body than other species, it is nevertheless susceptible to pesticide exposure.

Another major hazard to honey bee numbers is climate change. The intricate timing of plant-bee interactions can be upset by variations in temperature and precipitation patterns, which makes it more challenging for bees to locate the materials they require. Despite being more tolerant of temperature fluctuations, *A. cerana indica* is nevertheless susceptible to droughts and other extreme weather conditions because it is native to tropical regions.

In addition to diseases like nosema and American foulbrood, varroa mite infestations are major risks to honey bee populations. These pests and illnesses, which have the ability to wipe out entire colonies, have a special impact on *A. mellifera* because of its worldwide dispersion.

Finally, the genetic diversity of these species is at danger due to the disappearance of conventional beekeeping methods and the homogenisation of honey bee populations. Due to their distinctive traits and adaptations, Apis dorsata and *A. cerana indica* are especially susceptible to the loss of genetic diversity, which may hinder their capacity to adjust to shifting environmental conditions.

Conservation Efforts and Strategies

The diversity and well-being of honey bee populations depend heavily on conservation tactics and initiatives. One important strategy is to preserve and rehabilitate natural habitats, such woods and meadows, which give honey bees vital places to nest and forage. For example, *A. mellifera* thrives when floral resources such as sunflowers and lavender are present, whereas *A. dorsata* needs tropical forests to survive.

Agroforestry and permaculture are two examples of sustainable agriculture techniques that can support honey bee populations. These methods increase biodiversity, lessen the need for pesticides, and allow honey bees a wide variety of crops to pollinate. Furthermore, preserving habitat connectivity and biological corridors can support honey bee populations' long-term survival.

The conservation of honey bees is significantly impacted by beekeeping techniques. The impact of pests and diseases on honey bee colonies can be lessened by the use of best management methods, such as routinely monitoring and controlling Varroa mite populations. In addition, strategies for queen introduction and selective breeding can assist maintain the long-term resilience and health of honey bee populations by fostering genetic variety.

Education and community involvement are also crucial for the protection of honey bees. Educating people about the value of honey bees and the dangers they face might motivate them to take action, such as creating bee-friendly landscaping or helping out local beekeepers. Furthermore, incorporating nearby communities in conservation activities can support their long-term viability.

Lastly, in order to comprehend the intricate interactions that exist between honey bees, their surroundings, and the effects of different threats, research and monitoring initiatives are essential. Through examining the behaviour and ecology of *A. mellifera*, *A. dorsata*, and *A. cerana indica*, scientists can create conservation plans that are effective and suited to the unique requirements of each species.

Conclusion

In conclusion, the conservation of *A. mellifera*, *A. dorsata*, and *A. cerana indica* is crucial for maintaining ecosystem health and food security. To address the threats they face, a multi-faceted approach is necessary, incorporating habitat protection, sustainable agriculture, improved beekeeping practices, and community engagement. By working together, we can ensure the long-term health and resilience of these vital pollinators and the ecosystems they inhabit.

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THE IMPACT OF SEAWEED HARVESTING ON MARINE LIFE AND ECOSYSTEMS

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Introduction

Seaweed plays a crucial role in marine ecosystems, acting as a habitat, food source, and carbon sink. As global demand for seaweed growth spurred by its use in industries ranging from food to biofuels and cosmetics seaweed harvesting is expanding rapidly. While seaweed offers a sustainable resource with many benefits, the intensification of its harvesting, particularly wild seaweed, raises concerns about the potential impact on marine life and ecosystems. This article explores the ecological role of seaweed, the effects of harvesting, and how sustainable practices can mitigate environmental risks.

The Ecological Importance of Seaweed

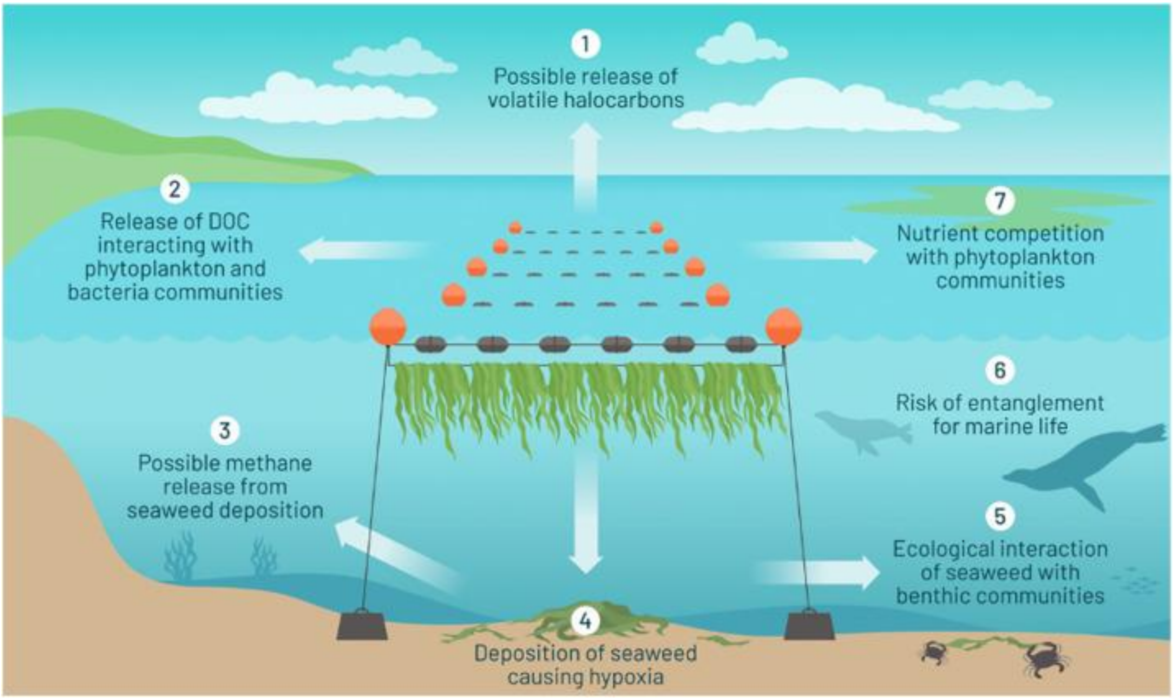
Seaweed, a form of macroalgae, forms the backbone of many coastal ecosystems. Kelp forests, for example, are some of the most productive and biodiverse ecosystems on Earth, supporting a wide array of marine species. Seaweed contributes to marine environments in several key ways:

1. **Habitat and Shelter**: Seaweed provides critical shelter and breeding grounds for many marine species, from small invertebrates to fish and sea urchins. Kelp forests and seagrass meadows offer protection from predators and provide a stable environment for organisms to thrive.
2. **Primary Food Source**: Seaweed is a primary food source for many marine herbivores, such as sea snails, fish, sea urchins, and crustaceans. These species, in turn, support higher trophic levels, including predators like seals, seabirds, and larger fish.
3. **Carbon Sequestration**: Seaweed absorbs carbon dioxide (CO_2) from the atmosphere during photosynthesis, playing a role in mitigating climate change. Large-scale seaweed forests sequester carbon and help reduce greenhouse gases, acting as natural carbon sinks.
4. **Coastal Protection**: Seaweed forests, particularly kelp, help buffer coastlines from wave action, reducing erosion and protecting coastal communities from storms and sea-level rise. These vegetative barriers also help trap sediments, improving water quality.

The Rise of Seaweed Harvesting

The global seaweed industry has grown exponentially, driven by demand for seaweed in food, agriculture, cosmetics, biofuels, and pharmaceuticals. In Asia, where seaweed farming has been practiced for centuries, large-scale cultivation occurs in countries like China, Indonesia, and South Korea. However, wild seaweed harvesting—particularly of valuable species like kelp—is also on the rise in Europe, North America, and South America.

While farming seaweed offers a controlled and renewable means of production, wild seaweed harvesting can have more significant ecological consequences if not carefully managed.



Impact of Seaweed Harvesting on Marine Life

1. **Loss of Habitat and Biodiversity** When seaweed is harvested in large quantities, especially from wild sources, it can lead to habitat destruction for many marine species. Kelp forests, for instance, are home to a diverse range of organisms. Removing too much seaweed can displace fish, invertebrates, and other organisms that depend on these habitats for shelter and food. In particular, species such as abalone, lobsters, and crabs are heavily reliant on kelp forests, and their populations may decline if these habitats are diminished.
2. **Disruption of Food Chains** Seaweed serves as a critical food source for many marine herbivores. Over-harvesting can reduce food availability for species that graze on seaweed, such as sea urchins and certain fish. This disruption in the food chain can lead to imbalances in the ecosystem, affecting predator species as well. For example, a decline in sea urchin populations could impact species that feed on them, such as sea otters and seabirds.
3. **Alteration of Marine Ecosystems** The removal of large amounts of seaweed can alter the physical structure of marine ecosystems. Without seaweed to anchor them, sediments can be more easily stirred up by currents and waves, reducing water clarity and affecting photosynthesis in other aquatic plants. This can lead to further declines in the biodiversity and health of the ecosystem.
4. **Impacts on Fish Populations** Fish populations, particularly juvenile fish, rely on seaweed beds for protection and food. The loss of these habitats can make fish more vulnerable to predators and reduce their survival rates. Some commercially important fish species, such as cod and herring, depend on kelp forests during their life cycles, meaning that seaweed depletion can negatively impact fisheries and local economies(Tano et al.,2017).

Ecological Impacts of Large-Scale Harvesting

1. **Ecosystem Imbalance** Large-scale harvesting of seaweed, especially in wild ecosystems, can create imbalances by reducing the number of grazing species and increasing the

prevalence of others. For example, sea urchins can overgraze the remaining seaweed, leading to what is known as an "urchin barren"—an area where the ecosystem collapses due to the loss of vegetation and the dominance of sea urchins.

2. **Reduced Carbon Sequestration** Seaweed plays a key role in sequestering carbon from the atmosphere. Harvesting large amounts of seaweed without giving ecosystems time to regenerate can reduce the carbon absorption potential of marine environments. This, in turn, can affect efforts to combat climate change, as fewer carbon sinks are available.
3. **Impact on Coastal Protection** Seaweed forests help mitigate coastal erosion by acting as a buffer between the ocean and the shore. When seaweed is removed in large quantities, this natural barrier is weakened, making coastlines more vulnerable to erosion and the impacts of extreme weather events such as storms and hurricanes.

Sustainable Seaweed Harvesting Practices

To mitigate the negative impacts of seaweed harvesting, sustainable practices are essential. These practices aim to balance economic interests with ecological preservation, ensuring that marine ecosystems remain healthy and productive. Some sustainable approaches include:

1. **Rotational Harvesting**: Rotational harvesting involves harvesting seaweed from specific areas while leaving other areas undisturbed. This allows the seaweed to regenerate naturally and helps prevent over-harvesting in any one location. By spreading the impact across multiple areas, the ecosystem has time to recover and maintain biodiversity (Smaleand Orr, 2019).
2. **Size and Seasonal Restrictions**: Setting size limits on harvested seaweed can protect younger, smaller plants that are vital for future regeneration. Seasonal restrictions can also help ensure that seaweed is harvested outside of critical breeding or growth periods for marine species, allowing ecosystems to remain resilient.
3. **Farming Over Wild Harvesting**: Encouraging seaweed farming rather than wild harvesting can help reduce pressure on natural ecosystems. Seaweed farming can be done sustainably with minimal environmental impact, and farmed seaweed can meet industrial demand without damaging marine habitats.
4. **Monitoring and Regulation**: Governments and environmental organizations can play a critical role by enforcing regulations that limit the amount of seaweed harvested and ensuring that these practices are sustainable. Monitoring programs can assess the long-term impact of harvesting on marine ecosystems and make adjustments as needed to protect biodiversity (Mantri et al.,2023).

The Role of Seaweed in Ecosystem Restoration

In addition to sustainable harvesting, seaweed can play a role in ecosystem restoration. In regions where marine environments have been degraded by human activity, seaweed farming can help restore biodiversity and improve water quality. Seaweed farms act as artificial habitats, attracting marine life and promoting ecosystem recovery. By absorbing excess nutrients like nitrogen and phosphorus, seaweed can also help mitigate the effects of agricultural runoff and prevent harmful algal blooms.

Conclusion

Seaweed harvesting, if done unsustainably, can pose significant risks to marine life and ecosystems by disrupting habitats, food chains, and ecosystem balance. However, with careful management and sustainable practices, seaweed can be harvested in a way that maintains the health of marine environments while supporting industries that rely on this valuable resource. As demand for seaweed continues to rise, it is essential to prioritize sustainability, ensuring that seaweed remains a renewable and ecologically sound resource for the future.

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RECLAMATION OF SALT AFFECTED SOIL

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Abstract

As we all know soil is a basic component for any type of crop production. The soil reclamation is an essential process for maintaining the health and functionality of soil affected by natural and artificial intervention of human beings. This paper explores various reclamation of affected soils by various physical, chemical and biological methods for solving the problem of farmers. Emphasis done on the practical methods to mitigate their effect or escalate the natural properties of soil. Findings indicate that integrated reclamation strategies not only rehabilitate contaminated soils but also promote biodiversity and sustainability. This article underscores the importance of tailored reclamation practices that consider specific site conditions and ecological goals, contributing to the broader field of environmental restoration and land management.

Introduction

Soil salinity is one of the main environmental problems affecting extensive areas of land in both developed and developing countries. Salinity is common in the region of arid and semi-arid regions where rainfall is too low to maintain a regular percolation of rainwater through the soil and irrigation is practiced without a natural or artificial drainage system. Such irrigation practices without drainage management trigger the accumulation of salts in the root zone, affecting several soil properties and crop productivity negatively.

Reclamation involves a combination of physical, chemical, and biological strategies aimed at reducing salinity levels and restoring soil health. Effective reclamation practices not only enhance agricultural productivity but also improve water quality, support biodiversity, and contribute to climate resilience. This introduction explores the importance of reclaiming salt-affected soils, the various methodologies employed, and the broader implications for food security and environmental sustainability. By addressing these challenges, we can pave the way for more resilient agricultural systems and healthier ecosystems.

It is conjectured that about 1.2 billion ha of land around the world are affected with different levels of salinity. In India, about 6.7 million ha of land are affected by salt, including salinity and sodicity.The states with the largest areas of salt-affected soil include Gujarat, Maharashtra, Rajasthan, Uttar Pradesh, Tamil Nadu, Haryana, and Punjab.

Estimates suggest that around 10% of India's land is becoming salinized each year. By 2050, it is estimated that around 50% of India's arable land will be salt-affected. Salinity and sodicity are major factors that cause crop yield loss in these areas. Salt-affected soils can be caused by natural factors, such as the presence of soluble salts in the soil, or by human activities, such as agricultural practices.

Types of salt affected: The major three types of salt affected soils found in India that mainly hamper the crop production or deterring the high yield of farmers.

1. Acidic soil

2. Alkaline / Sodic soil
3. Saline soil

1. **Acidic soil :** Soil acidity refers to presence of higher concentration of H+ in soil solution and at exchange sites. They are characterised by low soil pH and with low base saturation. The soil have pH value less than 6. It may have different ranges - The pH range for acidic soil is less than 6.5:

* 5.6–6.0: Moderately acidic
* 5.1–5.5: Strongly acidic
* <5.0: Very strongly acidic

Occurrence

Acidic soils in India are primarily found in the northeastern states, such as Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, and Nagaland. These regions have high rainfall, which leads to leaching of basic cations and the accumulation of acidic ions.

Other areas with acidic soils include parts of the Western Ghats and some regions in the Himalayas. The main causes of soil acidity in India include:

Climate: High rainfall promotes leaching.
Parent Material: Soils derived from acid rock types (like granite) tend to be more acidic.
Organic Matter Decomposition: The breakdown of organic matter can produce organic acids. These soils can affect crop production, necessitating the application of lime or other amendments to improve soil health.

Management of acidic soil

Management of the acid soils should be directed towards enhanced crop productivity either through addition of amendments to correct the soil abnormalities or by manipulating the agronomic practices depending upon the climatic and edaphic conditions.

Soil amelioration

Lime has been recognized as an effective soil ameliorant as it reduces Al, Fe and Mn toxicity and increases base saturation, P and Mo availability of acid soils. Liming also increases atmospheric N fixation as well as N mineralization in acid soils through enhanced microbial activity.

However, the economic feasibility of liming needs to be worked out before making any recommendation

Liming materials

Commercial limestone and dolomite limestone are the most widely used amendments. Carbonates, oxides and hydroxides of calcium and magnesium are referred to as agricultural lime. Among the naturally occurring lime sources calcitic, dolomitic and stromato litic limestones are important carbonates. The other liming sources are marl, oyster shells and several industrial wastes like steel mill slag, blast furnace slag, lime sludge from paper mills, pressmud from sugar mills, cement wastes, precipitated calcium carbonate, etc equally effective as ground limestone and are also cheaper.

Considering the efficiency of limestone as 100%, efficiencies of basic slag and dolomite are 110 and 94 % respectively. Basic slag and pressmud are superior to calcium oxide or carbonates for amending the acid soils. Fly ash, a low- density amorphous ferro-alumino silicate, also improves pH and nutrient availability

Crop that tolerate acidic soils are - rice, cassava, mango, cashew, citrus, pineapple, cowpeas, blueberries and certain grasses.

Alkaline soil

Alkaline soil is characterised by a high pH level, typically above 7.0, indicating a lower concentration of hydrogen ions. This type of soil often contains elevated levels of calcium carbonate and other alkaline minerals. Alkaline soils can occur in arid and semi-arid regions, where evaporation exceeds precipitation, leading to salt accumulation.

Key Characteristics

pH Level: Alkaline soils usually have a pH range of 7.5 to 8.5 or higher, Ec less than 4 dS m-1 and an exchangeable sodium percentage (Esp) greater than 15. Nutrient Availability: Certain nutrients, like iron, manganese, and phosphorus, may become less available to plants in alkaline conditions, potentially leading to nutrient deficiencies.

Texture: They can vary in texture, including sandy, loamy, or clayey types.

Occurrence

These soils are formed in canal rinsed lands and locations with a higher subsurface water table. This type of soil may be found in parts of Karnataka, Telangana, Andhra Pradesh, Uttar Pradesh, Bihar, Punjab, Haryana, Rajasthan, Punjab, and Maharashtra. Alkaline soils cover 68,000 square kilometres in India. The states with the most alkaline soil are: Uttar Pradesh: 35.75% of the total alkali-affected area

Gujarat	: 14.36%
Maharashtra	: 11.21%
Tamil Nadu	: 9.41%
Haryana	: 4.86%
Punjab	: 4.02%

These six states account for about 80% of India's total alkaline lands.

Management

1) Gypsum @ 8 qt/ha used for reclamation of sodic or alkali or soils having Ph > 8.5.
2) Iron pyrite (Fes2) @ 12 qt/ha can be used for amendments of alkali soil
3) Green manuring should be adopted
4) Addition of acidic fertilizer in the field eg. Anhydrous ammonia ,DAP etc.
5) Deep ploughing is adopted to break the hard pan developed at subsurface due to sodium and improving free-movement water. This also helps in improvement of aeration.
6) Providing drainage is also practised to improve aeration and to remove further accumulation of salts at the root zone.
7) Sand filling which reduces heaviness of the soil and increases capillary movements of water.
8) Cultivation of salt tolerant crops -

Field crops : Barley, dhaincha, Rice, sorghum, Sunhemp, pea,sugarbeet, pearl millet, arhar, groundnut, moong,tobacco, cotton, wheat, rye, oat gram, urd,mustard.

Fodder crops : Rhodes grass, Sudan grass, Cluster bean,Khush grass, berseem, Lucerne, sorghum.

Vegetables : Spinach, Cabbage, Sam, raphanus, sugar cauliflower, tomato, English varieties of raphanus, beet, B. repa. carrot, onion, potato.

Fruit crops : Date palm, Phalsa Pomegranate, Apple, ber, lemon,grapes, guava, straw bery, almond, mango, banana.

Saline soil

White crust of salt hence called white alkali/solon chalk.Saline-alkali / sodic soil is defined as a soil having a conductivity of the saturation extract greater than 4 dS m-1 and an exchangeable sodium percentage greater than 15. The pH is variable and usually above 8.5 depending on the relative amounts of exchangeable sodium and soluble salts. When soils dominated by exchangeable sodium, the pH will be more than 8.5 and when soils dominated by soluble salts, the pH will be less than 8.5.

Occurrence

Saline soils are distributed in the coastal, deltaic plains and mangrove regions in Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal and the Andaman and Nicobar Islands. The inland saline soils are predominantly found in Gujarat and Rajasthan.

About 2.1% of India's geographical area is affected by soil salinity. This includes 2.96 million hectares of saline soil and 3.77 million hectares of sodic soil.

Uttar Pradesh: The largest area of saline soil, at 71.2% Gujarat: The largest area of sodic soil, at 35.6%

West Bengal: More than 72% of coastal saline soils .

Formation

Soil becomes saline when soluble salts are retained in the soil, either naturally or due to human activities:

Natural causes :

- Low precipitation and dry climates: When salts aren't flushed out of the soil
- High evaporation rates: Salts are added to the ground surface
- Salty groundwater: When the water table rises, salty groundwater can reach the upper soil layers
- Parent rock: The soil may be rich in salts from the parent rock it was formed from
  Human activities :
- Irrigation: Irrigation water often contains salts that are left behind in the soil after the water evaporates or is used by the crop
- Poor water quality: Poor water quality can contribute to soil salinization
- Inappropriate fertilizer application: Excess nitrification can accelerate soil salinization
- Removal of deep-rooted vegetation: This can raise the water table
- Sea-level rise: Sea salts can seep into lower lands
- Salty air masses: In coastal areas, salty air masses can blow to nearby territories
- Saline soils can be recognized by a white layer of dry salt on the soil surface.

