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Research Trends in Agriculture Science Volume I

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PREFACE

We are delighted to publish our book entitled ***"Research Trends in Agricultural Science Volume I".*** *This book is the compilation of esteemed articles of acknowledged experts in the fields of basic and applied agricultural science.*

The Indian as well as world population is ever increasing. Hence, it is imperative to boost up agriculture production. This problem can be turned into opportunity by developing skilled manpower to utilize the available resources for food security. Agricultural research can meet this challenge. New technologies have to be evolved and taken from lab to land for sustained yield. The present book on agriculture is to serve as a source of information covering maximum aspects, which can help understand the topics with eagerness to study further research. We developed this digital book with the goal of helping people achieve that feeling of accomplishment.

The articles in the book have been contributed by eminent scientists, academicians. Our special thanks and appreciation go to experts and research workers whose contributions have enriched this book. We thank our publisher Bhumi Publishing, India for taking pains in bringing out the book.

Finally, we will always remain a debtor to all our well-wishers for their blessings, without which this book would not have come into existence.

Editors

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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN AGRICULTURE: TRANSFORMING FARMING SYSTEMS

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Abstract:

The agricultural sector is crucial for sustaining human civilization by providing food, fiber, and raw materials. Technological advancements have revolutionized agriculture, with Artificial Intelligence (AI) and Machine Learning (ML) playing a key role. This article provides an overview of the agricultural sector and emphasizes the importance of technological advancements in agriculture. It explores how AI and ML have transformed farming systems. The agricultural sector encompasses crop production, animal husbandry, aquaculture, forestry, and agribusiness. Technological advancements have become crucial to address challenges such as limited resources, climate change, and population growth. The importance of technology in agriculture is evident in increased productivity, precision agriculture, efficient resource management, disease and pest management, and supply chain optimization. AI and ML technologies have emerged as powerful tools in agriculture. They enable crop and soil monitoring, precision farming, agricultural robotics, predictive analytics, livestock management, and the use of agricultural drones. The integration of AI and ML holds promise for enhancing productivity, reducing resource waste, promoting sustainability, and enabling data-driven decision-making in the agricultural sector.

Keywords: Agricultural sector, artificial intelligence (AI), machine learning (ML), sustainability and technological advancements.

1. Introduction:

The agricultural sector plays a vital role in providing food, fiber, and raw materials to sustain human civilization. Over the years, advancements in technology have revolutionized agriculture, leading to increased productivity, efficiency, and sustainability. One of the key drivers of this transformation is the integration of Artificial Intelligence (AI) and Machine Learning (ML) techniques in agricultural practices. In this article, we will provide an overview of the agricultural sector, discuss the importance of technological advancements in agriculture, and delve into the role of AI and ML in transforming farming systems.

1.1 Overview of the agricultural sector

The agricultural sector encompasses a wide range of activities involved in cultivating crops, raising livestock, and producing other agricultural commodities. It is a multifaceted industry that contributes to the overall economic growth of a nation and is crucial for ensuring food security and nutrition. The sector includes various sub-sectors such as crop production, animal husbandry, aquaculture, forestry, and agribusiness.

Crop production involves the cultivation of plants for food, feed, fiber, or industrial purposes. This includes the production of staple crops like wheat, rice, maize, and soybeans, as well as specialty crops such as fruits, vegetables, and herbs. Animal husbandry focuses on the rearing of livestock for meat, milk, eggs, and other products. Aquaculture involves the farming of fish, shellfish, and aquatic plants in freshwater or marine environments. Forestry deals with the sustainable management of forests and the production of timber, pulp, and other forest products. Agribusiness encompasses the entire value chain of agricultural production, processing, distribution, and marketing.

The agricultural sector is influenced by a range of factors, including climate, soil conditions, water availability, market dynamics, and government policies. It faces numerous challenges such as limited natural resources, climate change, population growth, and the need for sustainable practices. To address these challenges and meet the growing demand for food, technological advancements have become crucial.

1.2 Importance of technological advancements in agriculture

Technological advancements have played a pivotal role in the development and improvement of agriculture throughout history. From simple tools like plows and sickles to the adoption of modern machinery and equipment, agriculture has witnessed significant transformations. In recent years, advancements in information technology, data analytics, and AI have brought about a new era of innovation in agriculture. The importance of technological advancements in agriculture can be seen in several areas:

- **Increased productivity:** Technology has enabled farmers to increase their productivity by improving cultivation techniques, crop varieties, and animal breeds. Mechanization has reduced manual labour, increased efficiency, and allowed for larger scale operations.
- **Precision agriculture:** Technology has enabled precision agriculture, which involves the use of sensors, drones, and satellite imagery to monitor and manage crops with precision. Farmers can collect data on soil moisture, nutrient levels, and crop health to optimize resource allocation, reduce waste, and increase yields.
- **Efficient resource management:** Technology has facilitated efficient management of key resources such as water and fertilizers. Irrigation systems can be automated based on real-time data, minimizing water usage. Similarly, smart fertilization techniques can deliver nutrients precisely where and when they are needed, minimizing environmental impact.
- **Disease and pest management:** AI and ML techniques can analyse large volumes of data to detect and predict disease outbreaks and pest infestations. Early detection allows farmers to take proactive measures, reducing crop losses and the need for excessive pesticide use.
- **Supply chain optimization:** Technology has improved logistics and supply chain management in agriculture. From farm to fork, digital systems can track and trace products, ensuring quality, safety, and timely delivery. This transparency benefits both farmers and consumers.

1.3 Role of Artificial Intelligence (AI) and Machine Learning (ML) in agriculture

Artificial Intelligence (AI) and Machine Learning (ML) technologies have emerged as powerful tools in the agricultural sector, transforming farming systems and revolutionizing traditional practices. AI refers to the development of computer systems that can perform tasks that typically require human intelligence, such as visual perception, speech recognition, and decision-making. ML, a subset of AI, focuses on algorithms and statistical models that enable computers to learn and improve from experience without explicit programming.

The application of AI and ML in agriculture is diverse and encompasses various areas:

- **Crop and soil monitoring:** AI and ML algorithms can analyse satellite imagery, drone data, and sensor inputs to monitor crop growth, identify nutrient deficiencies, detect diseases, and predict yield potential. This information enables farmers to make data-driven decisions and take proactive measures to optimize crop performance.
- **Precision farming:** AI and ML techniques can create precise field maps, guiding farmers in optimizing inputs such as irrigation, fertilization, and pesticide application. By tailoring these practices to specific crop needs and growth patterns, farmers can maximize resource efficiency and minimize environmental impact.
- **Agricultural robotics:** AI-powered robots can perform tasks such as planting, harvesting, weeding, and monitoring crop health. These robots can navigate fields autonomously, collect data, and execute actions based on predefined algorithms. This reduces labour costs, increases efficiency, and enables round-the-clock monitoring.
- **Predictive analytics:** AI and ML models can analyse historical and real-time data to make predictions about weather patterns, market trends, and crop performance. Farmers can use these insights to make informed decisions regarding planting schedules, market timing, and crop diversification.
- **Livestock management:** AI and ML techniques can be used to monitor animal health, behaviour, and productivity. Sensors and wearable devices can collect data on parameters such as temperature, heart rate, and milk production, enabling early disease detection and timely intervention.
- **Agricultural drones:** Drones equipped with AI and ML capabilities can capture high-resolution imagery and perform aerial surveys. This data can be used for crop monitoring, mapping, and identifying areas of concern, providing farmers with actionable insights.

The integration of AI and ML in agriculture holds great promise for addressing the challenges faced by the sector. It enhances productivity, reduces resource waste, promotes sustainable practices, and enables farmers to make informed decisions based on data-driven insights.

2. Fundamentals of AI and ML

2.1 Definition and Basic Concepts of AI and ML:

Artificial Intelligence (AI) is a branch of computer science that focuses on creating intelligent machines capable of performing tasks that typically require human intelligence. AI systems aim to mimic human cognitive abilities such as learning, reasoning, problem-solving, and decision-making. Machine Learning (ML) is a subset of AI that focuses on the development of algorithms and models that enable computers to learn from data and make predictions or decisions without being explicitly programmed. In AI and ML, the key concepts include:

- **Data:** Data is the foundation of AI and ML. It can be in various forms such as text, images, audio, video, or structured data. The quality and quantity of data greatly impact the performance and accuracy of AI and ML models.
- **Training:** ML models are trained on labeled or unlabeled data to learn patterns and relationships. Training involves feeding the model with input data and corresponding output or target values. The model then adjusts its internal parameters to minimize the difference between predicted and actual values.
- **Algorithms:** ML algorithms are mathematical procedures that enable machines to learn patterns from data. They provide the logic and rules for data processing, feature extraction, pattern recognition, and prediction. Different types of algorithms are used depending on the problem at hand.
- **Supervised Learning:** In supervised learning, the ML model learns from labeled data, where the input data is associated with known output labels. The model generalizes from this labeled data to make predictions on new, unseen data.
- **Unsupervised Learning:** Unsupervised learning involves training the model on unlabeled data, where the input data does not have corresponding output labels. The model explores the data to discover patterns, relationships, and structures on its own.
- **Reinforcement Learning:** Reinforcement learning is an area of ML where an agent learns to interact with an environment to maximize a reward signal. The agent learns by trial and error, receiving feedback in the form of rewards or penalties based on its actions.

2.2. Types of Machine Learning Algorithms Commonly Used in Agriculture:

Machine learning algorithms have various applications in agriculture, contributing to improved crop yield, disease detection, pest management, and precision agriculture. Some commonly used ML algorithms in agriculture include:

- **Decision Trees:** Decision trees are tree-like structures that represent decisions and their possible consequences. They are useful for tasks such as crop classification, disease diagnosis, and yield prediction.
- **Random Forests:** Random forests combine multiple decision trees to create a more robust and accurate model. They can handle large and complex datasets, making them suitable for tasks like crop yield estimation and plant disease detection.
- **Support Vector Machines (SVM):** SVM is a powerful algorithm used for classification and regression tasks. It separates data into different classes by finding an optimal hyperplane in a high-dimensional space. SVMs can be applied to tasks such as weed detection and crop classification.
- **Neural Networks:** Neural networks are computational models inspired by the human brain. They consist of interconnected nodes (neurons) organized in layers. Deep

Learning, a subset of neural networks, has been successful in image analysis tasks like plant disease identification, yield prediction, and weed detection.

- **K-Nearest Neighbors (KNN):** KNN is a simple algorithm that classifies objects based on their similarity to neighboring examples. It is useful for tasks such as crop disease classification and weed identification.
- **Gaussian Processes:** Gaussian processes are probabilistic models that can be used for regression and uncertainty estimation. They are beneficial in predicting crop yield, water stress, and soil properties.

2.3. Data Collection and Preprocessing for AI and ML in Agriculture:

Data collection and preprocessing play a crucial role in the success of AI and ML applications in agriculture. Here are the key steps involved:

1. **Data Collection:** Agricultural data can be collected from various sources such as sensors, satellites, drones, and manual observations. This data may include climate information, soil data, crop characteristics, disease symptoms, and yield records. Data collection should ensure data quality, accuracy, and representativeness.
2. **Data Cleaning:** Raw agricultural data often contains errors, missing values, outliers, and noise. Data cleaning involves removing or correcting errors, filling in missing values, and handling outliers to ensure data integrity and consistency.
3. **Feature Selection and Extraction:** In many cases, the collected data may contain a large number of features or variables. Feature selection involves identifying the most relevant and informative features for the specific task at hand. Feature extraction techniques can also be used to transform raw data into more meaningful representations.
4. **Data Normalization:** Data normalization involves scaling numerical features to a standard range, such as between 0 and 1. This step is necessary to ensure that features with different scales do not dominate the learning process.
5. **Data Splitting:** To evaluate the performance of ML models, the collected data is typically divided into training, validation, and testing sets. The training set is used to train the model, the validation set helps in tuning hyperparameters, and the testing set is used to assess the model's performance on unseen data.
6. **Handling Imbalanced Data:** In agricultural datasets, class imbalances may exist, where certain classes or conditions are underrepresented. Techniques like oversampling, undersampling, or generating synthetic samples can be employed to address this issue and prevent bias in the models.
7. **Data Augmentation:** Data augmentation techniques, such as image flipping, rotation, or adding noise, can be used to artificially increase the size of the dataset. This helps to improve the generalization and robustness of ML models, especially in image-based tasks.

By following these steps, researchers and practitioners can ensure that the data used for AI and ML in agriculture is of high quality, properly processed, and ready for training accurate and reliable models.

3. AI and ML Applications in Crop Production

3.1. Precision farming and site-specific crop management:

AI and machine learning (ML) are revolutionizing crop production through precision farming and site-specific crop management techniques. These technologies enable farmers to optimize their agricultural practices by collecting and analysing vast amounts of data about their fields. AI and ML algorithms can process data obtained from various sources, such as satellite imagery, drones, weather stations, soil sensors, and crop sensors. By integrating this data, farmers can gain insights into the variability of their fields, including soil composition, moisture levels, and nutrient content.

With this information, AI algorithms can generate precise and customized recommendations for farmers, such as optimal planting times, seed varieties, fertilizer application rates, and irrigation schedules. By tailoring these practices to specific areas within a field, farmers can maximize yields while minimizing resource wastage.

3.2. Crop yield prediction and optimization:

AI and ML techniques play a crucial role in predicting and optimizing crop yields. By analysing historical and real-time data, including weather patterns, soil conditions, and crop growth stages, algorithms can generate accurate predictions of crop yields. These predictive models take into account various factors that influence crop productivity, such as temperature, rainfall, sunlight, nutrient availability, and pest infestations. By understanding these relationships, farmers can make informed decisions regarding the application of fertilizers, pesticides, and other inputs to maximize yields.

Additionally, AI algorithms can optimize crop yield by recommending optimal planting densities, crop rotations, and intercropping strategies. By analysing large datasets and considering multiple variables, such as soil health, climate patterns, and market demand, algorithms can identify the most effective cultivation techniques for specific crops.

3.3. Weed detection and management:

Weed control is a critical aspect of crop production, as weeds compete with crops for nutrients, water, and sunlight. AI and ML applications offer efficient and accurate methods for weed detection and management. Using computer vision techniques, AI algorithms can analyse images of fields captured by drones or cameras mounted on agricultural machinery. These algorithms can identify and differentiate between crops and weeds, enabling farmers to target weed-infested areas precisely.

Once weeds are detected, AI-powered robotic systems can autonomously apply herbicides or use non-chemical methods, such as mechanical weeding or targeted laser treatment, to eliminate them. This reduces the reliance on broad-spectrum herbicides and minimizes their impact on the environment.

3.4. Disease and pest detection and control:

Early detection and control of diseases and pests are crucial for preventing significant crop losses. AI and ML technologies assist farmers in identifying and managing these threats efficiently. Using image recognition algorithms, AI can detect visual symptoms of diseases or pest infestations by analysing images of leaves, stems, or fruits. ML models trained on extensive datasets can accurately identify specific pathogens or pests and provide recommendations for appropriate treatments.

Moreover, AI algorithms can integrate data from various sources, such as weather conditions, historical disease patterns, and pest life cycles, to predict disease outbreaks or pest infestations. This enables farmers to take proactive measures, such as targeted spraying or the release of beneficial insects, to prevent or control the spread of diseases and pests.

3.5. Crop quality assessment and grading:

AI and ML technologies contribute to assessing and grading crop quality, ensuring consistency and efficiency in the agricultural supply chain. Computer vision algorithms can analyse images of harvested crops, grading them based on parameters such as size, colour, shape, and defects. By automating this process, AI systems eliminate human subjectivity and increase the speed and accuracy of crop quality assessment.

Crop quality assessment also extends to factors like sugar content, moisture levels, and nutritional value. ML models can correlate these parameters with environmental and cultivation data, providing insights into the factors that impact crop quality. This information enables farmers to adjust in their cultivation practices to improve the quality of their crops.

3.6. Irrigation and water management:

Efficient water management is essential for sustainable crop production, particularly in water-scarce regions. AI and ML applications aid in optimizing irrigation practices and conserving water resources. By analysing data from soil moisture sensors, weather forecasts, and crop water requirements, AI algorithms can generate precise irrigation schedules tailored to specific field conditions. These schedules ensure that crops receive adequate water without excessive usage, preventing water stress and optimizing water usage efficiency.

ML models can also learn from historical data and identify patterns to predict water demand accurately. This enables farmers to plan irrigation activities, optimize water allocation, and reduce water wastage.

3.7. Harvesting and post-harvest handling:

AI and ML technologies are transforming the harvesting and post-harvest handling processes by improving efficiency and reducing losses. Robotic systems equipped with AI vision algorithms can autonomously identify and harvest mature crops with precision and speed. These systems can assess factors such as colour, size, and ripeness to determine the optimal time for harvest, minimizing yield losses and ensuring consistent crop quality.

Furthermore, AI algorithms can optimize the logistics of post-harvest handling, including sorting, grading, and packaging. Computer vision systems can rapidly analyse the quality of harvested crops, sort them according to predetermined criteria, and facilitate appropriate packaging and storage methods. This streamlines the supply chain, reduces post-harvest losses, and enhances the shelf life and market value of crops.

4. AI and ML Applications in Livestock Production

AI and ML (Artificial Intelligence and Machine Learning) applications have made significant advancements in various industries, including livestock production. These technologies offer valuable insights and innovative solutions to enhance animal health, improve productivity, and optimize management practices. Let's explore in detail the applications of AI and ML in livestock production.

4.1. Animal health monitoring and disease detection:

One of the crucial aspects of livestock production is ensuring the health and well-being of the animals. AI and ML techniques have proven to be effective in monitoring animal health and detecting diseases early on. By analysing large volumes of data, including sensor readings, vital signs, and behavioural patterns, AI systems can identify abnormal patterns or symptoms that may indicate the presence of a disease or health issue. This early detection enables timely intervention and treatment, reducing the risk of spreading diseases within the herd and minimizing economic losses.

AI and ML algorithms can also aid in diagnosing specific diseases. By training models on extensive datasets of clinical records, labouratory results, and imaging data, these algorithms can recognize patterns and indicators that human experts might miss. This capability can help veterinarians make accurate diagnoses and develop appropriate treatment plans, improving overall animal health outcomes.

4.2. Precision livestock farming and individual animal management:

Precision livestock farming aims to optimize management practices by treating animals as individuals rather than a homogeneous group. AI and ML technologies play a crucial role in this context by enabling individual animal management and personalized care.

Using wearable devices and sensors, such as GPS trackers, accelerometers, and temperature sensors, data about each animal's behaviour, location, activity levels, and physiological parameters can be collected in real-time. AI algorithms can then process this data to generate insights about individual animals' needs and well-being. For example, they can detect estrus or heat in breeding animals, monitor feeding behaviour and consumption patterns, identify lameness or injury, and predict optimal times for insemination or medication administration.

Such information allows farmers to make data-driven decisions and take proactive measures to address specific animal requirements promptly. This level of individualized management not only improves animal welfare but also enhances production efficiency and reduces costs.

4.3. Feed formulation and optimization:

Feed is a significant cost factor in livestock production. AI and ML techniques can help optimize feed formulation to improve the nutritional balance, reduce waste, and enhance animal performance. By analysing the nutritional requirements of different livestock species, growth stages, and production goals, AI systems can suggest optimal feed compositions and ingredient combinations. These systems consider factors such as energy content, protein content, digestibility, and nutrient absorption rates to develop precise and cost-effective feed formulas.

Furthermore, AI can leverage real-time data on animal health, growth rates, and environmental conditions to dynamically adjust feed formulations. By continuously monitoring and analysing data, these systems can fine-tune feed rations to ensure optimal nutrition for each animal or group of animals. This approach maximizes feed efficiency, minimizes nutrient wastage, and improves overall productivity.

4.4. Livestock behaviour analysis and welfare monitoring:

Understanding livestock behaviour and ensuring their welfare is essential for sustainable and ethical livestock production. AI and ML techniques can analyse sensor data and video feeds to monitor and interpret animal behaviour patterns. For instance, computer vision algorithms can analyse video footage from barns or pastures to detect abnormal behaviour, such as aggression, lameness, or signs of distress. By automatically flagging these behaviours, farmers or caretakers can intervene promptly and address potential issues before they escalate.

Moreover, AI can analyse vocalizations or acoustic signals produced by animals to identify distress calls, pain indicators, or signs of illness. By continuously monitoring these signals, AI systems can provide early warnings and trigger appropriate actions, contributing to improved animal welfare and reduced suffering.

5. AI and ML in Agricultural Robotics and Automation

5.1. Role of AI and ML in Agricultural Robotics:

Artificial Intelligence (AI) and Machine Learning (ML) have revolutionized various industries, and agriculture is no exception. In the context of agricultural robotics, AI and ML play crucial roles in enhancing automation, precision, and efficiency in farming operations. These technologies enable robots and autonomous systems to perceive and interact with the agricultural environment, make informed decisions, and perform tasks with minimal human intervention.

AI and ML algorithms empower agricultural robots to analyse vast amounts of data collected from sensors, cameras, and other sources, enabling them to identify and respond to complex patterns and changes in the field. These technologies can process data related to soil conditions, weather patterns, crop growth, and pest infestations, among others, to make real-time decisions and optimize farming practices. By integrating AI and ML capabilities into agricultural robotics, farmers can improve crop yields, reduce costs, minimize resource wastage, and make data-driven decisions for sustainable and efficient farming.

5.2. Robotic Applications in Field Operations:

- **Planting:** AI and ML algorithms can analyse soil and weather data to determine optimal planting patterns, seed spacing, and planting depth. Robots equipped with precision planting mechanisms can autonomously plant seeds with high accuracy, ensuring uniformity and maximizing crop yield.
- **Spraying:** Agricultural robots equipped with AI and ML capabilities can identify and differentiate between crops and weeds. They can use this information to apply herbicides or pesticides only where necessary, reducing chemical usage and minimizing environmental impact.

- **Harvesting:** Harvesting is a labour-intensive and time-sensitive task. AI and ML-enabled robots can accurately detect ripeness indicators such as color, size, and texture, enabling them to selectively harvest crops at the right time. This reduces waste and improves efficiency in the harvesting process.
- **Weeding:** AI and ML algorithms can be used to identify and classify weeds in real-time. Robots equipped with weed detection systems can precisely target and remove weeds, reducing the need for herbicides and manual labour.

5.3. Automation in Farm Management and Monitoring Systems:

- **Crop Monitoring:** AI and ML technologies can analyse remote sensing data, satellite imagery, and drone footage to monitor crop health, growth rates, and detect early signs of diseases or nutrient deficiencies. This allows farmers to take proactive measures, optimize irrigation and fertilization schedules, and improve overall crop management.
- **Irrigation Management:** AI and ML algorithms can analyse soil moisture data, weather conditions, and crop water requirements to optimize irrigation scheduling. By automating irrigation systems based on real-time data, farmers can ensure efficient water usage and prevent under or over-irrigation.
- **Pest and Disease Management:** AI and ML can assist in early pest detection and disease diagnosis. By analysing data from various sources, including images and sensor data, robots can identify signs of pest infestations or diseases and alert farmers. This allows for timely intervention and targeted treatment, minimizing crop losses.
- **Equipment Monitoring and Maintenance:** AI and ML can enable predictive maintenance of farm machinery and equipment. By analysing sensor data and historical performance, algorithms can predict equipment failures, schedule maintenance tasks, and prevent breakdowns. This helps reduce downtime and increases the lifespan of the machinery.

6. Challenges and Limitations

6.1. Data Quality and Availability:

One of the major challenges in the application of Artificial Intelligence (AI) and Machine Learning (ML) in agriculture is the quality and availability of data. Agriculture is a complex domain with numerous variables and factors that influence crop growth, such as weather conditions, soil composition, pest and disease prevalence, and crop management practices. In order to build accurate and reliable AI and ML models, large volumes of high-quality data are required.

However, obtaining such data can be challenging in agriculture. There may be limited historical data available for certain regions or crops, making it difficult to train models effectively. Additionally, data collection and storage infrastructure in rural areas can be inadequate, resulting in data gaps and inconsistencies. The quality of the collected data may vary, as it can be affected by measurement errors or biases. Moreover, data from different sources may have varying formats and standards, making integration and analysis complex.

6.2. Technical Barriers and Adoption Challenges:

The successful implementation of AI and ML in agriculture also faces several technical barriers and adoption challenges. One of the primary technical barriers is the lack of computational resources in many agricultural settings, particularly in remote or underdeveloped regions. AI and ML algorithms often require substantial computing power and storage capabilities, which may not be readily available in such areas.

Furthermore, the complexity of AI and ML algorithms can present a challenge for farmers and agricultural professionals who may not have advanced technical knowledge or access to experts in the field. Training and education initiatives are necessary to bridge this knowledge gap and ensure effective utilization of AI and ML technologies. Moreover, the cost of adopting AI and ML technologies can be a significant hurdle for small-scale farmers or resource-constrained agricultural communities. The initial investment in hardware, software, and infrastructure can be prohibitive, making it difficult for these stakeholders to adopt and benefit from these technologies. It is crucial to develop affordable and accessible solutions that cater to the needs of diverse farming communities.

6.3. Ethical Considerations and Data Privacy in AI and ML in Agriculture:

The deployment of AI and ML in agriculture raises ethical considerations and data privacy concerns. Agriculture involves sensitive data, including farmers' personal information, farm management practices, and proprietary agricultural knowledge. Collecting and analysing such data using AI and ML technologies can raise questions about data ownership, consent, and privacy. There is a need to establish robust frameworks and regulations to protect farmers' data and ensure its responsible and ethical use. Data sharing agreements and policies should be implemented to define the rights and responsibilities of stakeholders involved in data collection, storage, and analysis. Safeguards must be put in place to prevent unauthorized access, data breaches, or misuse of farmers' data.

Additionally, AI and ML algorithms should be transparent and explainable to build trust among farmers and agricultural practitioners. It is essential to ensure that AI systems do not perpetuate bias or discrimination and that decision-making processes are fair and accountable. Ethical considerations, such as the potential impact on livelihoods and social equity, should also be considered when designing and deploying AI and ML solutions in agriculture.

7. Future Perspectives and Emerging Trends

7.1. Advances in AI and ML for sustainable agriculture:

Artificial Intelligence (AI) and Machine Learning (ML) have the potential to revolutionize the field of agriculture, making it more sustainable, efficient, and productive. Here are some key advances in AI and ML that are shaping the future of agriculture:

- **Precision Farming:** AI and ML algorithms can analyse vast amounts of data from various sources such as satellite imagery, weather patterns, soil conditions, and crop health sensors. This enables farmers to make data-driven decisions about irrigation, fertilization, pest control, and optimal planting and harvesting times. Precision farming minimizes resource wastage, maximizes crop yields, and reduces environmental impact.

- **Crop Monitoring and Disease Detection:** AI and ML can analyse images captured by drones, satellites, or sensors to monitor crop health, detect diseases, pests, or nutrient deficiencies. By identifying potential issues at an early stage, farmers can take preventive measures, reducing crop losses and the need for excessive pesticide or fertilizer usage.
- **Weed and Pest Control:** AI-powered systems can distinguish between crops and weeds, enabling precise targeting of herbicides. ML algorithms can identify patterns in pest behaviour and help develop effective pest management strategies. This reduces the reliance on harmful chemicals and promotes sustainable farming practices.
- **Agricultural Robotics:** AI and ML are transforming agriculture with the use of robots. Autonomous robots equipped with computer vision and ML algorithms can perform tasks such as seeding, planting, weeding, and harvesting with high precision and efficiency. This reduces labour costs, increases productivity, and improves overall farm management.
- **Crop Yield Prediction:** By analysing historical and real-time data, AI and ML algorithms can predict crop yields with high accuracy. This information helps farmers in planning logistics, estimating future production, and optimizing supply chains. Accurate yield predictions contribute to better decision-making and resource allocation.

7.2. Integration of AI and ML with other emerging technologies:

To further enhance the potential of AI and ML in agriculture, integration with other emerging technologies is gaining traction. Two such technologies are blockchain and edge computing:

- **Blockchain:** Blockchain technology provides transparency, immutability, and security in data management. By integrating AI and ML with blockchain, farmers can securely store and share agricultural data, including supply chain information, crop production history, and quality certifications. This ensures traceability, prevents fraud, and builds trust among consumers.
- **Edge Computing:** Edge computing involves processing data closer to its source, reducing latency and dependence on cloud infrastructure. In agriculture, AI and ML algorithms can be deployed on edge devices such as sensors, drones, and farm machinery. This enables real-time analysis of data, facilitating prompt decision-making, and reducing the need for continuous internet connectivity.

7.3. Potential impact of AI and ML on global food security:

AI and ML have the potential to address global food security challenges by improving agricultural productivity and sustainability:

- **Increased Crop Yields:** AI and ML algorithms enable farmers to optimize inputs, manage resources efficiently, and predict crop yields accurately. By maximizing productivity, these technologies contribute to meeting the increasing demand for food due to population growth.
- **Resource Optimization:** AI and ML algorithms aid in optimizing the use of resources such as water, fertilizers, and pesticides. Precision farming techniques minimize resource wastage, reduce environmental impact, and ensure sustainable agricultural practices.

- **Early Disease Detection and Prevention:** AI and ML systems can detect crop diseases, pests, and nutrient deficiencies at early stages. Early detection allows farmers to take timely action, preventing the spread of diseases and minimizing crop losses.
- **Climate Resilience:** AI and ML algorithms can analyse historical climate data and predict weather patterns. This information helps farmers adapt their cultivation practices and make informed decisions in the face of climate change, ensuring the resilience of agricultural systems.
- **Improved Supply Chain Management:** By integrating AI and ML with supply chain management systems, the traceability and transparency of food products can be enhanced. This helps identify and address inefficiencies, reduce food waste, and improve the overall efficiency of the food supply chain.

Conclusion:

The integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies in agriculture has emerged as a transformative force, revolutionizing the way farming and related practices are conducted. The advancements in AI and ML have enabled farmers and agricultural stakeholders to make more informed decisions, optimize resource allocation, increase productivity, and promote sustainable practices. One of the key benefits of AI and ML in agriculture is the ability to gather, process, and analyse vast amounts of data from various sources, such as weather patterns, soil conditions, crop health, and market trends. This data-driven approach empowers farmers to make real-time decisions and take proactive measures to mitigate risks, maximize yields, and minimize environmental impact. By leveraging AI and ML algorithms, farmers can accurately predict weather patterns, identify disease outbreaks, optimize irrigation schedules, and efficiently manage crop rotation strategies.

Furthermore, AI and ML have played a crucial role in precision agriculture, allowing farmers to tailor their approaches to specific areas of their fields. Through the use of sensors, drones, and satellite imagery, these technologies can provide detailed information on soil quality, moisture levels, and nutrient deficiencies, enabling farmers to apply fertilizers and pesticides with precision, reducing waste and costs. This targeted approach not only enhances crop health but also reduces the environmental footprint associated with traditional agricultural practices. The integration of AI and ML also extends to farm machinery and automation. Intelligent robots and autonomous vehicles equipped with AI algorithms can perform a range of tasks, from seeding and planting to harvesting and sorting crops. These advancements in automation not only streamline labour-intensive processes but also increase efficiency and reduce the dependency on manual labour. Farmers can focus on higher-value tasks such as data analysis, decision-making, and innovation, ultimately leading to increased profitability and sustainability.

However, while the potential of AI and ML in agriculture is vast, there are still challenges to overcome. Issues such as data privacy, access to reliable internet connectivity in rural areas, and the digital divide must be addressed to ensure equitable adoption of these technologies. Additionally, there is a need for continuous research and development to improve algorithms, enhance data accuracy, and build trust among farmers and stakeholders. In short, Artificial Intelligence and Machine Learning have the potential to revolutionize the agriculture sector, promoting sustainable practices, optimizing resource utilization, and increasing productivity. By harnessing the power of data-driven insights and automation, farmers can make more informed decisions, mitigate risks, and contribute to a more efficient and environmentally friendly food production system. With ongoing advancements and collaborative efforts, AI and ML will continue to play a crucial role in shaping the future of agriculture, enabling us to address global food security challenges and build a more sustainable future.

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WEATHER HAZARDS AND THEIR IMPACT ON CROPS

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Weather Hazards has been subjected to natural disasters over which have little control. The weather hazards i.e. frost, high temperature, droughts, storms, Tornadoes, lightning, Blizzard, earth quack and tsunami waves. In dealing with weather hazards, meteorological information are used to predict their occurrence rather than to prevent them.

- **Frost**

  Frost refers to the white ice crystals that condensate on the ground or objects when the air temperature near the earth's surface drops below the frost point (the dew point is lower than 0 ◦C) under the influence of ground radiation cooling. Cold advection is more deleterious in winter season because it cause typical hazards when the field crops are in their seedling stage. Frost generally forms and develops under cold and wet conditions. Frost is very common in middle and high latitudes. Frost is more dangers for vegetable (tomato, potato) crops. Crops in North West India frost incident of moderate to severe intensity.

  Present time technologies and methods related to frost detection continue to appear, but there has never been a relatively mature program suitable for the detection of frosting leaf surfaces. In addition, the difficulty of frost detection is also the main reason for the inefficiency of frost protection, especially in agriculture [

  Protection: The temperature of the plants is increases with increasing of soil temperature. The soil temperature can be increased through giving the irrigation to the crops.

1. Covering the nursery plants with mulch/plastic sheet.
2. Sprinkling irrigation also increased the temperature of the air.

(a)

(b)

- **High temperature:** High temperature effect more observed in summer season many parts of the tropical and sub-tropical regions. Prolonged high temperature conditions can lead to heat wave conditions chiefly heat wave conditions can occur during the months of April, May and even June.High temperature conditions occur in the tropical areas during summer season if the maximum and minimum temperature remains above normal for a few days, than excessive thermal energy accumulates which decreases the relative humidity.

  Protection: The crops can be protected through the irrigations. For long term protection can be protected by Shelter belts, they can be minimise the high temperature effect on crop plants.

Drought: Occurring the drought conditions where soil moisture is not sufficient to meet of potential evapotranspiration. In these areas high evapotranspiration compare to rainfall, results failure of crop due to low moistures in soil. Generally occurring of droughts when supply of soil moisture from rainfall and stored water is insufficient to fulfil the demand of crop plants. The initial effect of drought on the plants is the poor germination and impaired seedling establishment. Various studies have reported the negative impacts of drought stress on germination and seedling growth (Kaya *et al.*, 2006; Farooq *et al.*, 2009b).

Types of droughts: Major four type of drought- (1) Permanent drought (2) Seasonal drought (3) Contingent drought (4) Invisible drought

(1) **Permanent drought:** This type of drought is found in desert areas where always soil moisture is low due to less rainfall and plants not completed their water demands. In this conditions evapotranspiration always higher compare to rainfall and crop is not possible without the irrigation.

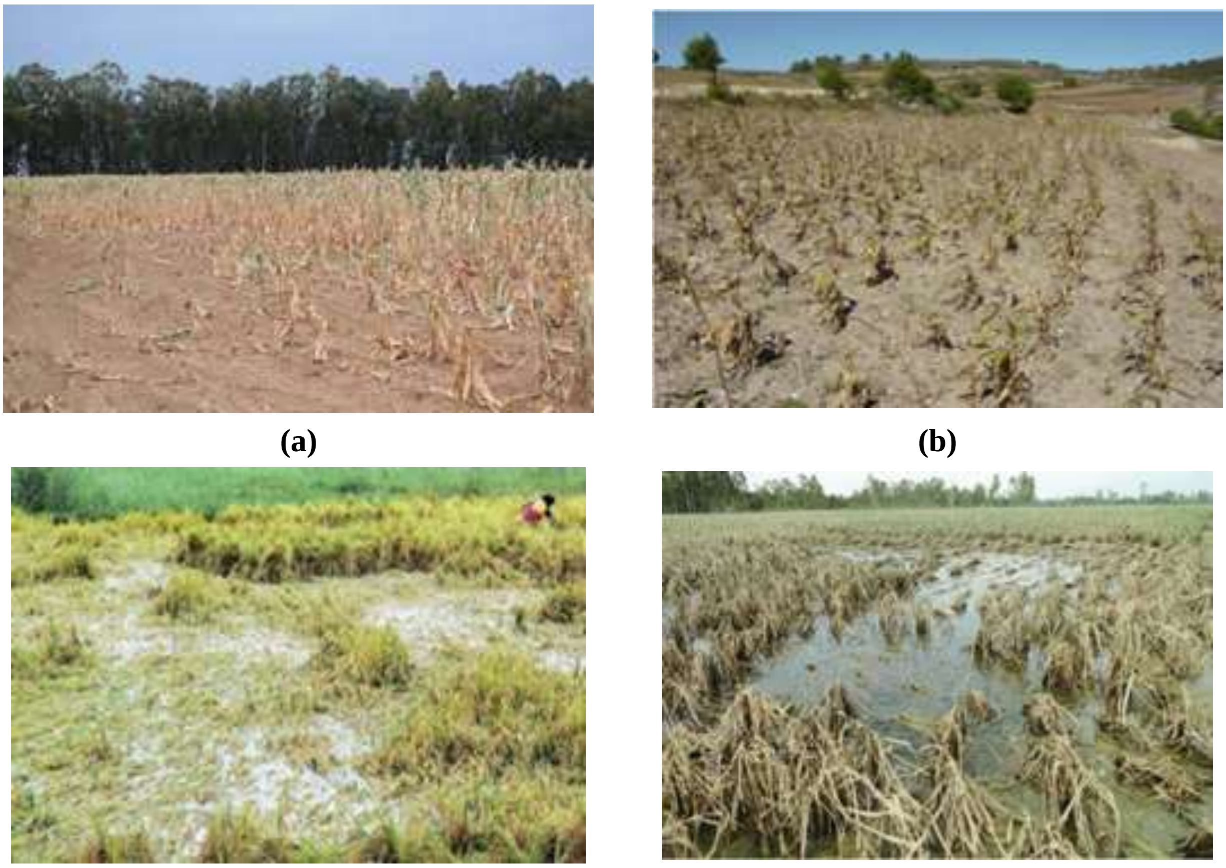
(2) Seasonal drought: This type of drought occurs in those areas where well defined of dry and rainy season. Before the rainy season some period is dry in which irrigation is required for the growing of crops.

(3) Contingent drought: Contingent drought occurs in humid and sub humid region where erratic rainfall is received. Before and after of erratic and variable rainfall during dry spell the crop needs water demand.

(4) Invisible drought: This type of drought is not easily identified because its can be occur at any time. Invisible drought where daily supply of moisture to is not equal to requirements of the plants. The agriculture point of view it's very important because ignores of this farmers bears the great loss of production.

- **Floods:** Receiving of heavy rainfall in short period due to pooling of water in the field damage of crops. The floods cause a greater loss of agriculture and other properties.

  The floods occurring to intense rainfall in a short time a large amount of water is precipitated in small areas. In such conditions the precipitation rate is much higher than infiltration rate due to this water is standing on field so growth rate is affected.



(a) **(b)** **(c)** **(d)**

- **Stroms:** Mainly three types of stroms- (a) Tropical Stroms (b) Hail stroms (c) Dust stroms
  - (a) Tropical Stroms: its known as a thunder stroms also, this type of stroms is most destructive. In which unstable air and strong motions that produce cumulonimbus clouds. They release latent heat of condensation in the rising of humid air (critchfield, 2002). The tropical stroms occurring in ocean where the sea surface temperature exceeds 26^0C, due to higher temperature created low pressure area and winds changes into cyclonic circulation. Low pressure area gets intensified into a depression due to the availability of abundant water vapour and later pressure decreases rapidly and depression changes into cyclone. Mostly these type of stroms occurring in Bay of Bengal and Arabian Sea.
  - (b) Hail Stroms: This type of stroms develop from cumulonimbus clouds and it's connected with thunder Stroms. The hail stroms mostly occur in the month of March- April, due to this have a great loss to wheat crop every year.
  - (c) Dust stroms: It occurring in summer season when the atmospheric pressure may decrease suddenly, in this area the winds coming to travel 100 km/hr or more than 100 km/hr. In these conditions the trees and electrical poles are uprooted.

- **Tornadoes and Water Spouts:**

A tornado is a violently rotating column of air extending from the base of a thunderstorm down to the ground. Tornadoes are capable of completely destroying well-made structures, uprooting trees, and hurling objects through the air like deadly missiles. Tornadoes can occur at any time of day or night and at any time of the year. The diameter of chimney vary from 10 to 100 meter or 1 to 2 km. Tornadoes associated with cumulonimbus clouds and its extended downward from the base of cloud in the form of chimney. When tornadoes touches to water body it's called water spouts.

- **Lightning:** It's natural calamity and associated with cumulonimbus cloud, this cloud extended vertically up to 16km height above the surface. Lightning created due to potential differences in charge between cloud and earth surface, resulting giant sparkle is generated. Sometimes a lightning may hit to trees or building on the surface.
- **Blizzards:** This type of weather hazards occurring in high latitude in which combination of very low temperature and very strong winds with snow is known as blizzard. Due to this cause heavy loss to agriculture and associated property.
- **Earthquakes and Tsunami waves:** Due to the movement of seismic plates crates the Earthquakes. Most of the parts of our country comes in moderate to severe intensity and reasons of its development are- fracturing of rocks, volcanicity and faulting, initiation of new faults is responsible for seismicity. As many as 80% of the earthquakes in the world occur in pacific plate and about 15% along Himalayan alpine belt.
- **Tsunami waves:** Due to the earthquake change the level of ocean and rising and lowering substantially and create a large disturbances in ocean. The size and energy of disturbances depends on the magnitude of the earth quake.

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GENOTYPE-ENVIRONMENT INTERACTION WITH RESPECT TO VARIETAL STABILITY IN SUGARCANE

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Abstract:

The performance of sugarcane genotypes varied under different environmental conditions as a result of GE interactions. GE interaction impacts the selection and formulation of breeding strategies. If there is no interaction, then the genotype shows stable performance in all the environments, but if there is significant interaction, genotypes must be sought specifically for different environments. The sugarcane genotypes are tested in multi-location trials at various agro-climatic zones and analysed for stability with the help of various stability models. There is an established system of multi-location testing in sugarcane and for various crops, under the All India Coordinated Research Projects. Based on multi-location testing and performance in different environments, the outperforming varieties are recommended to be released.

Introduction:

Sugarcane (*Saccharum* sp. Complex) is one of the major industrial crops grown all over the world from tropical to subtropical regions. Sugarcane is being utilized as a source of sweetener from very beginning as jaggery, khandsari and white sugar. Molasses are being used for ethanol production and bagasse for paper industry. Sugarcane belongs to the family Poaceae, sub-family Panicoidae, tribe Andropogonae, sub-tribe Saccharineae and genus *Saccharum* (Watson *et al.*, 1985). There are five recognized species in this genus *viz.*, *S. officinarum* L., *S. barberi* Jeswiet, *S. sinense* Roxb. amend Jeswiet, *S. robustum* Brandes et Jeswiet Ex Grassl. and *S. spontaneum* L. The former three are cultivated species and the latter two are wild ones. Besides, another species, *S. edule* Hasak is also recognized which produces aborted inflorescence and is used as food in Indonesia (Heinz, 1991). The cultivated varieties of sugarcane are interspecific hybrids involving at least three species, *S. officinarum*, *S. barberi*, and *S. spontaneum* (Rao *et al.*, 1983) which themselves represent complex polyploidy. The chromosome number among varieties varies from 2n=100 to 120 (Price, 1963) due to this the sugarcane varieties are described as *Saccharum* sp. Complex hybrid.

Sugarcane undergoes four distinct stages of growth, namely germination (0-60 days), formative (60-150 days), grand growth (150-240 days), and maturity (240-360 days). Each phase necessitates specific conditions of light, temperature, and water availability to obtain a high yield. Being a long-duration crop, it is susceptible to various challenges posed by both living organisms and environmental factors. In subtropical regions, this crop confronts severe cold in December-January and exceptionally high temperatures during the formative phase, which occurs from April to June.

Sugarcane production affected by variable climatic conditions (Zhao and Li, 2015) and the performance of a particular variety is the result of interaction of its genetic constitution and environment in which it has been grown. The changes in the varietal performance under the influence of different environmental conditions are defined as Genotype and environment (GE) interaction (Baker, 1988). GE interaction complicates selection and testing of plant genotypes. Maximizing yield across different environments is a challenging task due to the interactions between genotypes and varying environmental conditions. Genotype adaptable to target environments are selected under an optimum strategy, this strategy is determined by measuring GE interaction. In sugarcane breeding programmes, by multi-location yield trials, the genotypes have been tested in different environmental conditions for identifying varietal stability. If the rank of genotypes varies from one location to another, it indicates strong GE interaction, which is a widely recognized phenomenon in sugarcane clonal selection trials (Kang and Miller, 1984). GE interaction is important source of variation in crops and the term stability is used to characterize a genotype which shows a relatively constant yield, independent of changing environmental conditions. Based on this concept, genotypes that exhibit minimal variation in yield across diverse environments are considered stable or demonstrate a high buffering capacity within the population. The meticulous observation and analysis of the GE interaction in multi-environment yield trials are crucial for the effective evaluation, selection, and recommendation of crop varieties (Mendoza-Batista *et al.*, 2021).

Estimation of phenotypic stability involves regression analysis which has proved to be a valuable technique for assessing the response of various genotypes under changing environmental conditions. Various parametric and non-parametric statistical models have been used for stability analysis in sugarcane. The regression-based models *viz.,* (1) Finlay and Wilkinson (1963), (2) Eberhart and Russel (1966), (3) Perkins and Jink (1968) and (4) Freeman and Perkins (1971) and multivariate models such as additive main effects and multiplicative interaction (AMMI) model and the genotype main effects and genotype × environment interaction effects (GGE) model (Gauch, 2006) is widely used for stability analysis in sugarcane now days. Knowledge on the components of the GE interaction is of great importance for sugarcane breeding, stability and adaptability analysis used for the identification of superior genotypes in various environments.

Stability concept

The adaptability of genotypes is the result of interaction between genotypes and environment. Lewis (1954) defined phenotypic stability as the ability of an individual or population to produce a certain narrow range of phenotypes in different environments. According to Allard and Bradshaw (1964), stability is determined by the ability to maintain some characteristics of morphology and physiology in a steady state. The study of the GE interaction allows the classification of genotypes in different situations by their behaviour, either stable or adapted to a particular environment in terms of their yield or in some other desirable agronomic feature or unstable. They also suggested that heterozygous and heterogenous populations offer the best opportunity to produce varieties which show small GE interactions. They pointed out that heterozygous or homozygous genotype may possess individual buffering and a heterogenous population will possess population buffering. Backer and Leon (1988) defined the stable genotype as a constant performer irrespective of any changes in the environmental conditions. The genotype is regarded to be stable if it has low contribution to GE interaction.

In the final stage of plant breeding, the newly developed strains are grown for many generations under different environments, climatic and soil conditions (Fasahat *et al.,* 2015). In all experiments, the plant breeders usually emphasis on modelling the genotypic mean in j^{th} environment. The linear model considers as:

$$Y_{ij} = \mu + g_i + e_j + ge_{ij} + e_{ij}$$

Where, Y_{ij} is the observed mean of the i^{th} genotype in j^{th} environment; μ is the general mean; g_i is the i^{th} genotype effect; e_j denotes the effect of the j^{th} environment; ge_{ij} is the effect of interaction between i^{th} genotype and j^{th} environment (GE interaction) and e_{ij} is the mean error related to the observed $Y_{ij.}$

Finlay and Wilkinson (1963) determined the regression coefficient by regressing variety mean on the environmental mean, and plotting the obtained genotype regression coefficients against the genotype mean yields. The regression coefficient (bi) for each genotype is then taken as its stability parameters. Absolute phenotypic stability is expressed by bi = 0. Finlay and Wilkinson's model seems to be quite useful as for as the regression coefficient represents a greater part of yield variation caused by the environmental fluctuation (Matsuo, 1975). However, other methods are needed when the regression coefficient represents a small portion of variance. Eberhart and Russell (1966) described deviation parameter (S^2di). The residual mean square (MS) of deviation from regression is the measure of stability of each genotype. A desirable variety is the one which has a high mean, bi=1.0, and S^2di=0. The regression coefficient described by Perkin and Jinks (1968) is comparable to that of Finlay and Wilkinson, with the exception that the observed values are modified for location effects prior to the regression.

Freeman and Perkins (1971) criticized the use of linear regression model for stability analysis. They pointed out the drawbacks of these models as follows:

i) Regression of varietal mean into dependent measure of environment, and

ii) The sum of squares (SS) for environmental (linear) component allocated with one degree of freedom was the same as the total SS for environments with (n-1) degrees of freedom, where n was the number of environments.

Lin *et al.* (1986) identified three concepts of stability:

Type 1: A genotype is regarded as stable if its variance among environments is low. This stability was referred to by Becker and Leon (1988) as static stability or a biological concept of stability. Any change in the environmental conditions has no effect on the performance of a stable genotype. This conception of stability is valuable for quality attributes, disease and insect resistance or for abiotic-stress characters like winter hardiness. The coefficient of variability (CV_i), which Francis and Kannenburg (1978) utilised as a stability parameter for each genotype, and the genotypic variations across environments (S_i^2) are variables used to define this kind of stability.

Type 2: A genotype is regarded as stable if its response to environmental changes is parallel to the mean response of all genotypes in the trial. This stability was referred to as the dynamic or agronomic concept of stability by Becker and Leon (1988). A stable genotype allows for a predictable response to environments since it does not deviate from the general response to environments. Type 2 stability can be assessed using Shukla's (1972) stability variance (σ^2_i) and the regression coefficient (b_i) (Finlay and Wilkinson, 1963).

Type 3: A genotype is regarded as stable if the residual MS from the regression model on the environmental index is low. The environmental index estimates as mean yield of all genotypes in each location minus the overall mean of all genotypes in all locations. Becker and Leon (1988) assert that Type 3 is a component of the dynamic or agronomic stability concept.

Methods to describe type 3 stability are Eberhart and Russell (1966) and Perkins and Jinks (1968). According to Becker and Leon (1988), the dynamic concept encompasses all stability approaches based on assessing GE interaction effects. This includes the methods for partitioning the GE interaction of Wricke's (1962) eco-valence and Shukla's (1972) stability of variance, as well as non-parametric stability analyses and methods utilising the regression approach as proposed by Finlay and Wilkinson (1963), Eberhart and Russell (1966), and Perkins and Jinks (1968). However, from both a biological and a statistical perspective, there are a number of restrictions and critiques with regard to these analyses. The primary biological issue arises when the study only takes into account a small number of extremely low and extremely high yielding sites, and the fit is based solely on the genotype behaviour in a small number of extreme environments (Crossa, 1990). The primary statistical issue is that, according to Freeman and Perkins (1971), the average of all genotypes assessed in each environment is not independent of the average of each genotype in a specific environment. Another statistical limitation is that the errors associated with the slopes of the genotypes are not statistically independent. The last problem is the assumption of a linear relationship between interaction and environmental means, when the actual responses of the genotypes to the environments are inherently multi-variated (Crossa *et al.,* 1990). According to Crossa (1990), multivariate analysis has three main objectives: (i) to eliminate "noise" in the data set (for example, to distinguish systematic and non-systematic variation); (ii) to summarize the information and (iii) to reveal a structure in the data (Crossa *et al.,* 1990; Gauch, 1992). In contrast with classic statistical methods, the function of multivariate analysis is to reveal the internal structure of the data from which hypotheses can be generated and later tested by statistical methods.

Interpretation of GE interaction

Crop growth and potential yield are essentially defined by availability of resources such as light, water and nutrients, and the efficiency to use these resources, and the extent to which the attainment of such potential is limited by biological and physical hazards. The GE interaction can be explained as the differential yield response of genotype over environments. The aim of stability analysis is to identify genotypes whose phenotypic performance remain same under variable environmental conditions. The stability analysis makes sense in the presence of GE interaction (Fasahat *et al*., 2015). The presence of GE interaction reduces the correlation among phenotype and genotype, makes difficult to assess the genetic potential of variety and changes the relative ranking of different varieties. The presence of GE interaction diminishes the correlation between phenotype and genotype, creating difficulties in accurately assessing the genetic potential of a variety and altering the relative rankings of different varieties. For efficient breeding strategies, identify the predominant limiting factor within a studied population of environments in a MET. Also, characterization of environments on the bases to a range of environmental factors offers the potential to improve the gain from selection through better selection of environments for field trials. Therefore, prior to the successful commercial release of a specific variety, plant breeders conduct trials of different varieties across multiple locations and years to assess the extent of GE interaction. This process ensures the stability of the varieties under varying environmental conditions (Fasahat *et al*., 2015). GE interactions can be categorized into three different groups:

(i) "No" GE interaction: Occurs when one genotype performs constantly better than the other genotype by approximately the same amount over the environments.

(ii) Non crossover GE interaction: A non-crossover type where the ranking of genotypes remains constant across environments and the interaction is significant because of changes in the magnitude of the response. Moreover, the changes due to environmental modifications in the two genotypes are in the same direction.

(iii) Crossover GE interaction: The different and inconsistent performance of genotypes to varied environments is defined as crossover GE interaction, in which the ranks of genotypes changed from one environment to another. Crossover interaction suggests that no genotype is superior in multiple environments.

In the selection of genotypes across multiple environments, plant breeders look for a non-crossover type of GE interaction or preferably the absence of a GE interaction for general adaptation, and a crossover type of GE interaction for specific adaptation. The recommendation of cultivars for commercialization and evaluation of germplasms in advanced stage adaptation and performance stability trials are essential breeding objectives.

Widely used methods of stability analysis

Regression based model (Eberhart and Russell model)

The Eberhart and Russell model (1966) which is more widely used regression based method nowadays for detecting the stable varieties. Stability parameters computing by this model is follows:

$$Y_{ij} = \mu + \beta_i I_j + S_{ij}$$

Where, Y_{ij} = Mean of ith genotype in jth environment, μ= Mean of all genotypes over all environments, β_i = Regression coefficient of ith genotype on the environmental index which measures the response of this genotype to varying environments, I_j = the environmental index which is defined as the deviation of the mean of all the genotypes at a given location from the overall mean, S_{ij} = the deviation from regression of the ith genotype at jth Environment.

The analysis of variance as proposed by Eberhart and Russell (1966) is given in Table 1.

Table 1: Analysis of variance for estimates of stability parameters over environments

Source of variation	Degrees of freedom	Sum of squares	Mean squares
Total	(ge-1)	$\sum_i \sum_j Y_{ij}^2 - CF$	
Genotypes	(g-1)	${}^{1}/_{e} \sum_{i.} Y_{i.}^2 - CF$	MS1
Environment + (Genotype x Environment)	g(e-1)	$\sum_i \sum_j Y_{ij}^2 - \sum_i Y_{i.}^2 / e$	
Environment (Linear)	1	$1/g \left(\sum_j Y_{.j} I_j \right)^2 \Big/ \sum_j I_j^2$	
Genotype x Environment (Linear)	(g-1)	$\sum_j \left(\langle \sum_j Y_{ij} I_j \rangle^2 / \sum_j I_j^2 \right) -$ Environmental (linear) *ss*	MS2
Pooled deviations	g(e-2)	$\sum_i \sum_j S_{ij}^2$	MS3
Deviation due to genotype	(e-2)	$\left[\sum_j Y_{ij}^2 - (Y_{i.})^2 / e \right] - \left[\sum_j Y_{ij}^2 I_j \right]^2 / \sum_j I_j^2 = \sum_j S_{ij}^2$	MS4
Pooled error	e(g-1) (r- 1)		MS5

Where, g = number of genotypes, e = number of environments, r = number of replications. In this model two parameters of stability are calculated, the first parameter, regression coefficient (bi) is the same proposed by Finley and Wilkinson and the second parameter is mean square deviation (S2di) from linear regression.

$$bi = \frac{\sum_j \boldsymbol{Y_{ij} I_j}}{\sum_j \boldsymbol{I_j^2}}$$

$$S2di = \frac{\sum_j S_{ij}^2}{\boldsymbol{e-2}} - \frac{\boldsymbol{Pooled\ errorMS}}{\boldsymbol{r}}$$

According to this model, a desirable variety is the one that has a high mean, unit regression coefficient (bi = 1.0), and zero deviation from regression (S2di = 0). A stable variety in this context is one with bi = 1.0 and S2di = 0.

Multivariate models (AMMI and GGE biplot)

The concept of biplot was a breakthrough of Gabriel (1971). Since then, biplot analysis has emerged as a crucial statistical tool in the realms of plant breeding and agricultural research. A biplot is a scatter plot that approximates and graphically displays a two-way table by both its row and column factors in such a way that relationships among the row factors, relationships among the column factors, and the underlying interactions between the row and column factors can be visualised simultaneously. Bradu and Gabriel (1978) were the first to apply biplots to agricultural data analysis. So, a genotype-trait biplot can also be used to visualise the merits and shortcomings of individual genotypes, which is important for both cultivar evaluation and parent selection. The additive main effect and multiplicative interactions (AMMI) and genotype plus genotype × environment interaction (GGE) biplot are principal components analysis based models with an additive component (the main effect of the environment or genotypes) and a multiplicative component (G×E interaction). These models served as powerful tools for effective analysis and interpretation of multi-environment data structure in breeding programs.

AMMI biplot

In the AMMI model, introduced by Mandel (1971) and popularized by Zobel *et al.*, (1988) and Gauch (1992), the GE interaction magnitude is estimated according to the response of each variable in a rather original approach, by the combination in a single model between ANOVA and the PCA. In this, genotype and environmental effects consider as purely additive effect components, and GE interactions as multiplicative components (Durate and Vencovsky, 1999). The AMMI statistical model is given as follows, and the AMMI ANOVA is given in Table 2.

$Y_{ij} = \mu + g_i + a_j + \Sigma^{n}_{k=1}\lambda_k Y_{ik}\alpha_{jk} + e_{ij}$

Where, Y_{ij} is the mean response of the genotype I in the j^{th} environment, μ is the general mean of trials, g_i is the fixed effect of i^{th} genotype, a_j is the fixed effect of the j^{th} environment, λ_k is the k^{th} scalar value of the original interaction array, Y_{ik} is the element corresponding to the i^{th} genotype in the k^{th} scalar vector of the column of the interaction array, α_{jk} is the element corresponding to the j^{th} environment in the k^{th} singular vector in the line of the array, and e_{ij} is the residual effect.

Table 2: AMMI ANOVA (Gauch, 2013; Hongyu, 2014)

Source of Variation	Degree of freedom	Sum of square	Mean of square	F-ratio
Genotypes (G)	(g-1)	SS1	MS1	MS1/MS3
Environment (E)	(e-1)	SS2	MS2	MS2/MS3
G X E	(g-1)(e-1)	SS3	MS3	MS3/MSE
IPCA1	(g+e-1-2n)	SS4	MS4	MS4/MSE
IPCA2	(g+e-1-2n) - 2	SS5	MS5	MS5/MSE
IPCA3	(g+e-1-2n) - 4	SS6	MS6	MS6/MSE
Residual	(g-1)(e-1)-(g+e-1-2n)-4			
Error	ge(r-1)	SSE	MSE	

Where, g= no. of genotypes; e= no. of environments; r= no. of replication; n= PC axis 1, 2,….. K; K= 1, 2, . . . , p, $p = \min\{g - 1, e - 1\}$

Graphical representation of GE interaction using AMMI interaction parameters is known as biplot. The interpretation of a biplot graph relies on examining the variation attributed to the additive main effects of genotype and environment, as well as the multiplier effect of the GE interaction (Oliveira *et al*., 2013). Till date, the stability conclusion made from AMMI model; are based on biplots. Biplot formulation of interaction will be successful only when significant proportion of GE interaction is concentrated in the first or first two PC axes. A desirable genotype is characterized by high yield and IPCA (interaction principal component axis) values that approach zero. Conversely, an undesirable genotype is characterized by low stability, which is associated with low yields.

In the AMMI1 biplot, which utilizes a single principal component (PC) axis, the first PCA scores of genotypes and environments are graphed against their respective means. Now the pattern of GE interaction may be visualized from this plot. When a genotype or environment exhibits a PCA score close to zero, it indicates smaller interaction effects and greater genotype stability. While, in AMMI2 biplot (biplot with two PC axis), second PCA scores of genotypes and environments are plotted against their respective first PCA scores. For a better description of the interaction, both first and second PCA scores of genotypes and environments may be considered for plotting. Genotypes that are positioned in close proximity to specific environments on the IPCA2 vs IPCA1 biplot demonstrate specific adaptation to those particular environments. A genotype that falls near the centre of the biplot (small IPCA1 and IPCA2 values) may have broader adaptation. The AMMI1 biplot help in identification of stable genotypes. While AMMI2 biplot besides to identify stable genotypes also representing which genotype adaptable in which environmental condition.

GGE biplot

GGE biplot was proposed by Yan *et al.* (2000) that allows visual examination of the GE interaction pattern of multi environment trial (MET) data. The difference between GGE and AMMI is that GGE biplot analysis is based on environment-centered PCA, whereas AMMI analysis refers to double-centered PCA. The GGE biplot stresses two concepts. First, although the measured yield is the cumulative effect of genotype (G), environment (E), and GE interaction, only G and GE are relevant to and must be considered simultaneously for appropriate genotype and test environment evaluation in cultivar evaluation, hence, termed as “GGE”. Second, the biplot technique is employed to approximate and display the GGE of a MET, hence its term "GGE biplot."

GGE biplot analysis uses environment centred data for analysis as the emphasis is on G and GE interaction so as to arrive meaningful conclusion about the genotypic performance across varying locations. Environment centring is done by subtracting the environment mean ($\overline{Y}_{.j}$) from the $\overline{Y}_{ij}$ values and transforming the two-way table. Therefore, the GGE biplot analysis is based on the following model.

$$\overline{Y}_{ij} - \overline{Y}_{.j} = \lambda_1 \xi_{i1}\eta_{j1} + \lambda_2\xi_{i2}\eta_{j2} + \varepsilon_{ij}$$

where, $\overline{Y}_{ij}$ is the average phenotypic value of genotype i in the j^{th} environment; $\overline{Y}_{.j}$ is the mean of the j^{th} environment (μ_j); $\lambda_1 \xi_{i1}\eta_{j1}$ and $\lambda_2\xi_{i2}\eta_{j2}$ are the first and second PCs, of which λ_1 and λ_2 are the singular values, ξ_{i1} and ξ_{i2} are the genotypic PC scores, and η_{j1} and η_{j2} are the environment PC scores for the PC1 and PC2 respectively.

A GGE biplot that sufficiently approximates the GGE of a MET data set allows, among other things, visualisation of three important aspects: (i) Genotype × Environment relations as represented by the "which won where" pattern, which assists in mega-environment investigation; (ii) the interrelationship among test environments, which assists in the identification of better environments for cultivar evaluation by “discrimination vs representativeness” biplot; and (iii) the inter-relationship among genotypes ranking based on mean yield and stability by “mean vs stability biplot”.

The AMMI and the GGE biplot analyses are more efficient than the Eberhart and Russell method because AMMI and GGE analyses explained around 50% of the sum of squares of the GE interaction, whereas the method of Eberhart and Russell explained only 9.1% and 15.8%. The GGE biplot explains a higher proportion of the sum of squares of the GE interaction and is more informative with regards to environments and cultivar performance than the AMMI analysis. Yan *et al.* (2007) compared GGE Biplot against AMMI analysis of GE interaction Data. They observed AMMI differed from GGE biplot only in that it contained less G + GE interaction and had less functionality than the GGE biplot. The AMMI analysis separates G from GE interaction first and then puts them together again, whereas GGE biplot analysis deals with G + GE interaction directly.