Management

- Flooding or leaching of soluble salts by good irrigation water. Keep soil moist or frequent irrigated the field.
- Use of FYM for saline reclamation.

- Waterlogged condition in the field help to leach down the salt into deep horizon of th the soil. Cultivation of tolerant crops - Oat, rye , sunflower, safflower, wheat,barley, sugarbeet, triticale etc.

Conclusion

In conclusion, the reclamation of salt-affected soil is essential for restoring soil health, enhancing agricultural productivity, and promoting sustainable land use. Effective strategies, such as the application of organic amendments, leaching practices, and crop rotation, can significantly mitigate salinity issues. By adopting integrated management practices, farmers can not only reclaim degraded lands but also contribute to improved food security and environmental sustainability. Continued research and innovation in soil management will be vital to address the challenges posed by salinity and to ensure resilient agricultural systems for the future

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A BRIEF INTRODUCTION TO COMMON SOFTWARES FOR AGRICULTURAL DATA ANALYSIS

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Abstract

Agricultural research is concerned with the analysis of data collected from various sources to solve a perceived problem. As research and technology are progressing in the field of agriculture, one of the universal problems faced by researchers in agriculture is the decision-making of using the appropriate software needed for the concerned analysis. With a variety of softwares available, it is often common for researchers of non-technical backgrounds to be perplexed about the choice of softwares for their research problem. The most widely used softwares are R, STATA, MATLAB, OPSTAT, Python, SPSS and SAS. Softwares with their specific usages are briefly explained in this article.

Introduction

Agricultural data refers to a wide range of information related to agriculture, including crop production, livestock, soil conditions, genetic and breeding information, weather patterns, market prices, remote sensing, farmer details, credits, schemes and resource management. Agricultural data can be both quantitative and qualitative and comes from different sources such as sensors, satellite imagery, experimental research, farm field and laboratory records and government surveys. Agricultural data analysis includes the collection, tabulation and interpretation of data to identify solutions to problems as well as for making new discoveries. To analyse any problem, proper tools are to be utilised. There are many softwares available today that conduct statistical research for a variety of fields including agriculture. There are special packages available in the softwares exclusively for agricultural research. While some softwares are available for free, some require a licensed subscription. Given below is a description of a few of the common softwares used commonly for agricultural research data analysis.

1. **SAS:** SAS (Statistical Analysis System) is a licensed software suite used in agricultural problems for improving decision-making, analyzing crop data, performing genetics and breeding analysis, optimising resource allocation, fertilizer and irrigation strategies and predicting the weather. SAS software development started in 1966 at North Carolina State University by Anthony Barr (Nourse et al., 1978) originally for agricultural data analysis. Currently, it is being developed by SAS Institute. One can install the software for free from https://www.sas.com/en_us/software/university-edition/download-software.html for university or use a cloud version- SAS Viya available at https://www.sas.com/en_in/software/viya-for-learners.html and SAS OnDemand is available at https://www.sas.com/en_in/software/on-demand-for-academics.html for academicians, students, learners and educators. SAS offers a range of tools and solutions tailored for agricultural research enabling data-driven insights.

2. **R:** R is an open-source software widely used in agricultural research for various purposes such as crop and climate modelling and prediction, time series analysis, design of experiments, correlation, regression analysis, multivariate analysis, machine learning etc. R is inspired by the S programming language which was developed by professors Ross Ihaka and Robert Gentleman of the University of Auckland as a programming language (Ross, n.d.). R can be downloaded free of cost from https://cran.r-project.org/. R Studio is an Integrated Development Environment (IDE) that is usually used with R which boosts R with user-friendly features for coding, visualization, storage, and reporting. R studio is available at https://posit.co/downloads/. It offers packages like 'forecast','tseries' for time series analysis, 'sp' for spatial data, 'EnvRtype' for quantitative genomics, 'metan' for correlation, 'stats' for linear regression, 'ggplot2' for visualization, 'nnet' and 'randomForest' for machine learning and 'agricolae' for agricultural design of experiments. R excels in handling complex data types and integrates well with other programming languages and platforms as well.
3. **Python:** It is a versatile programming language known for its ease of use for both beginners and experienced developers. Python was developed by Guido van Rossum in the Netherlands in 1989 (Guido, 2009). Python can either be downloaded from https://www.python.org/downloads/ or used in Jupyter Notebook, GoogleColab https://colab.research.google.com/ and Spyder. Python's flexibility supports IoT applications, automating irrigation systems, monitoring crop health, precision farming and automation of tasks. Libraries like 'Pandas' and 'NumPy' help process agricultural data, while 'Matplotlib' and 'Seaborn' visualize crop trends and environmental factors. In precision agriculture, machine learning libraries such as 'Scikit-learn' and 'TensorFlow' are used for yield prediction, soil analysis, and pest detection. Geospatial data analysis with Python's 'GeoPandas' and 'Shapely' allows for better resource management and land use planning. The popularity of Python has increased due to its flexibility, availability of agricultural-specific packages and functions, computational efficiency, customization options, visualization, technical support and community resources (Bhardwaj and Kaushik, 2024).
4. **SPSS:** SPSS (Statistical Package for the Social Sciences) is a software for statistical analysis that is user-friendly and includes tools for both simple and advanced analytics. It is adopted in agriculture for evaluating extension programs, conducting socio-economic analysis, descriptive statistics, ANOVA, regression analysis, and multivariate analysis. It was developed by Nie et al. (1970) and is now acquired by IBM (International Business Machines Corporation). IBM's SPSS is available at https://www.ibm.com/spss. It is a licensed software, so it is not freely available. SPSS features robust statistical analysis tools, data management capabilities, graphical visualization and predictive modelling, making it ideal for diverse data analysis needs.
5. **STATA:** STATA is a general-purpose statistical software package (Wikipedia, 2024) used for data management, panel data analysis, regression, spatial data analysis, time series analysis, advanced econometric methods, automated reporting and survey data analysis. Stata was developed by Computing Resource Center of California in 1985 (Cox, 2005). The company is now called StataCorp and it is available at https://www.stata.com/. STATA is being used in agricultural studies for its dynamic documentation in easy reproducibility and transfer.

6. **MATLAB:** MATLAB or MATrix LABoratory is a high-level programming language and environment for matrix manipulation, numerical computation, machine learning, signal processing, data analysis and algorithm development. It is a proprietary programming language invented by Cleve Moler in the 1960s (Chonacky and Winch, 2005). The integrated development environment (IDE) developed by MathWorks facilitates scripting, debugging, and executing the codes efficiently (Bhardwaj and Kaushik, 2024). MATLAB is used in agriculture for modeling and simulating complex agricultural systems, impact assessment, optimize farming practices. MATLAB's specialized toolboxes enable applications like precision agriculture and machine learning techniques too.
7. **OPSTAT:** OPSTAT is a web tool for analyzing design of experiments and statistical methods in agriculture. It was developed by O. P. Sheoran and his colleagues at Hissar Agriculture University in 1998 (Sheoran et al., 1998). It is a free software package available at http://14.139.232.166/opstat/. OPSTAT module is divided into three categories: Social Sciences, Design of Experiments and Biometrical Analysis
    1. Social Sciences: Generating Frequency, Cross Tabulation, comparing means and correlation and regression analysis, Principal Component Analysis
    2. Design of Experiments: One Factor Analysis, Two Factor Analysis, Three Factor Analysis, Pooled Experiments for Time Series Analysis, Augmented Design, Balanced Lattice Design, Alpha Design, Multiple Comparisons, etc.
    3. Biometrical Analysis: Path Analysis, Line × Tester Analysis, Partial Diallel Analysis, Stability Analysis.

    Depending on the need of the research, the module from the software can be used for the effective utilization of agricultural data. As bugs and issues are reported, they are fixed and the softwares are upgraded. They are also upgraded for the inclusion of new features as developers identify the potentials and risks associated to the softwares.

Conclusion

Agricultural research is constantly evolving with advanced technology. Emerging trends include the integration of machine learning algorithms, cloud-based computing, open-source platforms, collaborative research, and data-sharing to improve transparency and duplicability in agricultural research (Bhardwaj and Kaushik, 2024). The selection of statistical software for agricultural data analysis depends on the level of technical expertise, the nature of research problem, available computational resources, and the preferences of researchers. Depending on the suitability and nature of the outcomes expected, the researcher can make his choice of the appropriate software needed for agricultural analysis.

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MICROBIAL CONSORTIA AS PLANT PROBIOTICS

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Abstract
In agriculture, the use of microbial consortia as plant probiotics has grown in popularity as a sustainable substitute for chemical pesticides and fertilisers. Microbial consortia, as opposed to single-strain probiotics, are made up of several microbial species that work together to improve plant growth, nutrition uptake and stress tolerance. The processes by which microbial consortia support plant health are reviewed in this article, along with their benefits over single-strain probiotics and uses in sustainable agriculture. Future research objectives and the difficulties involved in using microbial consortia are also covered. Microbial consortia can be optimised for usage in a variety of agricultural contexts and help to produce food in a sustainable manner by comprehending their dynamics.

Introduction
The need for environment friendly agricultural methods has fuelled the hunt for chemical input substitutes that can boost crop yield without sacrificing environmental integrity. Microbial inoculants, especially plant probiotics, have drawn interest among these substitutes due to their capacity to enhance plant development, soil health and disease resistance. Plant probiotics are good microorganisms that colonise the rhizosphere, improve nutrient availability and inhibit pathogens to boost the health of plants.

Compared to single-strain inoculants, microbial consortia—which are made up of several microbial species—offer clear advantages. Plant productivity and health can be enhanced by the synergistic interactions that these consortia can display.

Microbial consortia have the potential to promote sustainable agriculture by lowering the need for chemical pesticides and fertilizers, according to recent research. These microbial communities are crucial to the functioning of ecological systems, including the nitrogen and carbon cycles in organic matter and the health of humans and other animals. Ancient societies investigated the use of natural microbial consortia in the fermentation of food and drink.

Microbial consortia can characterized as artificial, synthetic or semi-synthetic. According to Massot et al. (2022), artificial consortia consist of selected microbial strains that do not naturally coexist but are selected for specific functions. Synthetic consortia comprise two or more genetically modified microorganisms, while semi-synthetic consortia combine microorganisms from natural and genetically modified populations. This review aims to provide an in-depth analysis of microbial consortia as plant probiotics, exploring their mechanisms of action, benefits, challenges and future prospects.

How microbial Consortia works as plant probiotics

Microbial consortia promote plant health through various mechanisms, including nutrient acquisition, plant growth promotion and disease suppression (Figure 1).

Through nutrient acquisition which support soil health

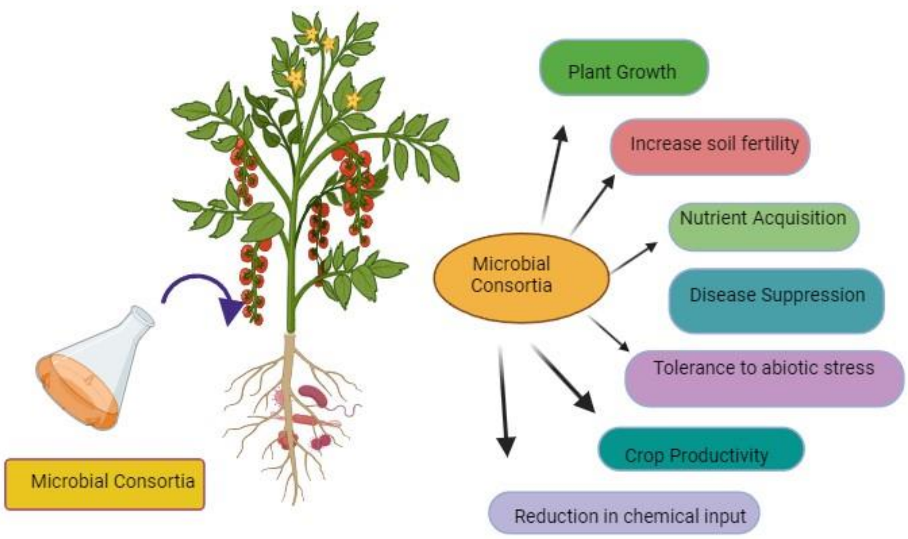
Microbial consortia enhance nutrient availability and uptake by plants. Certain bacterial species within the consortium can fix atmospheric nitrogen, solubilize phosphorus and secrete siderophores that chelate iron, making these essential nutrients more accessible to plants. Additionally, microbial consortia can improve soil structure and fertility by increasing organic matter decomposition and nutrient cycling (Wang et al. 2020).

Plant Growth Promotion

The production of plant growth-promoting hormones such as indole-3-acetic acid (IAA), gibberellins and cytokinins by microbial consortia contributes to enhanced root and shoot development. For example, certain consortia produce ACC deaminase, an enzyme that lowers ethylene levels in plants, thereby reducing stress and promoting growth (Backer et al. 2018). The ability of consortia to modulate hormone levels offers a broad spectrum of growth benefits compared to single-strain probiotics.

Disease Suppression through biological control

Microbial consortia can suppress plant pathogens through various mechanisms, including competition for nutrients and space, production of antimicrobial compounds and induction of systemic resistance in plants (Mendes et al. 2017). The diversity within consortia provides a wider range of biocontrol strategies, making them more effective against a variety of pathogens compared to single-strain inoculants.



Advantages of using multistrain consortia

Synergistic Interactions

Microbial consortia offer synergistic interactions that enhance their overall efficacy. Different microbial species within the consortium can complement each other's functions, leading to improved nutrient cycling, stress tolerance and disease suppression (Kong et al., 2021). For instance, one species may degrade complex organic matter, making nutrients available for other members of the consortium and the host plant.

Environmental Stability

Compared to single-strain inoculants, microbial consortia exhibit greater resistance to environmental variations. Consortia are more dependable in a variety of agricultural contexts because of their ability to respond to changing soil conditions, temperature swings and moisture levels due to their diversity. For constant performance in the field, this steadiness is essential.

Broader Functional Traits

Microbial consortia can simultaneously address several plant demands because of their functional variety. For example, a consortium may include nitrogen-fixing bacteria, phosphate-solubilizing fungi and biocontrol agents, offering comprehensive benefits to the plant. Microbial consortia are a more flexible tool than single-strain probiotics for improving plant health because of their multifunctionality.

Applications in Sustainable Agriculture

Reduction of Chemical Inputs

By lowering reliance on chemical pesticides and fertilizers, microbial consortia may promote more environment friendly farming methods. For instance, consortia including fungus and bacteria that fix nitrogen and phosphate can greatly reduce the need for synthetic fertilizers. Furthermore, microbial consortia's biocontrol abilities can lessen the need for chemical pesticides, reducing pollution to the environment and fostering biodiversity.

Use in Different Cropping Systems

A wide range of agricultural systems, including cereals, legumes, fruits and vegetables, can benefit from the application of microbial consortia. They are appropriate for usage in a variety of agricultural contexts due to their adaptability to various soil types and climatic conditions. Microbial consortia, for instance, have been effectively used in organic farming systems to improve crop yields and soil fertility without the need for artificial inputs.

Enhancing Crop Resilience to Abiotic Stresses

Plant resistance to abiotic stressors like drought, salt and heavy metal pollution can be increased by microbial consortiums. Exopolysaccharides, which aid in retaining soil moisture and shield plants from drought, are produced by a few consortia. In a similar vein, certain microbial consortiums can protect plant health by absorbing or changing heavy metals and reducing their harmful effects.

Challenges and Future Perspectives

Despite the promising potential of microbial consortia as plant probiotics, several challenges must be addressed to optimize their use in agriculture.

Formulation and Stability

The creation of microbial consortia is difficult because it involves preserving the health and functionality of several different microbial species while they are being stored and used. Creating stable formulations that are simple to use in the field is still a major difficulty.

Compatibility with Agricultural Practices

Microbial consortia must be compatible with current agricultural techniques, such as crop rotation, irrigation, and fertilization, in order to be successful. For microbial consortia to be successfully integrated into farming systems, it is imperative that these activities are understood in relation to their performance.

Regulatory and Commercialization Issues

The commercialization of microbial consortia is hindered by regulatory challenges and the need for extensive field trials to demonstrate their efficacy across different crops and environments. Clear guidelines and standardized protocols for the development and use of microbial consortia are needed to facilitate their adoption by farmers (Johnston-Monje et al., 2019).

Conclusion

Microbial consortia, through their capacity to suppress diseases, improve nutrient uptake, and enhance plant growth, present a promising alternative for sustainable agriculture. They are more effective than probiotics with a single strain because of their capacity to work in concert and adapt to a variety of environmental situations. To reach their full potential, though, a number of obstacles including formulation, compliance with agricultural standards and legal concerns need to be resolved. Subsequent investigations ought to concentrate on refining the composition of consortiums, enhancing the stability of formulations, and creating protocols for their application in diverse farming systems. Microbial consortia have the potential to significantly contribute to the advancement of sustainable food production and the mitigation of agriculture's environmental effect by surmounting these obstacles.

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DAMASK ROSE: A POTENTIAL FLOWER CROP FOR SUBTROPICAL REGION

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Introduction

One of the most significant species in the Rosacea family is the oil-bearing Damask rose (*Rosa damascena).* Geographically and historically, it is believed that the Damask rose originated in the distant past of Persia, or nowadays known as Iran, and then spread to European nations and the northern part of Africa. In the 16th period, following the Ottoman Empire's growth, *R. damascena* was first widely cultivated in Europe for the purpose of producing rose oil in Bulgaria and Turkey. Iran, Bulgaria, Turkey, India, Morocco, China, southern France, southern Italy, Russia, Libya and Ukraine are among the nations where it is grown. In India, it is grown in Rajasthan, Uttar Pradesh, Jammu and Kashmir, and some areas of Himachal Pradesh and Uttarakhand on 2500-3000 ha of land to generate 0.2 MT of rose essential oil every year. The damask rose oil, also referred to as "attar" or "otto," is an extremely precious product that is often referred to as "liquid gold." 45 tons of concrete, absolute, and damask rose oil are required annually on a global scale. Bulgaria and Turkey are the world's leading rose oil producers, accounting for 80-90% of global production. Consequently, rose essential oil became more expensive globally, achieving roughly $7500 per kilogram. Many factors influence the quality of rose oil, including genotype, prevailing weather conditions, propagation method, level of trimming, time and way of flower picking, distillation method, and flower storage period.

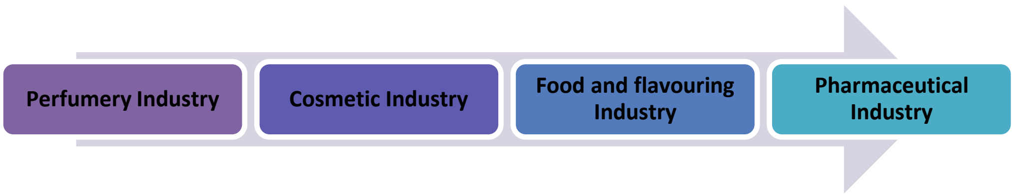
Botanical description

It is a perennial shrub that has many branches above ground and a deep root system. This tall (1-2 m) deciduous shrub has stiff bristles and curved prickles, and the stems are packed thickly with stouts. It has pinnate leaves with five to seven leaflets. The flower colour ranges from light red to moderate pink. The small flowers grow in clusters. It is found in elevations ranging from 300 to 3500 meters above sea level. It has a life span of 10-15 years and requires a three-year gestation period for commercial production. In most of the western hemisphere, it is also utilized as an ornamental plant.

Economic importance

Essential oil, rose water, rose absolute and concrete are the most valuable products made from Damask rose. Steam distillation is used to produce rose oil and water. While, solvent extraction is used to produce rose absolute and concrete. Rose essential oil has a complex composition with over 275 minor ingredients and a small number of significant compounds, including citronellol, geraniol, nerol, phenethyl alcohol, linalool, farnesol, eugenol, and eugenol methyl ether. Rose essential oil is used in many different industrial applications, such as fragrances and cosmetics, tobacco, liquor and sweet foods in the culinary and the pharmaceutical industry sectors. Rose oil is used to flavour tea and liquors, as well as to provide fragrance to soap and cosmetic products. It is also utilized in lotions, soaps, and creams due to its strong aroma and mild antibacterial properties.

Furthermore, Damask rose has high levels of antioxidants such as phenolics, flavonoids, carotenoids and anthocyanins. Damask rose formulations have traditionally been used as astringents, tonics, mild laxatives, and antibacterials to treat chest pain, constipation, depression, gastrointestinal, eye sickness, inflammation, respiratory problems and menstrual bleeding.



Soil and Climate

A deep and fertile loamy soil is ideal for commercial rose cultivation. Nonetheless, it can be produced effectively on a variety of soils with proper agronomic procedures. Roses thrive best in soil that ranges in pH from 6.0 to 7.5, which is moderately acidic to moderately alkaline.