Effects of variable climate events on sugarcane production

Sugarcane is an important cash crop used for sugar and bioenergy. It is one of the world’s major C4 crops that mainly grow in the tropics and subtropics regions. Major growing countries, Brazil, India, China, Thailand, Pakistan, and USA. Weather and climate-related events (i.e., the growth environment of atmospheric CO_2, temperature, precipitation, and other extreme weather) are the key factors for sugarcane production worldwide (Figure 1). The sugarcane and sugar yields have varied with extreme climate events (Zhao and Li, 2015). Due to extreme weather events like heat, drought, flooding, typhoons, and frost are occurring more frequently and with greater intensity as a result of climate change, cane production is highly affected. In most areas with a short growing season, like Louisiana in the United States, the frost is a significant productivity constraint (Zhao and Li, 2015). Whereas, high temperatures because of climate change in North-eastern Brazil will cause evapotranspiration rates to rise, decreasing the amount of water in the soils, and making the planting of sugarcane increasingly difficult (Carvalho *et al*., 2015). The decreased yield was mainly due to increased water deficit stress due to the warmer climate. Effects of drought due to climate change on sugarcane growth and development depending on the stage of plant growth, the severity of water deficiency stress, and the duration of the stress (Reyes *et al.,* 2020). Drought conditions in the early and middle growth stages primarily reduces cane production, which resulting low sucrose yield; however, drought conditions in the late development stage can improve sucrose content in stalks. China is majorly affected by this stress and more than 80% of sugarcane grown in rainfed conditions. Water logging is another abiotic stress that severely reduces the growth and survival of cane and causes an 18–64% reduction in sugarcane yield, dependind on the duration of the water logging, plant growth stage, and cultivars (Zhao and Li, 2015). The damage by diseases and pests in cane production is also afffected by temperature. The damage by smut disease is likely to increase due to high temperatures, and dry weather intensifies the symptoms of ratoon stunting disease. The warmer winter and high humidity are favourable climate conditions for sugarcane orange rust spore survival and rapid development. The fluctuating climate conditions result in an increase in disease pathogens, overwintering pests, and additional input costs required to mitigate these risks and sustain a certain level of sugarcane production. The production of sugarcane is significantly influenced by these changing climatic conditions. Hence, enhancing our understanding of the mechanisms behind these climate factors and their influence on sugarcane production can enable the manipulation of plants to fulfil human requirements while also formulating strategies for adaptation and mitigation.

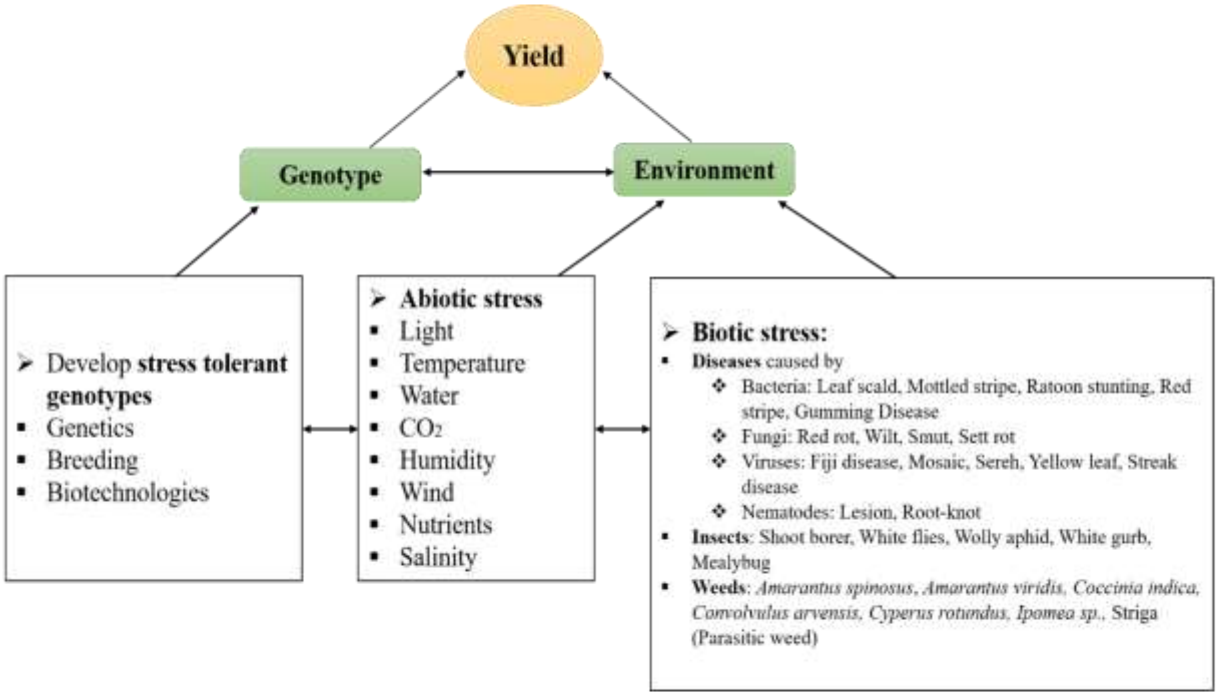

Figure 1: A flow chart to demonstrate factors influencing sugarcane yield

Implication of GE interaction during selection in sugarcane breeding programme

The selection of varieties that are consistently high in performance over a range of environments in different location and different seasons is the major task of sugarcane breeders. This selection is often inefficient due to GE interaction *i.e.* failure of varieties to have the stable performance in different locations. The optimum number of locations and years for variety trials depends on the contribution of varieties x location and varieties x year interaction in overall phenotypic performance. The genotype values and relative rankings for sugarcane characteristics that are quantitatively inherited, like cane and sugar yield, can vary significantly between environments (Kang 2002). These rank changes confound the determination of the whole true genetic value of the potential varieties. If the GE interaction is significant, it is essential for the plant breeder to accurately assess the specific environmental conditions under which the cultivated varieties will be grown after their release (Zhou *et al.*, 2012; Duma *et al.*, 2019). As sugarcane is a perennial crop, the choice of environments for its cultivation depends on specific locations and different stages of the crop, such as the initial planting and subsequent ratoon crops. Selecting appropriate locations allows for consideration of various agro-climatic conditions and diverse soil types (Nuss, 1998). In most sugarcane breeding programs, advanced-stage variety trials (AVT) are carried out at multiple locations over several years. The yield and quality data in the first and second ratoon crops of sugarcane are measured from the same plots as the plant cane to facilitate the assessment of ratooning ability. Consequently, the impact of different years becomes intertwined as each crop stage is cultivated in a separate year. As a result, the combined effects of years and crop stages are referred to as "crop years" (Kang *et al*., 1987). In the early selection stages, it is important to determine the optimum number of locations. Therefore, different countries are to provide several locations to not to eliminate all but one or few varieties before large scale testing in mill areas. Large GE interaction would make the concluding procedure inefficient because most of the gains in selection would become lost when the selected varieties are planted in mill areas and the discarded group contains most of the potentially valuable commercial varieties (Shanthi *et al.*, 2011). When the trial is conducted in several location and years, the yield of all varieties at a site (general mean) can be used to provide environmental index *i.e.* a measure of that environment. According to Finley and Wilkison (1963), the regression of the yield of individual varieties on these environments was used to measure the adaption and stability of varieties. Hence, investigations into GE interaction provide valuable insights and guidance for the development of strategies aimed at testing and selecting genotypes that exhibit the highest adaptation to the desired environments (Ali *et al*., 2020). Additionally, these investigations aid in ranking genotypes based on their varied response to diverse environmental conditions, particularly in relation to traits like yield (Verma *et al*., 2023).

Multilocation testing of sugarcane genotypes in India

The Sugarcane varietal improvement programme under the All India Coordinated Research Project on Sugarcane (AICRP-Sugarcane) has played a significant role in the development of improved, location-specific sugarcane varieties for the nation. There are 5 agro-climatic zones that have been identified for sugarcane variety testing. Comprises, North West Zone, North Central Zone, North East Zone, East Coast Zone and the Peninsular Zone. The National Hybridization Programme and the Zonal Varietal Testing Programme are the two components that make up the AICRP-Sugarcane crop improvement programme. The AICRP-Sugarcane programme annually conducts the zonal varietal trials in 5 agroclimatic zones across the nation. In this, from the breeding stations, the elite clonal selections take place across the country, pooled on a zonal basis, and evaluated in two stages. The entries are evaluated in the Initial varietal trial (IVT) for one year, and those that perform poorly are discarded. The remaining entries are examined in 2 plant and 1 ratoon crops for all yield and quality traits under the AVT. In the early and mid-late groups, various trials are conducted. For the varieties to be released in individual zones, varieties are identified based on the overall performance over the locations within the zone in plant and ratoon crops. The red rot resistance is required for a variety to be identified for release (Nair 2011). The AICRP-Sugarcane system ensures that superior locally adapted varieties from several sugarcane research stations will continue to be available at the time of multi-location evaluation of the elite clones AICRP trials allow for the simultaneous interchange of elite genetic materials among research stations as well as their evaluation at numerous locations within the agro-climatic zone. That provides detailed information about the yield potential of the varieties and their general adaptability for different agro-climatic conditions.

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CALOTROPIS GIGANTEA PLANT AND ITS USE IN THE TEXTILE SECTOR

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Abstract:

Natural fibre production is a major agricultural activity and it is a valuable raw material used for textile and non-textile production. *Calotropis gigantea* stem fibre also comes under natural fibre which is a soft shrub that grows in dry habitats and in excessively drained soils. Like other natural fibres, the obtained *Calotropis gigantea* stem cellulose fibres show good strength and these strength properties are an advantage for the use in textile industry. With strength (tenacity) as basic properties, fibres and fibrous products should possess some primary properties for acceptance as suitable raw materials. These properties include length to diameter ratio (aspect ratio), flexibility, as well as acceptable extensibility for processing, cohesion, and uniformity of properties, which are also important. These properties are present in Calotropis stem fibre. *Calotropis gigantea* plant also possesses various medicinal properties.

Keywords: *Calotropis gigantea*, Cellulosic fibre, Bast fibre, Stem, Properties

1. Introduction:

Natural fibre production is a major agricultural activity worldwide. Natural fibres are an important part of the human environment, which are also valuable raw materials used for textile and non-textile production. These fibres are biodegradable in nature. The textile and paper industries are the primary converters of fibres into the numerous products which are needed in our modern society. Most natural fibres are lignocellulosic in nature; they are considered low-value industrial fibres. But the progress in fibre and yarn production technologies through constant and serious research over the years and ecological considerations have created a renewed research interest in lignocellulosic fibres to explore their potential in textile and allied fields.

Bast fibres have a tradition of extended utilization. These fibres have been used for more than 8000 years. Now a days bast fibres are raw materials not only used for the textile industry but also for eco-friendly composites used in different areas of applications like building materials, particle boards, insulation boards, food, cosmetics, medicine, and source for other biopolymers, etc.

Bast fibres are well-defined as those fibres obtained from the outer cell layers of the stems of various plants. Bast fibres are comprised of a bundle of tube-like cell walls. Each cell wall comprises primary and secondary layers (Jones, 2017). Strands of bast fibres are released from a stem's cellular and woody tissue by a process of natural rottenness called retting (controlled rotting). Often the strands are used commercially without separating the individual fibres one from another (Koh, 2011).

As all bast fibres comprise non-cellulose matter such as pectin, lignin, and hemicellulose, degumming or retting is required to remove the non-cellulose matter. Degumming using chemicals and retting in water has a lot of undesirable environmental effects. However, recently enzyme-retting and enzyme or microbial degumming have been developed and put into practice, resulting in less water pollution, less damage to fibre, and more efficient processing. (Yu, 2015). The properties of bast fibres are influenced by different conditions of cultivation, different retting methods, and processing.

Calotropis gigantea is a soft shrub that can grow in dry habitats and in excessively drained soils. Like other natural fibres, the stem of Calotropis plants can be used to acquire natural cellulose fibres with good strength and elongation. These Calotropis fibre can be taken out using different retting methods such as water retting, chemical retting, enzyme retting, etc.

2. **Ecology and distribution of Calotropis species:**

Calotropis is extensively distributed and it has two species – *Calotropis gigantea* and the *Calotropis procera* mainly. Both species are found throughout the world. Physically the main difference between the two species that are easily differentiated is their flower colour while in the bud, or bloomed condition (Verma, 2014). *Calotropis gigantea* is a wasteland weed well known as Milkweed, a habitat of Asian countries that includes, India, Indonesia, Malaysia, Philippines, Thailand, Sri Lanka, and China (Kumar *et al.,* 2010).

Table 1: Systematic position of *Calotropis gigantea* (Source: Kumar *et al.,* 2013)

Kingdom:	Plantae
Order:	Gentianales
Family:	*Asclepiadaceae*
Subfamily:	*Asclepiadoideae*
Genus:	*Calotropis*
Species:	*gigantea*

Calotropis is drought resistant plant; salt tolerant to a relatively high degree, grows wild up to 900 meters (msl) throughout the country, and prefers disturbed sandy soils with mean annual rainfall: 300-400 mm. Through its wind and animal dispersed seeds, it quickly becomes established as a weed along degraded roadsides, lagoon edges, and in overgrazed native pastures. It has a preference for and is often dominant in areas of abandoned cultivation especially disturbed sandy soils and low rainfall. It is assumed to be an indicator of over-cultivation (Kumar *et al.,* 2013).

Calotropis gigantea R.Br. Asclepiadaceae, includes 280 genera and 2,000 species of world-wide distribution but is most abundant in the sub-tropics and tropics, and rare in cold countries. Other familiar plants of Calotropis are Milkweed or Silk weed (Asclepias syriaca L.), Butterfly weed (Asclepias tuberosa L.), and *Calotropis procera* (Ait.f). A comparison of these plants is given in Table 2. Native to India (Lindley, 1985) Calotropis grows wild throughout the country (Sastry and Kavathekar, 1990) on a variety of soils in different climates, sometimes where nothing else grows.

Table 2: Comparison of Calotropis and Asclepias species

Species **Common name(s)**	**Origin**	**Height (ft.)**	**Leaf arrangement**	**Flower**		**Leaves**	**Fruits**
				Size (inches)	**Color**		
Calotropis gigantea Gigantic swallow wort, Madar	India	8-10	Opposite	2	White to purple, rarely light green yellow, or white. Flowers not scented	Sessile	Follicles recurved, 2 or 1 follictes, second more often suppressed, 3-4" long
Asclepias tuberosa Butterfly weed	South America	2-3	Alternate	0.5	Corolla greenish-orange, scented	Sessile or very short petiolated	Follicles finely pubescent, 4-5" long
Asclepias syriaca Common milkweed Sikweed	South America	Up to 5	Opposite or verticillate	0.5	Corolla greenish to purplish white, scented.	Petiolated	Follicles tomentose and echinate, 3-5" long.
Calotropis procera Swallow-wort	India	3-6	Opposite	1.5	White to pink, scented.	Sub-sessile	Follicles 3-4", recurved

Table 3: Vernacular names of *Calotropis gigantea*

India	(Sanskrit)Arka, Ganarupa, Mandara, Vasuka, Svetapushpa, Sadapushpa, Alarka, Pratapass, (Hindi) Aak, Madar, (Kannada) Ekka, (Tamil and Malayalam) Erukku and (Telugu) Jilledi Puvvu
Malaysia	Remiga, rembega and kemengu
English	Crown flower and giant Indian milkweed
Indonesia	Bidhuri (Sundanese, Madurese), sidaguri (Javanese) and rubik (Aceh)
Philippines	Kapal-kapal (Tagalog)
Laos	Kok may, dok kap and dok hak
Thailand	Po thuean, paan thuean (northern), and rak(central)
French	Faux arbre de soie and mercure vegetal

Source: Kumar. *et al.* (2013) Review on a potential herb *Calotropis gigantea* (L.) R.Br.

In ancient ayurvedic medicine, the plant *Calotropis gigantea* is known as "Sweta Arka" and *Calotropis procera* as "Raktha Arka". Both are often alike in their botanical aspects and have similar pharmacological effects (Kaumar *et al.,* 2013).

Table 4: Vegetative characters of *Calotropis gigantea*

Habit	Shrub or a small tree up to 2.5 m (max.6m) in height.
Root	Simple, branched, woody at the base and covered with a fissured; corky bark; branches somewhat succulent and densely white to mentose; early glabrescent. All parts of the plant exude white latex when cut or broken
Leaves	Opposite-decussate, simple, sub sessile, extipulate; blade-oblong obovate to broadly obovate, apex abruptly and shortly acuminate to apiculate, base cordate, margins entire, succulent, white tomentose when young and later glabrescent and glacouse.
Flowers	Bracteate, complete, bisexual, actinomorphic, pentamerous, hypogynous, pedicellate, and pedicel 1-3 cm long.
Floral Characteristics	Inflorescence: A dense, multiflowered, umbellate, peducled cymes, arising from the nodes and appearing axillary or terminal
Calyx	Sepal 5, Polysepalous, 5 lobed, shortly united at the base, and glabrescent quincuncial aestivation.
Corolla	Petals five, gamopetalous, five lobed and twisted aestivations
Androcium	Stamens are five, gynandrous, another dithecous, and coherent.
Gynoecium	Bicarpellary, and apocarpus, styles are united at their apex, peltate stigma with five lateral stigmatic surfaces. Anthers adnate to the stigma forming a gynostegium.
Fruit	A simple, fleshy, inflated, subglobose to obliquely ovoid follicle up to 10 cm or more in diameter.
Seeds	Many, small, flat, obovate, 6x5 mm, compressed with silky white pappus, 3 cm or longer.

Calotropis gigantea is one of the latex-bearing plants that belong to the family Asclepiadaceae and is known for its medicinal properties (Singh *et al.,* 1996; Rastogi *et al.,* 1991).

C. procera and *C. gigantea* are closely related species. A comparison of their flowers can be used for species identification. *C. procera* is distinguished by its erect corollas and white petals with dark purple tips. *C. gigantea* has reflexed (bent backward or downwards) corollas that become twisted with age. The petals are white to pale lilac-blue. Flowers of *C. procera* are fragrant unlike those of *C. gigantean* (Brown, 2013).

Calotropis gigantea R. Br. (Asclepiadaceae) plant has been reported to possess a number of medicinal properties (1) and other purposes (2) generally known as the crown flower. It has clusters of waxy flowers that are either white or lavender in colour. Each flower consists of five pointed petals and a small, elegant "crown" rising from the centre, which holds the stamens (Gupta *et al., 2009).*

The plant has oval, light green leaves and a milky stem. It is a large shrub with oval leaves that are woody beneath and has clusters of waxy flowers that are lavender in colour. The scentless flowers are about 1 cm across and long-lasting, the seeds are dispersed by wind.5-12 cm long, and the stalk of an individual flower is 2.5-4 cm long. The egg-shaped or boat-shaped fruits are mostly in pairs, inflated, 6.5-10 cm x 3-5 cm (Gupta *et al.*, 2009).

3. **Physico-chemical properties of *C. gigantea***

Physico – Chemical properties of *C. gigantea* given by (Misra *et al*.,1993) are described below.

Plant parts contain 23.38% of ash, acid insoluble ash 5.08%, water soluble extractive 33.38%, and alcohol soluble extractive 6.66%.

The Root bark contains β-amyrin, 2-isomeric crystalline alcohols, gigantea (m.p.:2230-240), and iso-giganteol (m.p.1170-780). A colourless substance (m.p.:1620) of Tetracyclic triterpene alcohol has been found from an unsaponifiable fraction of the fatty matter.

The plant leaf contains an active principle – Mudarine and three glycosides calotropinuscharin, calotoxin, and phenol.

Latex contains water and water soluble (86 – 95.5%) and caoutcohouc (0.6 – 1.9%). The calcium consists of caoutchouch (5.5 –18.6%), resin (73.6 – 87.8%), and insoluble matter (4.5 – 13.8%) Seeds: Contains moisture (7.4%), protein (27%), ether extracts (26.8%), crude fibre and nitrogen free extract (32.4%) and ash (6.55%). Oil extracted from seeds is an olive-green liquid, an acid fraction of which contains palmitic (15%), oleic (52%), linoleic (32%), and linolenic acid (0.9%). The unsaponifiable fraction (31%) of seed wax yields phytosterol (m.p.:1360), stigmasterol (m.p.:1700), melissyl alcohol, and laurane (0.6%).13.8%). Floss: Contains moisture (7.2%), soluble matter (4.7 – 9.7%), lignin (15.5%), wax (6.4%), saccharose (0.4%), and ash (3.64%). 2.1.2 Medicinal Properties of C. gigantea Plants are exploited as medicinal sources since the ancient age. The traditional and folk medicinal system usages plant products for the treatment of several infectious diseases. In recent times, plants are being extensively explored for harboring medicinal properties. Research studies have verified that plants are one of the key sources of drug discovery and development. Plants are reported to have antimicrobial, anticancer, antiinflammatory, antidiabetic, hemolytic, antioxidant, larvicidal properties, etc. (Kumar *et al.*, 2010).

Traditionally *Calotropis gigantea* is used alone or with other medicinal plants to treat common diseases such as fever, rheumatism, indigestion, elephantiasis, asthma, and diarrhoea (Kartikar *et al.*, 1975). Tribal people were using these plant parts to cure several illnesses such as toothache, earache, sprain, anxiety, pain, epilepsy, diarrhoea, and mental disorders. C. gigantean is scientifically reported for its anti-Candida activity, cytotoxic activity, antipyretic activity, and wound healing activity (Kumar *et al.*, 2010). Various parts of this plant are reported to possess multiple therapeutic properties like antipyretic, analgesic, anticonvulsant, anxiolytic, and sedative (Mueen *et al*, 2005).

The latex of the plant exhibited several pharmacological properties and are exploited in folk medicine (Ervatamia, 1952). Latex from several plant species has been shown to involve in hemostatis (Bolay, 1979; Gunter *et al.,* 2002), wound healing, and pain-killing effects (Thankamma, 2003). The latex *C. gigantea* shows digitalis like action on the heart. The latex is also used to induce abortion, and infanticide (The Wealth of India, 2004).

The latex is used as bitter, heating, oleaginous, purgative, cures, leucoderma, tumours, and ascites. The latex of Calotropis is also used as caustic, acrid; expectorant, depilatory, and anthelmintic; useful in leprosy scabies ringworm of the scalp, piles, eruptions on the body, asthma, enlargement of spleen and liver, dropsy; applied to painful joint swellings. In the latex calotropin, gigantin and uscharin show digitalis-like action on the heart (Nalwaya *et al*.,2009)

The latex is applied to soften the outer skin portion while removing thorns (Pankaj, 2003). The latex from C. gigantean and related species is commonly used on fresh cuts to stop bleeding (Ashwani, 1999) and has been used as an anti-inflammatory agent in folk medicine (Dhanukar *et al.,* 2000). Several tribal people used this latex for easy delivery, abortion, and other ailments (Bhuyan, 1994).

The principal constituent of the leaves and stems are milky latex, which contains protease enzymes, calotropain FI, calotropain FII, calotropisn DI and DII, and uscharine, glutathione, ascorbic acid, calotoxin, calactin, and caoutchouc and also nitrogen and sulphur containing cardiac and fish poison, gigantin. Stem and root barks α- and ß- calotropeols, amyrins, taraxerols, sitosterols, triterpenes, and other glycosides. Leaves contain glycolipids, phospholipids, waxes, and fatty acids. Various cardiac glycosides, including calotropin, uscharin, uscharidin, and calotoxin, and four ursane-type triterpenoids have also been identified in the roots. The presence of a novel insect antifeedant nonprotein amino acid, giganticine, has been reported in the root bark (Ghani, 2003). α-amyrin, ß-amyrin, taraxasterol, ψ- taraxasterol, and ß-sitosterol have also been isolated from the plant (Rastogi & Mehrotra, 1991).

The root bark of Calotropis is diaphoretic, emetic, alterative, and purgative; useful in dysentery, asthma, elephantiasis, and syphilis. It acts like digitalis on the heart. The powder of the root encourages gastric secretion and acts as a mild stimulant and may be given with carminatives in dyspepsia. Milky juice is a violent purgative; cures leucoderma, tumours, and ascites; used for criminal purposes for producing abortion or causing the death of new-born infants; useful in scabies and ringworm of the scalp and piles (Uddin, 2014).

Leaves are used as poultice against rheumatism, chest pain due to cold, paralysed parts, and in dropsy. It is also beneficial in piles, skin diseases, wounds, and insect bites. Flowers are asrtingent, digestive, stomachic, tonic, anthelmintic, and analgesic; useful in asthma, catarrh, and loss of appetite. Poultice of the warm leaf is applied to relief pain (Uddin, 2014).

4. Fiber properties and uses of *C. gigantea*

Fibres and fibrous products should possess some primary properties for acceptance as suitable raw materials among people. These properties are length to diameter ratio (aspect ratio), tenacity (strength), and flexibility. Acceptable extensibility for processing, cohesion, and uniformity of properties is also important (Bhatnagar, 2004).

Natural cellulose fibres with cellulose content, strength, and elongation higher than that of milkweed floss and between that of cotton and linen have been obtained from the stems of common milkweed plants. Natural cellulose fibres extracted from milkweed stems have been characterized for their composition, structure, and properties. Fibres obtained from milkweed stems have about 75% cellulose, higher than the cellulose in milkweed floss but lower than that in cotton and linen. Milkweed stem fibres have a low percentage of crystallinity when compared with cotton and linen but the strength of the fibres is similar to cotton and elongation is higher than that of linen fibres (Reddy and Yang, 2009).

As one type of natural cellulose fibre, akund fibre has a good touch to the skin like cotton and a beautiful lustre like silk. It has a large hollow structure with a thin wall that looks like an air-filled pipe (Yang *et al.*, 2012).

Stems of milkweed plants have been used to obtain natural cellulose fibres with better strength and elongation than milkweed floss fibres. Milkweed stem fibres have high cellulose content but a low percentage of crystallinity. The fibres have strength like cotton and elongation higher than that of linen fibres. The modulus and moisture regain of the milkweed stem fibres is between that of cotton and linen. Overall, the milkweed stem fibres have properties required for high value textile, composite, and other fibrous applications. Utilizing the milkweed stems for high quality natural cellulose fibres will add value and make milkweed a more useful fibre plant (Reddy and Yang, 2009).

The milkweed stem fibres are longer than the floss fibres and cotton but in the range of length of the linen fibres. The milkweed stem fibres have an adequate length for processing on both the short and long staple spinning machinery similar to cotton and linen, respectively (Reddy and Yang, 2009).

The short fibres of Calotropis (surface or floss) grow in the fruits of the plant, while the long fibres (bast fibres) are in the stems of the plant and have been evaluated for some applications such as their fibre characteristics in the production of cloth. The mean length of floss fibres is 23.8 mm and fineness are reported as 3.3 mg/in (Varshney and Bhoi, 1988). The Calotropis stem fibres (11.5 cm in length) are longer than the cotton (1.5-5.6 cm) but smaller than the length of the linen fibres (20-140 cm). The strength of the fibres is comparable to cotton and elongation, and the strength of the fibres is higher than linen fibres (Reddy and Yang, 2009).

Among the variety of newly known natural resources, milkweed is a versatile substitutive fibre with numerous unique properties which are mainly attributed to their hollowness structure. The presence of hollow channels along the fibre length is responsible for their light weight and good insulation properties. Because of the fibre ecological and chemical benefits, technical application fields could be considered for the eco-friendly and non-allergenic textile made of Milkweed fibres, especially in the production of medical goods (Hassanzadeh and Hsami, 2015).

The parts of the milkweed plants are used for various applications. Fibres (floss) produced from the plant have low density (0.9 g/cm3) unlike any other natural cellulose fibre and efforts have been made to use the floss as a filling material in jackets and for nonwovens.

However, the short lengths and low elongation limit the use of floss as a natural cellulose fibre for textiles and other applications (Reddy and Yang, 2009).

The moisture content of akund fibre in the standard state is a little more than that of kapok. The ability of moisture absorption and release of akund fibre is similar to that of kapok and it has a quick moisture release and slow moisture absorption performance. The initial rate of moisture release of akund fibre is much higher than that of cotton fibre. The mechanical performance of akund fibre changes as the relative air humidity changes. Its breaking strength increase gradually with the increase of relative humidity. The wet strength of akund fibre is much higher than the dry strength (Yang *et al.,* 2012).

Calotropis gigantea fiber was found to be suitable for the composite application. The composite was fabricated using *Calotropis gigantea* stem fiber and resin mixture formulation of PLA using compression molding. The mechanical properties of *Calotropis gigantea* composites are slightly inferior compared to flax fibre composites due to the better properties of flax (Karthik and Ganesan, 2012). The stem of the milkweed plant has also been used to extract oil and natural rubber. Milkweed stems were sensitive to extraction conditions.

Milkweed stems bark disintegrates into small fibres in strong alkali conditions and/or heating of the stalks at temperatures above 80° C, which is not suitable for high value fibrous applications (Reddy and Yang, 2009). Calotropis yields a durable fibre useful for ropes, carpets, fishing nets, and sewing thread. *Calotropis* yields a durable fiber (commercially known as Bowstring of India) useful for ropes, carpets, fishing nets, and sewing thread. Floss, obtained from seeds, is used for stuffing purposes. A fermented mixture of *Calotropis* and salt is used to remove the hair from goat skins for the production of "nari leather" and sheep skins to make leather which is much used for low-cost book-binding (Singh *et. al*. 1996). Fungicidal and insecticidal properties of *Calotropis* have been reported. Fibre from the inner bark was once used in the manufacture of cloth for the nobility (Srinivas and Babu, 2013).

Table 5: Composition of *Calotropis gigantea* (Source: Karthik & Ganesan, 2012)

Sl. No	Fibre composition	*Calotropis gigantea* fibre Composition (%)
1	Wax content	2.98
2	Lignin	3.5
3	Holocellulose	79
4	α-cellulose	51.5
5	Hemicellulose	27.5
6	Ash	2

5. Advantages of plant fibres

Vegetable fibres are produced from plants' bast, fruit, seed, leaf, and sheath. Vegetable fibres are biodegradable, annually renewable, non-carcinogenic, and therefore healthy and friendly (Das *et al.,* 2008).

The advantages of natural fibres over traditional reinforcing materials such as glass fibres and mica are specific strength properties, low cost, low density, high toughness, good thermal properties, reduced tool wear, reduced dermal and respiratory irritation, ease of separation, enhanced energy recovery and biodegradability (Ishak, 2007).

As its name implies, bast fibres are obtained from the outer layer, i.e., the inner bark or phloem of bast surrounding the plant stem. The fibres are relatively very long and strong. For this reason, the bast fibre is considered to be the most important fraction of any bast plant (Sur, 2005).

Plant fibre has also environmental advantages. The energy required to separate the plant into their component fibres is small compared with that needed for the production of synthetic fibres.

The plant fibres can also be used in many different areas, supplementing and/or replacing synthetic fibres which have received increasing attention from the industry. These can be used not only for traditional uses such as rope making and packaging, but also can be used for the production of other value -added products such as pulp and paper, geotextiles, plastic moulded products, and home textiles (Moore, 1979; Aimin, 2001*).*

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CLIMATE CHANGE AND THEIR IMPACT ON AGRICULTURE

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1. Introduction

Long-term deviation in regular weather patterns over an extended period of time (≥30 years) is referred to as climate change. It discusses unusual climatic changes and how they impact other parts of the world. It might take tens, hundreds, or even millions of years to make these modifications. But as anthropogenic activities like industrialization, urbanisation, deforestation, agriculture, and modifications to land use patterns increase, more greenhouse gases are emitted into the atmosphere, speeding up the rate of climate change. Climate change scenarios may result in high temperatures, changing precipitation patterns, and higher atmospheric CO_2 concentrations. Agriculture may be impacted by the greenhouse effect by increased atmospheric CO_2 levels have an impact on agriculture.

Weather and climate

Weather is the set of meteorological conditions such as wind, rain, snow, sunshine, temperature, etc. at a particular time and place. By contrast, the term climate describes the overall long-term characteristics of the weather experienced at a place. The ecosystems, agriculture, livelihoods and settlements of a region are very dependent on its climate. The climate, therefore, can be thought of as a long-term summary of weather conditions, taking account of the average conditions as well as the variability of these conditions. The fluctuations that occur from year to year, and the statistics of extreme conditions such as severe storms or unusually hot seasons are part of the climatic variability.

Projections for climate change

The northern regions of India may experience higher levels of warming. Under a changing climate, it is anticipated that maximum and minimum temperature extremes will increase. Some parts may see increased rainfall, while others may not. A 20% increase in summer monsoon rainfall is anticipated throughout all states in India, except for Punjab and Rajasthan in the North West and Tamil Nadu in the South, which show a little drop on average. In some areas of India, especially the North East, the number of rainy days may decline (like in MP), but the intensity is predicted to increase. India's gross water availability per individual will decrease from 1820 m^3/yr in 2001 to in 2050, it will only be 1140 m^3/yr. Corals in the Indian Ocean may soon be subjected to summer temperatures that are higher than those recorded over the past 20 years. From 2050, annual coral bleaching will almost certainly occur. The districts of Nellore and Nagapattinam in Tamilnadu, Jagatsinghpur and Kendrapara in Odisha, Junagadh and Porabandar in Gujarat, and Nellore and Nagapattinam in Tamilnadu are now the most vulnerable to the effects of increased severity and frequency of cyclones in India (NATCOM, 2004). The average sea level along the Indian coast has been rising at a rate of around 1.0 mm per year during the previous 100 years, according to historical data. The most recent data, however, indicates a 2.5 mm/year rising trend in sea level throughout the Indian coastline.

Atmosphere, oceans, and predicted increases in greenhouse gases resulting from socio-economic scenarios for the ensuing decades. The IPCC estimates that by 2100, the average global surface warming (change in surface air temperature) will increase by 1.1 to 6.4^{0}C after reviewing the published data from numerous models. Between 18 and 59 centimetres will be added to the sea level. The seas' acidity will rise. Extreme heat, heat waves, and heavy precipitation events are quite likely to continue increasing in frequency.

2. **Impact of climate change on agriculture**

Humans are concerned about climate change and variability. The life of billions of people who rely on land for most of their requirements is significantly threatened by unpredictable floods and droughts. Extreme disasters including cold and heat waves, landslides, forest fires, droughts, and floods frequently have a negative impact on the world economy. Although not associated with meteorological disasters, natural disasters such as earthquakes, tsunamis, and volcanic eruptions may alter the atmosphere's chemical composition. Disasters due to the weather will follow. Aerosols (atmospheric pollutants) have increased as a result of the release of greenhouse gases from the burning of fossil fuels, including carbon dioxide (CO_2), hydro chlorofluorocarbons (HCFCs), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), etc. Weather extremes are caused by ozone depletion, UV-B filtered radiation, volcanic eruptions, the "human hand" in deforestation in the form of forest fires, and the loss of wet lands. With less forest cover, precipitation spreads across the ground, eroding top soil and causing floods and droughts. Normally, the forest cover intercepts rainwater and allows it to be absorbed by the soil. Ironically, lack of trees speeds up soil evaporation, which worsened drought in dry years. Since CO_2 illustrates long wave radiation and radiates it back to the earth's surface, it is the main greenhouse gas contributing to global warming. The surface atmosphere gets warmer as a result of greenhouse gas emissions, which is the cause of global warming.

Climate change can affect agriculture in a variety of ways. Beyond a certain range of temperatures, warming tends to reduce yields because crops speed through their development, producing less grain in the process. And higher temperatures also interfere with the ability of plants to get and use moisture. Evaporation from the soil accelerates when temperatures rise and plants increase transpiration—that is, lose more moisture from their leaves. The combined effect is called "evapotranspiration." Because global warming is likely to increase rainfall, the net impact of higher temperatures on water availability is a race between higher evapotranspiration and higher precipitation. Typically, that race is won by higher evapotranspiration. But a key culprit in climate change—carbon emissions— can also help agriculture by enhancing photosynthesis in many important, so-called C_3, crops (such as wheat, rice, and soybeans). The science, however, is far from certain on the benefits of carbon fertilization. But we do know that this phenomenon does not much help C_4 crops (such as sugarcane and maize), which account for about one-fourth of all crops by value.

Future climate estimates are mostly dependent on computer-based climate models that consider the significant Indian climate, which is controlled by the southwest monsoon and brings the majority of the region's precipitation. It is essential for the provision of irrigation for agricultural and drinking water. There are two types of climate-related effects that affect agricultural productivity:

(1) Direct effects from changes in temperature, precipitation, or carbon dioxide concentrations; and

(2) Indirect effects from changes in soil moisture and the distribution and frequency of pest and disease infestation. With climatic changes, rice and wheat yields may decrease significantly (IPCC 1996; 2001).

For a temperature increase of 2^0C to 3.5^0C, it is predicted that the loss in net revenue at the farm level will be between 9% and 25%. Additionally, scientists predicted that a 2^0C rise in mean temperature and a 7% increase in mean precipitation would result in a 12.3% decrease in net earnings for the entire nation. The agriculture is observed to be most adversely impacted in Gujarat, Maharashtra, and Karnataka's coastal regions. Small losses are also predicted for Punjab, Haryana, and western Uttar Pradesh, which produce most the world's food grains. On the other side, it is anticipated that West Bengal, Orissa, and Andhra Pradesh will only marginally gain from warming.

3. **Impact on crop yields**

The results give little support to the optimists. Globally, the overall impact of baseline global warming by the 2080s is a reduction in agricultural productivity (output per hectare) of 16 per cent without carbon fertilization, and a reduction of 3 percent should carbon fertilization benefits materialize—when results are weighted by output. The losses are greater when weighted by population or country.

Crop Loss: Crops like carrot, sugar beetroot and radish typically exhibit increased partitioning of assimilates to roots at greater carbon dioxide levels. Root crop losses from soil-borne illnesses could be decreased under climate change if more carbon is stored in the roots. On the other hand, increases in temperature and precipitation due to climate change may cause more crop loss for foliar diseases that are preferred by high temperatures and humidity. Increased crop losses due to foliar diseases may be made worse by the impacts of expanded plant canopies brought on by higher CO_2.

Changes in agriculture productivity: Cotton Crop grown in a semi-arid climate and requires a mean temperature of 21–27^0C and with adequate soil moisture for proper vegetative growth, it can tolerate temperatures as high as 43^0C, but below 21^0C the growth slows down or ceases. Cotton crop requires 600–1000 mm of rainfall during its entire growth phase; however, heavy rainfall or moisture stress during bud development and boll shedding will substantially reduce the yield. Cotton is also called ‘white gold’ because of its economic value in the market. Figure 4 b shows the time series of cotton production over Maharashtra. The sudden boost in production after 2005 was due to the large-scale commercial cultivation of high-yielding varieties. Rice crop require a hot and humid climate conditions. It is grown in the areas of high humidity, prolonged sunshine, good supply of water and requires 4–6 months for full growth. The average temperature required for rice crop development is 20–40^0C. The optimum temperature of 30^0C during daytime and 20^0C during night-time are favourable for growth and development of the crop. When the temperature is in the critical range, rainfall is the most crucial factor for cultivation of rice crops. Rainfed rice cultivation is limited to areas where rainfall is more than

1000 mm. Even though high rainfall is preferred, variation in the distribution of rainfall is the most critical factor. Throughout the years, total production has increased due to chemical fertilizers, advanced machinery, etc. This crop is tropical, and in warm, humid weather, it keeps growing until it flowers, at which point it stops. The average sugarcane life cycle lasts 15 to 18 months. Throughout all stages of its growth, a maximum temperature range of 27-38^{0}C is necessary. The ideal temperature range for germination is 32–38^{0}C. Equally important for crop development is a sufficient supply of water.

Conclusions:

Heavy crop and human losses are probably in store. The entire climate change is linked to rising greenhouse gases and human-caused aerosols, and the imbalance between them may cause unpredictability even in the behaviour of the monsoon over India from year to year. Therefore, both industrialised and developing nations should make a concerted effort to make industrialization environmentally benign by lowering the amount of greenhouse gases that are pumped into the atmosphere. In the same way, priority needs to be given to implementing awareness campaigns on climate change, including its effects on various sectors, including agriculture, health, infrastructure, water, forestry, fisheries, land and ocean biodiversity, sea level, and the role played by human interventions.

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CLIMATE CHANGE EFFECTS ON INDIAN AGRICULTURE

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Abstract:

Climate change is having significant impacts on Indian agriculture, posing challenges to food security and rural livelihoods. This review paper provides a comprehensive analysis of the effects of climate change on Indian agriculture, encompassing crop production, water availability, pests and diseases, and farmer livelihoods. It highlights the vulnerabilities, risks, and potential adaptation strategies for the agricultural sector. The review synthesizes scientific literature, government reports, and field studies to present an overview of the current understanding of climate change effects on Indian agriculture. The findings emphasize the need for a multi-dimensional approach that integrates technological, socioeconomic, and policy interventions to enhance climate resilience. The review also identifies key research gaps and future directions, including improving climate modeling, developing climate-smart technologies, conducting socioeconomic studies, and promoting stakeholder engagement. By addressing these challenges and embracing opportunities, India can build climate-resilient agricultural systems for sustainable food production and rural development.

1. Introduction

1.1 Background

Indian agriculture is a vital sector of the country's economy and plays a critical role in ensuring food security for its large population (Government of India, 2020). However, this sector is vulnerable to the impacts of climate change. Climate change refers to long-term shifts in weather patterns and average temperatures, resulting from factors like greenhouse gas emissions (IPCC, 2014). These changes in climate parameters can have significant consequences for agricultural systems, including crop yields, water availability, livestock health, and overall rural livelihoods. India, with its diverse agro-climatic zones and dependence on rain-fed agriculture, is particularly susceptible to the effects of climate change. The country has already witnessed changes in temperature and precipitation patterns, including increasing temperatures, altered monsoon patterns, and a rise in extreme weather events such as droughts, floods, and cyclones (Krishnan *et al.,* 2013; Patwardhan *et al.,* 2016). These changes pose substantial challenges to agricultural productivity and sustainability.

1.2 Objective of the chapter

The objective of this comprehensive book chapter is to examine the effects of climate change on Indian agriculture. By analyzing scientific literature, government reports, and field studies, this review aims to provide a holistic understanding of the vulnerabilities, risks, and potential adaptation strategies in the face of a changing climate. The chapter synthesizes existing knowledge to identify the key areas where climate change impacts are observed in Indian agriculture.

Understanding the effects of climate change on Indian agriculture is crucial for policymakers, researchers, and stakeholders in developing effective strategies to mitigate and adapt to these changes. By assessing the current state of knowledge, this review aims to provide insights into the multidimensional impacts of climate change on Indian agriculture and guide the formulation of policies and interventions to enhance the sector's resilience. In the subsequent sections of the review paper, we will delve into specific aspects of climate change effects on Indian agriculture, including changing weather patterns, crop production and agro ecosystems, livestock and fisheries, socioeconomic implications, adaptation strategies, and policy interventions.

2. Changing Weather Patterns

2.1 Temperature Rise and Heat Stress

Rising temperatures and heat waves can adversely affect crop growth, productivity, and livestock health. Studies have shown that higher temperatures can reduce crop yields, delay maturity, and increase the risk of heat stress in livestock (Singh *et al.,* 2019; Lobell and Gourdji, 2012). For example, research conducted in India has indicated that a temperature increase of 1°C can result in a 5-6 % reduction in wheat yields (Ahuja *et al.,* 2010). Heat stress can also impact livestock production, leading to reduced milk yield, lower fertility rates, and increased mortality (Bhattacharya *et al.,* 2018).

2.2 Altered Precipitation Patterns

Changes in rainfall distribution and monsoon patterns can impact crop water requirements, irrigation practices, and groundwater availability. Studies have shown that altered precipitation patterns, such as increased variability and more intense rainfall events, can affect agricultural productivity (Goswami *et al.,* 2019; Rai *et al.,* 2020). For example, a study in the Indo-Gangetic Plains of India found that changes in monsoon precipitation patterns have the potential to reduce wheat yields by 6-23 % (Sharma *et al.,* 2021). These changes in precipitation can also affect water availability for irrigation, with implications for crop water management and overall agricultural sustainability (Sharma *et al.,* 2019).

2.3 Extreme Weather Events

Increased frequency and intensity of droughts, floods, and cyclones can lead to crop losses, soil erosion, and infrastructure damage. Droughts can significantly impact agricultural productivity, causing water stress, reduced crop yields, and livestock fodder scarcity (Kumar *et al.,* 2018; Choudhury, 2021). Floods can result in soil erosion, loss of crops, and contamination of water sources, affecting both agricultural production and rural livelihoods (Singh, 2017; Patil, 2021). Cyclones can cause widespread destruction, including damage to crops, livestock, and agricultural infrastructure (Singh *et al.,* 2022; Sarkar *et al.,* 2023).

3. Crop Production and Agroecosystems

3.1 Crop Yield and Production

Climate change can have substantial impacts on crop yield and production in Indian agriculture. Rising temperatures, changes in precipitation patterns and increased occurrence of extreme weather events can disrupt crop growth, flowering, and maturation, ultimately affecting yields (Lobell *et al.,* 2011; Kumar *et al.,* 2022). For example, studies have shown that higher temperatures can lead to reduced rice yields, with a projected decrease of 6-14 % for every 1°C increase in temperature (Pandey *et al.,* 2020). Changes in rainfall patterns, particularly during the monsoon season, can also affect crop water requirements, resulting in water stress and reduced yields (Ramesh *et al.,* 2018; Roy *et al.,* 2020).

3.2 Shifts in Agroecological Zones

Climate change can cause shifts in agro ecological zones, altering the suitability of certain crops in different regions. As temperatures and rainfall patterns change, the optimal growing conditions for crops may shift, affecting crop distribution and cropping patterns (Challinor *et al.,* 2014; Rai *et al.,* 2022). For instance, studies have projected a decrease in the suitability of traditional crops like wheat and maize in certain regions of India due to changing climatic conditions, while other regions may become more suitable for different crops (Singh *et al.,* 2016; Srinivas *et al.,* 2021). These shifts in agro ecological zones can have implications for farmers' decision-making regarding crop selection and land use.

3.3 Pests and Diseases

Climate change can influence the dynamics and distribution of pests and diseases, posing challenges to crop health and productivity. Changes in temperature and rainfall patterns can impact the prevalence, abundance, and behavior of pests and disease vectors (Sridhar *et al.,* 2017; Ghosh *et al.,* 2020). For example, studies have shown that climate change can affect the distribution and intensity of pests like the brown plant hopper in rice fields (Kumar *et al.,* 2017). Likewise, altered climatic conditions can create favorable environments for the spread of diseases such as bacterial blight in crops (Babu *et al.,* 2019). These pest and disease pressures can require additional management strategies and have economic implications for farmers.

4. Livestock and Fisheries

4.1 Livestock Productivity and Health

Climate change can have significant impacts on livestock productivity, health, and welfare. Rising temperatures and heat stress can reduce feed intake, milk production, and reproductive efficiency in livestock (Bhattacharya *et al.,* 2019; Bhatta *et al.,* 2021). For example, studies have shown that heat stress can lead to a decline in milk yield in dairy cattle, with estimated losses of 10-35 % during heatwave events (Dash *et al.,* 2016; Gantait *et al.,* 2018). Furthermore, climate change can also increase the vulnerability of livestock to diseases and parasites, affecting overall herd health and productivity (Bansal *et al.,* 2017; Sejian *et al.,* 2018).

4.2 Changing Forage Availability

Altered rainfall patterns and prolonged droughts can impact forage availability for grazing livestock. Changes in precipitation can affect the growth and quality of pasture and fodder, leading to fodder scarcity and reduced nutritional value (Bhattacharya *et al.,* 2020; Islam *et al.,* 2022). These challenges can force farmers to seek alternative feed sources, increase feed costs, or reduce livestock numbers, thereby affecting livelihoods and rural economies (Bhatta *et al.,* 2019; Joshi *et al.,* 2021).

4.3 Impact on Fisheries

Climate change can also influence fishery resources and aquaculture systems. Rising sea temperatures, ocean acidification, and changes in precipitation patterns can affect fish migration, reproduction, and distribution (Narain *et al.,* 2019; Islam *et al.,* 2021). For instance, studies have shown that rising sea temperatures can impact the breeding patterns and reproductive success of commercially important fish species (Acharya *et al.,* 2018). Furthermore, changes in precipitation and river flows can influence freshwater fish populations, affecting fish production and livelihoods in riverine areas (Bhattacharya *et al.,* 2021; Islam *et al.,* 2020).

5. Adaptation Strategies and Policy Interventions

5.1 Agricultural Practices and Technologies

Adapting agricultural practices and adopting innovative technologies can help mitigate the impacts of climate change on Indian agriculture. Several strategies focus on improving water management, such as the use of efficient irrigation techniques like drip irrigation and sprinkler systems (Sharma *et al.,* 2019). Additionally, conservation agriculture practices, such as zero-tillage and crop residue management, can enhance soil health, water retention, and carbon sequestration, thereby improving crop resilience and productivity (Kumar *et al.,* 2021). Moreover, the adoption of climate-resilient crop varieties and diversification of cropping systems can reduce vulnerability to climate change (Kumar *et al.,* 2018; Dwivedi *et al.,* 2020).

5.2 Weather Forecasting and Early Warning Systems

Accurate weather forecasting and early warning systems are crucial for farmers to make informed decisions in the face of climate variability and extreme events. Timely and reliable information on weather conditions, including rainfall, temperature, and pest outbreaks, enables farmers to plan their agricultural activities effectively (Kumar *et al.,* 2019). The integration of traditional knowledge with modern weather forecasting techniques can enhance the usability and effectiveness of such systems, benefiting farmers at the local level (Goswami *et al.,* 2017).

5.3 Institutional Support and Policy Interventions:

Effective institutional support and policy interventions play a vital role in facilitating climate change adaptation in Indian agriculture. Governments and agricultural institutions need to provide extension services, training, and capacity-building programs to equip farmers with the knowledge and skills required for climate-resilient farming practices (Mall *et al.,* 2019). Financial incentives, such as subsidies and insurance schemes, can help farmers adopt climate-smart practices and manage climate-related risks (Singh *et al.,* 2021). Furthermore, policy measures focusing on water management, sustainable land use, and disaster preparedness can enhance the resilience of the agricultural sector (Bisht *et al.,* 2020).

6. Challenges and Future Perspectives

6.1 Economic and Social Challenges

Climate change poses significant economic and social challenges for Indian agriculture. Rising temperatures, changing precipitation patterns, and increased frequency of extreme events can lead to yield losses, reduced income, and food insecurity for farmers (Verma *et al.,* 2019; Aggarwal *et al.,* 2020). Small-scale farmers, who often lack resources and access to information and technology, are particularly vulnerable to climate change impacts (Sharma *et al.,* 2021).

Additionally, climate change can exacerbate existing social inequalities, leading to increased poverty, migration, and social unrest in rural communities (Sinha *et al.,* 2018).

6.2 Technological and Infrastructural Constraints

The adoption of climate-smart agricultural practices and technologies faces several technological and infrastructural constraints. Limited availability and access to climate-resilient seeds, irrigation facilities, and farm machinery hinder the implementation of adaptive strategies (Sharma *et al.,* 2020; Dhawan *et al.,* 2021). Insufficient rural infrastructure, such as storage facilities, transport networks, and market linkages, further exacerbates post-harvest losses and reduces farmers' ability to benefit from agricultural innovations (Verma *et al.,* 2021).

6.3 Policy and Governance:

Effective policy frameworks and governance structures are critical for addressing climate change challenges in Indian agriculture. However, policy implementation gaps, inadequate coordination among different sectors, and lack of integration of climate change concerns into agricultural policies hinder progress (Aggarwal *et al.,* 2019; Singh *et al.,* 2021). Strengthening policy coherence, enhancing institutional capacities, and promoting multi-stakeholder collaborations can facilitate the implementation of climate change adaptation and mitigation measures (Kaur *et al.,* 2022).

6.4 Future Perspectives

Despite the challenges, there are opportunities for transformative changes in Indian agriculture. Integration of traditional knowledge and indigenous practices with scientific advancements can enhance climate resilience and sustainability (Gupta *et al.,* 2020; Shukla *et al.,* 2022). Promoting agro ecological approaches, sustainable intensification, and climate-smart landscapes can contribute to improved productivity, ecosystem services, and livelihoods (Kumar *et al.,* 2022; Lal *et al.,* 2022). Moreover, investments in research and development, capacity-building programs, and farmer-centric extension services are crucial for building climate-resilient agricultural systems (Bhatia *et al.,* 2021; Mishra *et al.,* 2022).

7. Future Research Directions

7.1 Climate Modeling and Projections:

Advancements in climate modelling and projections are crucial for understanding future climate scenarios and their potential impacts on Indian agriculture. High-resolution climate models incorporating regional-scale processes can provide more accurate predictions of temperature, rainfall patterns, and extreme events at local scales (Menon *et al.,* 2018). Furthermore, integrating climate models with crop models can enhance the assessment of crop responses to climate change and aid in decision-making for adaptive strategies (Singh *et al.,* 2020).

7.2 Climate-Smart Technologies and Practices

Further research is needed to develop and optimize climate-smart technologies and practices tailored to the diverse agro ecological regions of India. This includes the development of climate-resilient crop varieties with improved tolerance to heat, drought, and pests (Rani *et al.,* 2021). Additionally, the evaluation and promotion of sustainable and resource-efficient practices such as precision agriculture, agroforestry, and organic farming can contribute to climate change adaptation and mitigation (Rao *et al.*, 2022).

7.3 Socioeconomic and Policy Research

In-depth socioeconomic research is essential for understanding the implications of climate change on rural livelihoods, farm incomes, and food security. Studies examining the social dimensions of climate change adaptation and the effectiveness of policy interventions can inform the design and implementation of targeted measures (Srivastava *et al.*, 2020). Furthermore, investigating the economic feasibility and cost-effectiveness of different adaptation strategies can assist policymakers and stakeholders in making informed decisions (Kumar *et al.*, 2023).

7.4 Stakeholder Engagement and Knowledge Exchange

Enhancing stakeholder engagement and promoting knowledge exchange among researchers, policymakers, farmers, and other stakeholders are critical for effective climate change adaptation in Indian agriculture. Participatory research approaches, farmer field schools, and platforms for knowledge sharing can facilitate the co-design and dissemination of context-specific solutions (Sarkar *et al.*, 2019). Additionally, integrating indigenous knowledge and traditional practices into adaptation strategies can improve their relevance and effectiveness (Mukherjee *et al.*, 2021).

Conclusion:

In conclusion, climate change poses significant challenges to Indian agriculture, impacting crop production, water availability, pest dynamics, and farmer livelihoods. Adapting to climate change requires a multi-dimensional approach, integrating technological, socioeconomic, and policy interventions. Strategies such as resilient crop varieties, precision agriculture, water management, and stakeholder engagement are essential. Future research should focus on improving climate modelling, developing climate-smart technologies, conducting socioeconomic studies, and fostering knowledge exchange. By addressing these challenges and embracing opportunities, India can build climate-resilient agricultural systems for food security and sustainable livelihoods.

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RESEARCH TRENDS IN AGRICULTURAL SCIENCE: A COMPREHENSIVE REVIEW

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Abstract:

Agricultural science plays a crucial role in addressing the global challenges of food security, environmental sustainability, and climate changes. This research aims to provide an overview of the current trends in agricultural science by analysing recent studies and advancements in the field. The content will cover various sub-disciplines of agricultural science, including crop science, soil science, plant breeding, agricultural engineering, and precision agriculture, with relevant references to support the discussed trends. This comprehensive review explores the current research trends in agricultural science, highlighting key areas of focus, emerging technologies, and innovative approaches that are shaping the future of agriculture.

Introduction:

Importance of agricultural science in global food production Key challenges faced by the agricultural sector Role of research in addressing these challenges. The introduction provides an overview of the importance of agricultural science in addressing global challenges such as feeding a growing population, mitigating climate change impacts, and ensuring sustainable agricultural practices. It emphasizes the need for continuous research and innovation to enhance productivity, efficiency, and environmental sustainability in agriculture[1].

1.Precision Agriculture:

Precision agriculture involves the use of advanced technologies, such as remote sensing, geographic information systems (GIS), and global positioning systems (GPS), to optimize farm management practices. This section discusses the applications of precision agriculture in crop monitoring, yield prediction, resource management, and decision support systems.

2.Sustainable Crop Production:

With the increasing demand for food, there is a pressing need to enhance crop productivity while minimizing environmental impact. This section explores research trends in sustainable crop production, including the development of drought-tolerant and disease-resistant crop varieties, integrated pest management, soil health management, and agroecological approaches[2].

3.Agricultural Biotechnology:

Biotechnology plays a crucial role in agricultural science, enabling the development of genetically modified organisms (GMOs) and biotechnological tools for crop improvement. This section covers advancements in gene editing technologies, genetic engineering, and the potential of biotechnology in addressing crop diseases, pests, and nutritional deficiencies.

4.Climate Change Adaptation and Mitigation:

Climate change poses significant challenges to agricultural systems worldwide. This section focuses on research efforts to develop climate-resilient crops, sustainable irrigation practices, carbon sequestration in soils, and the use of renewable energy sources in agriculture. It also discusses the role of agricultural practices in mitigating greenhouse gas emissions[3].

5.Digital Agriculture and Big Data:

The digital revolution has transformed agriculture, enabling farmers to collect and analyze vast amounts of data for improved decision-making. This section explores the role of big data analytics, artificial intelligence (AI), and Internet of Things (IoT) in agriculture, including farm automation, smart sensors, and predictive modeling for optimized resource allocation.

6. Agricultural Waste Management:

Effective management of agricultural waste is essential for sustainable farming. This section discusses research trends in the utilization of crop residues, animal manure, and agro-industrial byproducts for bioenergy production, organic fertilizers, and waste reduction strategies.

7.Water Management in Agriculture:

Water scarcity is a critical issue in many agricultural regions. This section focuses on research advancements in water-efficient irrigation systems, precision irrigation technologies, water harvesting, and wastewater treatment for agricultural reuse.

8.Agricultural Policy and Economics:

Agricultural policies and economic factors significantly influence the development and sustainability of the agricultural sector. This section explores research trends in agricultural policy analysis, market dynamics, trade, and the economic impact of technological innovations in agriculture.

9. Future Perspectives and Challenges:

The review concludes by summarizing the key research trends in agricultural science and identifying future challenges. It highlights the importance of interdisciplinary collaboration, knowledge sharing, and the adoption of sustainable agricultural practices for a resilient and food-secure future [4,5]

10.Crop Science

- Genomic and molecular approaches in crop improvement
- Development of stress-tolerant and disease-resistant crop varieties
- Application of biotechnology in crop production
- Sustainable intensification of cropping systems

11.Soil Science

- Soil health and fertility management
- Precision soil mapping and nutrient management
- Soil microbiology and its impact on plant health
- Soil conservation and erosion control techniques

12.Plant Breeding

- Marker-assisted breeding for accelerated crop improvement
- Hybridization and genetic diversity in breeding programs
- Application of genomic selection in plant breeding
- Breeding for nutritional quality and functional traits [6]

13.Agricultural Engineering

- Automation and robotics in agricultural operations
- Sensor technologies for monitoring and optimization
- Smart irrigation and water management systems
- Energy-efficient and sustainable farming practices

14.Precision Agriculture

- Remote sensing and GIS applications in agriculture
- Farm data analytics and decision support systems
- Variable rate technology for optimized input management
- Integration of Internet of Things (IoT) in agriculture[7]

15.Sustainable Agriculture

- Organic and regenerative farming practices
- Agroecology and biodiversity conservation
- Climate-smart agriculture and carbon sequestration
- Circular economy approaches in agricultural systems

16.Emerging Technologies

- Gene editing and CRISPR-Cas9 technology in agriculture
- Artificial intelligence and machine learning applications
- Nanotechnology for enhanced nutrient delivery and pest control
- Biodegradable materials for sustainable packaging

17. Future Perspectives

- Role of interdisciplinary research in agricultural science
- Integration of digital technologies for data-driven farming
- Adoption of climate-resilient and resource-efficient practices
- Collaboration and knowledge-sharing for global agricultural development [8,9]

Conclusion:

Summary of the key research trends in agricultural science. Implications for sustainable food production and environmental stewardship. These emerging research trends in agricultural science highlight the ongoing efforts to address global challenges related to food security, climate change, and sustainable agriculture. By leveraging innovative technologies, ecological principles, and genetic advancements, scientists are paving the way for more resilient, productive, and environmentally friendly agricultural systems. Continued research and collaboration in these areas [10].

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ORGANIC FARMING IN INDIA: ENVISION FOR A HEALTHY NATION

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Abstract:

Organic farming ensures that nature remains clean and abundant. We will notice a buzz of animal, bird, and insect activity if we visit an organic farm. According to research, there is approximately 30% more wildlife and plants near ecological production fields than near conventional farming. This is due to the absence of pesticides and the use of far less fertilizer. It is time to talk about nutritional security rather than just food security (which consists solely of carbohydrates). Organic food is perceived as the preferred choice among a plethora of healthy food options. Organic agriculture is one of several environmentally friendly producing strategies. The demand for organic food is gradually expanding in both industrialized and emerging countries, with an annual average growth rate of 20 -25%. Without question, organic agriculture is one of the fastest-expanding segments of agricultural production. Its potential environmental benefits and compatibility with integrated agricultural approaches to rural development, may be viewed as a development tool for the nation.

Keywords: Organic farming, Need for organic, Income, Integrated approach.

1. Introduction:

Northbourne created the phrase 'organic' in his book 'Look to the Land' in 1940. Organic farming, according to Northbourne, is "an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity." Organic product is produced without the use of synthetic pesticides, antibiotics, growth hormones, genetic alteration techniques (such as genetically modified crops), sewage sludge, or chemical fertilizers (Nourthbourne, 2003). Conventional farming, on the other hand, is the cultivation procedure in which synthetic pesticides and artificial fertilizers are used to increase crop output and profit. Organic farming as a growing method has grown in popularity in recent years (Dangour *et al.*, 2010). Organic foods have emerged as one of the finest options for both consumers and farmers. Organically farmed foods are an important aspect of living a green lifestyle (Chopra *et al.*, 2013). It is based on using on-farm resources more efficiently than industrial agriculture to reduce the use of external inputs. As a result, synthetic fertilizers and pesticides are avoided. The term "organic" in organic agriculture refers to products that have been produced in compliance with specified standards during the food production, handling, processing, and marketing stages, and have been certified by a duly established certification agency or authority. In this context, organic farming, focusing on optimal, balanced, efficient and scientific management of land, water, biodiversity and external inputs has emerged as a solution.

2. Relevance of organic farming

The need for an eco-friendly alternative farming system arose as a result of the negative consequences of chemical agricultural practices used globally in the second part of the last century. For generations, our forefathers' farming methods evolved and were less harmful to the environment. People began to consider various alternative farming systems based on environmental protection, which would increase human welfare in a variety of ways such as clean and healthy foods, an ecology conducive to the survival of all living and non-living things, low use of non-renewable energy sources, and so on as depicted in figure 1. Many farming systems have resulted from the efforts of both specialists and ordinary people. However, organic farming is thought to be the greatest of all because of its scientific approach and widespread acceptance around the world.