High air humidity and moderate temperatures are needed for damask roses. They are typically grown in temperature between 20 and 30°C during the day and 18 to 20°C at night. Vernalization and short days are required to initiate flowering, which occurs in late spring and early summer. Low night temperatures of 10-12° C during the flowering stage significantly reduce oil synthesis, whereas temperatures of 20° C or higher promote oil synthesis. 70% humidity is ideal for a good Damask rose harvest.

Recommended varieties

- Noorjahan: This variety is developed from Central Institute of Medicinal and Aromatic Plants (CIMAP) which can be grown in Uttar Pradesh and the neighbouring states of subtropical climates. The oil has a subtropical oil content of 0.025–0.030% and a temperate oil content of 0.035–0.040%. The oil of Noorjahan variety has almost 30% geraniol, 24% citronellol, 12% nerol and 1.3% rose oxide.
- Ranisahiba: This variety yields up to 40 q/ha of flowers in three months, which makes it perfect for rose water production. According to the report, the oil contains 35% geraniol, 7% geranyl acetate, 5% citronellol and 10% trans-rose oxide.
- Jwala: It can be grown in northern plains of subtropical, low hills, and mild temperate climates at elevations up to 1200 meters. It is resistant to hail, rain, and strong wind, and it blooms in March and April and again in the month of September.

Propagation

The three methods used to propagate Damask roses are grafting, budding and stem cutting. The simplest technique for multiplying roses is stem cutting. Stem cuttings with 5-6 buds, measuring 20-25 cm long and 0.75-1.25 cm thick, are made from one-year-old stems that have begun to lignify. The best time to harvest the cutting is between November and December. After planting the cuttings, it takes 3 months for root initiation to begin and it takes 9 -12 months for the sprouted cuttings to reach the maturity stage at which they can be shifted into the main field.

Transplanting

In subtropical areas, the land is prepared in full during the month of April and left open during the summer. During field preparation, farmyard manure @ 10–15 tons per hectare is applied. After that, the planting area is correctly arranged out into beds of appropriate dimensions. The planting of rose is carried out in 0.45 m^3 pits spaced one meter apart. Rooted plants can be transplanted from July to August, but autumn planting is ideal. To plant one hectare of land, approximately 10,000 plants are required. During the first year, after each hoeing, 4-5 cm of soil is added around each plant.

Nutrient management

After pruning, FYM @15 to 20 tons/ha is applied and thoroughly mixed with the soil. It has been discovered that applying 120 kg of Nitrogen, 60 kg of Potassium and 60 kg of Phosphorus per ha y^{-1} enhance Damask rose flower yield. The nitrogen is applied in two equal dosages. Half of the nitrogen is applied during pruning and the other half is applied 15 days later.

Weeding and hoeing

During the early stages of rooted stem cutting establishment in the field, plants are more susceptible to competition from weeds. At least 2-3 weeding are required after transplanting, with monthly intervals. To suppress the growth of weeds, hoeing and light intercultural operations are done. At least three hoeing are required in the first year after planting, followed by one deep hoeing after pruning in subsequent years.

Irrigation

Adequate water is required throughout the vegetative and blooming stages. For Damask rose, 10–12 irrigations are needed annually. During the rainy season, it may be unnecessary to irrigate the plants. However, irrigation may be done every week during the warmer months and once every two weeks in the winter.

Pruning

The rose plant is simply pruned to create artificial dormancy. Annual pruning is required to maintain the right shape of bushes and promote new branches. Heavy pruning is done during a height of 15 to 20 cm above the earth's surface. Soil around the plants should be removed immediately after pruning and left open for at least 25-30 days. After pruning, the plants take 70–90 days to flower.

Harvesting and Storage

The main flowering season in the north Indian plains occurs between March and April. For the best essential oil quality and quantity, harvesting should be done at the cup-shaped stage. Flower harvesting should begin before dawn and end when the sun has dried the dew on the flowers. Petals are often hand-picked due to their exceptional delicacy. Flowers can be kept for 16 hours at 4 °C before being processed.

Plant Protection

The crop is prone to disease and pests in the early months. After pruning, fungus (*Diplodia rosarum)* can cause dieback disease. After pruning, the cut ends are immediately sprayed with copper fungicide. Bollworms and aphids are major pests during the spring. Bollworm moths lay eggs on buds, and the larvae eat leaves, buds and flowers. Nymphs and adult of aphids feed on the fluids of rose plants, attacking leaves, stems, buds and flowers.

Yield

Good agronomic practices can yield an average of 40-45 quintals per hectare. It can be sold directly or further processed, such as essential oil, rose water, or dried petals. And from one hectare 1 - 1.25 kg of oil yield can be obtained.

Challenges and opportunities of Damask oil production

Damask rose cultivation is a significant commercial dynamic that comprises all agricultural activities such as planting, harvesting and processing. Nonetheless, its cultivation is problematic in all countries that grow it.

1. Roses are frost sensitive and show uneven flowering patterns.
2. One major challenge is space availability, as the current gardens are small and dispersed because of the inheritance of the land.
3. Producers are shifting from cultivation of rose to other agricultural crops or economic activities to increase income and reduce risk due to market fluctuations.
4. Rose cultivation is labour intensive, especially for flower picking.
5. The temperature during harvest influences the amount of oil in the flower, high temperatures cause the trichomes on the petals to lose their essential oil content.
6. These flowers have low yield and oil content.
7. Current oil distillation processes yield low oil recovery rates for roses.
8. Most rose growers are unaware of new production technologies.

Conclusion

Rosa damascena Mill. is a popular *Rosa* species used in flavouring, aroma, and oil extraction. *R. damascena* products are primarily used in the scent and skincare industries, but they also possess beneficial medical properties such as antimicrobial, antioxidant, and cytotoxic properties. Despite the fact that its cultivation has a high economic potential, it is restricted due to the numerous constraints that rose producers face. Only about half of the world's total rose oil demand (15-20 tons) is currently produced. Therefore, farmers must adopt scientific cultivation of it in large areas and establish processing facilities because this crop is in high demand in both national and international markets.

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CELEBRATION OF THE SEA: ANNUAL FISHERIES OBSERVANCES

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Abstract

This article highlights globally significant days dedicated to raising awareness about aquatic resource protection, biodiversity conservation, and ecosystem sustainability. These observances focus on key environmental challenges, such as sustainable fisheries management, water conservation, habitat restoration, pollution control, and species protection. Days like World Fisheries Day, National Fish Farmers Day, and World Fish Migration Day emphasize the importance of maintaining ecological balance for both aquatic wildlife and human communities. The observances serve as platforms for public engagement, policy advocacy, and sustainable practices to protect the aquatic environment for future generations.

Keywords: Fisheries, Fish farmers, Wetlands, Ocean

Introduction

The aquatic environment is classified into freshwater, brackish and marine based on their salinity levels. Freshwater ecosystems, such as rivers, lakes, and streams, have low salt content (less than 1%) and are crucial for drinking water and household activities. Brackish water, found in estuaries where freshwater meets seawater, has moderate salinity and supports activities like fishing and aquaculture. Marine ecosystems, including oceans and seas, have high salinity (around 3.5%) and provide fish, salt, and energy resources. Freshwater is only about 2.5% of Earth's total water, while marine waters comprise around 97%. Brackish water ecosystems form a small fraction, often included in coastal regions. Many important days are celebrated to distinguish the importance of key issues like endangered species, pollution, and habitat loss, thereby encouraging public participation, policy change, and sustainable practices to ensure a balanced relationship with nature, which is essential for human survival and the planet’s well-being. Each of these days celebrated serves as a call to protect the aquatic environment for current and future generations. Some important days celebrated regarding fisheries, their origin and themes of 2023 are given below.

World Fisheries Day (November 21)

World Fisheries Day, celebrated for the first time on November 21, 1997, originated from a historic gathering in New Delhi where the "World Forum of Fish Harvesters & Fish Workers" from about 18 countries formed the "World Fisheries Forum". This global movement led to a landmark declaration promoting sustainable fishing practices and policies worldwide. The day highlights critical issues like overfishing, habitat destruction, and threats to marine and inland resources. It serves as a platform to advocate for better fisheries management, ensuring sustainable fish stocks and healthy ecosystems for future generations. The theme in 2023 was “Towards Blue Transformation: Supporting Small-Scale Producers”. This theme emphasizes the crucial role of small-scale fishers in sustainable fisheries management.

National Fish Farmers Day (July 10)
National Fish Farmers Day was celebrated first in the year 2001, proposed to honor those involved in aquaculture, including fish farmers and experts. It commemorates the pioneering work of Dr. Hiralal Chaudhury and Dr. K. H. Alikunhi, great Indians who achieved the first successful induced breeding of fish through hypophysation on July 10. In 2023 theme of this day was, "Transforming the Fisheries Value Chain for Sustainable Development," which emphasized innovation and sustainable practices to boost aquaculture and to support the sector’s growth.

World Wetlands Day (February 2)
World Wetlands Day is observed every year on February 2, with an aim to raise global awareness about the importance of wetlands for both people and the environment. It also marks the anniversary of the adoption of the Ramsar Convention on Wetlands, signed on 2 February 1971 in Ramsar, Iran. The 2023 theme, "Wetland Restoration," emphasizes the critical need to prioritize efforts in restoring degraded wetlands. First celebrated globally in 1997, the day emphasizes the vital role of wetlands in maintaining ecological balance and supporting livelihoods.

World Tuna Day (May 2)
World Tuna Day was established by the United Nations General Assembly in December 2016 to protect endangered tuna species, with the first celebration held in 2017. According to the UN reports, around 7 million metric tonnes of tuna and similar species are fished each year and around 80 countries rely on tuna for food security, economic growth, employment, and culture. The expansion of tuna fisheries poses significant challenges by contributing to overfishing, which threatens tuna populations, and by disrupting marine ecosystems, impacting species diversity and balance. The Marine Stewardship Council (MSC) chose "Yes We Can" as the theme for World Tuna Day in 2023, focusing on sustainable fishing efforts.

World Oceans Day (June 8)
World Oceans Day was officially recognized by the UN in 2008 to celebrate the oceans and their vital role in sustaining life on Earth. It was first celebrated globally in 2009. The idea originated at the 1992 at Rio Earth Summit, proposed by the Canadian delegation, and gained further support in 1998 from UNESCO's Intergovernmental Oceanographic Commission. Conservation groups like the “World Ocean Network” and “The Ocean Project” also played key roles in advocating for its official recognition. The theme for World Oceans Day 2023 was "Planet Ocean: Tides are Changing," emphasizing the need for sustainable ocean management.

International Day for Biological Diversity (May 22)
International Day for Biological Diversity was proposed by the UN to raise awareness about the importance of biodiversity to promote conservation. First celebrated globally in the year 1993, the day emphasizes the role of biodiversity in maintaining ecosystems and supporting life on Earth. The concept of this day was introduced to encourage actions that protect species, habitats, and ecosystems. The theme for the 2023 observance was "From Agreement to Action: Build Back Biodiversity," focusing on implementing global agreements to restore and safeguard biodiversity.

World Environment Day (June 5)

World Environment Day was established by the United Nations General Assembly in 1972 to raise global awareness about environmental issues and promote action to address them. It is observed annually on June 5 and has since become the largest global platform for environmental advocacy. The celebration of this day originated from 1972 United Nations Conference on the Human Environment held in Stockholm, Sweden, where world leaders agreed to create an event to encourage environmental protection. The theme for World Environment Day 2023 was "Solutions to Plastic Pollution," under the campaign #BeatPlasticPollution, focusing on addressing the global plastic crisis.

World Maritime Day (Last week of September)

World Maritime Day, an annual event celebrated on the last Thursday of September, was established by the International Maritime Organization (IMO) in 1978 to raise awareness about the importance of international shipping and maritime activities. The day highlights maritime safety, security, and environmental protection, emphasizing the critical role of shipping in global trade. First observed globally in 1978, the event focuses on maritime issues and aims to promote the IMO's efforts to regulate the industry. The 2023 theme was "MARPOL at 50 – Our commitment goes on," celebrating 50 years of the MARPOL convention, which plays a key role in preventing marine pollution from ships. MARPOL stands for the "International Convention for the Prevention of Pollution from Ships."

World Fish Migration Day (Date varies)

World Fish Migration Day is a global event first celebrated in 2014 to raise awareness about the importance of free-flowing rivers and migratory fish. The event highlights the need for healthy rivers to support fish species and other wildlife reliant on migration, such as water insects, birds, otters, and river dolphins. Celebrated every two years, it promotes the restoration of river ecosystems. The 2022 theme, "Breaking Free," focused on removing barriers to restore rivers, while the 2024 theme, "Free Flow," expands the focus to all creatures, including humans, that depend on these waterways. The next celebration on May 25, 2024, will mark the sixth edition.

Conclusion

These globally significant observances to celebrate the aquatic resources related to fisheries, biodiversity, and the environment highlight the vital role of natural resources in sustaining life on Earth. By focusing on specific challenges such as sustainable fishing practices, water conservation, habitat restoration, and pollution control, these days serve as important reminders of our collective responsibility to protect and to evolve strategies to conserve ecosystems. Each event encourages public participation, promotes sustainable practices, and calls for action to ensure the well-being of future generations. Through these celebrations, we can continue to raise awareness, foster global cooperation, and drive positive change for the planet's health and aquatic biodiversity.

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RECENT ADVANCES IN CRISPR/Cas9 TECHNOLOGY FOR PLANT GENOME EDITING

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Abstract

With increasing population, demand for food also increases. As the rate of increase in population is also rising with traditional breeding practices, we are at a point to fail to feed each and every hungry mouth. So, use of genome editing tool became a ray of hope in this problem and CRISPR/Cas systems have become ground-breaking instruments for exacting genetic alterations in crops providing notable improvements in yield, durability, and nutritional content. CRISPR/Cas also helped by increasing photosynthetic efficiency, nutrient uptake, and resistance to lodging, as well as by enhancing flavour, texture, shelf life, and nutritional content through biofortification, CRISPR/Cas plays a critical role in increasing agricultural output and quality. Although obstacles including unintended consequences, the requirement for more effective delivery techniques, and moral and legal issues, the analysis highlights the significance of CRISPR/Cas in tackling issues related to global food security and sustainability.

Keywords: Genome editing, CRISPR/Cas, Biofortification, Sustainability, Food security

Introduction

Nature goes with the law of survival of the fittest, as who are fit in the environment those only will survive. The fitness of the species depends on various factors like environment, survival and reproduction of species and variation in the genetic makeup of the species. Genetic variation in species plays crucial role for the survival as it contributes in adaptability, environment resilience, disease resistant, plant breeding and evolutionary studies. Genetic variation shows available diversity in the species and loss of diversity leads to risk of extinction.

Variation can be secured through conventional plant breeding practices which requires significant amount of time or through random mutagenesis having very low chance of success. Either it is laborious work or has a lower chance of obtaining desired result. Evidentially by using modern techniques like genome editing guarantees precise and faster development of improved plant varieties.

Techniques which are developed to make specific changes or alteration in the genome of an organism are called as genome editing techniques. Some most commonly used genome editing technologies include-

a) Zinc-finger nucleases (ZFNs)- ZFN is fusion of custom tailored Cys_2-His_2 zinc-finger protein with cleavage domain of *Fok*I restriction endonuclease. ZFN cuts double-strand break (DSB) at specified location to induce modification of targeted site.
b) Transcription activator-like effector nucleases (TALENs)- TAL Effectors are combined with *Fok*I restriction endonuclease. The TALEN pair binds to their respective target sites on the DNA, and the *Fok*I domains induce a Double-Strand Break (DSB).

c) Meganucleases- Meganuclease are designed to identify long DNA sequence (so they are more specific and have low off-target effects). After meganuclease is introduced in the cell it attaches to the target sequence and induces Double-Strand Break (DSB).

CRISPR/CAS in Plant Genome Editing

The CRISPR/Cas system was discovered as a result of the detection of odd structures in *Escherichia coli* downstream of the iap gene. Five homologous sequences having 29 nucleotides (nt) are placed in direct repeats within the structure, with 32 nt acting as a spacer between each sequence (Ishino et al.,1987). Then the structure formed is regularly interspaced sequences and it is labelled as Clustered regularly interspaced short palindromic repeats (CRISPR). It is paired with CRISPR associated protein (Cas) acts as molecular scissor to induce Double-strand break and guide RNA to steer the Cas towards a designated DNA sequence (Chen et al.,2024).

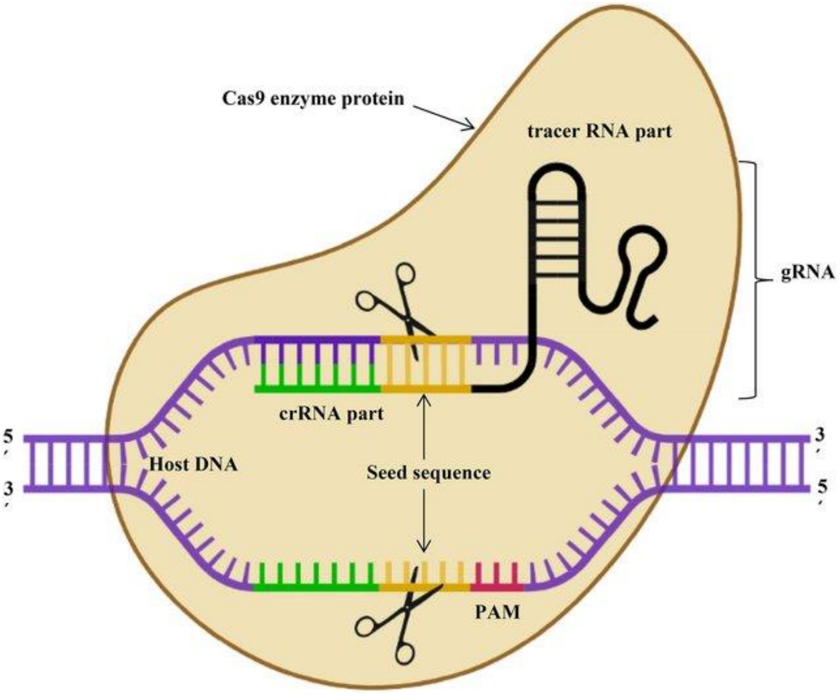

Figure 1. Components of CRISPR/Cas Complex

CRISPR/Cas complex comprises subunits of gRNA and Cas9 protein. Trans-Activating CRISPR RNA (tracr RNA) and CRISPR RNA (crRNA) are the two components responsible for making up guide RNA (gRNA). The short stretch of 2–6 bp (NGG) known as the protospacer adjacent motif (PAM) is necessary for Cas9 nuclease action. It is located three or four nucleotides downstream of the cut location. Presence of complementary bases is necessary for gRNA to get attached to the target DNA and for Cas9 to cut it.

Components of CRISPR/Cas Complex and their function

Components	Function	References
tracrRNA (trans-activating CRISPR RNA)	• Helps in processing pre-crRNA. • Forms complex with Cas9 and crRNA for DNA DSB.	(Deltcheva et al., 2011)

Components	Function	References
crRNA (CRISPR RNA)	• Target DNA recognition. • Directs CRISPR/Cas9 system.	(Jinek et al., 2012)
PAM (Protospacer Adjacent Motif)	• Cas9 activation. • Prevents off-target cut/ activity.	(Mojica et al., 2009)
Seed Sequence	• Initial binding between crRNA and target DNA.	(Cong et al., 2013)

DNA repair pathways in plants

Site-directed nucleases are used in genome editing technologies to cause double-strand breaks at specific genomic regions. Host DNA repair components that function in either of the two repair pathways—homologous recombination or non-homologous end-joining—are drawn in when DSBs are formed. Sequences flanking the DSB that possess sequence homology are integrated by HR to repair the DSB. In order to insert desired sequences, exogenous repair or donor templates can be recombined with the target locus using HR-mediated repair.

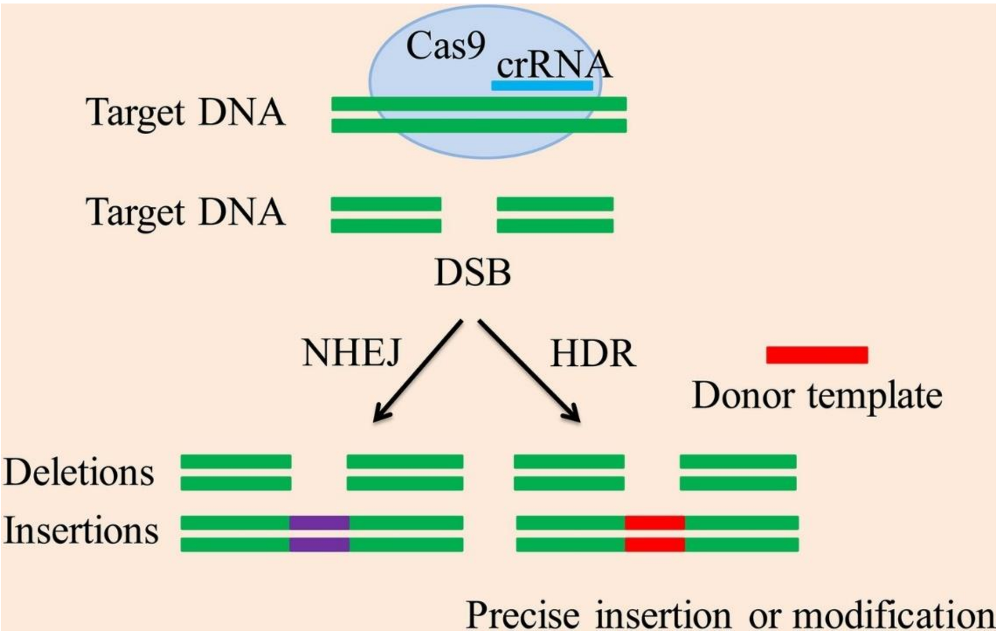

Figure 2. Different DNA repair pathways in plants

The NHEJ pathway can also be used to repair double-strand breaks (DSBs). This mechanism introduces random insertion or deletion mutations (indels) of different lengths that cause frameshift alterations in the coding sequence, which in turn results in gene knockouts. But frequency of happening of NHEJ is more in nature.