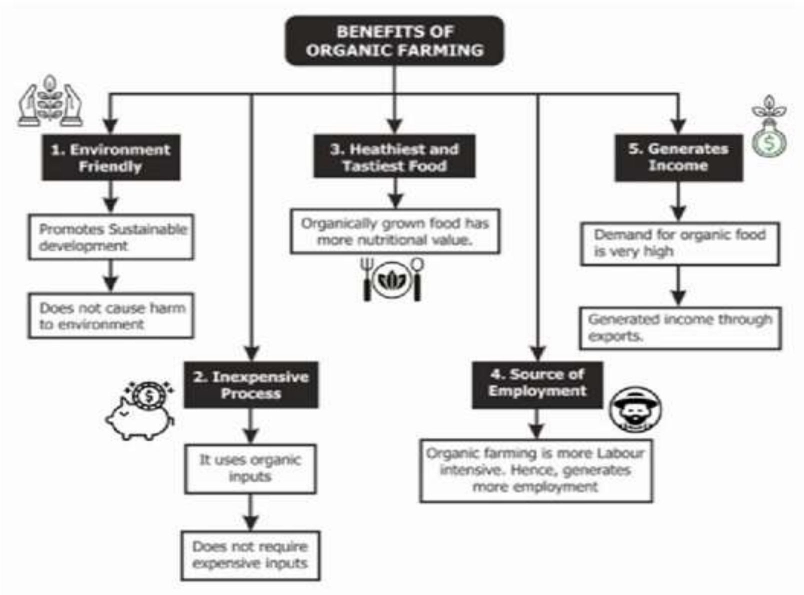

Figure 1: Importance and benefits of organic farming
Source: Adopted from Meemken and Qaim 2018

3. The international scenario

There are numerous organizations in Europe, America, and Australia that promote the organic agricultural movement. These organizations, such as the International Federation of Organic Agriculture Movements (IFOAM) and Greenpeace, have investigated the problems associated with chemical farming practices and compared the benefits of organic farming to the latter. Since then, organic agricultural movements have extended throughout Asia and Africa. IFOAM was created in 1972 in France. It leads and manages global organic farming activities by promoting organic agriculture as an environmentally benign and sustainable practice. IFOAM engages in a wide range of organic farming-related activities, such as exchanging knowledge and ideas among its members and representing the movement in governmental, administrative, and policy-making forums on a national and international scale (IFOAM, 1998).

The United Nations FAO supports organic farming in member countries. It also aims to harmonize national organic standards, which is critical for increasing worldwide trade in organic products. During this time, international trade in organic foods grew at a rate of about 20-22 percent per year. Cotton. Cut flowers, animals, and pot plants are popular non-food items on global markets. Organic farming is expected to expand globally as many countries adopt their own standards and rules. The United States and the European Union have extensive National Organic Programmes, while Japan implemented organic agricultural rules in the early 1990s. Australia and Canada. New Zealand, Israel, and Brazil have established organic criteria comparable to those of the United States and the European Union. China. Thailand, South Korea, the Philippines, Turkey, and Mexico have all formed certification bodies. India has also implemented the National Programme for Organic Production (NPOP), which includes national standards. Organic items are trusted because of the label or logo that has been recognized by the certification process.

(a) provide a distinguishable label, logo, or symbol

(b) deliver consumers with assurance that the product is truly organic.

4. Need for organic farming in India

The necessity for organic farming in India stems from the unsustainable nature of agriculture production and the environmental damage caused by traditional farming practices. The current system of agriculture, which we call 'conventional' and which is practiced all throughout the world, emerged in western nations as a result of their socioeconomic context, which supported an overarching goal for wealth creation. Other countries' farming methods are essentially self-destructive and unsustainable. The current farming method was developed by Americans who dispossessed Indians of their farms from the beginning. Agriculture and associated sectors in India employ 65 percent of the workforce and generate 30 percent of the national GDP. In the future, population expansion and income growth will raise demand for food grains as well as agricultural raw materials for industry. Obviously, the area under cultivation cannot be enlarged, and the current 140 million hectares will have to meet future growth in such demands. There is a strong case for even a decrease in cultivated land as a result of urbanization and industrialization, which will put significant strain on the existing farmed area. India, which includes semi-arid and desert parts, can gain from the experiment. IFOAM, which has 600 organizational members from 120 countries, inspired and assisted the organic agriculture movement in India.

As per current status in India there are several states practicing Natural Farming. Prominent among them are Andhra Pradesh, Chhattisgarh, Kerala, Gujarat, Himachal Pradesh, Jharkhand, Odisha, Madhya Pradesh, Rajasthan, Uttar Pradesh and Tamil Nadu. As of now more than 10 lakh ha. area is covered under natural farming in India as shown in Fig. 2. Different State governments are promoting natural farming through various schemes. Recently Andhra Pradesh Government Launch Indo German Global Academy for Agro-ecology Research and learning (IGGAARL) at Pulivendula on 7th July 2022. As per the study, India which holds almost 20 %

of the world population has consumption of only 1 % organic produce of the total organic produce.

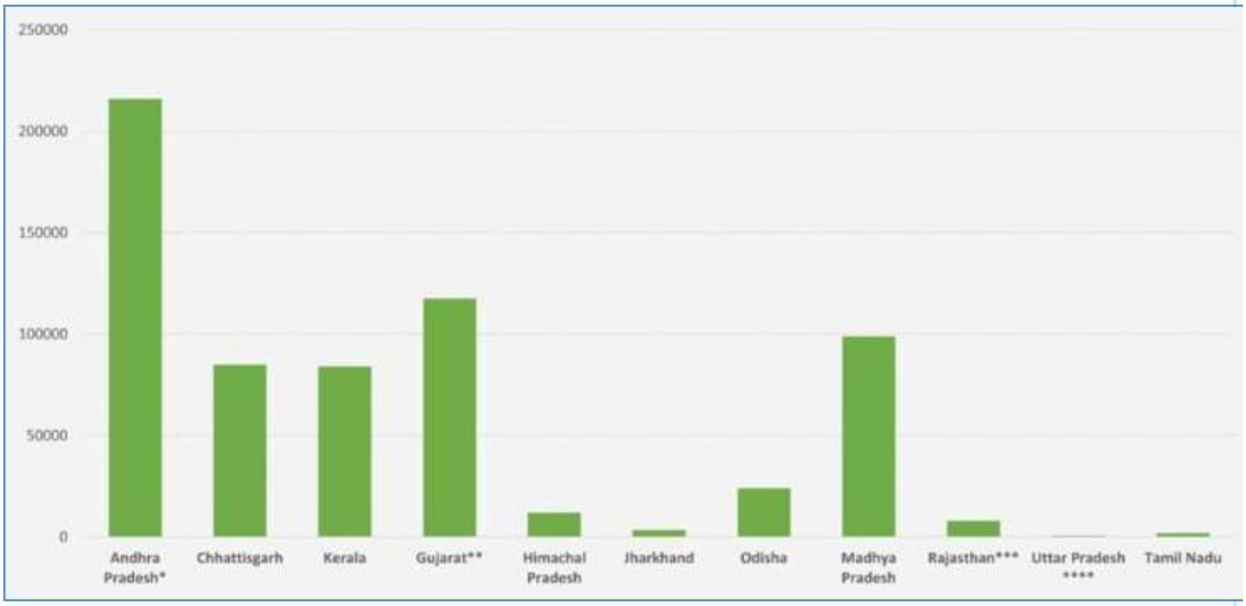

Figure 2: Major states in India practicing Natural Farming (Source: http://naturalfarming.dac.gov.in)

5. Organic agriculture and characterstics

5.1 Organic agriculture and yield

Yields relative to comparable conventional systems are closely related to the conventional systems' farming intensity. This is true not only for comparing areas, but also for crops within a region and for specific crops across time. An oversimplification of the impact of organic agricultural conversion on yield. Several studies have found that in drought conditions, crops in organic agriculture systems produce much better yields than comparable conventional agricultural crops. Other research has found that organic systems have reduced long-term production variability. An assessment of 208 projects in poor tropical countries that implemented modern organic practices revealed average yield gains of 5-10% in irrigated crops and 50-100% in rainfed crops (Pretty and Hine, 2001). Some assessments of yield comparison studies have not supported the so-called organic transition effect, which predicts a yield reduction in the first 1-4 years of transition to organic agriculture, followed by a yield increase once soils have generated appropriate biological activity (Neera *et al.*, 1999).

5.2 Organic agriculture and food security

The widely held belief that widespread conversion to organic agriculture will cause a catastrophic reduction in the world's food supply or a sharp increase in the conversion of undisturbed lands to agriculture has not been substantiated by modelling studies. According to conversion studies, domestic food consumption wouldn't change much, exports would depend on the crop, but farming structures would surely change as agriculture diversified. If organic agriculture were extensively practiced, increased investment in research and extension would lead to increases in agricultural productivity above current averages. According to Stanhill

(1990) and Wynen (1994), with today's knowledge and technology, organic farmers cannot worldwide supply enough food for everyone. This is especially true for developing countries with high population growth.

6. Nutrient management in organic farming

Many people think of organic farming as a type of agriculture that uses exclusively organic inputs for nutrition delivery and disease and insect management. In actuality, it is a specialized type of diversified agriculture in which farming issues are only resolved with the aid of regional resources. The word "organic" alludes to the idea of a farm as an organism rather than the specific type of inputs that are employed. On the basis that farm production and profitability might not increase with just organic inputs due to the extremely limited supply of organic sources, organic agriculture has frequently come under fire. creation of many composting techniques, such as vermicomposting, phosphor composting, N-enriched phosphor composting, etc. improves the quality of composts through enrichment with nutrient-bearing minerals and other additives. These manures have the ability to effectively meet the nutrient needs of crops and encourage the activity of good macro- and microflora in the soil. Scientists and farmers alike have some reservations about whether organic sources alone can provide crops with the minimum amount of nutrients they need. Only 30% of our total cultivable land is currently equipped with irrigation, which results in a greater pesticide use rate than rain-fed zones. Increasing input usage efficiency at each stage of farm operations is a fundamental necessity for organic farming. As a result, organic farming is frequently referred to as knowledge-based farming rather than input-based farming. Agrochemical-based, high-input agriculture is not sustainable over the long term due to a slow drop in factor productivity, which has a negative effect on the health and condition of the soil (Subbarao, 1999; Stockdale, 2000).

7. Environmental benefits of organic agriculture

The effects of organic farming on the environment support agro-ecosystem interactions that are essential for both agricultural production and nature preservation. Environmentally beneficial services include soil formation and stabilization, waste recycling, carbon sequestration, nitrogen cycling, predation, pollination, and habitat maintenance. The environmental costs of conventional agriculture are high, and there is compelling evidence that switching to organic agriculture will significantly improve the environment. A review of over 300 reports found that none of the 18 environmental impact indicators (floral diversity, faunal diversity, habitat diversity, landscape, soil organic matter, soil biological activity, soil structure, soil erosion, nitrate leaching, pesticide residues, CO_2, N_2O, CH_4, NH_3, nutrient use, water use, and energy use) showed a significant difference between organic farming systems and conventional farming systems (Stolze *et al.,* 2000).

8. Problems, constraints and prospects

A change in the agricultural system in a nation with more than a billion citizens should naturally be carefully considered and necessitate extreme care and prudence. There might be a number of obstacles along the road.

8.1 Problems and Constraints

The most significant barrier to the development of organic farming is the government's reluctance to make a definite decision to support organic farming. According to research, the following are the main obstacles to the expansion of organic farming in the nation:

a) Lack of awareness

It is a reality that many farmers in the nation are only vaguely familiar with organic farming and its benefits over traditional farming practises. The agricultural community must be aware of and willing to use bio-fertilizers and biopesticides. It's also essential to have knowledge of the availability and value of additional nutrients that can enrich the soil in order to boost productivity. Farmers are ignorant of how to make compost using contemporary methods and how to use it.

b) Shortage of bio-mass

Many specialists and knowledgeable farmers are unsure as to whether organic materials can provide all of the nutrients in the necessary proportions. They believe that even if this issue can be resolved, the organic matter that is now accessible is insufficient to satisfy the needs. After harvest, the farms remove the agricultural remains needed to create vermicompost, and these residues are utilized as fuel and feed.

c) Inadequate supporting infrastructure

Despite the NPOP's approval in 2000, the state governments have not yet developed policies or a reliable implementation plan. Only four organizations may be accredited, and they only have knowledge of fruits and vegetables, tea, coffee, and spices.

d) High input costs

India's small and marginal farmers have been using the traditional agricultural method as a kind of organic farming. The cost of applying organic manures such as groundnut cake, neem seed and cake, vermicompost, silt, cow dung, and others is rising, making them expensive for small producers.

e) Marketing problems of organic inputs

Due to the low demand for these items, shops do not want to deal with them, hence they lack a marketing and distribution network. Other significant issues influencing the markets for organic inputs in India include higher profit margins for chemical fertilizers and pesticides used in retail, as well as extensive advertising efforts by producers and dealers.

f) Absence of an appropriate agriculture policy

Promotion of organic farming for both export and internal consumption, the needs of millions of the poor in terms of food security, and national self-sufficiency in terms of food production and product are crucial concerns that must be addressed in an effective agriculture policy of India. To effectively promote organic agriculture, a suitable agriculture policy must be developed.

g) Lack of financial support

In India, there is no such thing as financial assistance like there is in developed nations like Germany. Additionally, neither the State nor the Union governments offer any support for the marketing of organic products. For the promotion of organic farming, not even the financial aid given to conventional agricultural methods is present.

h) Low yields

When farmers go from conventional to organic agricultural practises, some yields are lost as a result of the removal of synthetic inputs. Small and marginal farmers are unable to convert to organic farming and bear the first 2–3 year production risk. There are no plans in place to pay them while they are pregnant. If organic agricultural goods are made available, the price surcharges on such products will not assist much.

i) Inability to meet the export demand

The sophisticated western nations like the United States, the European Union, and Japan have a significant demand for organic products. According to reports, US customers are willing to pay a premium price of 60% to 100% for organic goods.

j) Conflicts of interest

In order to react to fertilizers and chemicals, hybrid seeds are created. The traditional agricultural business has a stake in it, as do the importers of seeds, fertilizer, and pesticides into the nation. These interests are the reason for their hostility to organic farming.

k) Social and political factors

Political interference in India's agricultural sector aims to grant privileges in exchange for electoral advantages.

9. Status of organic agriculture in india: production, popularity, and economics

Global demand for organic food and farming has increased. Over the past three decades, the overall area of farmland used for organic cultivation has continuously expanded since 1985 (Willer and Lernoud, 2019). Globally, there were 69.8 million hectares of land that was organically managed as of 2017, which is a 20% increase over 2016 (or 11.7 million hectares of land). According to Willer and Lernoud (2019), this is the organic agricultural industry's biggest increase ever observed. With a total area of 1.78 million hectares dedicated to organic agriculture, India moved up to eighth place, surpassing Australia, which has the highest organic land area at 35.65 million hectares (Willer and Lernoud, 2019). In 2017, Additionally, it was said that the availability of organic vegetables is reportedly growing significantly on a daily basis worldwide. India is the country with the most organic producers (835 000), and Asia accounts for the highest share (40%) of global organic output. In India, organic farming has grown very slowly, making up approximately 41 000 hectares, or 0.03% of the country's total arable land. The production of organic farming in India in 2002 was 14 000 tonnes, of which 85% were exported (Chopra *et al.,* 2013). The lack of a solid government policy to support organic agriculture was deemed to be the biggest obstacle to the development of organic farming in India. The expansion of organic farming in India also faced a number of significant challenges, including poor marketing strategies, a lack of biomass, inadequate infrastructure, high input costs, inappropriate marketing of organic inputs, ineffective agricultural policies, a lack of financial support, an inability to meet export demand, poor manure, and low yields (Bhardwaj and Dhiman, 2019).Numerous initiatives and programmes have recently been put into place by the Indian government to promote organic farming there. Among these the most important include

1. The Paramparagat Krishi Vikas Yojana,
2. Organic Value Chain Development in North Eastern Region Scheme,
3. Rashtriya Krishi Vikas Yojana,
4. The mission for Integrated Development of Horticulture
   a. National Horticulture Mission, b. Horticulture Mission for North East and Himalayan states, c. National Bamboo Mission, d. National Horticulture Board, e. Coconut Development Board, d. Central Institute for Horticulture, Nagaland
5. National Programme for Organic Production,
6. National Project on Organic Farming, and
7. National Mission for Sustainable Agriculture (Yadav, 2017).

10. Future opportunities for organic agriculture in India

In India, 55% of the work force and 67% of the population depend on agriculture and allied industries. India's fastest-growing population's basic needs are satisfied by agriculture, which generated 30% of the nation's GDP. It has been discovered that organic farming is an ancient Indian tradition that has been followed for millennia in innumerable farms and rural communities. Modern farming methods' introduction and the growing weight of the population have given rise to a preference for conventional farming, which uses synthetic fertilizers, chemical pesticides, the employment of genetic modification techniques, etc. Even in developing nations like India, there is a growing demand for produce cultivated organically since consumers are more conscious of the safety and quality of their food, and the organic approach has a significant impact on soil health because it uses no chemical pesticides. The potential for generating revenue from organic farming is enormous (Bhardwaj and Dhiman, 2019). According to Reddy (2010) and Deshmukh and Babar (2015), India's soil is endowed with a variety of naturally occurring organic nutrient supplies that support organic farming. India is a nation with an established traditional agricultural system, creative farmers, vast drylands, and minimal usage of chemical pesticides and fertilizers. Additionally, when very minor chemicals are used for a long time, the north-east hilly portions of the nation produce naturally organic soils (Gour, 2016). Based on their expertise, in-depth observation, tenacity, and practices for sustaining soil fertility and pest control that are deemed helpful in bolstering organic output and ensuing economic progress in India, traditional Indian farmers have a keen understanding. It's impressive how far organic farming has come. With 1.78 million hectares of organic agricultural land in the world (Willer and Lernoud, 2019), India was the eighth-largest producer of organic food in the world as of today.

11. Important issues regarding organic farming

India is experiencing negative repercussions of the conventional farming system, including unsustainable agricultural productivity, environmental degradation, issues with health and sanitation, etc. As an alternative to the current system, organic agriculture is gaining popularity.

8. With the current state of knowledge and technology, a large-scale switch to organic agriculture would cause a food crisis since, especially in intensive agricultural systems, organic systems' yield losses from conventional agriculture range from 10 to 15%.
9. An alternate sustainable source of fertilizer supply is organic manure. The potential for using organic wastes and its actual use is far apart.
10. By managing farming systems strategically and making structural improvements, organic farming systems may help both the environment and agriculture. Both rich countries like the United States and emerging ones like India may profit from organic farming.
11. While the advantage of organic foods in terms of health and safety has been established, there is no scientific proof to support their superiority in terms of flavour and nutrition, as the majority of research are frequently ambiguous.
12. Lower input costs and favourable price premiums can balance off lower yields and make organic farms as lucrative as conventional farms, if not more so.
13. Pest and disease control techniques used in organic agricultural systems are mostly proactive rather than reactive. In contrast to conventional farms, the prevalence of pests and diseases is often lower on organic farms.

Conclusion:

In India, the unsustainable agricultural productivity, environmental degradation, health and sanitation issues, etc. are all a result of the traditional farming system. The popularity of organic agriculture as an alternative to the current system is growing. Many nations have been successful in converting 2–10% of their farmed land to organic farming. The demand for organic goods is increasing quickly (20% annually in the major industrialized nations). India looks to be far behind other countries in the use of organic farming. The NSOP, which have been established, and the acceptance of four accrediting agencies (all government organizations) with specialized knowledge of only a few crops appear to be the sole accomplishments to date. The future for organic farming in India is to increase the area under cultivation, promote farmer-to-consumer linkages, and create an enabling policy environment. While the government has taken some initiatives to promote organic farming in the country, the private sector has also promoted organic farming in India.

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RECENT ADVANCES IN MECHANISATION OF PRE-COCOON SERICULTURAL ACTIVITIES

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Abstract:

Sericulture is an agro-based, labour-intensive, cottage industry that is practised commercially in 25 countries recruiting nearly 30 million people globally. The various sericultural activities can be broadly classified as pre-cocoon and post-cocoon activities. The pre-cocoon activities encompass moriculture (raising of mulberry plantations), sericulture (raising of silk worms), and cocooning /spinning activities of the worms generating huge scope for employment. Although India is the 2nd largest producer and consumer of silk across the globe, it is still witnessing a big blow from the Chinese and Japanese silk Industries primarily because foreign silk is superior in quality and less expensive to buy. In India, approximately 65-70% of cost involved in cocoon production is spent is paying the wages to professionals for various activities. Manual operation also requires lump sum money, time and resources that further hikes the production costs. Therefore, mechanisation in all the three sectors of pre-cocoon activities can aid in production of superior and affordable silk products, cutting down the labour costs to minimal. This article summarises the importance of mechanisation in pre-cocoon sericultural activities and various innovative tools and machines available currently in the sector.

Keywords: Mechanisation, Moriculture, Pre-cocoon, Sericulture, Silk

1. Introduction:

Mechanisation precisely means scientific application of tools, machines, and mechanical aids to procure higher benefits and scale up production, productivity, profitability, and efficiency with which the work is done. Apart from scaling up production, it reduces the time and cost involved in doing a particular operation. Mechanisation is also the solution to drudgery currently witnessed by workers in the sector. It helps in precisely managing the inputs as seeds, fertilizers or various agro-chemicals and resources. Thus, it helps to boost up the overall income of farmers and improve the quality of their lives.

Sericulture is the art of rearing silkworms for obtain glossy silk fibers (Vijayakumar *et al.*, 2007). The sericultural sector demands huge labour in operations like preparation of land, tillage, planting of seeds or saplings, training and pruning, intercultural operations, application of agro-chemicals for crop production and protection, intercultural operations, chopping leaves to required size depending on the stage of the larvae, silkworm egg production, rearing of chawki and late age worms, selection and mounting of the ripe worms over the cocoonages or mountages, care during cocoon spinning, cocoon harvesting, and transport of cocoons, and proper protective measures for disinfection at all stages (Srivastav *et al.*, 2005). In countries like Japan most of these activities are mechanized, however India is still dependent on manual labour or tools that have limited efficiency that further questions the timeliness of these critical operations. Under tropical conditions approximately 5-6 crops are taken per year, that allots nearly 60-70 days for each crop (Dandin *et al.*, 2003). Under such situation, assuring the timeliness of the activities as pruning, weed management in mulberry garden, intercultural operations, leaf harvests, storage and larval feeding, application of body and bed disinfectants, mounting and harvesting of cocoons etc. needs to ensure for successful seri-crop production (Rangaswami and Jolly, 1976). The number of man day required for major pre-cocoon sericultural activities is represented in percentage for India and Japan (Fig. 1) (Dandin *et al.*, 2003). It can be clearly understood that a greater number of man days are required for every activity in India as compared to Japan, suggesting that sericulture in Japan is highly mechanized. Further the labour efficiency index of the two countries shows that labour output is 10 times higher for mulberry cultivation and 4 times higher for silkworm rearing in Japan as compared to India (Fig. 2). Therefore, mechanisation becomes critical for various operations in Indian sericulture industry (Dandin *et al.*, 2003).

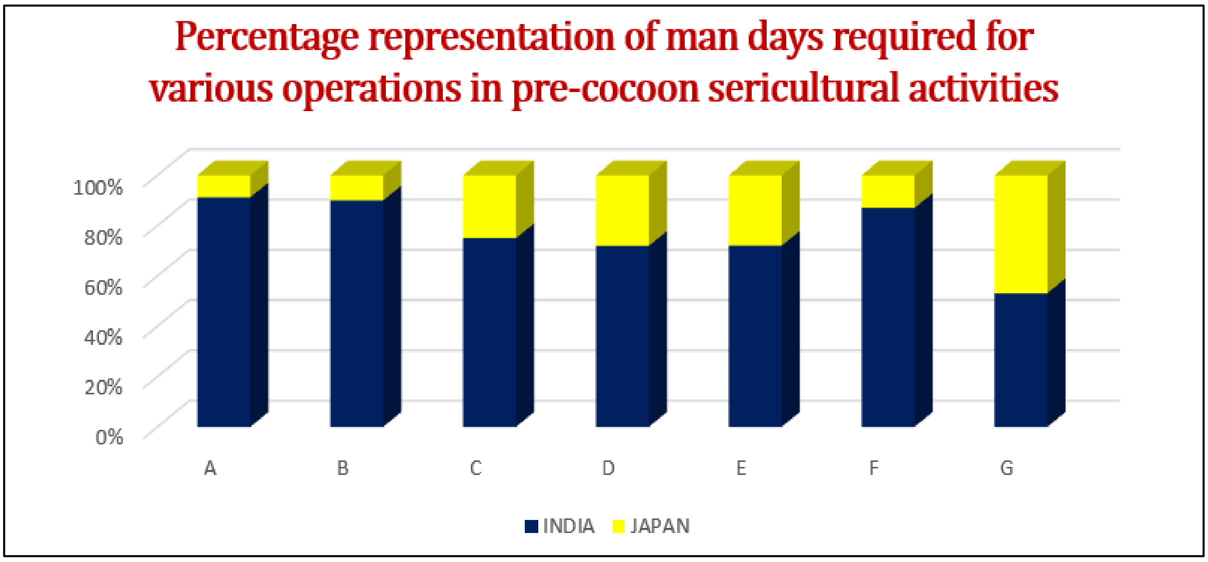

Figure 1: Percentage representation of man days required for various operations in pre-cocoon sericultural activities. (A) Mulberry cultivation (To produce 1500 kg leaf): Cultivation, fertilizer application and inter-cultivation; (B) Mulberry pruning and other operations; (C) Plant protection; (D) Silkworm rearing (To produce 60 kg cocoons): Preparation of rearing house, cleaning, disinfection; (E) Mulberry leaf harvest; (F) Silkworm rearing; (G) Mounting of worms, cocoon harvesting & marketing. The man days required for all the above activities are higher in India as compared to Japan

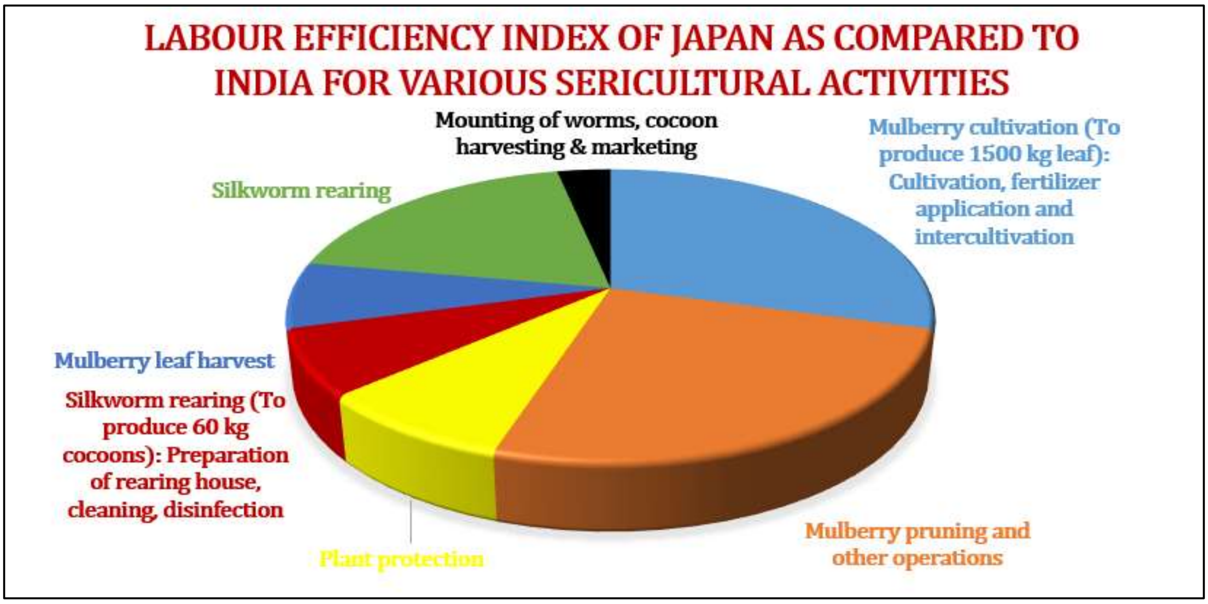

Figure 2: Labour efficiency index of Japan as compared to India. The labour output in Japan is 10 times higher for mulberry cultivation and 4 times higher for silkworm rearing as compared to India

2. **Machineries developed**

Mulberry cutting preparation machine

Mulberry is the sole food plant of monophagous silkworm *Bombyx mori* (Dewangan, 2018). It is a hard, woody, recalcitrant, perennial food plant that is mostly propagated by hardwood cuttings. Preparation of cuttings manually using secateurs, knifes, and conventional tools is laborious and time consuming. Therefore, CSRTI, Mysore have invented an electrically operated mulberry cutting preparation machine (Fig. 3a) that is fast, highly efficient and minimizes drudgery. It prevents any damage or wounds to the cuttings preventing disease development (Rangaswami and Jolly, 1976). While manual preparation of cuttings for plantation generates 1500-2000 cuttings/day, the machine is known to generate nearly 1200-1400 cuttings/hour. It must be noted that shoots must be firmly held against the cutting blade of the machine while preparing the cuttings. Also, care must be taken use shoots of optimum thickness, using too thick shoots may harm the machine and the operator. The machine costs around INR 10,000 (Kawakami and Yanagawa, 2003).

Mulberry leaf chopper

Mulberry leaves are the sole food of silk worm larvae. Larvae of silkworm possess 5 instars and each instar must be fed with leaves of different sizes to meet its nutritional and physiological demands. Chawki worms/ young age worms (I-II instar) require finely cut fresh, tender leaves whereas late age worms (III-V instar) require coarse and mature leaves to feed (Rangaswami and Jolly, 1976). Therefore, chopping the leaves and shoots of mulberry to required size is critical to ensure the health of the larvae. Thus, CSRTI, Mysore developed a mulberry leaf chopper (Fig. 3b), manually or electrically operated and chops leaves to different sizes as per the age of the larvae. The machine can chop nearly 150-175 kg of mulberry leaves

/hour (Srivastav *et al.,* 2005). The leaves are gently fed to the machine with sufficient work area around the machine. Thus, it saves a lot of time in leaf chopping and ensures the freshness of the leaves fed to the larvae.

Mulberry shoot crushing machine

Left over mulberry shoots and leaves from the rearing operations serve as raw material for the compost and vermin compost making which is effectively utilized to enrich the organic matter of the soil. The mulberry shoot crushing machine (Fig. 3c) is an electrically operated invention of CSRTI, Mysore that effectively cuts and crushes all types of plant materials including coconut fronds, thus facilitating quick conversion and fast decomposition of the shoots. The compost is made ready by 4-5 months instead of 9-12 months in the conventional processes due to the smaller size of the shoots facilitating easy and quick decomposition (Srivastav *et al.,* 2005). The machine costs around INR 40,000. Care must be taken not to feed too hard shoots into the machine that may damage its working and operations.

Disinfectant dusting machine for chawki worms

The chawki worms are susceptible to deadly diseases that may cause severe crop losses. Therefore, use of silkworm body and rearing bed disinfectants is a curative and a protective measure to ensure healthy crop. Dusting worms with lime (to reduce moisture in the rearing bed before the worms settle for moulting) and disinfectants like Vijetha/ Vijetha Supplement/ Ankush/Amruth (to prevent silkworm diseases) etc. is highly important. The electrically operated dusting machine (Fig. 3d) invented by CSRTI, Mysore, durable, fast, efficient, and ensures uniform dusting. The machine also minimizes human exposure to the disinfectants and thus is user-friendly. It is used widely in the chawki rearing centers (CRCs) that facilitates easy disinfection of the worms. The machine is capable of dusting nearly 18-20 trays per minute. The estimated cost of the machine is around INR 30,000 (Chanotra and Bali, 2019). While using the machine care must be taken to use smooth or clump free dry powder formulations.

Mature silkworm separator

Silkworms reach the stage of maturity after the completion of V instar. Therefore, the ripe worms need to be separated from the mulberry twigs and mounted timely to warrant synchronization and uniformity in spinning and harvesting operations. Using the silkworm separator (Fig. 3e) innovated by CSRTI, Mysore, delay in spinning procedures due to manual handling and operations especially in use of rotary cardboard mountages. The separator is manual or electrically operated. Manually operated machines costing INR 6000 are used by small and marginal farmers sufficient for 45-50 dfls/hour whereas electrically operated machines costing INR 10,000 are used by large farmers sufficient for 120-125 dfls/ hour. The machine ensures that the mature larvae are not injured during separation from the mulberry twigs. Care must be taken not to resort separation before the larvae ripe or mature (Chanotra and Bali, 2019).

Seri-Room heater

It is an electrically operated room heater (Fig. 3f) used to maintain desired temperature in the rearing room. It is durable, efficient and is set to desired temperature as per the age and stage of the larvae. The heater is supposed to be placed on ground on a levelled surface. The heater comes with a cost of INR 5000 (Chanotra and Bali, 2019). It is never recommended in open type rearing house.

Seri- Humidifier cum heater

It can be used to set desired temperature and humidity (Fig. 3g) as per the larval stage. It must be ensured that a minimum level of water is maintained in the machine. The machine comes with a cost of INR 16, 000 (Chanotra and Bali, 2019). It is never recommended in open type rearing house.

Figure 3: (a) Mulberry cutting preparation machine; (b) Mulberry leaf chopper; (c) Mulberry shoot crushing machine; (d) Disinfectant dusting machine for chawki worms; (e) Mature Silkworm separator; (f) Seri-Room Heater; (g) Seri-Humidifier cum Heater

Plastic tray washing machine

Plastic trays are used to rear young and late age worms. The trays need to be frequently cleaned and disinfected to prevent transmission of diseases. This process is time consuming and laborious. Additionally, it is not considered user-friendly and leads to excessive use of water. To counter the above listed issues CSRTI, Mysore has developed a pressurized water spray and washing and scrubbing system (Fig. 4a) to promote proper disinfection and hygienic rearing of chawki worms at CRCs and various grainages and egg production centers. It optimizes the utilization of water and disinfectants. The machine works with an efficiency of cleaning nearly 60-70 trays/ hour (Chanotra and Bali, 2019) and is estimated to cost around INR 35, 000. Care must be taken to use and wash trays only of specified dimensions in the machines.

Cocoon harvester for rotary mountages

Rotary mountages are mountages having specific section (1560 sections) for mounting the ripe worms. The mountages are known to yield cocoons of superior quality with uniform size and high reelability. As the cocoons are separated by slots, the manual harvesting of the cocoons from such mountages is time consuming and labor-intensive (Chanotra and Bali, 2019).

Therefore, hand or foot operated cocoon harvesters (Fig. 4b) have been devised for rotary cardboard and plastic mountages. It is easy, quick and incur no damage to the cocoons while harvesting (Chanotra and Bali, 2019). The cardboard frame of the mountage is fixed in the machines and the cocoons are harvested by applying gentle pressure from the back. The machine costs INR 8000. Care must be taken to apply uniform pressure from all sides in hand operated cocoon harvesters.

Cocoon harvester for plastic collapsible mountages

Plastic collapsible mountages are plastic wavy corrugations web and are widely used mountages for spinning cocoons. They are used in self-mounting of the worms. A cocoon harvester device (Fig. 4c) simplifies the process of obtaining healthy, uniform cocoons from such mountages (Bindroo and Kishur, 2011). Cleaning and deflossing (removal of outer floss layer of the cocoon) is also done along with harvesting (Rangaswami and Jolly, 1976). The machine also efficiently sorts out the flimsy and defective cocoons before harvesting. It works with an efficiency of harvesting cocoons from 150-160 mountages/ hour and costs nearly INR 18000. Care must be taken to insert only one mountage between the shafts of the machine and allow gentle movement. Inserting more than one mountage in layers may block the shaft area of the machine (Rangaswami and Jolly, 1976).

Cocoon deflossing machines

Figure 4: (a) Plastic tray washing machine; (b) Cocoon harvester for rotary mountages; (c) Cocoon harvester for plastic collapsible mountages; (d) Cocoon deflossers

Floss is the outermost layer of the cocoon which must be removed to find the true reeling end. Cocoon deflossers (Fig. 4d) are fast, efficient, labour and time saving, cost-effective machines that work to remove the floss layer of the cocoons. Cocoons are fed to machine in a single layer and the floss is carefully removed without damaging the cocoon. They can be manual (INR 2500), motorized (INR 12,500) and motorized cum hand operated (INR 10,000). Care must be taken to remove the floss collected or deposited in the machine frequently for its efficient working (Chanotra and Bali, 2019).

Folding and bundling tool for plastic collapsible mountages

Plastic collapsible mountages are reusable and durable. However, they must be stored while maintaining its proper shape and using less space. The bundling tool (Fig. 5a) helps to properly fold the mountage after use and the folded mountages are kept one above the other into a frame that maintains its shape and integrity (Srivastav *et al.*, 2005). It is metal frame to fold and hold the plastic collapsible mountages and costs INR 200.

Silkworm seed cocoon cutting machine

The machine (Fig. 5b) facilitates the fast cutting of the seed cocoons and reduces the drudgery involved in the process (Rangaswami and Jolly, 1976). It is finely adjustable to the cocoon size. It works with an efficiency of cutting approximately 5000-5500 cocoons/ hour and costs INR 35000. Care must be taken to place only uniform size cocoons to the slot avoiding double, pierced and flimsy cocoon (Verma and Dandin, 2006).

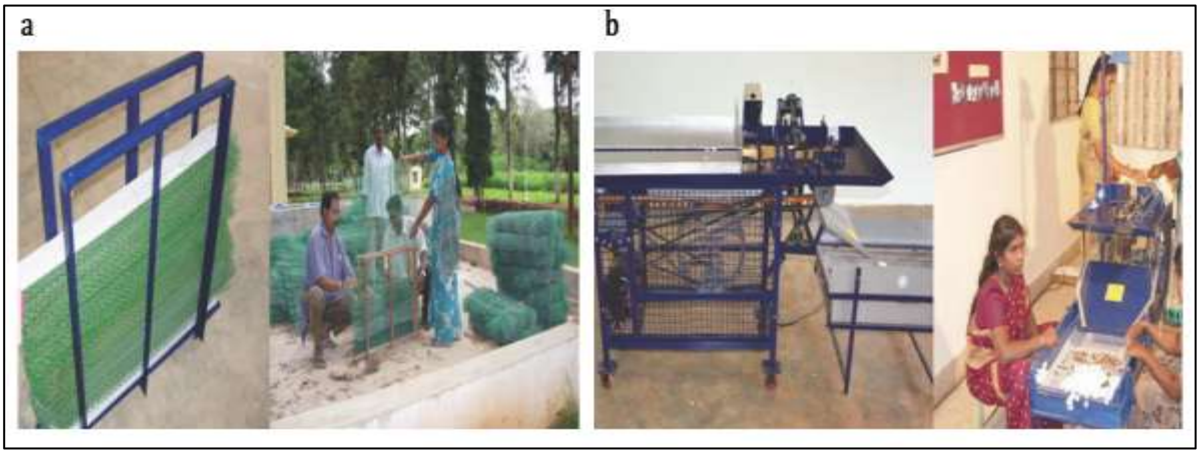

Figure 5: (a) Folding and bundling tool for plastic collapsible mountages; (b) Seed cocoon cutting machine

Conclusion:

Mechanisation is the key to efficient utilisation of manpower. It reduces labour requirement, curtails the cost of production, reduces the drudgery, and ensures timeliness at various levels of production. Mulberry cultivation is known to require 800-man days/ha/year which can be reduced to just 80-man days ($1/10^{th}$) /ha/year involving mechanisation of operations (Rangaswami and Jolly, 1976). Similarly, rearing of silkworms demands labour that can be reduced to minimum using mechanisation. Hence, mechanisation in pre-cocoon sericultural activities is essential to endure profitability of sericultural sector, reduce import dependency, expand sericultural operations horizontally and elevate the quality of Indian silk.

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A SUSTAINABLE AND ECO-FRIENDLY ALTERNATIVE TO TRADITIONAL PESTICIDES IN AGRICULTURAL CROPS

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Abstract:

Agricultural practices that are sustainable integrate effective resource utilization with minimal environmental impact. As a result of these practices, a potential tool that is highly effective, target-specific, and responsible for reducing environmental risks may be found as an alternative to synthetic pesticides. Biopesticides are of various origin that includes several types of entomopathogenic viruses, fungus, bacteria,certain nematodes, and alsoplant secondary metabolites, are gaining increasing importance as they are alternatives to chemical pesticides and are a major component of many pest control programs. It also plays an important role in sustainability of agricultural bio-economy. Given how quickly the world's population is growing, managing agricultural production systems in a sustainable way is one of humanity's greatest challenges going forward. The advantages to the ecosystem provided by many significant biological resources justify the incorporation of biopesticides in IPM programmes. The use of biopesticides has been advanced via research and development, significantly reducing environmental contamination. The creation of biopesticides encourages agricultural modernization and will undoubtedly lead to a progressive abolition of chemical pesticides. The main objective of biopesticide research is to develop cheap biopesticide products that may be used on farms as a tool in integrated pest management strategies. Further research is required in several areas, including bioformulation and areas like commercialization, and biopesticide research is still ongoing. The development of biopesticides at this time is primarily focused on expanding their action spectrum and replacing chemical pesticides, its role in integrated pest management, use of botanical and semiochemical in pest management have been discussed in this review.

Keywords: Biopesticides, Eco-friendly pesticide, Sustainable Agriculture, Microorganisms, Bioeconomy, Bacteria, Fungi

1. Introduction:

According to FIFRA, a pesticide is "any substance or aggregate of substances meant for use as a plant regulator, defoliant, or desiccant, as well as any substance or aggregate of substances meant for use in stopping, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, or weeds, or any other forms of lifestyles declared to be pests." From the till the existing, numerous combinations were advanced to govern fungi, insects, weeds, and different pests. Starting in the past due Nineteen Sixties, the capability of the chlorinated hydrocarbons for bioaccumulation and lengthy-term toxicity became widely identified [1]. Herbicides or weed-killers may also be taken into consideration as pesticides, and are used to kill undesirable plant life that allows you to go away the desired crop surprisingly unharmed and properly supplied with vitamins, main to a more worthwhile harvest [2].

However, the world meals manufacturing is continuously stricken by bugs and pests at some point of crop increase, harvest and storage. As a be counted of truth, there may be a predicted loss of 18–20% concerning the once-a-year crop production international, accomplishing a cost of greater than USD 470 billion [3]. Moreover, bugs and pests now not only represent a menace to our homes, gardens and reservoirs of water, however also, they transmit a number of sicknesses through appearing as hosts to a few ailment-causing parasites. consequently, the mitigation or manipulate of pests' sports may also lead to a good-sized reduction of the world food crisis in addition to the improvement of human and animal health [4]. Very few insecticides applied after DDT have long half-lives in the environment, and none of them bioaccumulate in the same way as organochlorines did. This intricate is illustrated as properly via the neonicotinoid insecticides (inclusive of imidacloprid, clothianidin, thiamethoxam, acetamiprid and thiacloprid). This greater latest class of molecules is active towards several pests (focused on the acetylcholine receptors) and may be implemented to distinct cultures (which include tobacco, cotton, peach and tomato).

This focus on pest issues and the environment has led to the search for efficient and insecticides that break down over time, preventing pest resistance, which is likewise pest-precise, non-phytotoxic, trustworthy to mammals and comparatively less high-priced to be able to reap a sustainable crop production. in addition to the attention completed inside the numerous international locations (which includes China, united states of america, Brazil or Turkey) and also in European Union, the law has end up increasingly more stringent and binding with the effects of a inexperienced preference inside the use of pesticides and approbation of plant derivatives allowed in the organic manipulate regulation (as an instance: clove (*Syzygium aromaticum* [L.] Merr. and L.M. Perry [Myrtaceae]) crucial oil within the European Union, the derived terpenes from *Chenopodium ambrosioides* L. (Amaranthaceae) in US, Ginkgo (*Ginko biloba* L. [Ginkgoaceae]) fruit extract and *Psoralea corylifolia* L. (Leguminosae) seed extract in China or the extract of *Tephrosia candida* DC. (Fabaceae) in Brazil. When biopesticides are economically priced, target-specific, less harmful to human health, bio-degradable, and thus ecologically friendly, they can achieve the necessary criteria, become crucial for resolving pest issues, and promote sustainable production. Biopesticides are pest control sellers based totally on biochemicals derived from dwelling microorganisms, bugs and plants. In this review, we can attention on biopesticides from plant foundation. The insecticides that are derived from plants include (elements that kill bugs in any degree of improvement: adults, ova and larvae), which act with the aid of numerous exclusive mechanisms affecting one or greater biological systems, along with anxious, breathing and endocrine structures, as well as water balance. Additionally, pesticides can also be categorized relying at the mode of its access into the insect, specifically: belly poisons, touch poisons and fumigants.

2. Biopesticides: A historical perspective

Insecticides are substances or mixtures of substances that may be used specifically in agriculture or in public health safety programmes to protect plants from pathogens, weeds, or diseases, as well as people from vector-borne illnesses like malaria, dengue fever, and schistosomiasis. Typical examples include insecticides, fungicides, herbicides, rodenticides, and plant growth regulators.

In her book "Silent Spring," released in 1962, Rachel Carson discussed the problems that could arise from the widespread use of insecticides. The effects of pesticides on human health and the environment were greatly sparked by this work Ratcliffe observed an increase in the number of raptor nests with damaged eggs in the UK in 1967. Pest resistance began to appear in the 1970s, and this, together with the book "Silent Springinfluence's and mounting evidence of the effects of pesticides, led to the U.S.'s 1972 ban on the use of DDT.Thereafter, different nations discontinued using DDT, as nicely [5].

From another study that can be concluded that pesticides are regularly considered a short, clean and less expensive answer for controlling weeds and insect pests in urban landscapes. Insecticides have infected almost every factor of our environment. Stable phase extraction (SPE) is used to extract organochlorine pesticide residues from water samples [1]. The study conducted inside the floor water of Sharda River Place in Lakhimpur Kheeri, Uttar Pradesh, India, reports the concentration tiers and distribution patterns of the 21 organochlorine pesticide residues. The highest amount often encountered Dieldrin, heptachlor epoxide, and isomers were some of the organochlorine pesticides found in surface water. The incidence of these compounds in Sharda River region floor waters may be attributed to severe agricultural interest in addition to trans-boundary pollution [3]. However, it has been found that agrochemicals pose serious risks, and certain pesticides may potentially have an impact on human endocrine and immunological systems and promote the growth of cancer.

One of the important studies found a relationship between the amount of pesticides applied and the signs and symptoms of illnesses brought on by exposure in the spray farmers of Bhopal, Madhya Pradesh, India, who sprayed insecticides by themselves and were thus immediately exposed to insecticides. Most acute symptoms and signs and symptoms reported by the 18-month spray farmers included burning/stinging of the eyes (18.42%), impaired vision (23.68%), skin redness/itching (50%) excessive sweating/breathlessness (34.2%), a dry sore throat (21.05%), and burning of the nose (28.9. That look at honestly talks approximately the urgency and there may be a need for developing greater focus many of the farm sprayers and government in imposing and making sure the usage of protecting tools whilst managing pesticides [6]. Pesticide residues have been found in soil, air, surface, and groundwater, indicating that pesticides have contaminated practically every aspect of our environment.Pesticide infection poses big risks to the surroundings and non-target organisms ranging from useful soil microorganisms to insects, plants, fish, and birds. An assessment was done to show the effect of changing agricultural practices on human health in Sri Lanka and concluded that unfavorable agricultural conduct, which include the immoderate and indiscriminate use of poisonous agrochemicals, permitting endured environmental infection and contamination of the human meals chain [7]. However, considering the fact that a number of destructive outcomes of this insecticide had been pronounced, utilization of DDT changed into banned global huge. Regardless of the excessive restrict, DDT is still illegally used in lots of areas, particularly in developing countries. DDT's terrible effects on human fitness had been widely publicized in order to warn the public and head off unforeseen catastrophes [4].

3. Need toward cleaner and safer agricultural practices

Current agricultural practices include the extensive production and considerable use of chemical compounds regarded for their capacity to motive poor health consequences in humans and wildlife and to degrade the herbal surroundings. Therefore, a pressing strategic approach is wanted for a discount inside the use of agrochemicals and for the implementation of sustainable practices [8]. The reduction in the use of agrochemicals via applying them best whilst and wherein they're important, the spatiotemporal variability of all of the soil and crop factors of a given field should be considered. This variability consists of yield, field, soil, and crop variability however additionally factors, which include wind harm or flooding. Technology-based structures, such as global positioning systems, geographic statistics systems, and other sensors, can be helpful [9]. A modern idea evolved with the aid of the worldwide movement "through Campesina," become the democratic concept of food sovereignty that has followed the development toward sustainability for more than two decades. It obtained a robust basis in 2007 in the African village the big appleéléni in Mali, where representatives from more than 80 countries adopted the "statement of nyéléni." according to its concepts, all the people of the world have the proper to choose their very own national and neighborhood regulations to eliminate poverty, malnutrition, and hunger, to guard their traditions and additionally the natural surroundings [10].

4. Types of biopesticides

Biopesticides are substances with pesticidal residences that originate from natural dwelling organisms, together with microorganisms, flowers, and animals. There are 3 fundamental classes that biopesticides fall into:

4.1 Microbial pesticides:

These biopesticides are produced with the aid of microorganisms, which includes microorganism, viruses, and certain fungi. Every form of microbial pesticide objectives a particular species or small institution of species. It's far commonplace that microbial insecticides manipulate a large kind of pests. A number of the prominent examples are: inexperienced-Verticillium, Tricho-inexperienced, Micromix-guard, Micromix-Biofert, Pseudo inexperienced, inexperienced-Beauveria, Meta inexperienced Pacelo inexperienced. *Beauveria* spp., *Isaria* spp., *Lecanicillium* spp., *Metarhizium* spp., etc.

4.2. Biochemical/herbal pesticides:

Those are materials certainly going on in the environment that control pests. This could encompass plant extracts that lure and lure bugs or insect pheromones that interfere with mating. It is able to consist of botanical extractions which might be lively in opposition to plant disorder pathogens and different pests. A biochemical pesticide, one of 3 primary instructions of biopesticides, is a natural pesticide that utilizes obviously happening materials in place of chemical compounds to manipulate pests.

4. 3. Plant-incorporated Protectants (PIPs):

Those insecticides are comprised of plants as a result of every other genetically integrated cloth introduced to that plant (aka. GM vegetation). At the same time as this utility of insecticides originates from herbal fabric, it additionally interferes with the herbal biochemistry of the goal organism and is as a consequence extensively contested. While PIP vegetation goal insects; they may be called "insect-resistant." PIP-producing vegetation can help growers lower the amount of pesticides they use on their fields. Some of the plants that can be made to produce PIPs are corn, soybeans, cotton, potatoes and plums. As a natural pesticide choice, herbal microbial and biochemical insecticides are the type usually used by farmers and growers to govern a present pest hassle, due to the fact they may be implemented like synthetic pesticides however without the poisonous damage. Right here at Soil technology Corp., we utilize herbal microbial and biochemical pesticides in our merchandise to correctly target pests in an environmentally sound way. Let's focus a little more on these biopesticides and how they function. In order to target the crucial area of the plant, microbial and biochemical pesticides are increasingly used as soil additives or seed treatments.While microorganisms are brought to the soil/plant complex they launch families of biochemical molecules to a centered environment, which includes the surface of the leaf or stem or in the root rhizosphere.The pesticidal residences of the microbial biochemical excretions then resource the plant in its affected regions.The maximum extensively used microbial pesticide are varieties of the bacteria *Bacillus thuringiensis* or Bt. every pressure of bacterium produces distinctive proteins which can be toxic to certain bugs, in particular focused on insect larvae.Certainly derived materials consisting of copper, baking soda, sesame oil, clove oil, rosemary oil and canola oil are also taken into consideration biopesticides.

Other classes of Bioinsecticides of current era are as follows:

4.4. Mycopesticide

Mycopesticides consist of fungi and fungi mobile components. Propagules which include conidia, blastospores, chlamydospores, oospores, and zygospores had been evaluated, at the side of hydrolytic enzyme mixtures. The position of hydrolytic enzymes specially chitinases within the killing process, and the viable use of chitin synthesis inhibitors are the top research regions.

4.5. Nanotechnologically designed pesticides

The encapsulation of some biological compounds in nanoparticulate structures has been proven to enhance their effectiveness in opposition to pests, reduce their toxicity in the direction of human beings and the surroundings, and lessen the losses as a result of physical deterioration (which includes volatilization and leaching). For that reason, nanotechnology can also useful resource within the advent of much less poisonous biopesticides with perfect safety profiles, extra energetic agent balance, stepped forward efficacy against the supposed pests, and higher quit-person attractiveness. Neem (*Azadirachta indica*) oil can be successfully covered from short degradation via the usage of nanoparticles, imparting a more sustained action on the intended pests. Due to the fact there's currently a lack of tremendous expertise concerning risk evaluation factors and the subsequent toxicity of nanoparticles toward additives of agro ecosystems after their release into the surroundings, destiny studies need to cognizance on ways to keep away from the dangers related to the use of nanoparticles.

Table 1: A broad description of some common biopesticides, their types, sources, and target crops with the authors who published such reports

Source	Type	Organism	Pest Type	Target Crop	References
Virus	Insecticide	*Cydiapomonella granulovirus*	codling moth	apples and pears	[13]
Oomycetes	Herbicide	*Phytophthora palmivora*	*Moreniaorderata*	citrus crops	[14]
Talaromyces flavus; *Clitoriaternatea* (butterfly pea); *Trichoderma harzianum*; *Bacillus thuringiensis* var. *tenebrionis*; *Lactobacillus casei* fermentation products	Biopesticides		*Glomerellacingulata* and *Colletotrichum acutatum; Helicoverpa* spp.; *Fusariumoxysporum Agelastica alni*; *Spodoptera litura, Helicoverpaarmigera, Aphis gossypii*; *Xanthomonas fragariae*; *Spodoptera littoralis* and others	Strawberry, Cotton, Gladiolus hybrids, alder leaf, and hazelnut, other economically important plants and trees	[15 - 21]
Arbuscular Mycorrhizal Fungi	Mutual inhabitant in the roots	Fungi	*Fusarium verticillioides*; pathogens affecting below ground plant organs	*Zea mays*	[22 - 24]
Microalgae	Filamentous cyanobacterium; Single-celled green algae	*Nostoc piscinale; Chlamydopodium fusiforme*; *Chlorella vulgaris*			[25]
		Anabaena laxa and *Calothrix elenkinii*	Increase in fungicidal activity	Coriander, cumin, and fennel	[1]

	Attractant	Citronellol	tetranychid mites	apples, cucurbits, grapes, hops, nuts, pears, stone fruit, nursery, and ornamental crops	[26, 27]
Semiochemical	Attractant	Multi-component sex pheromone, such as (E,E)-8,10-dodecadien-1-ol	codling moth	Fruits, such as apples and pears	[28]
Nanobiopesticide	Silver nanobiopesticide	None	*Alternaria alternata*solani	Alternaria leaf blight and leaf spot diseases in tomato, pepper, and potato	[29]
	Sargassum muticum derived nps	None	Lepidopteran pest		[29]
	Caulerpa scalpelliformis & Mesocyclops longisetus-derived nps	None	Culex quinquefasciatus		[29]
Bacteria	Insecticide	*Bacillus thuringiensis* var kurstaki *B. thuringiensis* var tenebrionis	caterpillars, fungi (Botrytis), Elm Leaf Beetle, Alfalfa weevil	vegetables, fruits, ornamentals, cereals Potato	[30];[31];[32].
	Fungicide	*Bacillus subtilis*	Botrytis spp.	vegetables, fruits, and ornamentals	[33];[31]

	Insecticide	*Beauveria bassiana*	Whitefly	protected edible and ornamental plant production	[34]
Fungi	Fungicide	*Trichoderma harzianum*	*Sclerotinia S sclerotiorum spp*	outdoor edible and nonedible crops and protected crops Starwberry crops	[35];[36]
	Herbicide	*Chondrostereum purpureum*	cut stumps of hardwood trees and shrubs	Forestry	[37]
	Nematicide	*Paecilomyceslilaci nus*	nematodes in soil	vegetables, soft fruit, citrus, ornamentals, tobacco and turf	[38]
Neem (Azadirachta indica)	Insecticide	Azadirachtin	aphids, scale, thrips, whitefly, eafhoppers, weevils	vegetables, fruits, herbs, and ornamental crop	[39]
Plant extracts	Fungicide	*Reynoutria sachalinensis* (giant knotweed) extract	powdery mildew, downy mildew, Botrytis, late blight, citrus canker	protected ornamental and edible crops	[40]
	Herbicide	Plant essential oils	Ragwort, many arthropods	Grassland	[37]
	Nematicide	*Quillajasaponaria*	plant parasitic	vineyards, orchards, field crops, ornamentals and turf	[33]

4.6. RNA interference enabled pesticide technology

RNAi has been used to goal weeds that tolerate Roundup. RNAi may be mixed with a silicone surfactant that shall we the RNA molecules enter air-exchange holes inside the plant's surface. This disrupted the gene for tolerance long sufficient to allow the herbicide paintings. This method could allow the ongoing use of glyphosate-primarily based herbicides. Companies like Syngenta and Bayer are researching the use of RNA interference in spray-on (RNAi) insecticides. However, the Australian Safe Food Foundation asserted in 2012 that the RNA trigger intended to alter the starch content of wheat might disrupt the gene for a human liver enzyme. Supporters responded that RNA no longer seems to be present in human saliva or stomach juices. The EPA was warned by the US Honey Bee Advisory Board that using RNA might put natural systems at "the pinnacle of risk."The beekeepers advised that pollinators can be harm with the aid of unintended results and that the genomes of many insects are nonetheless undetermined. Differentunassisted risks encompass ecological (given the need for sustained presence for herbicides) and feasible RNA goes with the flow across species boundary [11]. A European RNA companion named Devgen was given to Syngenta in 2012. RNA is being studied by startup forest improvements as a potential treatment for the citrus greening disease that, in 2014, caused 22 percent of Florida's oranges to fall off the trees [12].

5. Advantages and disadvantages of biopesticides

Why then utilize biopesticides when other synthetic pesticides are readily available everywhere? One is that biopesticides have been simply recognized and comprehended for hundreds of millions of years. These plants are accustomed to and responsive to biopesticides, thus there are no significant negative effects. Also, natural microbial and biochemical materials are common to our worldwide ecology and are without problems processed in our ecology with minimal opportunity of environmental imbalancethat is the tremendous distinction from artificial pesticides. Plants and different living organisms are not accustomed or responsive to synthetic molecules, and this unfamiliarity outcomes in rejection or terrible response and side effects. Because the plant doesn't know how to store these synthetic substances, malignant cells that grow abnormally and cause flaws in normal organic characteristics can develop in the plant. Biopesticides also show a number of other advantages over synthetic pesticides, including. Further to controlling pests and sicknesses, they produce little toxic residue, and are of minimum danger to human fitness. By providing alternatives to traditional chemical pesticides, they can minimize the pressure on pest populations to develop pesticide resistance. It is generally believed that there is little chance that diseases and pests would evolve a resistance to biopesticides. They often have desirable compatibility each with biological pest control sellers (natural enemies) and conventional chemical pesticides, so may be quite simply integrated into IPM programmes. Similarly, to their ability to control pests and illnesses, biopesticides produce very little poisonous residue and in part for that reason they may be usually considered to be minimal danger products for human fitness. Many biopesticides do not have to be automatically monitored by regulatory bodies or retailers since they are residue-exempt. Re-access and managing times are becoming more important considerations when choosing a plant protection product to be utilized, especially in covered crops. Some microbial biopesticides can proliferate on or near the target pest or illness, providing a degree of self-perpetuating control, and biopesticides can frequently be applied with existing spray systems. There is strong evidence that some microbial biopesticides can inhibit the expression of resistance as soon as it has evolved. As alternatives to traditional chemical pesticides, they could help minimize the selection pressure for the evolution of pesticide resistance in pest populations.

6. Regulatory framework of biopesticides

Biopesticides have attracted interest in pest control in current many years, and feature long been promoted as potential alternatives to artificial pesticides. In India, the pesticides Act of 1968 and the rules created under it govern all pesticides, including biopesticides. In order to eliminate any harm to people or animals, the legislation governs the import, manufacturing, delivery, sale, distribution, and use of pesticides. As of 26/02/2018, 287 pesticides are registered for use in India under section 9(3) of the Insecticide Act, 1968, and technical grade insecticides are produced locally. Globally, biopesticides manufacturing is 4.5% and in U.S. it is 6%, whereas in India, it accounts most effective three% of the full chemical pesticides manufacturing. Currently, most effective 12 styles of biopesticides together with neem primarily based and microbial primarily based formulations are registered under the Insecticide Act, 1968 in India. As a result, there has been an increase in the demand for food safety and quality in recent years, which is reflected in the severe safety requirements on product imports and the rules for the amount of pesticide residue on commodities [39]. Furthermore, an increasing number of high standards concerning product satisfactory are continuously being set. Of the total insecticides produced, the usage of artificial insecticides in India is set 50% on cotton crop by me followed through 17% on rice [41]. In India, the average per-hectare consumption of pesticides is currently around 280 g/ha, and the use of insecticides is increasing at a rate of 2 to 5% per year. Biopesticides had been registered beneath the tips of the pesticides Act, 1968, which become approved by means of the pesticide Registration Committee in India. Numerous stakeholders, along with scientists, regulators, entrepreneurs, and quit-users, are worried inside the development and commercialization chain of pest manipulate merchandise. Some participants on this chain are often worried from the earliest stages of the development manner, but there are many troubles nonetheless to be resolved; the entrepreneurs may frequently disagree with the regulators and scientists, such that end-users are often perplexed with the aid of perceived weaknesses inside the very last product [40].

7. Production, formulation and commercialization of biopesticides

There are 361 biocontrol laboratories and devices operating in India, according to the Directorate of Plant Protection, Quarantine and Storage (DPPQS), but only a small number of them are focused on manufacturing. Records indicate, however, that during the past few decades, the consumption of biopesticides has increased in India. For instance, consumption of neem, one of the most widely used biopesticides in India, went from 83 metric tonnes (MT) in 1994–1995 to 686 MT in 1999–2000, while consumption of *Bacillus thuringiensis* (Bt) climbed from 40 to 71 MT during the same time period. But, it became only a few years ago that the status committee on chemicals and fertilizers (2012–2013) throughout the fifteenth Lok Sabha submitted its file on the production and availability of pesticides in India. The committee reported that from 123 metric tonnes (MT) in 1994-1995 to 8110 MT in 2011-2012, the use of biopesticides has increased above and beyond expectations. According to information obtained from DPPQS, the overall intake of biopesticides in India increased by 40% between 2014–2015 and 2018–2019. According to statistics, Himachal Pradesh and Goa used the least amount of biopesticides—36 and 38 MT, respectively—while Maharashtra, West Bengal, and Karnataka used the most—5549, 4416, and 3478 MT, respectively. This information also explains why biocontrol programmes in northern US states have a lower reach than those in the south. In previous couple of years, the improvement of microbial biostimulants or biopesticides for reinforcing plant growth and disease eradication has emerged as an alternative, but a broader element of their application as biostimulant merchandise has remained in infancy specially in developing nations. At the financial and social degree also, this climate friendly method is going through many hurdles and lagging a long way behind their competition, the synthetic fertilizers and insecticides. Most of the instances, it has been discovered that bioformulations available for a particular crop do not deliver properly results in field equal to the ones inside the laboratory situations. Diverse experts from around the world are always working to develop bioformulated products that are easier to use, more aggressive toward plant diseases, and capable of protecting more target plants. The entire bioformulation development process, from microbe screening to product enhancement and implementation, should be examined. Microbe-based formulations, also known as bioformulations or biopesticides, are more potent than synthetic poisons because they can directly interact with pathogens and have a variety of mechanisms for preventing illness and stimulating plant growth [42].