Recent Technological Advances in CRISPR/Cas9 for Plants

CRISPR Variants and advancements

a) CRISPR/Cas3

Cas3 is a Class 1 CRISPR system that works by breaking down longer segments of DNA. This makes it less accurate but beneficial for applications that require large-scale deletions of DNA. When substantial genomic deletions are needed, like when producing massive knockouts in bacteria or deleting extended regions of viral DNA, CRISPR/Cas3 is an ideal tool.

b) CRISPR/Cas9
Cas9 is a class 2 CRISPR system which uses single guide RNA (gRNA) and a RNA guided Cas9 endonuclease which induces double stranded break (DSB).

It is most abundantly used in genome editing as it has high efficiency and broad applicability among all Cas9 variants.

c) CRISPR/Cas12a
Cas12a (previously known as Cpf1) is an alternative CRISPR-associated protein with different features compared to Cas9. After identifying a T-rich PAM (Protospacer Adjacent Motif), it cleaves DNA unevenly, producing overhangs instead of blunt endings. Cas12a is useful for editing in animals with high AT content because it has advantages including more flexible PAM requirements and improved targeting of AT-rich areas of the genome. Cas12a may be utilized for multiplex genome editing since it is capable of processing its own crRNA arrays.

d) CRISPR/Cas13
A CRISPR variant called Cas13 may identify and cut RNA instead of DNA. This makes it useful for altering how genes express at the transcriptome level. Cas13 does not induce lasting alterations to the DNA, which makes it suitable for short-term gene knockdown or researching RNA-related processes. RNA editing, antiviral treatments, and transcriptome regulation all make use of CRISPR/Cas13. It has demonstrated potential in combating RNA viruses such as SARS-CoV-2.

e) CRISPR interference (CRISPRi) technique
In this modification it uses dCas9 (dead Cas9) that binds to coding region of a gene. It acts as a physical barrier in the transcription process to avoid or suppress the gene expression.

CRISPRi is an effective method for gene knockdown without changing the DNA sequence. It makes it possible to specifically and reversibly suppress the expression of a gene, which is especially helpful in functional genomics investigations where the main aim is to examine the consequences of decreasing rather than completely removing gene expression. Applications of this include researching gene function, and creating disease models.

f) CRISPR activation (CRISPRa) technique
dCas9 is also employed by CRISPRa, although in this specific case, it is fused to transcriptional activators such p300, VP64, or VPR (VP64, Rta, and p65). These activators enhance transcription and increase gene expression by pulling or guiding the transcriptional process to the target gene.

CRISPRa is a great technique for investigating overexpressed phenotypes, reactivating silenced genes, and examining gene function since it can enhance/ upregulate gene expression. It helps with pathways where gene activation is necessary because it to produce more of a specific protein. Determining genes linked to cell differentiation, illness resistance, and curing diseases by upregulating specific gene expression are some applications.

g) Base editing
Base editors are modified versions of CRISPR systems that provide direct base-to-base conversion of DNA without causing double-strand breaks (DSBs). This is accomplished by combining a deaminase enzyme that changes one base to another, like C→T (cytosine base editors, CBE) or

A→G (adenine base editors, ABE), with a catalytically impaired Cas9 enzyme (dCas9 or nCas9). Point mutations linked to hereditary illnesses can be corrected via base editing. It reduces the possibility of errors by enabling precise genomic alterations without causing significant insertions or deletions.

h) Prime editing

Prime editing is a flexible CRISPR variation that eliminates the requirement for donor templates or DSBs and enables accurate "search-and-replace" editing of DNA. It combines a reverse transcriptase enzyme, a primary editing guide RNA (pegRNA), and a catalytically impaired Cas9 (nickase) that targets the DNA and encodes the desired change. Prime editing provides a more versatile tool for precise genome editing by allowing the introduction of targeted nucleotide modifications, tiny insertions, or deletions.

Some advancements to minimise off-target effects

Unintentional DNA modification that takes place when CRISPR-Cas complex edits similar DNA sequence but not the exact DNA sequence as it is supposed to do. Reduction of such off-target effects is necessary for effective genome editing.

a) High-Fidelity Cas9 Variants

To increase the precision factor these are some engineered variants of Cas9 to reduce off-target DSB-

Variants	Purpose of Modification
eSpCas9 (Enhanced SpCas9)	To reduce non-specific DNA interactions.
SpCas9-HF1 (High-Fidelity Cas9)	Altering residues involved in non-specific DNA interactions.
HypaCas9 (High-fidelity Cas9)	Increase specificity with no effect on cutting efficiency.

b) Paired Nickases

Cas9 nickase, a modified form of Cas9 that adds single-strand breaks, or "nicks," in place of double-strand breaks, is used in the paired nickase technique. To minimize off-target effects and solely create a DSB at the on-target site, two nickases are engineered to cut opposite strands of DNA in close proximity to one another. For applications that need to minimize off-target effects without compromising editing performance, paired nickases are useful.

c) Prime and Base editing

Techniques like these are used for small and precise changes in genome by genome editing. As it creates precision cut up to single nucleotide, it helps in mitigation of off-target effects.

Conclusion

In conclusion, this review emphasizes on advancements in CRISPR/Cas9 technique to increase efficiency of genome editing techniques. Innovations like different variants of CRISPR and their specific use. Recent advancements including base and prime editing, high-fidelity Cas9 variants, paired nickases increases efficiency of genome editing work. CRISPR/Cas technology can also be used in gene silencing to induce disease resistance and removing allergens. Furthermore, it can be helpful in enhancing or upregulating gene expression and reactivating silenced genes. It will be crucial for biofortification and the enhancement of both qualitative and quantitative gene expression in the future.

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SCOPE AND USES OF LOTUS (*Nelumbo nucifera*): AN IMPORTANT UNDEREXPLOITED FLOWER PLANT IN MANIPUR, NORTH EAST INDIA

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Introduction

The lotus, or *Nelumbo nucifera*, a species of water plant from the Nelumbonaceae family, has long been revered in the regions where it naturally grows, with its name originating from the Greek word "lotos," historically used to describe the ancient Egyptian “water lily” *Nymphaea caerulea* and related Nelumbo species from India and East Asia.

Lotus rhizomes were traditionally cultivated in ponds but later harvested in shallow waterlogged areas, with harvesting costs being a major expense in the system. The genus comprises only two species, *Nelumbo nucifera*, found in Asia and Oceania, and *Nelumbo late* wild, native to North and South America, with *Nelumbo nucifera* Gaertn being a perennial aquatic plant widely grown and consumed in China, India, Japan, and Australia, not only for food and medicine but also for its cultural and religious significance. The lotus plant's rhizome, known as lotus root, is edible and typically cultivated in submerged ponds or fields, with the plants initially growing in shallow water before extending into deeper areas. Its flowers, which range from 10 to 15 cm and can reach a diameter of 20 cm when fully bloomed, produce showerhead-like seeds after fertilization, while its round, crenulated leaves, measuring 20 to 60 cm in diameter, usually float on the water’s surface but can sometimes rise up to 45 cm, giving them a shallow bowl-like shape.

While the lotus is often used for decorative purposes, its roots are sweet, flavourful, and rich in vitamins and starch, and can be consumed in various ways, including raw, dried, preserved, powdered, cooked in soups, brewed into teas, or mixed into salads; additionally, other parts of the lotus plant are also edible. The lotus flower holds different meanings based on its color, with the white lotus symbolizing purity, grace, and beauty, while other colors convey various concepts: the yellow lotus represents spiritual ascension, the pink lotus embodies the essence of Buddha, and the red lotus signifies compassion and love, along with associations of power, procreation, wealth, tranquillity, knowledge, and self-confidence.

Moreover, the lotus is a widely consumed vegetable and traditional medicinal plant of significant economic value in Southeast Asia, with China being a major centre for lotus cultivation and breeding, boasting a history of several thousand years. This extensive period of domestication and cultivation has led to the development of numerous lotus cultivars exhibiting diverse morphological characteristics and other traits. Cultivated lotus is typically classified into three categories—rhizome, seed, and flower lotus—based on their practical uses. Both the lotus rhizome and seeds can be consumed as vegetables and utilized for propagation, while the flower is primarily used for ornamental purposes and environmental enhancement.

Export data reveals that 340 buyers received 8,800 shipments of lotus seeds from 236 international exporters, with the United States, Vietnam, and Canada being the primary destinations. Vietnam is the leading exporter with 5,356 shipments, followed by China with 1,327 shipments and India with 781 shipments.

Due to rising incomes, lotus cultivation has become widespread in India, particularly in Chhattisgarh, where wetlands such as small rivers, ponds, reservoirs, and lakes are utilized for growing lotus. In Manipur, this aquatic plant is also significant as an ornamental species, with its rhizome, known as "Thambou," being a popular vegetable, while in some northeastern regions, it is referred to as Tawisampala or Kamal kakdi and cultivated for its high value as a vegetable crop; consequently, the rapid increase in the human population and demand in Manipur presents opportunities for cultivating this important underexploited ornamental crop.

Importance, its uses and medicinal values

The lotus is an important horticultural plant widely utilized in Southeast Asia for various nutritional and medicinal purposes, with traditional medicine employing its leaves to treat a range of ailments, including infections, fever, weakness, diarrhea, skin irritations, and temperature imbalances, as well as conditions associated with abnormal bleeding, such as metrorrhagia, hematuria, hemoptysis, and hematemesis. Lotus leaf extracts have shown strong antioxidant and radical scavenging properties, along with an inhibitory effect on factors related to diabetic complications. While the phenolic, tannin, and flavonoid content in the aqueous extracts from lotus rhizomes differed from that of the leaves, they still exhibited some antioxidant activity, albeit not as significant as that of the leaf extracts. **N R Mehta *et al.* (2013)** The rhizomes can be consumed raw, pickled, stewed, or fried, and the stems, leaves, and petals are also edible, with the stamens commonly used to prepare herbal tea. In Manipur, lotus is considered a popular underutilized vegetable, with its leaves and tubers/roots used locally in a salad known as “singju.”

Nutritional value of lotus root (raw)

According to the USDA, a 100 g serving of lotus root contains 60 calories, along with 0.1 grams of fat, 2.6 grams of protein, 17.2 grams of carbohydrates, 0 grams of sugar, and 4.9 grams of dietary fiber, with the remaining content primarily made up of complex carbohydrates.

Distribution in India

The lotus is originally native to Asia, including regions such as India, China, and Vietnam, and it can also be found in parts of Australia. This species is commonly referred to as the "Sacred Lotus" due to its long-standing reverence in the religious traditions of Buddhism and Hinduism. The earliest fossilized record of *Nelumbo nucifera* in India dates back to the Pleistocene epoch in Kashmir, while its presence during the Tertiary period in Assam is indicated by leaf and rhizome impressions discovered in Eocene deposits near Damalgiri. These findings provide evidence that *Nelumbo nucifera* is indigenous to India. *Nelumbo nucifera*, often referred to as the "East Indian Lotus," is distributed across a broad range of phytogeographical regions and displays considerable diversity in flower shapes, sizes, and shades of pink and white. As an old-world Asiatic species, it is commonly found in many Asian countries, including India, Sri Lanka, Indonesia, Korea, Cambodia, Thailand, Vietnam, Japan, and China. **S.C. Sharma and A.K. Goel (2000).**

Morphotypes of lotus in Manipur

As a cross-pollinated plant, the lotus has developed significant genetic variation over generations In Manipur, one specific morphotype known as the 108-petal lotus is characterized by its long stems and broad leaves, typically growing in lakes or ponds, reaching heights of 20 to 25 cm, and featuring light pinkish flowers.

Propagation

Lotuses are propagated by dividing rhizomes and seeds, with newly sprouting rhizomes cut into small segments containing three or more nodes. To encourage early germination, the seeds are scarified at both ends, and they are typically planted in a moist soil mix of clay and loam. Lotuses need a minimum of six hours of sunlight daily, and during their first year, fertilizer should be used sparingly to avoid freezing the roots. Furthermore, rhizome propagation is a faster method for growing the plant compared to seed propagation. **S.C. Sharma and A.K. Goel (2000).**

Processed products from lotus

Various processed products can be made from the lotus flower, and in Manipur, approximately 45% of households cultivate lotus for commercial purposes in the large ponds and lakes of the valley. However, there is significant waste due to market issues, limited shelf life, and a lack of knowledge among growers regarding its processed products. Lotus tubers can be processed into achar (pickle), and dried petals can be utilized to make herbal tea. Furthermore, the fibres extracted from the stems can be used to create handloom products like bags, scarves, and cloths. By expanding the range of processed products, growers can enhance their income and minimize waste during peak harvesting seasons.

Major problem for cultivation of lotus cultivation in Manipur

1. Lack of wetland areas due to increase of human population.
2. There is no scientific farming method in place.
3. One of the biggest issues throughout the harvesting season is marketing.
4. Little is known about the various processed goods made from this flower plant.
5. No appropriate government scheme was provided to the farmers.

Conclusion

In Manipur, the rapid increase in the human population is leading to a decline in wetlands and other water bodies in the valley region, resulting in a loss of lotus growing areas. Therefore, it is crucial to conserve the local lotus, known as “Thambal chamnipal” or the 108-petal type, to prevent the extinction of this important high-value ornamental crop in Manipur, Northeast India.

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ADVANCED ANALYTICAL TECHNIQUES IN SEAFOOD QUALITY ANALYSIS: FLUORESCENCE MICROSCOPY, SCANNING ELECTRON MICROSCOPY, TRANSMISSION ELECTRON MICROSCOPY, AND X-RAY DIFFRACTION

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Abstract
The examination of seafood for quality is a crucial practice to protect the safety of consumers, the nutrition of the product, and its therapeutic value. In this regard, advanced analytical procedures like Fluorescence Microscopy (FM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and X-ray Diffraction (XRD) are slowly taking center stage as they provide clear information about the structure, composition, and functions of sea food. This paper therefore aims at looking into the principles of work, mechanisms, applications as well as advantages and disadvantages of these techniques in seafood quality evaluation quantitatively. In particular, all these techniques make it easy for seafood quality assessment due to their individual and synergistic effects. On the other hand, these techniques come with some issues on their applicability, for example, tedium in sample preparation, expensive equipment, or even chances of damaging the sample. Notwithstanding these constraints, the synergistic application of FM & SEM & TEM as well as XRD techniques is important to enhance the quality control of seafood for the consumers, that is, its safety, and acceptance.

Keyword : Advanced analytical techniques, consumer safety, microscopy methods, seafood quality control.

Introduction

In the food sector where seafood extends over nutrition and international trade, quality and safety are essential. Seafood is a bulk product that has a very short shelf life and quality deterioration may occur due to various reasons such as contamination from microorganisms, action of enzymes or simply damage sustained during handling and storage. Therefore, it is important to assure the hygiene of seafood in order for it to comply with the safety standards, and for the nutritional and taste value to be preserved more sophisticated analytical methods need to be applied.

Evaluation of traditional techniques to seafood quality analysis such as sensory evaluation or chemical assessment did have their worth but always lacked the required threshold of detection and level of specifics needed to realize minute changes within and into the smallest cells and molecules. As a consequence, there are more complex methods been recommended like Fluorescence Microscopy (FM), Scanning Electron Microscopy (SEM) or Transmission Microscopy (TEM) and X-ray Diffraction (XRD). These techniques present quality and quantity data that include structure and the composition of the seafood materials. Comprehensively, these methods of imaging give a clear interpretation of the textural components, their functions, and the makeup of the marine products. A more in-depth account of these imaging techniques, including the principles of operation, underlying mechanisms, usages, pros and cons is presented below.

1. Fluorescence Microscopy (FM)

Working Principle and Mechanism: In Fluorescence Microscopy, fluorescent molecules referred to as fluorophores are excited. These are molecules that absorb light at specific wavelengths and re-emit at light of longer wavelengths. The mechanism begins with the absorption of light and excitation of fluorophores bound to a specimen in a higher energy state or higher than the ground state. Typically, this light is from a laser or a mercury lamp. As the electrons drop back to the ground state, light energy in form of rays is emitted and collected by apparatus that assembles the images of cellular or tissue components of high contrast.

Preparation of the Sample: The sample is often prepared by the fluorescent dyes or antibodies that specifically bind to the target molecules present in the seafood sample. This process of staining is vital to record the presence of certain proteins, lipids or even other biomarkers.

Excitation and Emission: The sample that is already stained is then subjected to illumination with light at a certain wavelength (excitation) leading the dye to light the specimens at different wavelengths (emission). The light emitted is used after appropriate filtering to obtain the corresponding image.

Application: In recent years, seafood fluorescence microscopy has been greatly applied in quality assessment of seafood mainly to visualize biomolecules like protein and lipid. This is especially important in seafood product where the consumers mind is inundated with pathogenic, contaminating and even spoilage indicative signs as highlighted on the description of seafood quality freshness and safety (Lamas et al. 2023).

Advantages

a) Very specific and sensitive methods for detecting specific biomolecules of interest.
b) Visualizing live cells and tissues is possible, enabling monitoring in real time.
c) If applied correctly, does not destroy the sample.

Disadvantages

a) Only fluorescent stains can be used which may modify the sample.
b) Thick samples have a shallow effective penetration limit.
c) As a result of photobleaching, there may be a loss of fluorescence over time.

2. Scanning Electron Microscopy (SEM)

Working Principle and Mechanism: Scanning Electron Microscopy takes advantage of a directed high energy focused beam of electrons that moves in a controlled fashion along the surface or microstructure of a specimen. The interaction of the electrons within and outside the specimen results in a plethora of signals pertaining to the composition, surface texture, and other features of the object. As noted by Goldstein et al. (2017), the key processes involved in scanning electron microscopy architecture include:

- Generating Electron Beams: The beam of electrons is generated by an electron generator and focused on the specimen by means of magnetic lenses.

- Scanning Process: The electron beam is rastered over the sample creating X-ray, back scattered electrons, and secondary electron production in the process.
- Signal Detection: The low energy secondary electrons collected by the imaging system are used to reconstruct the picture of the scanned area of the specimen. The image quality is affected by the surface structure and material of the specimen where the image is taken from.

Application: In the assessment of seafood quality, SEM is used in microstructural evaluation of muscle, the fibrous element organization, connective tissue, and presence of microorganisms within the seafood. This is mostly the case for studying processed seafood and drawing conclusions on the beneficial or adverse effects of preservation technologies like freezing, drying, or smoking on the surface structure of seafood and its textural properties (Sharma and Bhardwaj, 2019).

Advantages:

a) Offers sharp focused images of the surface.
b) Enables examination of extensive areas of the sample with information on the microstructural elements.
c) Efficient in analyzing the types of samples, such as biological tissues and non-organic substances.

Disadvantages:

a) In most cases, the sample becomes dehydrated and covers with some conducting metals; hence, sample preparation is sometimes tedious.
b) This technique is performed under vacuum atmosphere which is not applicable for all the specimens (Goldstein et al., 2017).
c) Does not provide information about internal structures.

3. Transmission Electron Microscopy (TEM)

Working Principle and Mechanism: A beam of electrons is introduced through very thin sections of the material so as to obtain a transmission type of electron microscope. The specimen is scanned with interaction of electrons and the resultant image is made out of the mapped electrons. The main mechanisms include:

- Electron Transmission: A high-voltage electron beam is created and transmitted across an ultra-thin layer of the sample.
- Interaction with Sample: While travelling through the sample, the electrons collide and scatter with the atoms and their arrangement, leading to some diffraction patterns. Some electrons get lost while some complete the journey through the other end.
- Image Formation: Transmitted electrons are focused by electromagnetic lenses on a fluorescent screen or some other type of detector to produce a sharp image of the device. The image reconstructs the interior content of the specimen within a nanometre scale, demonstrating the arrangement of cellular organelles, proteins and other microscopic river network structures.

Application: TEM is applied in the analysis of quality of all types of seafood to understand the cells, tissues in more detail with all their compartments such as organelles, muscle cells components and structural minutia. Very useful for the study of cellular elements in seafood after various preservation methods, for example, freezing (Hajalilou and Ghadimi, 2019).

Advantages:
a) Ultra-high power resolution, thus enabling the study and viewing of internal layers within the specimen at the nanometer scale.
b) Helps to understand better the future seafood ultra-structural quality changes because of the processes and live tissue preservation conditions.

Disadvantages:
a) It is very difficult to do the sample preparation where the sample should be provided in ultra-thin sectioning which could destroy the specimen.
b) Costly equipment and the cost of running the equipment is also very high.
c) Only small sample are can be covered.