It turns into necessary to isolate and pick out some neighborhood strains of biocontrol dealers and screen them towards the pests or pathogens of particular region. Such a diagnosed strain of biocontrol agent will adapt well to the local situation and provide a higher protection under discipline situations. So the studies were initiated to discover biocontrol capability of microorganisms in an effort to develop a price powerful and realistic control approach in augmenting sickness manage. Evaluation of massive wide variety of soil samples collected from extraordinary components of the arid vicinity brought about isolation of native biocontrol seller's viz., *Trichoderma harzianum, T. longibrachiatum, Aspergillus versicolor, A. nidulans, Penicillium oxalicum, Bacillus firmus, B. tequilensis, and Streptomyces mexicanus* from one-of-a-kind agricultural structures [43]. Those biocontrol marketers have proved their adverse capacity in laboratory exams. Within the subsequent step, their field efficacy on most generally grown crops, bushes, and their impact on resident microflora was studied in order to verify whether or not any bioagent has unfavorable impact on native organisms.

Commercialization of biopesticides is a multistep manner. Even though it is simple for any research organization to become aware of every location's particular biocontrol agent stress, it will be rather challenging to move it to an industrial level of manufacturing. Because any biocontrol agent must go through the same registration procedures as all chemical pesticides, which are arduous, expensive, and time-consuming. Farmers constantly look in their direction with skepticism since the effects of biopesticides are unpredictable. Once more, because microbial biopesticides are living organisms, a number of variables like temperature, moisture, pH, ultraviolet spectrum, and soil conditions have a negative impact on their survival. The sellers and shops also are least endorsed to sell biopesticides because of less shelf-existence of the product, low earnings margin and absence of normal demand amongst farmers. a lot of these together have led to restrained adoption of biopesticides many of the farmers. But, the diffusion and use of natural and merchandise for pest and sicknesses and nutrient control in agriculture has increased in recent decades in India as a result of several reasons:

1. To "make sure environment sustainability" turned into one of the 8 Millennium development desires (MDGs) of the united countries. All the countries inclusive of India are slowly transferring their national policies in the direction of renewable electricity assets and green technologies.
2. Self-sufficiency in food production: The country has attained self-sufficiency in food grain production due to the fact 1980's. This has enabled India to shift its awareness in the direction of satisfactory of meals production while maintaining the amount of modern meals grain production degrees. India's modern agricultural policies are aimed toward sustainable control of herbal assets, sustainability of agriculture, enhancing farm earning, and removing malnutrition. A few unproven technologies are being encouraged to eventually replace or lessen agriculture that uses a lot of chemicals.
3. Growing attention amongst customers: increase in great of existence and profits ranges have enabled the city population in becoming greater conscious at the pleasant of food products being fed on through them. Healthy food and lifestyle has become a concern and numerous and chemical loose food is trendy by means of this phase of the society.
4. Increase in region underneath organic/chemical loose agriculture: there's growth in location beneath natural agriculture in India, which once more illustrates the shift toward reduction in use of chemical fertilizers and pesticides as practiced in depth agriculture. The overall vicinity dedicated to organic agriculture in Asia changed into greater than 5.9 million hectares in 2019. There had been 1.4 million manufacturers, most of which have been in India.

The leading international locations by means of area were India (2.3 million ha) and China (over 2.2 million ha). With most effective 1.3% of total agricultural land beneath natural agriculture, India stands 5th most of the countries with largest regions of natural agricultural land in 2019 at the global level [44]. On a global scale, there were at least 3.1 million organic manufacturers in 2019. See Sustainability and the Economy, pp. 1376–1385. The top three producers are Ethiopia, Uganda, and India (1366226, 210353). (203602). While chemical insecticides failed to eradicate Helicoverpaarmigera, Spodoptera litura, and other pests of cotton, biocontrol made a major technological advance in India. It was discovered that biocontrol is the most effective and economical way to combat the significant resistance of pest insects to chemical insecticides. Later, biopesticides were incorporated into IPM, which had previously been only focused on the use of chemical pesticides. In this context, biopesticides are crucial in promoting organic and environmentally friendly farming.

8. Biopesticides Market

According to a Fortune Commercial Enterprise Insights report, a CAGR of 9.38% is predicted for the India biopesticides market, which is expected to increase from USD 69.62 million in 2022 to USD 130.37 million by 2029. Another data from the World Market Analysis Forum (GMAF) unequivocally demonstrates that the global market for biopesticides topped USD 2.5 billion in 2021 and is expected to increase by more than 11% CAGR from 2022 to 2030.Growing consumer demand for organic fruits and vegetables, along with advancements in farming technology, will drive market growth throughout the forecast period. Growing consumer preference for natural and organic foods as a result of the continued trend toward healthy living has favorably influenced the biopesticides industry over the anticipated timeframe. Biopesticides are pesticides that are unmistakably derived from plants, animals, minerals, and microbes. The global biopesticides market is expanding as consumers become more aware of the risks and health problems associated with eating food containing insecticides, such as respiratory problems, neurological damage, hypersensitive reactions, and many more. Increasing necessity to increase agricultural output because of hastily growing population and reducing arable land region is assisting the biopesticides business call for. Further, growing agricultural improvement in international locations like Indonesia, Vietnam, India, Africa, and Malaysia is major thing using the marketplace data. Agriculture plays an essential position within the monetary improvement of African and Asian location, contributing round 47% employments in 2021 across the area.Biopesticides are quite valuable for ecological and environmental stability in terms of crop safety.Additionally, speedy technological advancement thru systematic and sizeable research has positively motivated the industry penetration.Stringent rules to limit the pesticide residue in food products is growing new growth opportunities for the biopesticide producers. To meet consumer expectations inside the advanced economies of North America and Europe, the majority of food exporting nations utilise biopesticides. However, the COVID-19 epidemic has resulted in low customer purchasing power and delivery chain disruption, which may limit the market's demand for biopesticides.

9. Mode of action of biopesticides

In addition to being effective alternatives to conventional insecticides, biopesticides—which include entomopathogenic viruses, bacteria, fungi, nematodes, and plant secondary metabolites—are also a key component of many pest control strategies. Different biopesticides' virulence, including that of nuclear polyhedrosis virus (NPV), bacteria, and plant products, has been thoroughly examined in a lab setting. The selected ones have also undergone rigorous field testing with notable success. Currently, commercially available biopesticide products (including beneficial insects) are available for the control of pests and illnesses. The general intention of biopesticide research is to make those biopesticide products available at farm degree at alow cost rate, and this will grow to be a likely tool inside the incorporated pest management method. Moreover, biopesticide research continues to be going on and further studies is needed in lots of factors consisting of bioformulation and areas inclusive of commercialization. There has been a sizeable renewal of industrial interest in biopesticides as established by means of the full-size quantity of agreements among pesticide companies and bioproduct agencies which permit the improvement of effective biopesticides inside the market. Numerous bacterial species and subspecies, in particular *Bacillus*, *Pseudomonas*, and so forth., have been hooked up as biopesticides and are normally used to control insect and plant illnesses. Maximum salient amongst those are insecticides primarily based onseveral subspecies of *Bacillus thuringiensis* Berliner. The crystalline proteins produced by Bt kill a select group of nuisance insect species, such as lepidopteran species. The target insect pest is identified by the Bt crystalline proteins' attachment to the insect intestinal receptor [45]. The parasporal inclusion bodies (-endotoxins), which can be formed over the duration of sporulation period, are typically attributed to the toxicity of Bti and some other toxic lines. To achieve toxicity, those end toxins need to be ingested by the larvae. Bt and its subspecies create a special insecticidal crystal protein (-endotoxins) that has a distinctly toxic effect [46]. These pollutants can harm intestine tissues when consumed by larvae, leading to gut paralysis. After that, the inflamed larvae forestall feeding and finally they die from the blended results of starvation and midgut epithelium impairment [47,48]. Grey suggested Bt toxins produced by using plant boom-selling rhizobacteria, which additionally broaden bacteriocin compounds of insecticidal attributes. *M. anisopliae* Sorokin var. anisopliae is an essential entomopathogenic fungus. It propagates international in the soil, demonstrating a huge range of insect host species [49]. This subspecies turned into first defined in 1879 by way of Metschnikoff. These entomopathogenic fungi were regarded as safe and appeared as an environmentally fine opportunity to artificial chemical pesticides [50,51]. These entomopathogenic fungi are currently being developed for commercial use for the biological control of a number of pests and have recently been registered as microbial merchants [52].

Entomopathogenic nematodes are soil-dwelling, soft-bodied, un-segmented roundworms that are naturally present in water film near soil particles. Nematodes are obligatory or occasionally facultative parasites that seek for their host insects in response to chemical cues like vibration, carbon dioxide, and other gases. Commercially, two families—Steinernematidae and Heterorhabditidae—have been successfully discovered and applied as biological controls in pest management plans. Products containing *S. carpocapsae, S. thermophilum, H. bacteriophora,* and *H. indica* are authorised for sale in India.*M. azedarach*tree grows within the tropical and subtropical components of Asia, however nowadays it is also cultivated in different warm locations of the sector due to its great climatic tolerance. The leaves of *M. azedarach* are used for his or her insecticidal activity, while the fruit extracts of *M. azedarach* produce a spread of consequences in bugs, consisting of increase retardation, reduced fecundity, molting disorders, and conduct changes [53]. Luminum oxide, silver, titanium dioxide, and zinc oxide nanoparticles have been used in larvicidal experiments to treat grasseries disease in silkworms and rice weevils [54]. The larvicidal activity could be studied using the leaf dip method. Usually, the leaf discs of the host plant are dipped in different concentrations of synthesized nano biopesticides based on leaf extracts of plants. The activity is recorded after 24 h of treatment with a continuous supply of fresh leaves for healthy growth. The larval mortality rates are recorded after 24–96 h of treatment. Successful tests have been done on the effectiveness of CdS, nano-Ag, and nano-TiO2 nanoparticles against larvae [55]. The immersion methods have been used for recording the mortality of mosquito larvae and pupae. Ag NPs synthesized from the leaf extracts of *Ambrosia arborescens* were more toxic to *Aedes egypti* when the immersion method was used for various larval stages [56]. Similarly, the effectiveness of the immersion technique for mosquito larvae and pupae has been demonstrated by the pupicidal capacity of silver nanoparticles made from *Euphorbia hirta* against *Anopheles stephensi* [57].

10. Challenges and Future perspectives

Farmers need more secure insecticides to guard their plant crops, making biopesticides an super choice as opposed to chemical dealers. But implementation, production and improvement of biopesticides retain to have many challenges. To aid the commercialization of biopesticides, additional studies in manufacturing, shipping and system have to be carried out. Public-private quarter integrations have the potential to enhance the manufacturing, improvement and sale of environmentally pleasant options to chemical insecticides in developing nations. Further, additional guide of public-funded programs, business buyers and pesticide firms are wanted as properly. A crucial trouble is growing strict regulatory mechanisms to preserve biopesticides to be had at low priced fees in developing nations. Accordingly, several boundaries stay for the improvement of numerous biopesticide [58]. The "first technology" of transgenic vegetation containing Bt genes can be observed by means of more state-of-the-art "2nd" and "1/3" technology vegetation with more flexibility in IPM. These encompass plant life with inducible and tissue-precise expression structures and multiple engineered genes. For the reason that early Nineteen Eighties, scientific pastime in mycoherbicide studies additionally has more quickly in terms of the number of weeds that are controlled and prospective pathogens that are researched. The use of both registered and unlicensed mycoherbicides has increased globally. Additionally, the number of U.S.A. patents issued during the mycoherbicidal era increased dramatically [59]. New pursuits in biopesticides that combine fitness/environmental problems and commercial pressures for agrochemicals have precipitated significant advances in studies of organic manipulate marketers. Through the had era, the reliability and efficacy of biopesticides may be stepped forward. Further, product charges are persevering with to say no because of developments in manufacturing generation. There are still a number of challenges that want to be addressed, yet severa marketplace projections reflect the capacity for business biopesticide manufacturing. Bt manufacturing specially is anticipated to continue to grow, but big sales in bio-fungicides and bioherbicides are predicted as nicely [60].

Conclusion:

Chemicals are widespread on the market and have remained there for many years because natural products have economic value. Natural items are believed to have these qualities that give rise to novel mechanisms. The implementation of the concept of natural biopesticides and their impact on high-output displays has been challenging, but there have been some notable successes in circumstances where some crop disruption is acceptable. There have been several works carried out recently to enhance shelf life, immediate death, biological scheme, efficiency in the field, and dependability, as well as the effect of cost-of-living systems. Due to their ability to prevent the use of dangerous synthetic chemical pesticides in their place, biopesticides are essential to integrated pest control. Biopesticides, a sustainable substitute for traditional pesticides, can maintain agricultural output while defending the environment. To increase agricultural productivity, a pest control approach that makes use of efficient insect resistance management strategies is essential. Employing biological methods or implementing integrated biological conventional methods is the most efficient way to control pests. Because of advancements in application methods, eco-friendly substitutes, and less expensive possibilities for many formulations, the usage of biopesticides has increased. In light of this, using biopesticides to manage pests makes more sense, especially when higher cost-efficiency becomes a reality in the near future.

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DIGITALIZATION IN AGRICULTURE FOR INNOVATIVE TRANSFORMATION IN INDIA

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Abstract:

Digitalization holds immense potential to revolutionize India's agricultural sector, ushering in substantial innovation and transformation. By embracing digital technologies, India can bolster agricultural productivity, curtail wastage, boost agricultural exports, elevate farmers' income, and fortify food and nutrition security. Moreover, this shift towards digital solutions contributes to environmental conservation and fosters sustainable development within the agricultural domain. The escalating accessibility of the internet and mobile phones across India has already made a profound impact on multiple sectors, including agriculture, education, healthcare, and e-commerce. This trend serves as a testament to the readiness of Indian agriculture for a digital metamorphosis. Within this context, this chapter delves into the profound implications of digitalization on agriculture, illuminating its potential for innovative transformation in India. It confronts the existing challenges plaguing the Indian agricultural landscape while spotlighting the pivotal role of digital technologies in surmounting these obstacles. Noteworthy digitalization initiatives within Indian agriculture, such as precision farming, blockchain-based supply chain management, and data analytics, are also scrutinized in this chapter. Furthermore, the chapter assesses the benefits, risks, and future prospects tied to the digitalization of agriculture, underscoring the necessity for policy support and robust infrastructure development to fully harness its transformative capabilities. Through strategic implementation and concerted efforts, India's agricultural sector stands to leap into a more technologically advanced and sustainable future.

Keywords: Artificial intelligence, Digitalization, Innovation, Indian agriculture

Introduction:

India has long been an agrarian society, with agriculture playing a vital role in its economy. However, the sector faces several challenges, including limited access to information, outdated farming practices, fragmented markets, and inefficient supply chains. Digitalization, with its ability to leverage technology and data, offers innovative solutions to these challenges. By integrating digital technologies into agriculture, India can enhance productivity, improve resource management, and ensure sustainable agricultural practices. It can be seen that growth and penetration of digital infrastructure in India is quite high. India has the world's second-largest mobile phone market, with 1.2 billion mobile phone subscribers as of December 2021. The internet penetration in rural India is 41% as opposed to 71% in the cities and towns. The study estimates that India will be home to 900 million net users by the end of 2025 and that 56%

of the 141 million new netizens will be from rural India. The digitalization of agriculture can drive innovation and transformation in broadly four sectors of Indian agriculture, viz. (i) Precision agriculture, (ii) Climate-smart agriculture, (iii) Supply chain management, and (iv) Financial inclusion.

1. Precision agriculture

Precision farming involves the use of advanced technologies like satellite imagery, drones, and sensors to gather data on soil conditions, weather patterns, and crop health. This data-driven approach enables farmers to make informed decisions regarding irrigation, fertilization, and pest control. By optimizing resource allocation and minimizing waste, precision farming enhances productivity while reducing environmental impact. Using digital equipment, tools, software, process, farmers can monitor their crops, orchards, animals, aquaculture systems, soil, water, weather, post-production management of produce in real-time, enabling them to make more informed decisions about planting, irrigation, fertilization, pest management, harvest and post-harvest management of agricultural produce. This can help to reduce waste, improve yields and quality, and save costs. Briefs about some major precision agriculture digital technologies are given as:

1.1 Applications of sensors in agriculture: Sensors are being increasingly used in Indian agriculture to improve productivity, reduce waste and optimize resource use. Soil moisture sensors are used to measure real-time soil moisture levels, to optimize the irrigation practices. Nutrient sensors can provide real-time data to optimize fertilization practices. Weather sensors can provide real-time data on weather conditions. Crop health sensors are used to monitor the health and growth of crops. Sensor-based post-harvest management by using temperature sensors, humidity sensors, ethylene sensors and quality sensors of agricultural produce can help to reduce post-harvest losses, improve quality, and increase profitability for farmers. While monitoring quality, farmers can identify potential issues and take corrective action before the produce is shipped to market. GPS sensors can be used to track the location of harvested produce during transportation, enabling farmers to monitor temperature, humidity, and other factors that can impact quality. Further, sensor-based storage management is an effective method of post-harvest management that can help Indian farmers to increase their productivity and income, reduce post-harvest losses, and improve the quality of their produce. This can increase consumer confidence in the produce and help to build a brand reputation for quality. However, it is important to ensure that these technologies are accessible and affordable to small-scale and marginalized farmers, who may not have the resources to invest in such technologies. This may require government support in the form of subsidies, training programme, and infrastructure investments.

1.2 Variable rate technology (VRT): Variable Rate Technology (VRT) is a precision agriculture practice that involves the use of technology to apply different amounts of inputs (e.g. seed, fertilizer, water, pesticides, feed, chemicals) to different parts of a field, orchards, or any agricultural production system including livestock and fisheries, based on the specific needs. The use of VRT in agriculture can help to improve productivity, reduce input costs and minimize environmental impact. However, it is important to ensure that cost of these technologies are reduced to make it accessible and affordable to small-scale and marginalized farmers.

1.3 Drones: Drones, or unmanned aerial vehicles (UAVs), have become increasingly popular in agriculture due to their ability to collect data quickly and efficiently of an object without physical contact with object. Major applications of drones in agriculture are crop monitoring with high-resolution cameras, create detailed maps of agricultural land, soil quality, topography, and drainage patterns. spray crops with precise applications of pesticides and fertilizers, using in conjunction with other precision agriculture technologies, assess crop damage caused by natural disasters, monitor the water health and ecological conditions including fish health and biomass. However, it is important to ensure that drones are used safely and responsibly, and that farmers are trained in their use. Additionally, regulations around the use of drones in agriculture should be put in place to ensure that they are used legally and ethically.

1.4 Robotics: Robotics is the field of technology that involves the design, construction and operation of robots. In recent years, robotics has been increasingly used in agriculture to improve efficiency, reduce labour costs and increase productivity. Robots can be successfully employed for harvesting crops such as fruits and vegetables which can increase efficiency and reduce labour costs. For example, robotic arms can be used to pick fruits and vegetables, planting and seeding with precision to detect and remove weeds, water crops with precision, spraying chemicals which are dangerous to human health. Overall, robotics has the potential to revolutionize agriculture in India by increasing efficiency, reducing labour costs and improving productivity. However, the use of robotics in agriculture requires significant investment in technology, research, and development. Additionally, farmers and farm workers must be trained in the use of robotics technology to ensure that it is used effectively.

1.5 Artificial intelligence (AI): Artificial Intelligence (AI) has the potential to revolutionize Indian agriculture by enabling farmers to make data-driven decisions and optimize their crop yields. It can be effectively used for (i) predictive analytics, (ii) precision agriculture, (iii) pest and disease management, (iv) soil health management, (v) livestock herd management and dairy automation, (vi) aquaculture automation and management (vii) market prediction. In case of predictive analytics, AI can be used to analyse historical weather data and crop data to make predictions about future crop yields. This can help farmers to plan their planting and harvesting schedules and optimize their crop management practices. AI helps to identify pests and diseases early on and recommend appropriate treatment options. This can help farmers to minimize crop losses and reduce the need for chemical treatments. AI can be used to analyse soil data and provide recommendations for optimizing soil health. This can help farmers to reduce soil erosion, improve water retention and increase crop yields.

1.6 Protected cultivation: Protected cultivation is the practice of growing crops under a controlled environment using structures such as greenhouses, shade net houses and polyhouses. This method of cultivation has become increasingly popular in Indian agriculture due to its ability to protect crops from adverse weather conditions, pests, and diseases. This reduces the cost of crop management and improves the quality of the crops. This is particularly beneficial for high-value crops such as vegetables and fruits, which require high-quality produce to fetch better prices in the market. The protected cultivation is an effective method of cultivation that can help Indian farmers to increase their productivity and income. However, it is important to ensure that the structures used for protected cultivation are sustainable and do not have adverse effects on the environment. Additionally, farmers should be trained in the use of protected cultivation techniques to ensure that they are used effectively.

1.7 **Vertical farming:** Vertical farming is a method of growing crops in vertically stacked layers using artificial lighting and a controlled environment. This method of cultivation has become increasingly popular in Indian agriculture due to its ability to produce high yields of crops in a small space with minimal environmental impact. Apart from the benefits of protected cultivation it has efficient use of space i.e. vertical farming allows farmers to grow crops in a small space, making it ideal for urban agriculture and areas with limited land availability. This can help to increase the productivity of agriculture in cities and reduce the carbon footprint of transporting food from rural areas. It can be seen that vertical farming is an effective method of cultivation that can help Indian farmers to increase their productivity and income, particularly in urban areas.

1.8 **Aquaponics and hydroponics:** Aquaponics and hydroponics are two modern methods of cultivation that have become increasingly popular in recent years. Both methods involve growing plants without soil, using water as the primary growing medium. Aquaponics is a method of cultivation that combines aquaculture and hydroponics. In this method, fish are grown in tanks, and the waste produced by the fish is used to fertilize the plants grown hydroponically, whereas, Hydroponics is a method of cultivation that involves growing plants in a nutrient-rich solution without soil. The nutrients supplied by the fish waste help to produce high-quality crops, making aquaponics ideal for high-value crops such as herbs and leafy vegetables, whereas, in case of hydroponics we apply highly reduced chemical pesticides and herbicides. The aquaponics and hydroponics are effective methods of cultivation that can help Indian farmers to increase their productivity and income, particularly in urban areas or areas with water scarcity.

ICAR initiatives

Indian Council of Agricultural Research (ICAR) initiated a network program in the field of precision agriculture named as “ICAR- Network Program on Precision Agriculture (NePPA)”. This was initiated by the council initially with 16 ICAR research institutes with IARI as lead. The programme is focused on exploring potential applications of recent developments on technologies related to sensor, IoTs, drone and ICTs for precision smart agriculture. The major objectives span its scope over soil fertility, crop health, livestock, post-harvest operations, aquaculture and upscaling these using advanced technologies like drones, variable rate technologies (VRT's) to enhance input use efficiency and optimal production system. Following are the major achievements under this programme:

i. **Development of spectral models for quick assessment of different soil attributes:** Models were developed using machine learning (ML) algorithms such K-Nearest Neighbour (KNN), Random Forest (RF), Ridge Regression (RIDGE), Quantile regression forests (QRF), Least Absolute Shrinkage and Selection Operator (LASSO), Support Vector Machine (SVM) and Elastic Net (EN). The models were validated and compared, and the best pipeline was selected for assessment of different soil attributes.
ii. **Development of in-house drone:** Multirotor quadcopter design for agriculture health monitoring and surveying has been developed as part of project. It includes features like, real-time telemetry demonstration at any specified location, full HD live video transmission with dual camera support, all in one hand-held ground station for flying and mission planning. It has a payload capacity of 1.5 kg with a flight time of 40 to 45 minutes (without payload) and has the altitude capability of 120 m.
iii. **Development of IoT enabled irrigation scheduling system for field crops:** IoT (Internet of Things) based Irrigation Water Management System (IWMS) was developed and tested in wheat and chickpea to measure the soil moisture at three different depths, viz. 20 cm, 40 cm and 60 cm. The mobile application pertaining to the irrigation scheduling was also developed in python and is under testing.

Digital agricultural knowledge dissemination system

Agricultural knowledge dissemination systems are important for providing Indian farmers with the information they need to make informed decisions about their farming practices. Digital technologies can play an important role in improving the efficiency and effectiveness of these systems. In India, following systems are already being implemented by different organizations responsible for the same:

i. **Mobile-based applications:** Mobile applications can be developed to provide farmers with information on crop management practices, weather forecasts, market prices, and other relevant information. These applications can be designed to be user-friendly and accessible even for farmers with low literacy levels.
ii. **Interactive voice response (IVR) systems:** IVR systems can be used to provide farmers with information on demand, using a telephone. This can be useful for farmers who do not have access to smartphones or the internet. IVR systems can also be designed to provide personalized recommendations based on the specific needs of each farmer.
iii. **Digital kiosks:** Digital kiosks can be set up in rural areas to provide farmers with access to information on crop management practices, weather forecasts, market prices and other relevant information. These kiosks can be staffed by trained personnel who can assist farmers with accessing and interpreting information.
iv. **Farmer helplines:** Farmer helplines can be set up to provide farmers with advice and support on a wide range of issues related to agriculture. These helplines can be staffed by

trained agronomists and other agricultural experts who can provide personalized recommendations based on the specific needs of each farmer.

v. **Social media:** Social media platforms such as Facebook and WhatsApp can be used to disseminate agricultural information to farmers. Farmers can join groups and communities on these platforms where they can share information and advice with each other, as well as receive updates on new agricultural practices and technologies.

vi. **KISAN SARATHI**: Indian Council of Agricultural Research (ICAR) developed a digital platform for agricultural extension system named as **KISAN SARATHI**-System of Agri-information Resources Auto-transmission and Technology Hub Interface. This has been developed to support this emerging need of multi ways and multilingual communication among various agricultural stakeholders. The ultimate goal of this project is to implement an intelligent online platform for supporting agriculture at local niche with national perspective. A total of 731 KVKs are enrolled with the system, where more than 3,600 agricultural scientists and subject matter experts are registered with Kisan Sarathi. The services of Kisan Sarathi for the farmers is available through an IVR based calling system via toll free numbers 1800-123-2175 and a short number 14426. More than 65 Lacs farmers are registered on this portal.

2. Climate smart agriculture

Digitalization is rapidly transforming the agriculture sector, and climate-smart agriculture (CSA) is no exception. Digital technologies can help farmers make better decisions, increase productivity and reduce the environmental impact of agriculture. Some of the important area of digitalization related to above field are weather monitoring and forecasting, precision farming, crop management, market access, data management, and farm management. Digitalization in CSA is still in its early stages, and there are challenges to overcome, such as the digital divide in rural areas and the cost of technology. However, the potential benefits are significant, and digitalization can play a vital role in making agriculture more sustainable and resilient in the face of climate change.

3. Supply chain management

Digitalization is transforming supply chain management in agriculture by improving transparency, traceability and efficiency. There are number of ways by which digitalization is quite beneficial for supply chain management in the field of agriculture. Digital technologies can capture and store data at the farm level, such as crop yields, soil health, and pesticide use. This information can help supply chain managers better understand the origin and quality of the produce they are sourcing. However, there are challenges to overcome, such as the cost of technology and the need for standardization across the industry. Nonetheless, the potential benefits of digitalization in agriculture supply chain management are significant, and it is an area that is likely to see continued growth and innovation in the years to come.

4. Financial inclusion

It is well known that digitalization is a powerful tool for promoting financial inclusion in agriculture, particularly in developing countries where smallholder farmers often lack access to formal financial services. Success of Unified Payment Interface (UPI) which is a fast payment system, used largely for peer-to-peer payments and is also the most popular peer-to-merchant retail payment system in India with monthly transaction volumes of 8 billion in December 2022 (NPCI 2022) is quite motivational for adoption of digital platform of financial inclusion agriculture. Digital technologies such as mobile banking can help farmers access financial services such as savings accounts, credit and insurance. This can reduce the cost and complexity of accessing financial services, making it easier for smallholder farmers to participate in the formal economy. Digital platforms can facilitate payments between farmers, buyers, and financial institutions. Digital tools can facilitate communication and record-keeping within groups, making them more efficient and transparent. Further, these tools can provide farmers with access to financial education and training, enabling them to make informed decisions about financial management and investment. Digitalization is transforming the financial landscape of agriculture, and the potential benefits for smallholder farmers are significant.

5. **Data analytics:**

Data analytics plays a crucial role in transforming agriculture by providing actionable insights for decision-making. By analyzing large volumes of data, including weather patterns, market trends, and crop performance, farmers can optimize production, predict yields, and identify potential risks. Data-driven insights also enable personalized advisory services, ensuring that farmers receive tailored recommendations for their specific needs.

G20 perspective

The G20 is a forum of the world's largest economies, including both developed and developing countries. Digital agriculture is an area of growing importance in the G20, as it has the potential to improve the sustainability, productivity and profitability of agriculture. The G20 has recognized the importance of digital agriculture and included it in its agenda. In 2018, the G20 Agricultural Ministers' Meeting in Buenos Aires, Argentina, discussed the role of digital agriculture in sustainable food systems and agreed to develop a roadmap for the adoption of digital technologies in agriculture. G20 has identified several priority areas for digital agriculture, including (i) Digital infrastructure, (ii) Data governance, (iii) Standards and interoperability, (iv) Capacity building and (v) Financing. In G20 Meeting of Agricultural Chief Scientists (MACS) in Varanasi recently during the presidency of India, deliberations were held on Digital Agriculture and Sustainable Agri Value Chain and Public-Private Partnership. Digital agriculture is an area of growing importance in the G20, and there is a growing recognition of the potential benefits of digital technologies in agriculture. The G20 is working to promote the adoption of digital technologies in agriculture and to address the challenges and barriers to adoption.

Benefits of digitalization in agriculture

1. **Increased productivity:**

   Digitalization enables farmers to optimize resource allocation, leading to higher yields and enhanced productivity. By leveraging data and technology, farmers can make informed decisions regarding irrigation, fertilization, and pest management. Precision farming techniques, supported by data analytics, help farmers maximize crop productivity while minimizing input costs.

2. **Enhanced market access:**

   Digitalization provides farmers with direct access to markets, reducing dependence on intermediaries and enabling fair pricing. Through online platforms and mobile applications, farmers can connect with buyers, negotiate prices, and eliminate inefficiencies in the supply chain. This direct market access empowers farmers, improves their bargaining power, and ensures a more equitable distribution of profits.

3. **Sustainable agricultural practices:**

   Digitalization promotes sustainable agriculture by optimizing resource management and reducing environmental impact. Precision farming techniques minimize the use of water, fertilizers, and pesticides, resulting in improved resource efficiency. Moreover, data analytics can help identify climate change risks and enable farmers to adopt climate-smart practices for resilient agriculture.

Risks and challenges in adoption

1. Extent of profitability should be beyond of a threshold through in usage of the technology;
2. Amount of uncertainty and risk involved in adopting a technology including cost of the technology;
3. Availability and suitability of technology in the agricultural production cycle;
4. Requirement of skills and learning curve for adoption of the technology;
5. Eco-environment and digital infrastructure availability in a particular region;
6. Level of agricultural production system;
7. Ease of flow of agricultural credits, and
8. Overall policy support for promotion of a technology;
9. Limited Digital Infrastructure;
10. Data Privacy and Security.