4. X-ray Diffraction (XRD)

Working Principle and Mechanism: X-ray diffraction is a technique that relies on reflection of x-rays due to certain atomic planes in crystalline materials. Basically, XRD follows Bragg's law or lattice spacing equation. The principal mechanisms consist of:

- Primary X-ray emission: A source of x-rays, for example, an X-ray tube, sends X-rays to the sample under investigation. In turn, the crystalline structure of the sample X-rayed gives rise to scattering of the radiation at certain angles.
- Diffraction Pattern Formation: The dispersed X-rays create a pattern relating to the crystalline structure of that the sample planar covered. This scanned and recorded pattern is termed a Phased Array.
- Analyses: The diffraction pattern is utilized to determine the phase composition, crystal structure and several material characteristics of interest. The peaks and intensity of the diffractions peaks can help in determining the crystallinity and the atomic arrangement of the studied materials.

Application: XRD also finds a purpose in seafood quality analysis where it is used to study the crystalline structure of various ice in frozen seafood and shells minerals amongst others. Crystallinity of proteins is also studied as it influences texture and some quality parameters (Purohit et al., 2019).

Advantages:
a) Non-invasive method which gives detailed insight to crystal map and segregation of its phases.
b) Applicable to a wide range of materials, areas include inorganic and organic materials.
c) Can take up and analyze a variety of mixtures and take out the crystalline phase present.

Disadvantages:
a) Crystalline samples are a must which further limits its usage to solid samples alone and excluding powders.
b) Not so useful for dispersions and extremely low crystalline materials.
c) In many cases, simple patterns can be obtained but their analysis is very difficult and needs particular skills.

Conclusion

The combination of various techniques such as Fluorescence Microscopy, SEM, TEM, and XRD provides a global as well as a technological approach to seafood quality assessment. Each technique provides additional information at a specific level of structural and compositional analysis facilitating effective evaluation of seafood hygiene, textural attributes and nutritional composition. Even though these advances have both merits and demerits on their own, they serve an important purpose in modern seafood quality assurance systems since they make it possible for end products to be safe and satisfactory to consumers.

Conflict of interest

Authors declare no conflicts of interest.

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BARRIERS TO BREEDING: THE IMPACT OF DAMS ON FISH MIGRATION

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Abstract
While dams are useful for managing water resources, controlling flooding, and producing hydroelectric power, they also present serious problems for fish migration. Many fish species depend on free-flowing rivers to complete their life cycles, especially for spawning, and migratory species like salmon, eels, and sturgeons are particularly vulnerable because they migrate between freshwater and marine environments. Dams create physical barriers that disrupt these migration patterns, preventing access to vital breeding and feeding grounds, which causes fish populations to decline and endangers biodiversity and the ecosystems that depend on these species. In the context of global climate change, the cumulative impact of dams on fish migration becomes even more pronounced, as altered hydrological patterns intensify the barriers to fish movement. This paper reviews the extent of the constraint's dams place on fish migration, explores the ecological and economic consequences of these disruptions, and evaluates current mitigation strategies while highlighting the need for innovative approaches and integrated river basin management to ensure the survival of migratory fish species in dam-impacted ecosystems.

Keywords: Dams, breeding, flowing, season, behavior

Introduction

River damming has significantly improved flood control, irrigation, navigation, and water and energy supply globally, particularly in the past century, since the first masonry dam was built on the Wadi Rajil at Jawa, Jordan, about 3000 BCE (Best, 2019). Following World War II, there was a first worldwide boom in dam construction, which peaked in the 1960s and 1970s, mostly in Western Europe and North America. The 1990s saw a slowdown in the global trend of dam construction due to growing concerns about the ecological and socioeconomic effects of river damming (Moran et al., 2018). There has been a second boom in dam construction, though, primarily in developing nations and emerging economies in Asia, Africa, and South America, and especially in large river basins like the Amazon, Congo, and Mekong, in order to meet the rapidly increasing demands for energy and water for socio-economic development (Winemiller et al., 2016). To restore and make up for the fish habitats lost in the dammed mainstems, a few minor dams and obstacles have been taken down in tributary channels (L. Tang et al., 2021). By boosting the target fish populations, artificial breeding programs have been used to restore fisheries resources, with some degree of success.

However, there are some contentious views regarding fish conservation strategies in dammed rivers as a result of the lack of thorough research into the efficacy and efficiency of these conservation techniques. As a result, evaluating the performance and financial viability of various conservation strategies may greatly aid in locating and advancing good approaches.

River Damming Impacts on Fish Physical Habitat

2.1. Impacts on River Connectivity

According to Díaz et al. (2020), river longitudinal and lateral connections are essential for preserving the composition and functionality of riverine ecosystems. According to Fuller et al. (2016) and Grant et al. (2007), river systems are hierarchical tree-like networks whose ecological function is heavily reliant on physical connectedness. River connection and natural movement play a major role in meeting fish demands for a variety of habitats. Figures 1a and 1b demonstrate the importance of longitudinal connection for fish migration, while Figure 1c shows how lateral connectivity gives fish access to breeding and rearing sites in floodplains, side channels, oxbows, and floodplain lakes.

The longitudinal connectedness of the world's rivers is seriously threatened by the growing number of dams. almost 10% of worldwide river reaches have a Connectivity State Index (CSI) below 95%, the bare minimum for strong connectivity, and almost half of global river reaches now exhibit reduced longitudinal connectivity, with CSI below 100% (Grill et al., 2019). Only in isolated areas of the Arctic, Amazon, and Congo basins do large river networks have fully natural connectivity (CSI = 100%) (Grill et al., 2019). The degradation of river network connection grew worse in the latter part of the 20th century and is currently pervasive over the whole pan-European continent. There are at least 1.2 million river barriers (an average density of 0.74 per km) in the 36 European countries, and in general more than 50% of river length is affected (Duarte et al., 2021).

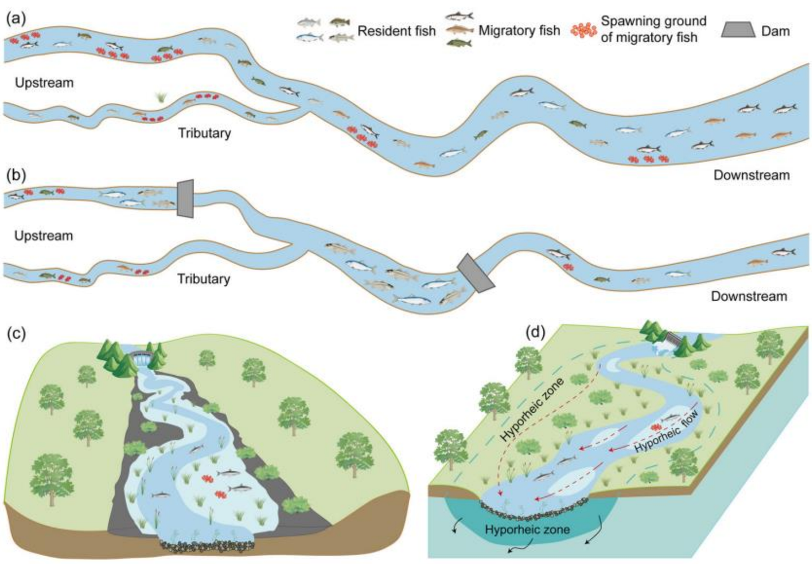

Figure 1. River connectivity and the impacts of dams. (a) Migration and spawning grounds of fish in free-flowing river. (b) Migration and spawning grounds of fish in dammed rivers, (c) Spawning and rearing grounds of fish in floodplain. (d) Hyporheic exchange and redd habitats

2.2. Alterations to River Hydrological Regimes

Riverine bio-habitats and ecosystems depend heavily on the hydrological regime, which includes elements like discharge, flow velocity, water depth, and peak flow. Hydrological circumstances have a significant impact on fish spawning, rearing, and wintering. Flooding processes can offer favourable circumstances for fish species that spawn floating eggs, since they require constant stimulation of flow velocity. Drifting eggs have a higher chance of surviving when the flow velocity is high enough to prevent them from sinking (George et al., 2017). Fish eggs can be dispersed by river flow, increasing their range of survival and fostering community stability.

Fish physical habitat is expanded and their access to baits is increased as a result of the lateral flow of materials between the floodplain and river channel caused by the yearly rise and decrease in river depth (Castello & Macedo, 2016). For overwintering, fish in cold climates need water bodies deep enough with warm water in the deeper layers.

2.3. Changes to River Sediment Regimes and Morphology

Rivers require sediment, which is crucial to preserving the biological health of river systems across the world (Ralph et al., 2009). Fish habitat and river morphology are influenced by the entrained, transported, and deposited sediment. River geomorphology, which determines a system's aggradation or degradational state as well as channel morphology and substrate textures, is largely determined by the equilibrium between a system's sediment supply and transport capacity. According to Latrubesse (2008), river planforms can take on a variety of shapes, including braided, straight, sinuous, anabranching, and anastomosing.

A variety of geomorphic units, including riffles, pools, barforms and bedforms, and flood plains, are formed by the hydrodynamic conditions induced by these various river planforms. These conditions lead to different patterns of sediment erosion and deposition, increasing the diversity of biological habitats, such as those utilised for fish spawning and wintering grounds (Chapuis et al., 2015). Additionally, rivers carry a lot of organic stuff, which gives aquatic life something to eat. Sediment properties such as particle size and density, surface site density, and particle shape influence the amount of organic matter in the sediment.

2.4. Alterations in River Water Temperature Regimes.

In river ecosystems, water temperature is a crucial and extremely sensitive component with clear and consistent seasonality. Aquatic species' phenological functioning is influenced by the natural cycle of water temperature, and the longitudinal fluctuation of water temperature is crucial for creating spatial patterns of species communities (Isaak et al., 2012). Fish migratory time, reproductive success, embryo health, and development rate are all impacted by water temperature regime (Servili et al., 2020).

2.5. Dissolved Gas Supersaturation

The physical state known as total dissolved gas (TDG) supersaturation occurs when the total partial pressures of dissolved gases in water surpass the total partial pressures of gases in the air at local atmospheric pressure. TDG supersaturation in natural rivers is frequently brought on by water dropping and temperature changes. During flood seasons, flood flow from dammed rivers can induce significant TDG supersaturation, which can have detrimental effects on fish downstream (Ji et al., 2019).

For example, the downstream Wells Dam was unable to meet water quality standards for 125 out of 133 days in 2012 when the Chief Joseph Dam released flow in the Columbia River that exceeded the 110% TDG compliance requirement (EPA, 1987) (Witt et al., 2017). Massive fish mortality occurred in the downstream reservoir during the July 2014 flood discharge of the Xiluodu Reservoir in the upper Yangtze River due to the average TDG saturation of the downstream water being 135%, with a maximum value of 144% (Zeng et al., 2020). As water depth increases and flow velocity slows, the release of TDG is delayed. Thus, in a reservoir cascade system, water with supersaturated TDG from the upstream reservoir is transported to the downstream reservoir and can cause cumulative effects. In reservoir cascade systems, TDG supersaturation effects are therefore very noticeable.

3. River Damming Impacts on Key Fish Species

3.1. Impact on Salmonids

Anadromous salmonids travel to saline seas for feeding, growth, and maturation, and to freshwater rivers for spawning and raising juveniles (Crozier et al., 2021). The spawning stage (egg, alevin), juvenile stage (fry, fingerling, parr), smolt stage, and adult stage comprise the primary life cycle of anadromous salmonids. In the fall, female salmonids dig redds, or nest pits, in the gravels of river beds and lay their eggs there. Salmonids spawn best at temperatures between 6 to 14°C, and the timing of spawning is particularly susceptible to temperature fluctuations. The eggs hatch into tiny salmonids (alevins) throughout the course of the winter.

The alevins emerge from the redds as fry in the spring, and as they mature, they develop into parr that are capable of defending themselves against predators. The parr spends two to three years growing in freshwater before changing into smolts. Silvery smolts spend one to two years developing into adults after swimming to the ocean in the early spring. Since Atlantic salmon prefer chilly water, the smolts that migrate downstream must swim to the ocean before the river temperature gets too warm. Once migration has begun, river outflow is crucial because it affects when smolting begins, lasts, and ends (Sykes et al., 2009).

3.2. Impact on Chinese Carps

Grass carp (*Ctenopharyngodon idellus*), black carp (*Mylopharyngodon piceus*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*) are the four major Chinese carps (FMCCs). When floods occur, the adults of FMCCs, which are freshwater fish, go upstream to spawning locations, where they lay semi-buoyant floating eggs. A minimal flow velocity is necessary for FMCC spawning activity in order to release eggs, and a proper flow velocity is necessary for the drifting eggs (P. Zhang et al., 2021).

3.3. Impact on Sturgeon

One of the oldest vertebrates still alive, sturgeons have a significant impact on the evolution of fish and maybe all vertebrates (Shen et al., 2020). The Acipenseridae and Polyodontidae families contain 27 species of sturgeons. The Chinese sturgeon (A. sinensis), Russian sturgeon (*Acipenser gueldenstaedtii*), Atlantic sturgeon (*Acipenser oxyrinchus*), ship sturgeon (*Acipenser nudiventris*), sterlet (*Acipenser ruthenus*), Dabry's sturgeon (*Acipenser dabryanus*), and starry sturgeon (*Acipenser stellatus*) are the most common species in the Acipenseridae family. The Chinese paddlefish (*Psephurus gladius*) and American paddlefish (*Polyodon spathula*) are both members of the family Polyodontidae, which is generally referred to as paddlefish. Due to overfishing, dam building, and habitat degradation, the global population of wild sturgeons has declined dramatically in recent years (T. Webb & Meyer, 2019).

3.4. Impact on Eel and Lamprey

Among the most profitable fisheries in the world are lampreys (genus Lampetra) and eels (genus Anguilla) (P. R. Almeida et al., 2021;). According to Righton et al. (2021), there are now 19 species or subspecies of eels known to exist worldwide, with two of those species found in the Atlantic Ocean and the other 17 dispersed across the Indo-Pacific. The European eel (*Anguilla anguilla*), American eel (*Anguilla rostrata*), and Japanese eel (*Anguilla japonica*) are among the eel species that are now classified as "endangered" or "critically endangered" in the wild. Because of their similar appearance, lampreys and eels are sometimes confused; however, lampreys are members of the Order Petromyzontiformes, whereas eels are members of the Order Anguillifomes . The majority of lampreys are anadromous parasite fish, including the Caspian lamprey (*Caspiomyzon wagneri*), Pacific lamprey (*Entosphenus tridentatus*), European river lamprey (*Lampetra fluviatilis*), and sea lamprey (*Petromyzon marinus*). In the Laurentian Great Lakes, the sea lamprey is a well-known invasive species that has decimated lake trout and whitefish fisheries (Zielinski et al., 2019).

4. Fish Conservation Measures in Dammed Rivers

4.1. River Connectivity Restoration and Fish Passage Facilities

Numerous conservation strategies, such as fish passage facilities, artificial breeding and release, ecological reservoir operation, and habitat compensation in tributaries, have been developed and put into practice to counteract or lessen the effects of river damming on fish. Each measure should be chosen based on the unique circumstances of a particular dammed river since each has unique benefits and drawbacks, application requirements, efficacy, and cost-effectiveness. Establishing nature reserves and germplasm resources reserves, enforcing laws and policies for no-catch measures, and limiting navigation during fish-sensitive seasons, like the spawning season, are a few examples of these policies (Maxwell et al., 2020).

4.2. Habitat Compensation and Dam Removal in Tributaries

Following river damming, the reservoir's lotic environment changes to a lentic one, permanently reducing the amount of habitat available for fish species' maturation and spawning (Liermann et al., 2012). This loss is largely unavoidable through reservoir ecological operations. In rivers with cascade dams, such as the Lancang River, where the lentic section extends for more than a thousand kilometres and an upstream dam is situated in the backwater zone of the closest downstream reservoir, the situation is more dire. Under such circumstances, relatively unaltered tributaries can provide possible alterative places to conserve indigenous species of the dammed mainstream by serving as high-value natural surrogates or supplements that can restore some function of the mainstem ecosystems (Nunes et al., 2015). The elements of natural flow fluctuations and the availability of food resources and shelter areas could be maintained in these tributaries. Moreover, diverse hydraulic conditions exist in the upper, middle, and lower tributary reaches, giving the migratory or rheophilic fish species chances to colonize new habitats. In addition, for some native fish species, their survival and life history requirements are directly related to intact longitudinal pathways, including the possibility of migration into tributaries for reproduction and rearing.

5. Future Perspectives

Prior to dam construction, the intensity of hydro power development should be determined at a basin scale, to balance river ecosystem conservation and economic benefits; it is essential to develop strategic dam planning, especially at the basin or regional scale, by performing multi-criteria optimisation schemes; mitigation measures should be implemented to minimise the potential impacts on fish during the entire river damming process, including planning and operation; and dam planning should be done at a system level to ensure that decisions are made in a more holistic manner (Flecker et al., 2022).

Within the local hydro-geophysical constraints, sufficient research should be done to determine the best location for dams in order to minimise the effects on fish spawning, feeding, and wintering grounds. It is important to increase research on how dam construction affects the services provided by river ecosystems, including water supply, sediment transport, and biodiversity preservation. The planning of dams on mainstream and tributary rivers must be collaborative, and consider the optimal combination of high dams, low dams and run-of-river dams, which is important to reduce impacts on the river ecosystem at a basin scale (Couto et al., 2021;).

Conclusion

Although dams are necessary for flood control, agriculture, and the production of hydroelectric power, they seriously hinder fish movement. Dams restrict fish species' access to vital breeding and feeding grounds by changing the normal flow of water, dividing habitats, and interfering with spawning paths. In addition to endangering aquatic ecosystems' biodiversity, this disturbance has an effect on fisheries, which rely on healthy fish populations. Despite the use of fish passage options such as fish ladders and bypass systems, their efficacy is frequently restricted. Maintaining aquatic life and ecosystem health while balancing human requirements requires creative ecological engineering and sustainable dam management.

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NANO FERTILIZERS: REVOLUTIONIZING AGRICULTURAL PRACTICES FOR SUSTAINABLE FUTURE

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Introduction

Agriculture has always been the backbone of the Indian economy, sustaining millions of livelihoods and feeding the nation. However, traditional farming practices face numerous challenges, including soil degradation, water scarcity, and inefficient use of fertilizers. As the world moves towards sustainable and precision agriculture, the adoption of nano fertilizers presents a revolutionary solution to these pressing issues. This article delves into the concept of nano fertilizers, their benefits, adoption in agriculture, challenges, and future prospects, aiming to provide a comprehensive understanding of how these advanced materials can transform farming practices. Nano fertilizers are materials engineered at the nanoscale to deliver nutrients to plants more efficiently and effectively than conventional fertilizers. These fertilizers can be organic or inorganic and are designed to improve nutrient use efficiency, reduce environmental impact, and enhance crop yields.

The key features of nano fertilizers include:

Enhanced Nutrient Absorption

Nano fertilizers significantly improve nutrient absorption in plants due to their unique properties:

- **Higher Surface Area-to-Volume Ratio**: Nano fertilizers are composed of particles that are measured in nanometers, which significantly increases their surface area relative to their volume. This enhanced surface area allows for greater interaction with plant roots. The small size of nano particles facilitates closer contact with root hairs and cellular structures, improving the efficiency of nutrient uptake. This is in contrast to conventional fertilizers, which have larger particles that do not interact as intimately with plant roots.

- **Controlled Nutrient Release**: Nano fertilizers can be designed to release nutrients slowly over time. This slow-release mechanism ensures a steady supply of nutrients, which is critical for sustained plant growth. Conventional fertilizers often release nutrients rapidly, which can lead to nutrient spikes followed by periods of deficiency. The slow-release property of nano fertilizers reduces the frequency of application, minimizes nutrient loss, and ensures that plants receive an optimal and consistent nutrient supply throughout their growth cycle.

Targeted Delivery

Nano fertilizers offer the ability to deliver nutrients with precision, targeting specific plant needs:

- Engineered Targeting: Nano fertilizers can be engineered to release nutrients in response to specific environmental triggers or plant signals. For example, they can be designed to dissolve and release nutrients at particular pH levels or in the presence of certain enzymes excreted by plant roots. This targeted delivery ensures that nutrients are made available to the plant exactly when and where they are needed most, improving the efficiency of nutrient use.
- Minimizing Waste and Maximizing Effectiveness: The precision targeting of nano fertilizers reduces nutrient wastage. Traditional fertilizers often suffer from issues such as leaching, volatilization, and runoff, which lead to significant nutrient losses and environmental contamination. Nano fertilizers, by contrast, can be formulated to remain stable in the soil and release nutrients in a controlled manner, directly at the root zone. This not only enhances the nutrient use efficiency but also reduces the overall quantity of fertilizers required, lowering the cost for farmers and minimizing the environmental impact.

Environmental Sustainability

Nano fertilizers contribute to more sustainable agricultural practices by addressing several environmental concerns associated with traditional fertilizers:

- Reduction in Fertilizer Usage: The increased efficiency of nano fertilizers means that farmers can use smaller quantities to achieve the same or even better crop yields compared to conventional fertilizers. This reduction in fertilizer usage helps decrease the environmental footprint of agriculture. Less fertilizer application means fewer resources used in the production, transportation, and application processes, leading to a more sustainable agricultural practice.

- Minimization of Leaching and Runoff: One of the significant environmental problems associated with conventional fertilizers is nutrient leaching and runoff. Excess nutrients from fertilizers often leach into groundwater or run off into water bodies, causing pollution and eutrophication. Nano fertilizers are designed to release nutrients slowly and in a targeted manner, significantly reducing the chances of leaching and runoff. This protective measure helps maintain soil health, preserves water quality, and prevents the detrimental effects of nutrient pollution in aquatic ecosystems.
- Protection of Soil and Water Quality: By reducing nutrient losses and improving nutrient use efficiency, nano fertilizers help maintain the natural balance of soil and water ecosystems. They reduce the accumulation of excess nutrients in the soil, which can lead to soil degradation and reduced fertility over time. Additionally, by preventing nutrient runoff into

water bodies, nano fertilizers help protect aquatic ecosystems from the harmful effects of eutrophication, such as algal blooms and hypoxia.

TYPES OF NANO FERTILIZERS

Nano fertilizers are engineered to deliver specific nutrients more efficiently and effectively than conventional fertilizers. Each type of nano fertilizer is designed to meet particular agricultural needs, ensuring optimal plant growth and development. Here is a detailed overview of the most common types of nano fertilizers:

1. Nano Nitrogen Fertilizers

Nitrogen is a critical nutrient for plant growth, involved in various physiological processes such as photosynthesis, protein synthesis, and chlorophyll production. Nano nitrogen fertilizers are designed to enhance the availability and absorption of nitrogen.

- **Easily Absorbed Nitrogen:**
  - ✓ Nano nitrogen fertilizers provide nitrogen in a form that plants absorb more efficiently, reducing losses from volatilization and leaching. These fertilizers, such as nano-encapsulated urea or ammonium ions, are more stable and environmentally friendly than traditional forms.
- **Slow-Release Mechanism:**
  - ✓ Nano nitrogen fertilizers are designed to release nitrogen slowly over time. This slow-release mechanism matches the nutrient demand of plants throughout their growth cycle, preventing the spikes and subsequent deficiencies associated with traditional fertilizers.
  - ✓ The controlled release also minimizes the risk of nitrogen volatilization and leaching, leading to more sustainable nutrient management.

2. Nano Phosphorus Fertilizers

Phosphorus is vital for energy transfer, root development, and overall plant vigor. However, phosphorus availability in soil is often limited due to its tendency to form insoluble compounds. Nano phosphorus fertilizers address this challenge by improving phosphorus availability and uptake.

- **Enhanced Phosphorus Availability**:
  - ✓ Nano phosphorus fertilizers enhance the availability of phosphorus in the soil by providing it in a highly soluble and easily absorbable form. These fertilizers often use nano-sized particles of phosphate minerals or phosphorus-encapsulated nanomaterials.
  - ✓ The increased surface area of nano phosphorus particles ensures more contact with plant roots, facilitating better uptake and utilization of phosphorus.
- **Prevention of Phosphorus Fixation:**
  - ✓ In traditional fertilization, phosphorus often becomes fixed in the soil, forming insoluble compounds that plants cannot access. Nano phosphorus fertilizers prevent this fixation by maintaining phosphorus in a soluble and plant-available form for longer periods.
  - ✓ This improved availability leads to better root development, energy transfer, and overall plant health.

3. Nano Potassium Fertilizers

Potassium plays a crucial role in water regulation, enzyme activation, and overall plant health. Nano potassium fertilizers are designed to ensure that potassium is readily available for plant uptake, enhancing crop performance.

- **Readily Available Potassium:**
  - ✓ Nano potassium fertilizers provide potassium in a form that is easily absorbed by plant roots. These fertilizers can be formulated as nano-sized potassium compounds, such as potassium nitrate or potassium sulfate.
  - ✓ The nano form increases the surface area, ensuring better interaction with plant roots and more efficient uptake of potassium.
- **Improved Drought Resistance and Plant Health:**
  - ✓ Potassium is essential for regulating water balance within the plant, helping plants cope with drought stress. Nano potassium fertilizers enhance the plant's ability to retain water, improving drought resistance.
  - ✓ Additionally, potassium is involved in enzyme activation and photosynthesis, contributing to overall plant health and productivity.

4. Multi-Nutrient Nano Fertilizers

Multi-nutrient nano fertilizers combine several essential nutrients into a single formulation, providing a balanced nutrient supply to plants. These fertilizers are designed to address multiple nutrient deficiencies simultaneously, ensuring comprehensive nutrient management.

- **Balanced Nutrient Supply:**
  - ✓ Multi-nutrient nano fertilizers contain a combination of macro and micronutrients, such as nitrogen, phosphorus, potassium, calcium, magnesium, zinc, and iron. These nutrients are encapsulated in nano particles, ensuring their efficient delivery and absorption by plants.
  - ✓ The balanced supply of nutrients supports various physiological processes, promoting healthy growth and development.

- **Simultaneous Nutrient Deficiency Management:**
  - ✓ By providing multiple nutrients in a single application, multi-nutrient nano fertilizers address various nutrient deficiencies simultaneously. This is particularly beneficial in soils with multiple nutrient imbalances.
  - ✓ The controlled release of nutrients ensures that plants receive a steady supply of essential elements throughout their growth cycle, improving overall crop performance and yield.

BENEFITS OF NANO FERTILIZERS IN AGRICULTURE

The adoption of nano fertilizers offers numerous benefits that can significantly enhance agricultural productivity and sustainability:

1. **Increased Nutrient Use Efficiency**:
   - ✓ Nano fertilizers ensure that nutrients are absorbed more efficiently by plants, reducing the amount of fertilizer needed.
   - ✓ This increased efficiency translates to cost savings for farmers and a reduced environmental impact.
   - ✓ The unique properties of nanoparticles, such as their high specific surface area and excellent biocompatibility, contribute to the increased release efficiency of nano fertilizer composites. For instance, urea-hydroxyapatite nanoparticles have exhibited great potential for prolonging the release time of nitrogen fertilizers. Field trials have shown that these nanohybrids increase agronomic nitrogen use efficiency by approximately 30% compared to pure urea (Abdel *et al.*, 2023).

2. **Improved Crop Yields**:
   - ✓ By providing a steady and targeted supply of nutrients, nano fertilizers can enhance plant growth and development, leading to higher crop yields.
   - ✓ They can also improve the quality of produce, resulting in better market prices for farmers.
   - ✓ A study on cotton plants revealed that spraying magnesium oxide (MgO) nanoparticles significantly increased the seed cotton yield by 42.2% relative to the untreated control (Abdel *et al.,* 2023). Similarly, in strawberries, ZnO nanoparticle fertilization resulted in significant increases in fruit setting and grain yield compared to traditional zinc sulfate fertilization (Haydar *et al.,* 2024).
3. **Reduced Environmental Impact**:
   - ✓ Conventional fertilizers often lead to nutrient runoff and leaching, causing soil and water pollution. Nano fertilizers minimize these issues by ensuring that nutrients are absorbed by plants rather than being lost to the environment.
   - ✓ This contributes to the sustainability of agricultural practices and protects natural resources.
   - ✓ Nanofertilizers are revolutionizing agricultural practices, offering significant environmental and economic advantages over conventional fertilizers. These innovative "smart fertilizers" have an impact on improving nutrient use efficiency and reducing environmental risks associated with traditional farming methods (Nongbet *et al*., 2022).
4. **Enhanced Soil Health**:
   - ✓ Overuse of conventional fertilizers can degrade soil health over time. Nano fertilizers promote soil health by reducing the chemical load and preventing nutrient imbalances.
   - ✓ Healthier soils are more productive and resilient to environmental stresses.
5. **Adaptation to Climate Change**:
   - ✓ Nano fertilizers can help farmers adapt to changing climatic conditions by improving water use efficiency and enhancing the resilience of crops to stressors such as drought and heat.
   - ✓ They contribute to the sustainability of agriculture in the face of climate change.

CHALLENGES IN THE ADOPTION OF NANO FERTILIZERS

Despite the numerous benefits, the adoption of nano fertilizers in agriculture faces several challenges:

1. **Cost and Accessibility**:
   - The production of nano fertilizers involves advanced technology, making them more expensive than conventional fertilizers.
   - Small and marginal farmers may find it difficult to afford these fertilizers without financial assistance or subsidies.
2. **Lack of Awareness and Education**:
   - Many farmers are not aware of the benefits and proper usage of nano fertilizers. This lack of awareness can hinder their adoption.
   - Extension services and training programs are needed to educate farmers about the advantages and application methods of nano fertilizers.
3. **Regulatory and Safety Concerns**:
   - The use of nanotechnology in agriculture raises concerns about the safety and environmental impact of nano fertilizers.

- Regulatory frameworks need to be established to ensure the safe production, use, and disposal of nano fertilizers.

4. **Infrastructure and Distribution**:
    - Adequate infrastructure and distribution networks are essential to make nano fertilizers available to farmers across the country.
    - Investments in supply chain logistics are needed to ensure timely and efficient delivery of these fertilizers.

FUTURE PROSPECTS

The future of nano fertilizers in agriculture looks promising, with significant potential for transforming farming practices and promoting sustainability. Continued research and development, coupled with supportive policies and infrastructure, can drive the widespread adoption of these advanced fertilizers.

1. **Research and Development**:
    - Ongoing research is crucial to further improve the efficiency and effectiveness of nano fertilizers. This includes developing new formulations, understanding their interactions with plants and soil, and assessing their long-term impacts.
    - Collaboration between research institutions, universities, and private companies can accelerate innovation and bring new products to market.
2. **Policy Support and Subsidies**:
    - Government policies and subsidies can play a vital role in making nano fertilizers more accessible and affordable for farmers.
    - Incentives for adopting sustainable practices and investments in infrastructure can facilitate the distribution and use of nano fertilizers.
3. **Farmer Education and Training**:
    - Extension services and training programs are essential to educate farmers about the benefits and proper use of nano fertilizers.
    - Demonstration farms and pilot projects can showcase the effectiveness of these fertilizers, encouraging more farmers to adopt them.
4. **Sustainable Agriculture Practices**:
    - The adoption of nano fertilizers aligns with the broader goals of sustainable agriculture. By reducing the environmental impact of farming and improving resource use efficiency, nano fertilizers contribute to the sustainability and resilience of agricultural systems.
    - Integrating nano fertilizers with other sustainable practices, such as organic farming and precision agriculture, can further enhance their benefits.

Conclusion

Nano fertilizers represent a ground-breaking advancement in agricultural technology, offering a sustainable solution to some of the most pressing challenges faced by farmers today. By enhancing nutrient use efficiency, improving crop yields, and reducing environmental impact, these fertilizers have the potential to revolutionize farming practices and promote a more sustainable future for agriculture. The successful adoption of nano fertilizers requires concerted efforts from all stakeholders, including researchers, policymakers, extension services, and farmers. With the right support and investments, nano fertilizers can play a crucial role in transforming Indian agriculture, ensuring food security, and promoting environmental sustainability. As we look towards the future, embracing the potential of nano fertilizers can pave the way for a new era of agricultural innovation, where technology and sustainability go hand in hand to feed a growing population while preserving our planet's resources.

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HARNESSING NATURE: THE ROLE OF PLANT GROWTH REGULATORS IN MODERN AGRICULTURE

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Abstract

This article explores the significant role of plant growth regulators (PGRs) in modern agriculture, highlighting their potential to enhance crop yields, improve quality, and increase resilience to environmental stress. PGRs, which include auxins, gibberellins, Cytokinins, ethylene, and abscisic acid, are crucial for regulating various physiological processes in plants. Their applications have been linked to improved root development, nutrient uptake, and stress management, making them essential tools for sustainable farming practices. By examining case studies in grape production, vegetable cultivation, and rice farming, the article illustrates the practical benefits of PGRs. Additionally, it addresses challenges such as potential misuse, environmental impacts, and regulatory hurdles. Looking forward, advancements in biotechnology and precision agriculture offer promising avenues for optimizing the use of PGRs, contributing to enhanced agricultural productivity and sustainability in the face of global food security challenges.

Introduction

In the quest for sustainable agricultural practices and increased food production, scientists and farmers are turning to innovative solutions that work in harmony with nature. Among these, plant growth regulators (PGRs) have emerged as essential tools that enhance plant development, optimize growth conditions, and improve crop resilience. This article explores the multifaceted role of PGRs in modern agriculture, their mechanisms of action, benefits, and future potential, highlighting their significance in addressing the challenges facing the global agricultural landscape.

Understanding Plant Growth Regulators

What Are Plant Growth Regulators?

Plant growth regulators are naturally occurring or synthetic substances that significantly influence plant physiological processes, often in minute concentrations. They can be classified into several major categories based on their functions:

1. **Auxins:** These compounds regulate various growth processes, including cell elongation, root development, and the formation of fruit. They are pivotal in coordinating plant growth in response to environmental stimuli.
2. **Gibberellins:** Primarily involved in promoting stem elongation, seed germination, and flowering, gibberellins are crucial for breaking dormancy and initiating growth processes.
3. **Cytokinins:** These regulators promote cell division and influence shoot and root growth. They also play a role in delaying leaf senescence, enhancing plant longevity.
4. **Ethylene:** Known as the "ripening hormone," ethylene regulates fruit ripening, flower opening, and leaf abscission. Its manipulation can optimize harvest timing and improve post-harvest quality.

5. **Abscisic Acid (ABA):** Primarily involved in stress responses, ABA helps plants manage water loss during drought conditions and regulates stomatal closure.

Historical Background

The discovery of PGRs dates back to the early 20th century when scientists identified the role of auxins in plant growth. Subsequent research led to the isolation and synthesis of various PGRs, paving the way for their application in agriculture. Initially, these substances were primarily used in horticulture, but their potential in broad-scale agricultural practices has since been recognized, leading to widespread adoption.

Mechanisms of Action

PGRs exert their effects through complex biochemical pathways, interacting with plant receptors and influencing gene expression. Understanding these mechanisms is crucial for effectively utilizing PGRs in agriculture.

- ✓ **Auxins**

  Auxins are primarily synthesized in the tips of shoots and roots. They promote cell elongation by facilitating the loosening of cell walls and increasing plasticity. Auxin distribution within the plant is essential for phototropism (growth toward light) and gravitropism (growth in response to gravity). This differential growth allows plants to optimize their exposure to light and stabilize their structure.
- ✓ **Gibberellins**

  Gibberellins stimulate growth by promoting cell elongation and division. They play a key role in seed germination by breaking dormancy and activating enzymes that mobilize stored nutrients. Gibberellins also influence flowering time and fruit development, making them vital for crop production.
- ✓ **Cytokinins**

  Cytokinins are synthesized in roots and transported to other plant parts. They promote cell division and shoot development while delaying senescence. Cytokinins can also enhance nutrient uptake and mobilization, contributing to overall plant vigour.
- ✓ **Ethylene**

  Ethylene is unique among PGRs as it is a gaseous hormone. It is produced in response to various environmental stimuli, including stress and ripening signals. Ethylene promotes fruit ripening by triggering the expression of specific genes involved in colour change, flavour development, and softening.
- ✓ **Abscisic Acid**

  ABA is synthesized in response to stress conditions, such as drought. It regulates stomatal closure, thereby reducing water loss through transpiration. Additionally, ABA influences seed dormancy and germination, ensuring that seeds remain dormant during unfavourable conditions.

Benefits of Plant Growth Regulators

The application of PGRs in agriculture offers numerous benefits, ranging from increased crop yields to improved quality and resilience.

Enhanced Crop Yields

One of the primary advantages of using PGRs is their ability to boost crop yields. By promoting optimal growth conditions and improving plant health, PGRs help maximize production potential. For example:

- ✓ **Gibberellins** can enhance the size and weight of fruits, as seen in grape production, where their application leads to larger berries and higher overall yields.
- ✓ **Auxins** can improve root development in cuttings, resulting in healthier plants that are more productive.

Improved Crop Quality

PGRs also play a crucial role in enhancing the quality of agricultural products. By optimizing growth patterns and nutrient uptake, PGRs can lead to more uniform and visually appealing fruits and vegetables. Key improvements include:

- ✓ **Colour and Flavour:** Ethylene is critical in fruit ripening, affecting colour, texture, and flavour. By regulating ethylene levels, farmers can ensure that fruits reach optimal quality before harvest.
- ✓ **Nutritional Content:** PGRs can enhance the concentration of essential nutrients in crops. For instance, cytokinin application has been shown to increase the levels of vitamins and minerals in certain vegetables.

Stress Resilience

In an era marked by climate change and environmental challenges, the resilience of crops is more important than ever. PGRs contribute to stress management in several ways:

- ✓ **Drought Tolerance:** Abscisic acid helps plants manage water stress by promoting stomatal closure, thus conserving water during dry periods.
- ✓ **Pest and Disease Resistance:** Healthy, well-regulated plants are often more capable of resisting pests and diseases. By enhancing overall plant health, PGRs can reduce the need for chemical pesticides.

Efficient Resource Utilization

The application of PGRs can lead to more efficient use of resources such as water, nutrients, and fertilizers. For instance:

- ✓ **Nutrient Mobilization:** Cytokinins enhance nutrient uptake and distribution, ensuring that plants make the most of available resources.
- ✓ **Water Management:** By regulating stomatal function, ABA helps reduce water loss, making plants more efficient in their use of water, especially in arid conditions.

Challenges and Considerations

While the benefits of PGRs are significant, there are also challenges and considerations that must be addressed to ensure their effective use in agriculture.

Potential Misuse and Overapplication: The improper use of PGRs can lead to negative consequences, including:

- ✓ **Excessive Growth:** Overapplication of gibberellins or auxins can result in abnormal growth patterns, leading to weak or structurally unsound plants.
- ✓ **Imbalanced Hormonal Levels:** An imbalance of PGRs can disrupt normal growth processes, negatively impacting crop health and yield.

Environmental Impact

The environmental impact of PGRs is a growing concern. While many PGRs are naturally occurring and biodegradable, synthetic alternatives may pose risks to ecosystems. Careful consideration of application methods and timing is essential to minimize unintended effects on non-target species and the environment.

Regulatory Challenges

The regulation of PGRs varies widely across different countries. In some regions, stringent regulations may limit the use of certain PGRs, hindering innovation and adoption. Establishing clear guidelines that balance safety and efficacy is crucial for advancing the use of PGRs in agriculture.

Case Studies of PGR Application

To illustrate the practical application of PGRs in agriculture, several case studies provide insight into their effectiveness and benefits.

1. **Grapes and Gibberellins**
   In viticulture, the application of gibberellins has transformed grape production. By promoting berry size and uniformity, growers can achieve higher yields and better-quality fruits. This practice has been particularly beneficial for table grape production, where appearance and size are critical for marketability.
2. **Vegetables and Cytokinins**
   The use of Cytokinins in vegetable production has shown promising results. For example, studies have demonstrated that cytokinin application can significantly enhance the yield and nutritional quality of crops like tomatoes and lettuce. The increased cell division and delayed senescence lead to healthier plants and improved harvest quality.
3. **Rice and Auxins**
   In rice cultivation, auxins have been utilized to enhance root development and improve overall plant growth. The application of auxins has resulted in stronger root systems, enabling plants to better absorb nutrients and water, ultimately leading to increased yields. This approach is particularly valuable in regions facing water scarcity.

Future Directions and Innovations

The future of plant growth regulators in agriculture is promising, driven by advancements in research, biotechnology, and sustainable practices. Key areas of focus include:

- ✓ **Biotechnological Advancements**
  Ongoing research into the genetic basis of plant growth regulation holds the potential for developing new PGRs tailored to specific crops and environmental conditions. Genetic engineering techniques may enable the production of plants with enhanced sensitivity to beneficial PGRs, maximizing their effects.
- ✓ **Sustainable Practices**
  As sustainability becomes a focal point in agriculture, the integration of PGRs with environmentally friendly practices will be paramount. By combining PGR application with organic farming techniques, farmers can achieve higher yields while minimizing environmental impact.
- ✓ **Precision Agriculture**
  The advent of precision agriculture technologies allows for targeted PGR application based on real-time data. Utilizing sensors and satellite imagery, farmers can monitor plant health and growth conditions, applying PGRs precisely when needed for optimal results.

Conclusion

Harnessing the power of nature through plant growth regulators represents a transformative approach to modern agriculture. By enhancing crop yields, improving quality, and increasing resilience to stress, PGRs align with the goals of sustainable farming and food security. As research and innovation continue to advance, the strategic use of PGRs will undoubtedly play a crucial role in addressing the challenges of a growing global population and a changing climate. In conclusion, the future of agriculture lies in the ability to work in harmony with nature. By leveraging the benefits of plant growth regulators, farmers can cultivate healthier, more productive crops while ensuring the sustainability of our agricultural systems. Embracing these natural allies is not just a step forward for farmers; it’s a vital stride towards a more sustainable and food-secure world.

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SMALL AREA ESTIMATION METHODS: AN OVERVIEW

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Abstract
Small area estimation is becoming important in survey sampling due to a growing demand for reliable Small Area Statistics (SAS) from both public and private sectors for preparing effective policies relations to issues of distribution, equity and disparity in various areas of interest such as, Agriculture, Public Health, Education, Business, Poverty, Census etc. It is now widely recognized that direct survey estimates for small areas are likely to yield unacceptably large standard errors due to the smallness of sample sizes in the areas. This makes it necessary to "borrow strength" from related areas to find more accurate estimates for a given area or, simultaneously, for several areas. This has led to the development of alternative methods such as demographic, synthetic estimation, model based, empirical best linear unbiased prediction, empirical Bayes and hierarchical Bayes estimation. The present article is largely an appraisal of some of these methods. Empirical best linear unbiased prediction as well as empirical and hierarchical Bayes, for most purposes, seem to have a distinct advantage over other methods.

Key Words: Small Area Estimation (SAE), demographic methods, synthetic estimation, model based estimation, empirical best linear unbiased prediction, empirical Bayes, hierarchical Bayes

Introduction

The terms "small area" and "local area" are commonly used to denote a small geographical area, such as a county, a municipality or a census division. They may also describe a "small domain," i.e., a small sub-population such as a specific age-sex-race group of people within a large geographical area. Surveys are normally planned with specific populations in view. Quite often, interest also lies in parts of the population known as subpopulations or domains of interest. Domain parameters may be estimated satisfactorily through usual sample survey approach provided the domains get sufficient representation of sampled units in the main sample. Sometimes, the sub-populations or domains are too small to provide reliable direct estimates. The term small domain or area typically refers to the part of a population for which reliable statistics of interest cannot be produced due to certain limitations of the data. Sub-population or domain like age, sex, ethnicity etc. are very less in such county so it can't provide complete data to get reliable estimates. In this case, need to construct new estimator for small domain, Carl-Erik Sarndal and Michael A. Hidiroglou (1989).

The topic of small area estimation has gained importance in view of growing needs of micro level planning. Demands for reliable Small Area Statistics (SAS) are increasing both from public and private sectors with growing concerns of governments relating to issues of distribution, equity and disparity. The need for statistics at lower levels has been felt for a long time and efforts have been made to meet the requirements through some traditional approaches.

In a historical perspective, Brackstone (1987) tracked the references of SAS to the eleventh century in England and seventeenth century in Canada. In late sixties small area estimation got an impetus with the application of synthetic method of estimation in a disability survey by National Centre for Health Statistics (NCHS 1968), Maryland, U.S. Purcell and Kish (1979) reviewed the methods for SAS available till that time. Most of the methods were developed in the context of population studies. Applications too were mainly in the field of population/demographic studies.

The current emphasis and recent advances in this area have been mainly due to significant advances in statistical data processing. The advances in computing facilities have also provided convenient tools for many theoretical developments in this area. Since traditional sampling theory fails to provide reliable and valid estimates in this situation, many Small Area Estimation(SAE) techniques have been developed which make use of information from other sources. They also borrow strength from related or similar areas through explicit and implicit models that connects the small area via supplementary data.

Methods for small area estimation

1. Demographic method
2. Synthetic estimation method
3. Model based
    a. Area level model
    b. Unit level model
4. Empirical Best Linear Unbiased Prediction (EBLUP), Empirical Bayes (EB) and Hierarchical Bayes (HB) approaches

1. Demographic Method

Most of the SAE techniques in the early stages were developed in the context of demographic studies. These may be broadly categorized as Symptomatic Accounting Techniques (SAT). Such techniques utilize current data from administrative registers in conjunction with related data from the latest census.

One of the most important SAT techniques is the Vital Rate (VR) method which uses birth and death rates as symptomatic variables.

The method heavily depends on the assumption that the ratio of birth (death) rates in current year to those in the latest census year for the local area is approximately equal to the corresponding ratios for the larger area.

There are several improvements on this method in the form of composite estimators. One of the main reasons for application of these techniques in population studies was, perhaps the availability of various demographic data, which could be effectively used in adjusting the estimates for small areas.
The VR method uses only birth and death data, and these are used asymptotic variables rather than as components of population change.

First, in a given year, say t, the annual number of births (bt), and deaths (dt), are determined for a local area. Next the crude birth and death rates, r_{1t} and r_{2t}, for that local area are estimated by,

$$\mathbf{r_{1t} = r_{10}(R_{1t}/R_{10}), \quad r_{2t} = r_{20}(R_{2t}/R_{20}) \qquad (1.1)}$$

where r_{10} and r_{20} respectively denote the crude birth and death rates for the local area in the latest census year (t = 0) while $R_{1t}(R_{2t})$ and $R_{10}(R_{20})$ respectively denote the crude birth (death) rates in the current and census years for a larger area containing the local area.

The population P_t for the local area at year t is then estimated by,

$$\mathbf{P_t = \frac{1}{2}\ (b_t/r_{1t} + d_t/r_{2t})} \qquad \textbf{(1.2)}$$

As pointed out by Marker (1983), the success of the VR method depends heavily on the validity of the assumption that the ratios $r_{1t}/\ r_{10}$ and r_{2t}/r_{20} for the local area are approximately equal to the corresponding ratios, R_{1t}/R_{10} and R_{2t}/R_{20}, for the larger area.

2. Synthetic Estimation Method

Gonzalez (1973) describes synthetic estimates as follows: "An unbiased estimate is obtained from a sample survey for a large area; when this estimate is used to derive estimates for subareas under the assumption that the small areas have the same characteristics as the large area, we identify these estimates as synthetic estimates."

The National Center for Health Statistics (1968), Maryland, U.S. first used synthetic estimation to calculate state estimates of long and short term physical disabilities from the National Health Interview Survey data.

This method is traditionally used for small area estimation, mainly because of its simplicity, applicability to general sampling designs and potential of increased accuracy in estimation by borrowing information from similar small areas.

Suppose the population is partitioned into large domains g for which reliable direct estimators, $\hat{Y}'_{.g}$ of the totals, $Y_{.g}$, can be calculated from the survey data; the small areas, i, may cut across g so that $Y_{.g} = \sum_i Yig$, where Y_{ig} is the total for cell (i,g). We assume that auxiliary information in the form of totals, X_{ig}, is also available.

A synthetic estimator of small area total $Y_i = \sum_g Yig$ is then given by

$$\hat{\mathbf{Y}}_{\mathbf{i}}^{\boldsymbol{s}} = \sum\nolimits_{\mathbf{g}} (\mathbf{X_{ig}}\ /\mathbf{X_{.g}})\hat{\mathbf{Y}}'_{\mathbf{.g}} \qquad \textbf{...... (2.1)}$$

where $X_{.g} = \sum_i Xig$ (Purcell and Linacre, 1976; Ghangurde and Singh, 1977). The estimator (2.1) has the desirable consistency property that $\sum_i \hat{Y}_i^s$ equals the reliable direct estimator $\hat{Y}' = \sum_g \hat{Y}'_{.g}$ of the population total Y, unlike the original estimator proposed by the National Center for Health Statistics (1968) which uses the ratio $X_{ig}/\sum_g Xig$ instead of $X_{ig}/X_{.g}$.

The direct estimator Y used in (2.1) is typically a ratio estimator of the form

$$\hat{\boldsymbol{y}}'_{\mathbf{.g}} = [\left(\sum\nolimits_{\mathbf{t\epsilon s.g}} \mathbf{w_t y_t}\right) / \left(\sum\nolimits_{\mathbf{t\epsilon s.g}} \mathbf{w_t y_t}\right)]\ \mathbf{X_{.g} = (\ \hat{Y} \cdot g\ / \hat{X} \cdot g\ )\ X_{.g}} \qquad \textbf{.......(2.2)}$$

where $s_{.g}$ denotes the sample in the large domain g and w_t, is the sampling weight attached to the i^{th} element. For this choice, the synthetic estimator (2.1) reduces to $\hat{Y}_i^s = \sum_i Xig(\hat{Y}'_{.g}\ / \hat{X}'_{.g})$.

If $\hat{Y}'_{.g}$ is approximately design-unbiased, the design-bias of $\hat{Y}_i^s$ is given by

$$\mathbf{E(\hat{Y}_i^s) - Y_i = \sum\nolimits_g X_{ig}\ \ (\ Y_{.g}\ /\ X_{.g} - Y_{ig}\ /\ X_{ig}\ )} \qquad \textbf{........(2.3)}$$

which is not zero unless $Y_{ig}/X_{ig} = Y_{.g}/X_{.g}$ for all g. In the special case where the auxiliary information X_{ig} equals the population count N_{ig}, the later condition is equivalent to assuming that the small area means Y_{ig} in each group g equal the overall group mean, $Y_{.g}$.

Such an assumption is quite strong, and in fact synthetic estimators for some of the areas can be heavily biased in the design-based framework.

It follows from (2.1) that the design-variance of $\widehat{Y}_i^s$ will be small since it depends only on the variances and covariances of the reliable estimators $\widehat{Y}'_{.g}$. The variance of $\widehat{Y}_i^s$ is readily estimated, but it is more difficult to estimate the MSE of $\widehat{Y}_i^s$.

Under the assumption cov($\widehat{Y}_i$, $\widehat{Y}_i^s$) = 0, where $\widehat{Y}_i$ is a direct, unbiased estimator of Y_i, an approximately unbiased estimator of MSE is given by

$$\mathbf{MSE(\widehat{Y}_i^s) = (\widehat{Y}_i^s - \widehat{Y}_i)^2 - V(\widehat{Y}_i)} \qquad \text{.......(2.4)}$$

Here V($\widehat{Y}_i$) is a design-unbiased estimator of variance of $\widehat{Y}_i$. The estimators (2.4), however, are very unstable. Consequently, it is customary to average these estimators over i to get a stable estimator of MSE (Gonzalez, 1973), but such a global measure of uncertainty can be misleading. Note that the assumption cov($\widehat{Y}_i$, $\widehat{Y}_i^s$) = 0 may be realistic in practice since $\widehat{Y}_i^s$ is much less variable than $\widehat{Y}_i$.

Nichol (1977) proposes to add the synthetic estimate, $\hat{Y}_i^s$, as an additional independent variable in the sample-regression method. This method, called the combined synthetic-regression method, showed improvement, in empirical studies, over both the synthetic and sample-regression estimates.

Chambers and Feeney (1977) and Purcell and Kish (1980) propose structure preserving estimation (SPREE) as a generalization of synthetic estimation in the sense it makes a fuller use of reliable direct estimates. SPREE uses the well-known method of iterative proportional fitting of margins in a multi way table, where the margins are direct estimates.

3. Model Based

The SAE methods described above are indirect methods in which information from other sources (records, registers etc.) is utilized and strength is borrowed from other similar areas.

They are invariably based on certain assumptions which are in the form of implicit models. Now consider some explicit model-based methods which are essentially mixed models and are used in specific situations based on data availability on the response variables of interest.

These are,

I. area level models where information on response variable is available only at the small area level; and
II. unit level models where information on the response variable is available at the unit level.

3.1 Area Level Model

An area level model has two components:

1. Direct survey estimator of the parameter based on the sampling design, expressed as

$$\boldsymbol{\widehat{\theta}_d = \theta_d + e_d}, \text{ d = 1, ..., D} \qquad \text{.......(3.1.1)}$$

where e_d's are assumed to be independent across small areas with mean zero and known variances X_d. The model (3.1.1) is a sampling model and X_d is a design- based sampling variance.

2. A linking model

$$\boldsymbol{\theta_d = z_d^T \beta + v_d}, \text{ d = 1, ..., D} \qquad \text{........(3.1.2)}$$

where the model errors$v_d$are assumed to be independent and identically distributed with mean zero and variance σ_d^2. The model variance σ_d^2 is a measure of homogeneity of the areas after accounting for the covariates Z_d .

Combining (3.1.1) and (3.1.2), the resultant mixed linear model is

$$\hat{\boldsymbol{\theta}}_{\mathbf{d}} = \mathbf{z}_{\mathbf{d}}^{\mathbf{T}}\boldsymbol{\beta} + \mathbf{v}_{\mathbf{d}} + \mathbf{e}_{\mathbf{d}},\ \mathbf{d = 1, ..., D} \qquad \mathbf{(3.1.3)}$$

Using the data $\{(\hat{\theta}_d , Z_d), d = 1, ..., D\}$, we can obtain estimates θ_d^* of the realized values θ_d from the model (3.1.3). Here e_d's and v_d's are design-based and model-based random variables respectively.

- Empirical Best Linear Unbiased Prediction (EBLUP),Empirical Bayes (EB) and Hierarchical Bayes (HB) methods have played an important role in the estimation of small area means $\overline{Y}_i$ under model (3.1.3).
- EBLUP method has been used in many practical applications. The other methods EB and HB are applicable under specific distributional assumptions, *viz,* the sampling distribution of the mean is normal or the distribution of means across samples is normal.
- An excellent example of application of this method is in a study on Small Area Estimates of School-Age Children in Poverty (Constance *et al.* (2000).

3.2 Unit Level Model

Consider a population of N units with d-th small area consisting of N_d units. Let y_{dj} and x_{dj} be the unit level y-value and correlated covariate x-value for j-th unit in the d-th small area. It is assumed that the domain mean $\overline{X}_d$ is known. Consider the following one-folded nested error linear regression model

$$\mathbf{y}_{\mathbf{dj}} = \mathbf{x}_{\mathbf{dj}}^{\mathbf{T}}\boldsymbol{\beta} + \mathbf{v}_{\mathbf{d}} + \mathbf{e}_{\mathbf{dj}},\ \mathbf{j = 1,\dots, N_d\ ;\ d = 1,\dots, D} \qquad \mathbf{(3.2.1)}$$

where the random small area effects v_d have mean zero and common variance σ_v^2 and are independently distributed. Also, e_{dj} are assumed to be independently distributed with mean zero and variance σ_e^2 and are also independent of area effects v_d. This model was initially considered by Battese *et al.* (1988).

If N_d is large, the population mean $\overline{Y}_d$ is approximately equal to $x_d^T\beta + v_d$ The sample data $\{y_{dj},x_{dj}$ j = 1,…, n_d ; d = 1,…, D} is assumed to satisfy the population model (3.2.1). This happens in equal probability sampling.

This will also follow in probability proportional to size sampling when the size measure is taken as the covariate in the model.

Assuming the $\overline{Y}_d = \overline{X}_d^T\beta + v_d$, EBLUP estimate of $\overline{Y}_d$ is of the form,

$$\bar{\mathbf{y}}_{\mathbf{d}}^{*} = \hat{\boldsymbol{\gamma}}_{\mathbf{d}}\ \{\ \bar{\mathbf{y}}_{\mathbf{d}} + (\ \overline{\mathbf{X}}_{\mathbf{d}} - \bar{\mathbf{x}}_{\mathbf{d}}\ )^{\mathrm{T}}\hat{\boldsymbol{\beta}}\ \} + (1 - \hat{\boldsymbol{\gamma}}_{\mathbf{d}})\ \overline{\mathbf{X}}_{\mathbf{d}}^{\mathbf{T}}\hat{\boldsymbol{\beta}}\ \ \mathbf{d = 1,\dots, D} \qquad \mathbf{(3.2.2)}$$

where $\hat{\gamma}_d = \hat{\sigma}_v^2\ /\ (\ \hat{\sigma}_v^2 + \hat{\sigma}_e^2 n_d^{-1})$ with estimated variance components $\hat{\sigma}_v^2$ and $\hat{\sigma}_e^2$, and $\hat{\beta}$ is the weighted least square estimate of β.

It may be noted that the EBLUP estimator is a composite estimator combining the survey regression estimator with the regression synthetic estimator.

Battese et al. (1988) applied the nested error regression model to estimate area under corn and soybeans at county level in North-Central Iowa using farm interview data in conjunction with LANDSAT satellite data.

A more recent paper by Jiang and Lahiri (2006) provides an excellent overview and appraisal of mixed model prediction in the context of small area estimation.

4 EBLUP, EB and HB Approaches

4.1 EBLUP (Variance Components) Approach

Most small area models are special cases of a general mixed linear model involving fixed and random effects, and small area parameters can be expressed as linear combinations of these effects.

Henderson (1950) derives BLUP estimators of such parameters in the classical frequentist framework.

These estimators minimize the mean squared error among the class of linear un biased estimators and do not depend on normality, similar to the best linear unbiased estimators (BLUEs) of fixed parameters.

Robinson (1991) gives an excellent account of BLUP theory and examples of its application.

Under model (3.1.3), the BLUP estimator of $\theta_i = x_i^T\beta + \text{vizi}$ simplifies to a weighted average of the direct estimator θ_i and the regression-synthetic estimator $x_i^T\tilde{\beta}$:

$$\tilde{\boldsymbol{\theta}}_i^H = \boldsymbol{\gamma}_i\hat{\boldsymbol{\theta}}_i + (1-\boldsymbol{\gamma}_i)\mathbf{x}_i^T\tilde{\boldsymbol{\beta}} \qquad \text{........(4.1.1)}$$

where the superscript H stands for Henderson,

$$\tilde{\boldsymbol{\beta}} = [\ \textstyle\sum_i \mathbf{X}_i\mathbf{X}_i^T / (\sigma_v^2 z_i^2 + \psi_i)\ ]^{-1} * [\ \textstyle\sum_{i=1}^m \mathbf{X}_i\hat{\boldsymbol{\theta}}_i / (\sigma_v^2 z_i^2 + \psi_i)\ ] \qquad \text{......(4.1.2)}$$

is the BLUE estimator of β and,

$$\boldsymbol{\gamma}_i = \sigma_v^2 z_i^2 / (\sigma_v^2 z_i^2 + \psi_i) \qquad \text{........(4.1.3)}$$

The weight γ_i measures the uncertainty in modelling the θ_is, namely, $\sigma_v^2 z_i^2$ relative to the total variance $\sigma_v^2 z_i^2 + \psi_i$ · Thus, the BLUP estimator takes proper account of between area variation relative to the precision of the direct estimator. It is valid for general sampling designs since we are modelling only the θ_i's and not the individual elements in the population. It is also design consistent since $\gamma_i \rightarrow 1$ as the sampling variance $\psi_i \rightarrow 0$.

4.2 EB Approach

In the EB approach, the posterior distribution of the parameters of interest given the data is first obtained, assuming that the model parameters are known. The model parameters are estimated from the marginal distribution of the data, and inferences are then based on the estimated posterior distribution. Morris (1983) gives an excellent account of the EB approach and significant applications.

Under model (3.1.3) with normal errors, the posterior distribution of θ_i given $\hat{\theta}_i$, β and σ_v^2 is normal with mean θ_i^B of and variance $g_{1i}(\sigma_v^2) = \gamma_i\psi_i$, where

$$\boldsymbol{\theta}_i^B = E(\boldsymbol{\theta}_i \mid \hat{\boldsymbol{\theta}}_i, \boldsymbol{\beta}, \sigma_v^2) = \boldsymbol{\gamma}_i\hat{\boldsymbol{\theta}}_i + (1-\boldsymbol{\gamma}_i)\ \mathbf{X}_i^T\boldsymbol{\beta} \qquad \text{......(4.2.1)}$$

Under quadratic loss, θ_i^B is the Bayes estimator of θ_i. Noting that the $\hat{\theta}_i \sim N(X_i^T\beta,\ \sigma_v^2 z_i^2 + \psi_i)$ are marginally independent, we can obtain the estimators $\hat{\sigma}_v^2$ and $\hat{\beta}$ as before using ML, REML(Restricted Maximum Likelihood) or the method of moments. The estimated posterior distribution is $N(\tilde{\theta}_i^{EB}, g_{1i}(\hat{\sigma}_v^2))$, where $\tilde{\theta}_i^{EB}$ is identical to the EBLUP estimator of $\tilde{\theta}_i^H$.

A naive EB approach uses $\tilde{\theta}_i^{EB}$ as the estimator of θ_i and measures its uncertainty by the estimated posterior variance,

$$\mathbf{V(\theta_i \mid \hat{\theta}_i, \hat{\beta}, \hat{\sigma}_v^2) = g_{1i}(\hat{\sigma}_v^2)} \qquad \text{.......(4.2.2)}$$

This can lead to severe underestimation of the true posterior variance $V(\theta_i \mid \hat{\theta}_i)$ (under a prior distribution on β and σ_v^2), although $\tilde{\theta}_i^{EB} = E(\theta_i \mid \hat{\theta}_i, \hat{\beta}, \hat{\sigma}_v^2)$ is approximately equal to the true posterior mean $E(\theta_i \mid \hat{\theta}_i)$, where $\theta = (\theta_1, \ldots, \theta_m)^T$.

The above point is better understood when writes

$$\mathbf{E(\theta_i \mid \hat{\theta}_i) = E_{\beta,\sigma_v^2}\,[E(\theta_i \mid \hat{\theta}_i, \beta, \sigma_v^2)]}$$

and

$$\mathbf{V(\theta_i \mid \hat{\theta}_i) = E_{\beta,\sigma_v^2}\,[V(\theta_i \mid \hat{\theta}_i, \beta, \sigma_v^2)] + V_{\beta,\sigma_v^2}\,[E(\theta_i \mid \hat{\theta}_i, \beta, \sigma_v^2)]}, \qquad \text{......(4.2.3)}$$

Where E_{β,σ_v^2} and V_{β,σ_v^2} respectively denote the expectation and variance with respect to the posterior distribution of β and σ_v^2 given the data θ. It follows from (4.2.3) that (4.2.2) is a good approximation only to the first variance term on the right side of (4.2.3), but the .second variance term is ignored in the naive EB approach, that is, it fails to take account of the uncertainty about the parameters β and σ_v^2. Note that the form of the prior distribution on β and σ_v^2 is not specified in the EB approach, unlike in the HB approach next.

4.3 HB Approach

In the HB approach, a prior distribution on the model parameters is specified and the posterior distribution of the parameters of interest is then obtained. Inferences are made based on the posterior distribution; in particular, a parameter of interest is estimated by its posterior mean and its precision is measured by its posterior variance.

The HB approach is straightforward and clear cut but computationally intensive, often involving high dimensional integration. Recent advances in computational aspects of the HB approach, such as Gibbs sampling (Gelfand and Smith, 1990) and importance sampling, however, seem to overcome the computational difficulties to a large extent.

If the solution involves only one or two dimensional integration, it is often easier to perform direct numerical integration as compared to use Gibbs sampling or any other Monte Carlo numerical integration method.

Datta and Ghosh (1991) apply the HB approach to estimation of small area means, $\bar{Y}$ under general mixed linear models, and also discuss the computational aspects.

Under model (3.1.3), we first obtain the posterior distribution of θ_i given $\hat{\theta}$ and σ_v^2, by assuming that β has a uniform distribution over R^P to reflect absence of prior information on β.

Straightforward calculations show that it is normal with mean equal to the BLUP estimator $\tilde{\theta}_i^H$ and variance equal to $M_{1i}(\sigma_v^2)$, the MSE of $\tilde{\theta}_i^H$, that is, $E(\theta_i \mid \hat{\theta}_i) = \tilde{\theta}_i^H$ and $V(\theta_i \mid \hat{\theta}_i) = MSE\,(\tilde{\theta}_i^H)$. Hence, when σ_v^2 is assumed to be known, the HB and BLUP approaches lead to identical inferences.

To take account of the uncertainty about σ_v^2, we need to calculate the posterior distribution of σ_v^2 given $\hat{\theta}$ under a suitable prior on σ_v^2. The posterior mean and variance of θ_i are then given by

$$\mathbf{E(\theta_i \mid \hat{\theta}_i) = E\sigma_v^2\,(\tilde{\theta}_i^H)} \qquad \text{.......(4.3.1)}$$

And

$$V(\theta_i \mid \hat{\theta}_i) = E\sigma_v^2[M_{1i}(\sigma_v^2)] + V\sigma_v^2\,(\tilde{\theta}_i^H) \qquad \text{......(4.3.2)}$$

where $E\sigma_v^2$ and $V\sigma_v^2$ respectively denote the expectation and variance with respect to the posterior distribution of σ_v^2 given $\hat{\theta}$. Numerical evaluation of (4.3.1) and (4.3.2) involves one dimensional integration.

Review of Literature

Ghosh and Rao (1994) was estimated EBLUP and HB estimators give similar values over small areas, and their average relative errors (%) 11.74 and 11.23 and squared errors are 2.84 and 2.69 respectively for business population data at America.

Sud *et al.* (2015) found that the SEBLUP method is providing better estimates than the usual EBLUP and the direct survey estimator. It can also be seen that there is a significant improvement in the %SE of the SEBLUP than the EBLUP and the direct estimates. Two points emerged from this analysis: (i) the small area estimate provides efficient and better estimates for crop yield as compared to the direct survey estimates (ii) the use of spatial information improve the efficiency of small area estimates.

Nazir *et al.* (2016) reported for Total yield of apple in Baramulla district that the proposed prior for lambda(λ) performed significantly better than the uniform gamma(γ) prior and EBLUP estimates in terms of all the four criterion, *viz.* ARB, ASRB, ABS, ASD. It is evident that HB model with proposed prior exhibits smaller errors and a lower incidence of extreme error than either of the HB (with uniform prior) and EBLUP estimates. Also reported that the MSE of the proposed prior is better than rest of two techniques, and new/proposed prior for λ provides better estimates than EBLUP and HB (uniform prior). In terms of standard error also new/proposed prior provides better estimates than the EBLUP and HB (uniform prior).

Aditya *et al.* (2019) was conducted district level crop yield estimation with reduced number of crop cutting experiments in Uttar Pradesh and Assam. They reported for Uttar Pradesh state that the CV% of the design based estimator varies from 0.35-10.86 with an average of 5.10, whereas the CV% of the SAE estimates varies from 0.07- 1.33 for all the sampled districts with an average of 0.7 and for the state of Assam it is visible that the CV% of the design based estimator varied from 1.83-16.51 with an average of 8.07, whereas the CV% of the SAE estimates varies from 1.83-10.97 for all the sampled districts with an average of 6.4.

Anonymous, (1999) at Washington D. C. carried out survey for school age children in poverty and calculated the small area estimates. Concluded that the Mean C.V. and Median C.V. for estimate ratio-adjusted from long form and short form are coupled with lesser magnitude than estimate from only long form sample which concluded that the estimates measure by ratio-adjusted form are more precise and better.

Conclusion

The Small Area Estimation (SAE) method is a powerful tool as the variability and reliability of its estimates are measurable and meaningful for approximating narrowly defined, eligible or target populations that are not represented fully in any one data source.

Looking to the growing demand of Small Area Statistics (SAS) from public and private sector for preparing effective policies relations to issues of distribution, equity and disparity in various areas of interest such as, Agriculture, Public Health, Education, Business, Poverty, Census etc.

As discussed above the EBLUP, EB and HB approaches are better than the direct estimator, Ratio Synthetic estimator or Sample-size Dependent Estimator to get reliable and precise estimation of parameters for small sub-populations.

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UNDERSTANDING SOIL SALINITY AND ITS MANAGEMENT IN COASTAL INDIA

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Soil salinity poses a major challenge to agricultural productivity in India's coastal regions. The accumulation of salts, often exacerbated by seawater intrusion, significantly impacts crop yields and threatens food security, affecting millions of hectares of arable land (Sabareshwari & Ramya, 2018). Understanding and managing soil salinity is essential for sustaining agriculture in these vulnerable areas.

Salt-affected soils, characterized by excess soluble salts, hinder plant growth. In coastal areas, salinity levels can fluctuate from 0.5 dSm^{-1} during the monsoon to 50 dSm^{-1} in summer. When soluble salts, particularly Sodium Chloride (NaCl) and Sodium Sulfate (Na_2SO4), reach harmful levels, they negatively impact crop growth and yield. Salts often accumulate on the soil surface through capillary action in dry seasons, making the land unproductive (Prasenjit Ray *et al.,* 2014).

Over-extraction of groundwater, driven by urban, industrial, and agricultural demands, can lower the water table and lead to seawater intrusion, further exacerbating soil salinity. Natural disasters, such as tsunamis, also contribute to this issue. Salinity impacts plant growth by disrupting water and nutrient uptake, limiting microbial activity, and causing osmotic imbalances, which can lead to wilting and drying of plants. In rice, for example, spikelet sterility has been noted in saline soils.

To tackle these challenges, a comprehensive approach is required. This includes salinity mapping, the development of salt-tolerant crops, and the implementation of innovative irrigation practices.

Bioengineering solutions and agroforestry techniques also offer promising methods to manage salt accumulation. Government policies are crucial in supporting these initiatives and promoting sustainable agricultural practices. By leveraging these strategies alongside advanced technologies like remote sensing and precision agriculture, it is possible to reclaim saline soils and secure the future of coastal agriculture in India.

Causes of Soil Salinity in Coastal India

Natural Causes

Soil salinization in coastal India occurs through various natural processes. The weathering of parent material with high salt content releases soluble salts, which are transported through surface or groundwater streams. In arid regions, limited natural precipitation and high evaporation rates lead to salt concentration and precipitation in the soil. Fossil salt deposits, such as marine and lacustrine deposits, also contribute to salinization in arid regions.

Coastal lands are particularly vulnerable to salinization due to sea water ingression. Salt-laden winds and rains (sea sprays) from the ocean carry oceanic salts inland, with salt content as high as 14.2 $\mu g\ m^{-3}$, impacting areas up to 80 km from the coast (Kumar & Sharma, 2020). Natural disasters like storms, cyclones, and tidal surges further exacerbate the risk of progressive salinization in coastal regions.

Anthropogenic Factors

Human activities significantly contribute to soil salinization in coastal India. Land clearing for cultivation, particularly the replacement of perennial vegetation with annual crops, can result in saline seepage processes. Incorrect irrigation practices, including the use of brackish or saline water and poor drainage conditions, lead to secondary salinization of land and water resources.

Over-extraction of groundwater is a major concern in coastal areas (Sabareshwari & Ramya, 2018) It lowers the normal water table, leading to the intrusion of. marine water into freshwater aquifers. This problem is often associated with growing urbanization, industrial demands, and agricultural needs.

Other anthropogenic factors include:

- Canal water seepage, causing water-logging and salinity development along canal banks.
- Over-use of agrochemicals, including chemical fertilizers and soil amendments
- Use of untreated sewage effluents and industrial brine dumping.

Climate Change Impacts

Climate change is expected to exacerbate soil salinization issues in coastal India. Projected hydrological consequences of climate change may result in physical, biological, biochemical, and chemical degradation of soils. The following factors contribute to increased soil salinity in a warmer world:

1. Increased evapotranspiration rates and altered precipitation patterns, particularly in arid and semi-arid areas, reducing soil leaching efficiency and increasing salt concentrations in top-soil horizons
2. Expansion of irrigated areas and higher water demand due to rising global temperatures, combined with poor drainage practices, leading to secondary salinization
3. More extreme climate events, such as prolonged droughts followed by severe floods, potentially releasing and redistributing large amounts of salts from geological substrates

4. Rising sea levels and unsustainable extraction of freshwater resources from coastal aquifers, worsening sea water-induced soil salinization in coastal regions

In coastal areas the impact of climate change on soil salinity is already evident. Rising seas are bringing saltwater into freshwater sources, rendering them unusable for everyday life. Studies have shown that salinity in the area has increased by 30% to 40% since 1971. Sea levels in the Kochi area have been rising by approximately 1.8 mm per year, based on satellite and tide gage data from the 1970s through 2020.

These combined natural, anthropogenic, and climate change-related factors contribute to the complex issue of soil salinity in coastal India, posing significant challenges to agriculture and water resource management in these regions.

Impact of Soil Salinity on Agriculture

Soil salinity poses a significant threat to agricultural productivity, affecting crop yields, soil properties, and economic stability in affected regions. The accumulation of salts in soil has far-reaching consequences for farmers and the agricultural sector as a whole.

Crop Yield Reduction

The impact of soil salinity on crop yields is substantial and often devastating. As salt concentrations in soil increase, plants struggle to absorb water and nutrients, leading to stunted growth and reduced productivity. This phenomenon is clearly illustrated by the experiences of farmers in Maharashtra, India. For instance, Babar Kamble's sugar cane farm saw a dramatic decline in production, with yields plummeting from 80 metric tons per acre in 2013 to just 35 metric tons in 2023, representing a 56% decrease (Annon.,2024).

Similarly, Rajendrakumar Chougule's farm in Akiwat village experienced severely stunted sugar cane growth, with plants reaching only one foot in height after 10 months, far below the expected 5-7 feet. These examples highlight the severe impact of soil salinity on crop development and yield.

The relationship between soil salinity and crop yield has been quantitatively described using the piecewise linear salt tolerance equation:

$Yr = 100 - b(ECe - a)$

Where:

- Yr is the relative crop yield
- ECe is the electrical conductivity of the saturation extract (dS m^{-1})
- a is the salinity threshold (dS m^{-1})
- b is the slope expressed as % per dS m^{-1}

Different crops have varying levels of salt tolerance.

Crop	Salinity Threshold (a)	Slope (b)
Carrot	1.0 dS m^{-1}	14.0%
Broccoli	2.8 dS m^{-1}	9.2%
Wheat	6.0 dS m^{-1}	7.1%
Cotton	7.7 dS m^{-1}	5.2%

Changes in Soil Properties

Soil salinity not only affects plant growth directly but also alters soil properties, further impacting agricultural productivity. The accumulation of salts in soil influences:

1. Soil structure: High levels of sodium can lead to soil structure degradation.
2. Permeability: Saline soils often experience reduced permeability, affecting water movement and root growth.
3. Nutrient availability: Salinity can upset the nutritional balance of plants and reduce nutrient content in the soil.

These changes in soil properties can lead to desertification and are closely associated with land degradation processes such as arable land abandonment and soil erosion.

Economic Losses

The economic impact of soil salinity on agriculture is substantial. In India alone, soil salinity and sodicity result in an annual loss of 16.8 million metric tons of crops, translating to a financial loss of 23 billion Rupees. The scale of this problem is global, affecting:

- Up to 3 million hectares in Europe
- More than 5% of arable land in Africa
- About 20% in West Asia
- 30% in Australia

In coastal regions, the economic impact is particularly severe. For example:

- In Bangladesh, coastal soil salinity significantly affects crop revenue and has led to internal migration of farmers.
- In Vietnam, over 30% of sugarcane plantations in the Mekong Delta have been either destroyed or significantly damaged by saltwater intrusion, resulting in substantial financial losses.

The deterioration of soil fertility due to salt accumulation is a growing concern in coastal areas, often leading to the abandonment of agricultural lands. This not only affects individual farmers but also has broader implications for food security and regional economies.

Methods for Identifying and Mapping Saline Soils

1. Soil testing

Identifying and mapping saline soils is crucial for effective agricultural management. Saline soils are characterized by the presence of sufficient neutral soluble salts to adversely affect the growth of most crop plants. By definition, saline soils have an electrical conductivity of the saturation soil extract exceeding 4 dS/m at 25°C.

In field conditions, saline soils can be recognized by several indicators:

1. Spotty growth of crops
2. Presence of white salt crusts on the soil surface
3. Blue-green tinge in mildly affected growing plants
4. Barren spots and stunted plants in cereal or forage crops

The extent and frequency of bare spots often indicate the concentration of salts in the soil.

2. Electrical conductivity mapping

Soil electrical conductivity (EC) measures the ability of soil water to carry electrical current. It serves as an effective indicator of soil salinity and other soil properties. EC is determined by the concentration of ions in the soil solution, primarily cations (Ca^{2+}, Mg^{2+}, K^+, Na^+, and $NH4^+$) and anions ($SO4^{2-}$, Cl^-, $NO3^-$, and $HCO3^-$).

The measurement of EC has several applications:
1) Assessing soil salinity: Saline soils are characterized by EC values ≥ 4 dS/m.
2) Estimating soil moisture and depth in non-saline soils
3) Inferring the concentration and movement of animal wastes in soils
4) Correlating with concentrations of specific ions like potassium, sodium, chloride, sulfate, ammonia, and nitrate

High EC values (> 4 dS/m) can indicate salinity problems that impede crop growth and microbial activity.

3. Remote sensing technologies

Remote sensing technologies have revolutionized the process of soil salinization monitoring and mapping. Sentinel-2 satellites, equipped with Multi Spectral Instrument (MSI), have proven particularly effective due to their high spatial resolution, multiple wavebands, and relatively quick return time.

Key aspects of remote sensing for soil salinity mapping include:
1. **Comparison of sensors**: The sensors now have higher spatial and temporal resolutions, such as the Multispectral Instrument (MSI) and the Operational Land Imager (OLI), enhancing their capability to track soil salinity more effectively.
2. **Data analysis**: Regression analysis of ground-measured and satellite data allows for the deduction of various salinity levels in different electrical conductivity (EC) ranges.
3. **Challenges**: Factors such as spectral variability, vegetation cover, air interference, and availability of ground-truth data can constrain the identification of soil salinity using GIS and remote sensing data.
4. **Mitigation strategies**: These constraints can be addressed through the use of multiple sensors, incorporation of vegetation indices, implementation of atmospheric correction algorithms, and augmentation of ground-truth data collection.
5. **Advanced techniques**: Machine learning, time series data analysis, and incorporation of hyperspectral data have the potential to enhance the precision and reliability of soil salinity detection.

Pre-processing of satellite images is crucial for accurate soil salinity mapping. This involves:
1. Geometry correction: Aligning the satellite image to a reference map using methods like ground control points (GCPs) or digital elevation models (DEM).
2. Atmospheric adjustment: Removing atmospheric effects that could obscure or warp the spectral signature of objects in the image.
3. Radiometric correction: Converting digital number (DN) values in the satellite image to reflectance values for accurate measurements.

These pre-processing techniques significantly improve the accuracy of calculated soil salinity indices, ensuring precise mapping and monitoring of saline soils.

Soil Salinity Management Strategies

Soil Amendments and Reclamation Techniques

Chemical amendments have proven effective in reclaiming alkali and sodic soils. The process involves field leveling, bunding, soil sampling, and application of gypsum or pyrite. This technology has successfully reclaimed about 1.8 million hectares in Punjab, Haryana, and Western Uttar

Pradesh, contributing 8-10 million tons of additional food grains to the national food pool. The benefit-cost ratio of this reclamation technique ranges from 1.29 to 2.30, with an internal rate of return of 22 to 56 percent.

Gypsum has emerged as the most preferred chemical amendment for sodic soils in India due to its availability and low cost. The gypsum-based alkali land reclamation technology has been widely adopted, bringing 2.07 million hectares of barren sodic soils under cultivation. Farmers are now harvesting 5 t ha^{-1} of rice and 3 t ha^{-1} of wheat from these reclaimed lands.

Integrated Water Management Practices

Sub-surface drainage technology has been developed to lower the water table in saline waterlogged areas. This system consists of a network of concrete or PVC pipes with filters installed below the soil surface to control water table depth. The socio-economic analysis of sub-surface drainage indicates that it generates 128 man-days of employment per hectare, with a benefit-cost ratio of 1.26 to 1.49.

In coastal regions, an innovative "Doruvu" technology has gained popularity. This technique involves skimming shallow depth fresh water floating on saline water and storing it in dug-out conical pits called "Doruvus".

Biological Methods

Biodrainage is an effective technique for lowering groundwater in waterlogged areas through tree plantations. This preventive method uses solar radiation energy to remove excess soil water through transpiration. Eucalyptus, Populus, Casuarina, and Bambusa have been identified as promising species for biodrainage.

Several salt-tolerant grass species, such as Leptochloa fusca and Bricharia mutica, have demonstrated the potential to yield high biomass even under high pH and prolonged waterlogged conditions.

Agroforestry and Bioengineering Solutions

Agroforestry systems, combining herbaceous and woody species for both productive and protective purposes, offer an effective solution for managing saline soils. These systems can enhance soil and environmental quality while increasing farm production variability.

Multi-storeyed integrated agroforestry systems involving fish or shrimp culture, poultry, plantation crops, cattle, and diversified arable crops have shown potential in coastal areas. Additionally, incorporating cover crops into crop rotation as mulch for the main crop is a promising practice.

Phytoremediation, which involves growing different plant species to remove excess salts from the soil, is another emerging bioengineering solution for salt-affected soils. This approach, combined with the development of salt-tolerant crop varieties through conventional breeding and modern genomic techniques, offers promising avenues for managing soil salinity in agricultural lands.

Policy and Institutional Support

Government Initiatives and Policies

The Indian government has recognized the critical need to address soil salinity issues and has implemented various initiatives to support farmers and promote sustainable agricultural practices. One of the key targets set by the Government of India is to restore 26 million hectares of degraded lands, including salt-affected soils, by the year 2030. This ambitious goal underscores the government's commitment to ensuring food security for the nation's growing population.

To achieve this target, the government has been actively involved in planning and executing soil reclamation programs. These efforts are guided by state-wise data and maps of saline and sodic soils, which provide policymakers and stakeholders with crucial information for decision-making. The government's approach involves collaboration with various stakeholders, including local communities, department officials, and research organizations.

A notable example of this collaborative approach is the vulnerability assessment carried out with government cooperation to identify key water challenges and issues driving soil salinity. Following this assessment, a micro-watershed approach was adopted to determine appropriate restoration actions. This process involved local community members, department officials, and the M.S. Swaminathan Research Foundation (MSSRF) team.

The government has also been supportive of implementing specific restoration activities. Currently, 66 restoration activities have been prioritized for implementation, including:

1. Construction of check-dams to prevent saline water intrusion in agricultural fields
2. Plantation of saline-tolerant tree species in fallow and common lands
3. Desilting available ponds and construction of rainwater harvesting structures to improve groundwater recharge
4. Community soak pits for gray water management

These initiatives demonstrate the government's multifaceted approach to addressing soil salinity issues, combining infrastructure development, ecological restoration, and water management strategies.

The Role of Agricultural Extension Services

Agricultural extension services play a crucial role in bridging the gap between research institutions and farmers, facilitating the implementation of soil salinity management strategies. While specific information about extension services is not provided in the given excerpts, their importance can be inferred from the collaborative nature of the initiatives described.

The involvement of local community members and department officials in the micro-watershed approach suggests that extension services likely play a key role in:

1. Disseminating information about soil salinity management techniques
2. Providing training and support to farmers in implementing restoration activities
3. Facilitating communication between policymakers, researchers, and farmers

To enhance the effectiveness of soil reclamation programs, the government needs to continue making policies favorable for the implementation of reclamation technologies in the country. This includes supporting ongoing research efforts for the management and reclamation of salt-affected soils, which are crucial for ensuring long-term food security.

The success of these initiatives relies heavily on periodic dialogs and discussions with state-level officials. These interactions have been instrumental in obtaining approvals for implementation of various restoration activities. By maintaining open lines of communication between different stakeholders, the government can ensure that policies and programs are responsive to the needs of farmers and aligned with the latest scientific research on soil salinity management.

Conclusion

Soil salinity in coastal India has a significant impact on agricultural productivity and food security. The combination of natural processes, human activities, and climate change has led to the degradation of vast areas of arable land. To tackle this issue, a range of strategies have been put into action, including soil amendments, integrated water management, and bioengineering solutions. These approaches, along with government support and agricultural extension services, are crucial to restore affected lands and ensure sustainable farming practices.

The road ahead requires ongoing collaboration between farmers, researchers, and policymakers to implement effective soil salinity management techniques. By putting these strategies into action and continuing to invest in research and development, India can make progress in reclaiming saline soils and boosting agricultural productivity in coastal regions. This multi-pronged approach is key to safeguarding food security and supporting the livelihoods of millions of farmers affected by soil salinity.

Reviews

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