Policy support and infrastructure development

To fully leverage the transformative potential of digitalization in agriculture, policymakers need to prioritize infrastructure development and create an enabling environment. This includes investments in rural connectivity, skill development programs for farmers, and the formulation of regulations to protect data privacy and security.

Future prospects

The future of agriculture in India lies in embracing digitalization as a key driver of innovation and transformation. As technology continues to evolve, emerging trends such as artificial intelligence, Internet of Things (IoT), and remote sensing hold tremendous potential for further advancements in agricultural practices. By embracing these technologies and fostering collaboration between stakeholders, India can unlock new opportunities for sustainable, productive, and inclusive agriculture.

Conclusion:

Digitalization has the power to revolutionize Indian agriculture by addressing existing challenges and fostering innovative transformation. Through precision farming, blockchain-based supply chain management, and data analytics, farmers can achieve higher productivity, enhanced market access, and sustainable agricultural practices. However, addressing infrastructure gaps, ensuring data privacy, and providing policy support are essential to fully realize the potential of digitalization in transforming Indian agriculture. With the right investments and collaborative efforts, India can pave the way for a digital revolution that benefits farmers, consumers, and the entire agricultural ecosystem.

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PHYSIOLOGICAL AND MOLECULAR BASIS FOR SALINITY TOLERANCE IN RICE

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Introduction:

Today's agriculture faces a daunting task of ensuring food security to the increasing human population on this planet (FAO, 2009). A great proportion (more than 60%) of this population depends on rice (*Oryza sativa* L.) as their staple food. Rice contributes up to 20% of the calories consumed by human nutrition worldwide. Therefore, rice production must increase during the coming time in order to keep pace with increasing world population. Asia is known as the main rice producer in the world by yielding more than 650 million tons (90% of total rice yield worldwide) grown in 145 million ha land. Understanding salinity responses Rice is grown in a diverse range of environments characterized by various climates and soil-water conditions. However, adverse environmental conditions critically threaten rice production and causes significant yield loss in large areas of main productive sectors. Both abiotic and biotic stresses frequently prevent the attainment of optimum growth and yield of rice. These stresses include high salinity, drought, heat, and cold which have negative effect on the yield and vegetative production of rice, and cause a key risk to worldwide food safety (Pareek *et al*., 2010). Amongst the various environmental stress factors, salinity is the main hazardous factor limiting crop productivity.

Rice has been grouped as salinity susceptible cereal at its young stage (Lutts *et al*., 1995) and confines its efficiency of production at mature stage (Todaka *et al*., 2012). To increase the grain yield of rice under salinity, it is imperative to first understand the basic molecular machineries of salt tolerance in this plant. Tolerance toward salinity is a quantitative attribute in plants, regulated by a host of genes (Chinnusamy *et al*., 2005). Since the last decade, numerous genes imparting salinity tolerance in plants (including rice) have been identified and characterized such as those involved in transcription regulation, signal transduction, ion transportation and metabolic homeostasis (Verma *et al*., 2007; Kumari *et al*., 2009). In the present text, we present our current understanding about effects of soil salinity on rice crop and the approaches used to increase the tolerance of this crop toward salinity. Further, critical evaluation of progress made toward raising salinity tolerant rice using functional genomics tools is also presented.

Salt affected soils classification and distribution:

Salt affected soils classify as saline, sodic, and saline sodic. The three parameters considered for such classification are electrical conductivity of the saturated soil extract (ECe), exchangeable sodium percentage (ESP), and pH (Figure 7). Mapped salt affected lands under different grades of severity in the world (Figure 7). Most of the salt affected lands correspond to saline soils (60%), followed by sodic soils (26%), and finally saline-sodic soils (14%). When considering the severity of the saline stress, 65% of salt-affected soils are slightly affected, followed by 20% moderately, 10% extremely, and 5% highly salt-affected soils

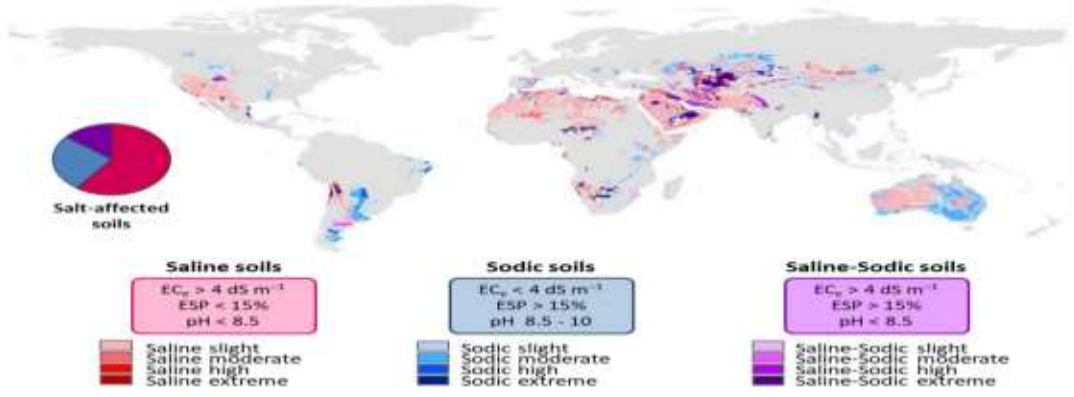


Figure 7. Classification and world distribution of salt-affected soils under different levels of saline stress. Saline soils (pink range) encompass 60% of the total salt-affected soils, sodic soils (blue range) include 26%, and saline-sodic soils (purple range) include the remaining 14%. Three main parameters are considered for the classification: electrical conductivity on the saturated soil extract (EC_e), exchangeable sodium percentage (ESP), and pH (modified from Wicke et al., 2011 [158]).

The major problem in soils classified as saline is the high concentration of soluble salts as Cl^-, SO_4^-, and sometimes NO_3^-, and in lower proportion low-solubility salts, such as $CaSO_4$ and $CaCO_3$.

In this case, exchangeable Na+ and soil clay dispersion are not a problem; therefore, saline soils maintain the structure of aggregates, and water permeability is good]. In sodic soils, Na+ is the major problem because high amounts of this cation along with low EC result in soil dispersion. Clay dispersion occurs when the electrolyte concentration decreases below its flocculation value.

These soils have weak structural stability and low hydraulic conductivity (HC) and infiltration rate (IR). These poor physical properties result in decreased crop productivity caused by poor aeration and reduced water supply. Historically, sodic soils were often called black alkali soils because sodium causes the dispersion of organic matter and dissolution of humic substances, which remain on the surface of the land resulting in a dark colour. Saline–sodic soils present both high soluble salts and exchangeable Na+. The soil maintains the aggregation with high electrolyte concentration. However, if soluble salts are leached out, usually Na+ becomes a greater problem since the soil pH rises above 8.5, and the soil aggregates can be dispersed. Soil salinity is a problem that is spreading globally and is projected to increase in future climate change scenarios. Salinity problems occur under all climatic conditions and can result from both natural and human induced actions. However, saline soils are more frequent in arid and semi-arid regions, where rainfall is insufficient to meet the water requirements of the crops and leach mineral salts into the root zone. Recent estimates of the global extent of soil salinization are not available. However, it is reasonable to assume that, since the data gathering in the 1970s and 1980s, salinization expanded and newly affected areas most probably exceed the areas restored through reclamation and rehabilitation.

According to the Harmonized World Soil Database (HWSD), salt affected land accounts for 1128 Mha (saline soils 60%, sodic soils 26%, and saline sodic soils 14%; Figure 7). Salt affected soils are found all over the world, although their extent and severity are variable (Figure 7). Regions with the largest salt affected land areas are the Middle East (189 Mha), Australia (169 Mha), North Africa (144 Mha), and the former USSR (126 Mha). Considering only salt affected land that is in use or has potential use for agriculture (excluding forest, wetlands, unsuitable land, high biodiversity areas, among others) Africa (295 Mha) and Asia (291 Mha) have the highest extensions (Table 2). In the world, 971 Mha are affected by salts (Table 2), an important area considering the increasing need of soils for agriculture as population growth is rising. According to Food and Agriculture Organization (FAO) records in 2011, the global population was 7.04 billion people, reaching 7.47 billion in 2016. Following this increasing trend, demographers are forecasting a population size of 8.01 billion for 2025 and 9.01 billion for 2050.

India:

- Arable land area of 159.7 million ha
- Total irrigated crop area 82.6 million ha,
- Total salt affected area 6.73million ha (5.5%)
- Sodic soils 3.77 million ha, Saline soils 2.96 million ha

Geographical distribution of salt affected soils in India:

- Semi-arid Indo-Gangetic alluvial tract: Punjab, Haryana, UP, Delhi, parts of Bihar
- Arid tract: Rajasthan and Gujarat
- Arid and semi-arid tract of central and southern states principally of the irrigated areas
- Coastal-alluvial soil

Table 1: Distribution of world population and land areas affected by salts and assigned to agricultural uses.

Region	Population (Millions)	Land Area with Irrigation a (* 1000 ha)	Arable Land b (* 1000 ha)	Permanent Crops c (* 1000 ha)	Salt-Affected Land d (* 1000 ha)
World	7043	324,548	1,395,490	162,100	971
Africa	1077	15,265	230,862	33,571	295
North America	346	27,730	194,640	7526	63
Central America	163	7306	28,195	5178	4
South America	400	15,880	133,326	14,199	57
Asia	4240	228,667	480,140	83,495	291
Europe	738	25,414	274,151	15,211	2
Oceania	37	3261	48,702	1603	144
Former USSR					117

A. Land area equipped with irrigation infrastructure and equipment to provide water to crops. **B.** Total of areas under temporary crops, temporary meadows and pastures, and land with temporary fallow **C.** Land cultivated with long-term crops. **D.** Salt-affected land excluding forest, wetlands, unsuitable and high biodiversity areas.

Salinity mechanisms in plants:

I. Avoidance: Avoidance is the process of keeping the salt ions away from the parts of the plant where they are harmful.

1. Salt Exclusion
2. Salt Extrusion
3. Salt Dilution
4. Compartmentation of ions

II. Tolerance

Osmotic adjustment

Hormone synthesis - ABA stress hormone, hardens plants against excess salts

Salt exclusion

The ability to exclude salts occurs through filtration at the surface of the root. Root membranes prevent salt from entering while allowing the water to pass through. The red mangrove is an example of a salt-excluding species.

Salt excretion/extrusion

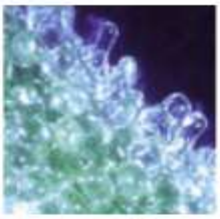
Salt excreters remove salt through glands or bladders or cuticle located on each leaf. Salt bladders -eg) *Atriplex*, *Mesembryanthemum crystallinum L*. Salt glands - active process, selective for sodium and chloride (eg) Black and white mangroves Secretion through cuticle – eg) *Tamarix* Salt glands- dump sites for the excess salt absorbed in water from the soil; help plants adapt to life in saline environments.

Salt Dilution

By dilution of ions in the tissue of the plant by maintaining succulence. Plants achieve this by increasing their storage volume by developing thick, fleshy, succulent structures Succulence is mainly a result of vacuoles of mesophyll cells filling with water and increasing in size. This mechanism is limited by the dilution capacity of plant tissues

Chenopodium quinoa salt glands

Salt glands of white mangroove



Close-up of epidermal bladder cells along the stems of *Mesembryanthemum*

Compartmentation of ions

Organ level - high salts only in roots compared to shoots especially leaves. At cellular level- high salts in vacuoles than cytoplasm thus protecting enzymes.

Mechanisms underlying rice salt stress tolerance

Regulation of ionic balance:

Salt stress is commonly caused by high concentrations of Na+ and Cl− in the soil. Na+ and K+ are imported into the cell using the same suite of transporters, and the two cations compete with each other. K+ is important for the catalytic activities of many central enzymes, and excess Na+ competes with K+ for uptake across the plasma membranes of plant cells. K+ is also necessary for osmoregulation and protein synthesis, the preservation of cell turgor, and optimal photosynthetic activity. The maintenance of cellular Na+/Homeostasis is therefore a crucial factor that determines the plant's ability to survive during salt stress.

Mechanisms to reduce cytoplasmic Na+ include restriction of Na+ uptake, increase of Na+ efflux, and compartmentalization of Na+ in the vacuole. The rice plasma membrane Na+/H+ antiporter (OsSOS1) excludes Na+ from the shoot, promoting a lower cellular Na+/K+ ratio and increasing salt tolerance. The vacuolar Na+/H+ antiporters OsNHX1, OsNHX2, OsNHX3, OsNHX4, OsNHX5, and OsARP/OsCTP play important roles in the vacuolar compartmentalization of Na+ and K+ that accumulate in the cytoplasm and thereby determine rice salt tolerance. Members of the rice high-affinity K+ transporter (HKT) family, OsHKT1;1, OsHKT1;4/OsHKT7, and SKC1/OsHKT1;5/OsHKT8, help to reduce Na+ accumulation in leaves during salt stress. OsHKT1;1, OsHKT2;1, OsHKT2;3/OsHKT3, OsKAT1, OsKAT2, OsHAK5, andOsHAK21/qSE3 transport Na+ or both Na+ and K+, helping to maintain Na+/K+ homeostasis in the cytoplasm and regulate rice response to salt stress

A number of genes influence rice salt tolerance by regulating the expression of *HKT*, *NHX*, and *CLC* genes. These include transcription factors such as OsMYBc, OsbZIP71, OsNF-YC13, and the sucrose nonfermenting1-related protein kinase2 (SnRK2) SAPK4, which directly activate the expression of K+/Na+ transporters, thereby improving the K+/Na+ ratio and positively regulating salt tolerance. The myristoylated Ca2+-bindingprotein OsSOS3/OsCBL4 phosphorylates OsSOS2/OsCIPK24, thereby activating the Na+/H+ antiporter OsSOS1and promoting rice tolerance to salt stress. The mitogen-activated protein kinase (MAPK) OsMAPK33plays a negative role in salt tolerance by promoting higher sodium uptake into cells and thereby lowering the K+/Na+ ratio. The results above suggest that the modulation of Na+/K+ homeostasis under salt stress may provide an effective way to improve salt tolerance in rice.

Osmotic adjustment:

Salt stress also causes osmotic stress and promotes the biosynthesis and accumulation of compatible osmolytes such as sugar, proline, glycine betaine, polyamines, and proteins from the late embryogenesis abundant (LEA) superfamily. These osmolytes play a dominant role in osmotic adjustment under salt stress by reducing cell osmotic potential and stabilizing proteins and cellular structures. The proline synthesis genes *OsP5CS1* and*OsP5CR* increase proline accumulation and improve rice tolerance to salt stress. *OsTPS1*, *OsTPS2*, *OsTPS4*, *OsTPS5*, *OsTPS8*, and *OsTPS9*, which encode trehalose-6-phosphate synthase (TPS), enhance rice tolerance to cold, salt, and drought stresses by increasing trehalose and proline contents under abiotic stress. *OsGMST1*, which encodes a monosaccharide transporter, increases monosaccharide accumulation and improves salt tolerance in plants. The Sugars will eventually be exported transporters (SWEETs) OsSWEET13 and OsSWEET15 regulate the transport and distribution of sucrose and maintain sugar homeostasis in rice under drought and salinity stresses. Rice glycine betaine is synthesized by the choline monooxygenase OsCMO and the betaine aldehyde dehydrogenase OsBADH1, which enhance rice tolerance to salt stress by promoting glycine betaine accumulation. The *LEA* genes *OsLEA3-2*, *OsLEA4*, *OsLEA5*, and *OsEm1* significantly improve plant tolerance to salt and osmotic stresses

ROS scavenging:

Plant exposure to salt stress can upregulate the production of ROS such as 1.O2 (singlet oxygen), O2− (superoxide radical), H2O2 (hydrogen peroxide), and OH− (hydroxyl radical). Although low ROS concentrations can function as a signal to activate salt stress responses, excess ROS accumulation causes phytotoxic reactions including DNA mutation, protein degradation, and the peroxidation of carbohydrates and lipids. Plants use enzymatic and nonenzymatic antioxidants to mitigate ROS stress.

Enzymatic scavengers include nicotinamide adenine dinucleotide phosphate oxidases (NOXs, also called respiratory burst oxidase homologs [Rbohs]), superoxide dismutase (SOD), ascorbate peroxidase (APX), catalase (CAT), glutaredoxin (GRX), glutathione peroxidase (GR), glutathione S-transferase (GST), and glutathione peroxidases (GPXs). Nonenzymatic scavengers include ascorbic acid (ASH), alkaloids, carotenoids, flavonoids, glutathione (GSH), phenolic compounds, and tocopherol. *OsRbohA* and *OsRbohI* are induced by salt treatment, whereas *OsRbohB*, *OsRbohC*, *OsRbohE*, and *OsNox6* are repressed. *OsMn-SOD1* and *OsCu/Zn-SOD* overexpressionlines show lower accumulation of O2− and H_2O_2under salt stress. *OsAPX2*, *OsAPX7*, *OsAPx8*, *OsAPXa*, and *OsAPXb* increase APX activity, lower H_2O_2 and malondialdehyde (MDA) levels, decrease oxidative stress damage, and enhance rice tolerance to salt stress. *OsGST4* is induced by heavy metals, hypoxia, and salt stress in rice.

Glutathione responsive rice glyoxalase II (OsGLYII-2) functions in salinity adaptation by maintaining better photosynthetic efficiency and increasing the antioxidant pool. *OsGR2*, *OsGR3*, and*OsGRX8* increase GSH content and enhance tolerance to various abiotic stresses, including salinity, osmotic, and oxidative stress. The cytosolic dihydroorotate dehydrogenase gene *OsDHODH1* improves rice tolerance to salt and osmotic stresses.

The calcium-dependent protein kinases OsCPK4 and OsCPK12 and the receptor-like kinaseOsSIK1 promote tolerance to salt stress by reducing the accumulation of ROS. The transcription factors OsZFP179, OsZFP182, OsZFP213, OsHBP1b/OsbZIP3, OsMADS25, OsMyb2, and OsMyb6 positively regulate salt tolerance by increasing ROS-scavenging ability, whereas the zinc-finger proteins DST and DCA1 negatively affect rice salt tolerance by regulating the transcription of ROS-scavenging genes. All these studies suggest that enhancing ROS-scavenging ability can efficiently increase the salt tolerance of rice.

Nutrient imbalance:

Salt stress causes plant nutritional deficiencies due to reduced transport efficiency and decreased uptake of nutrients such as N, P, K, Ca, Zn, and magnesium (Mg). Mg2+ transport by OsMGT1 in the mature root zone synchronously enhances OsHKT1;5 activity, which restricts Na+ accumulation in the shoots and improves salt tolerance.

The rice aminotransferase OsAMTR1 interacts with stress associated protein 1(OsSAP1) and regulates abiotic stress responses. The cytokinin type-B response regulator (RR) OsRR22 regulates Zn acquisition by directly modulating the expression of Zn-regulated transporter genes and the sensitivity to salt stress. *OsMADS27* regulates root development in a NO_3- dependent manner and modulates salt tolerance in rice.

Adaptive mechanisms in rice for salinity tolerance

Under salt stress conditions, rice plants exhibit various mechanisms to overcome the damage such as controlling the seedling vigour, reducing the intake of salt through roots, efficient intra cellular compartmentation and transport of salt.

Seedling vigour:

Salt stress leads to higher accumulation of Na+ in shoots, mainly in mature leaves. Various reports have shown that limiting Na+ accretion in shoot part under salt stress is linked to salinity tolerance of barley and wheat. In rice, it has also been verified that sodium ion accretion in shoot part is comparatively well linked with its growth under salt stress (Yeo *et al*., 1990). Rice varieties differ considerably in their rate of development with the most vigorous one being the conventional landraces and the shorter ones are the cultivated high yielding varieties. Naturally occurring salt tolerant varieties like Pokkali, Nona Bokora etc. belong to these conventional tall varieties. In spite of having comparable net transport of Na+ ion through their roots as partially dwarf salt susceptible cultivars, the high vigor of land races permits them to tolerate growth decline by diluting the Na+ content in rice cells.

Root permeability and selectivity:

The lethal ions enter into the root along with water that travels from soil to the vascular part of the root by two routes, *i.e.*, symplastic and apoplastic. In apoplastic pathway which is a non-energy driven pathway, water travels through intracellular regions to deliver the salt in xylem. In symplastic pathway, water enters in the roots through epidermal plasma membranes and then travels cell-to-cell through plasmodesmata until discharging to the xylem. Rice is a salinity susceptible crop and it has been revealed that a major quantity of sodium ion transported to the rice shoot parts at the time of salt stress is via apoplastic pathway (Krishnamurthy *et al*., 2009). Munns (1985) reported that, under 100 mM of sodium chloride stress, the transport rate of Na+ ion toward shoots of salt tolerant barley is quite lower (only 20%) in relation to salt sensitive rice plants.

This observation indicates that a major involvement of Na+ bypass movement in salt stress-induced shoot causes sodium ion accretion in rice shoots. Although water can passively move from roots through intercellular space, but there are morphological components called as suberin lamellae and Casparian band at the root endo and exo-dermis, which restricts the apoplastic flow of ions and water to go inside the stele (Schreiber *et al*., 1999). Casparian bands are formed by transverse and radial walls infusing the pores of primary cell wall with aromatic and lipophilic materials and suberin lamellae is deposited to the inside surface of cell walls (Ranathunge *et al*., 2004). Chemical nature of the root apoplastic barrier is crucial for their performance (Schreiber *et al*., 1999).

It was observed that in roots, apoplastic barriers suberization was most common in salinity tolerant plants, which also has the least Na+ accretion in the shoot parts (Krishnamurthy *et al*., 2009; Cai *et al*., 2011). Krishnamurthy *et al*. (2009) have also revealed that in both susceptible and tolerant varieties, the expression of suberin biosynthetic genes was induced under salinity stress, which increased the reinforcement of these barriers in roots of rice. Though the mechanism of apoplastic movement of Na+ has not been clear, Na+ over accretion through bypass movement in rice shoots is supposed to be the result of Na+ reflexive flow into the xylem. Roots with weak barrier areas like lateral root originating sites and cell walls of root tip area were expected to be the possible entrance sites for Na+ bypass movement. Ranathunge *et al*. 2004 reported the disruption of the endodermal casparian stripes, and ultimately crack through the fence in the exodermis at the time of lateral roots emergence at the pericycle region next to the phloem in the root of monocot.

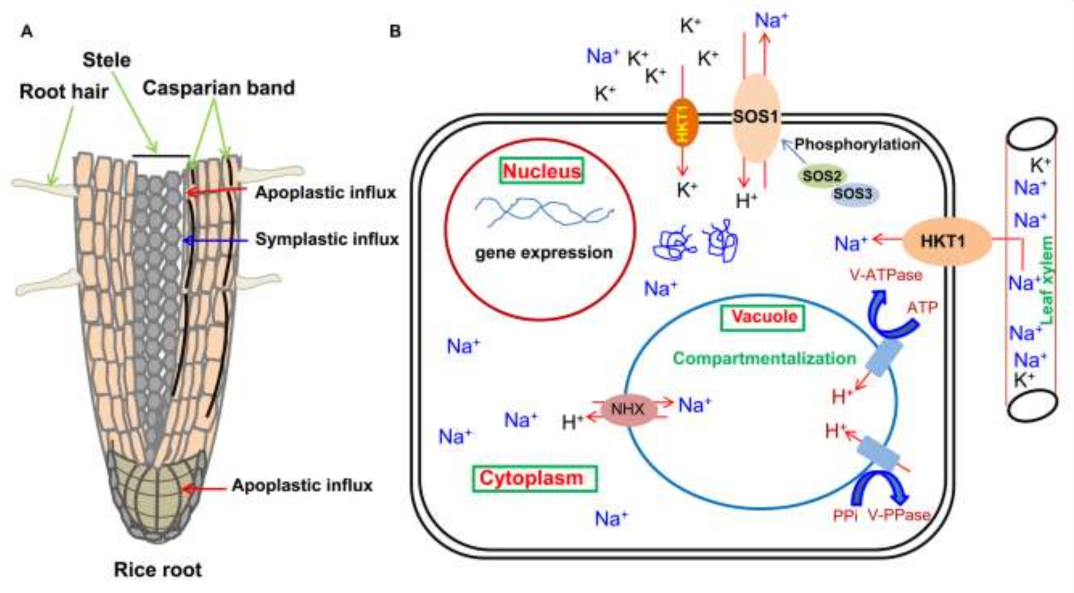


FIGURE 2 | Schematic representation of Na^+ influx in roots, its sequestration pathways and primary protective mechanisms as mediated by the transporters present on plasma membrane and tonoplast of the cell. (A) Influx of Na^+ through plant root. Red arrows represent probable Na^+ entry sites for the apoplastic bypass flow and blue arrow represents the path for symplastic movement. **(B)** Various transporters (NHX, HKT, SOS1) responsible for ion movement localized on the biological membranes have been shown for an individual cell of the plant. The energy providing (vacuolar H^+-ATPase or V-ATPase, vacuolar H^+-translocating pyrophosphatase or V-PPase) and activating molecules (SOS3, SOS2) are also shown.

Intracellular compartmentation:

Based on osmotic potential, plant can check Na^+ ion to go into the cell by energy driven process. K^+ and Na^+ are interceded by dissimilar transporters which have been verified by Garciadeblas *et al*. (2003).

Cell ion homeostasis is maintained by the ion pumps like symporters, antiporters, and carrier proteins present on the membranes. In cereals, Na^+ exclusion systems were suggested to be composed of several transporters present on cell membrane like H^+-pump ATPases, Na^+/H^+ antiporter and the high-affinity uptake of K^+ ion (Jeschke,1984). Salt Overly Sensitive or SOS pathway of homeostasis is an excellent example of ion management which is turned 'on' following the activation of the receptor in response to salinity and transcriptional induction of genes by signaling intermediate compounds (Sanders, 2000). Zhu *et al*. (1998) first reported three *sos* mutants of *Arabidopsis* which were hypersensitive to specific salt-NaCl.

When higher accumulation of Na^+ in cytosol occurs, Na^+ get sequested into the vacuole before it arrives to a toxic point for enzymatic reactions. This pumping action is regulated by vacuolar Na^+/H^+ antiporters. Increase in level of salt induces the Na^+/H^+ antiporter action but it amplifies more in salinity tolerant varieties than salinity susceptible ones. The Na^+/H^+ exchange in vacuole is determined through two separate proton pumps, *i.e.,* vacuolar H^+-ATPase and vacuolar H^+-translocating pyrophosphatase. Manipulation in the levels of vacuolar transporter (NHX1) leads to improve salinity tolerance in rice, *Arabidopsis, Brassica* and Tomato. One endosomal Na^+/H^+ antiporter (OsNHX5) and four vacuolar Na^+/H^+ antiporters (OsNHX1-4) in rice (Figure 2B).

Osmoprotectants:

Most of the organisms including plants and bacteria accumulate certain organic solutes (such as sugars, proline etc.) due to osmotic stress. These compounds are called osmoprotectants because even when present in high concentrations they do not hinder with cellular enzymatic reactions. These are found in cell cytoplasm and the inorganic ions like Cl^- and Na^+ are preferentially seized into the vacuole, consequently leading to the turgor preservation for the cell under osmotic pressure. The non-reducing sugar trehalose possesses a distinctive feature of reversible water storage ability to guard cellular molecules from dehydration stress. The trehalose biosynthesis and accumulation in transgenic rice can provide tolerance to salinity and drought stresses. Role of other osmoprotectants such as proline, glycine betaine, mannitol etc. in salt stress tolerance in plants has also been well documented.

Omics-based approaches in the modern era:

Plant molecular biology seeks to study biological and cellular processes like plant development, its genome organization, and communications with its surroundings. These multidimensional detailed studies require large-scale experimentation linking the whole genetic, functional and structural components. These large-scale experimentations are known as 'omics.' Chief contributors of 'omics' include genomics, transcriptomics, proteomics, metabolomics, and phenomics. 'Omics' approaches are regularly used in various research disciplines of crop plants, including rice. These approaches have enhanced very fast during the last decade as the technologies advance. Following section describes how 'omics-based' approaches have helped in understanding and dissecting out the mechanism of salinity tolerance in rice and helped in generating several salt tolerant germplasms.

Genomics-based approach molecular marker resources and quantitative trait loci (qtl) mapping for rice salinity tolerance:

Accessibility of the whole genome sequence of rice has contributed to the rapid development in the area of functional genomics of salinity tolerance in rice. This information further supported by development of a number of single nucleotide polymorphism (SNP) markers and simple sequence repeat (SSR) markers. Both SSR and SNP marker analysis have been successfully used to discover salt tolerant cultivars of rice. In the recent past, development of next generation sequencing (NGS) has enabled the sequencing based genotyping way more efficient. QTL studies for salt stress tolerance have been investigated by several researchers. Genetic maps of rice have been generated using recombinant inbreed lines developed from genetically distant varieties, such as indica and japonica rice as parents. Such combinations generate appreciably more polymorphism than that between the same subspecies. The first rice genetic map by restriction fragment length polymorphism technique; different fine maps have since been generated using various markers such as amplified SSR, random amplified polymorphic DNA and fragment length polymorphism.

Seven QTL linked with salinity have been recognized for rice seedlings and mapped to different chromosomes. Using F2 population obtained from a salinity tolerant mutant of rice (M-20) and the salinity susceptible wild variety (77–170A), a key gene for salinity tolerance has been mapped on chromosome 7. The chromosomal location selectivity traits of an ion transport which are companionable with agronomic demands. Mapped a major Saltol QTL which is flanked by markers RM23 and RM140 on chromosome 1, using a population raised from a cross among Pokkali and IR29. More than 70% of the difference in salt uptake has been accounted by this QTL. Pokkali was the basis of positive alleles for this QTL, which accounted for decreased sodium and potassium ratio under salinity. QTL for increased shoot K+ under salt stress in the similar position of chromosome 1. Mapping SKC1 on chromosome 1 was a breakthrough which preserves K+ ion homeostasis in the salinity-tolerant cultivar (Nona Bokra) under salinity conditions.

Introduction of desired gene/genes into the rice genome for salinity tolerance – the 'reverse-genetic' approach:

Plants react to salinity by limiting the intake of toxic ions like Na+ and regulate their osmotic potential by producing compatible solutes (sugars, glycine betaine, proline etc.) and partitioning toxic ions into the tonoplasts to maintain low Na+ levels in the cytoplasm. Salinity tolerant transgenic rice plants were generated by getting ideas from the above observation. Produced transgenic rice by introduction and over-expression of late embryogenesis abundant (LEA) protein from barley. Their study demonstrated that the transgenic rice possessed a better growth rate under 200 mM of salinity and better recovery upon removal of stress. Similarly, genetically engineered rice has also been developed with the capacity to produce glycine betaine bay gene (codA) encodes choline oxidase and it has been found to have better salt (150 mM NaCl) tolerance than the WT.

Genome modification through mutation breeding for salinity tolerance in rice – the 'forward-genetics'approach:

Although efforts to advance stress tolerance in plant by genetic manipulation have resulted in some significant achievements, mutation breeding technique has been accepted as a foremost strategy to obtain stress tolerant varieties as well as varieties with other desired traits. Mutation breeding has a significant contribution toward production of high yielding and salt stress tolerant rice varieties. There are many reports where mutation breeding has resulted in enhanced salinity tolerance in various rice cultivars. For example, rice seeds irradiated with carbon (C) or neon (Ne) ions have generated mutant variety with high salt tolerance. The Azolla-Anabaena symbiotic system provides green manure for flooded crops, mainly rice. Mutation breeding has produced Azolla variants tolerant to high salinity, toxic aluminium levels, and to herbicides.

Transcriptomics approach:

Transcriptomics, also called as expression profiling, generally require a systematic and entire study of all the RNA transcripts that signifies the spatial and temporal gene expression of a cell, tissue of an organism under a certain biological circumstance. This technique leads to identification of a large number of differentially regulated transcripts due to cross talks and overlapping pathways under particular stress/environmental situations. Microarrays have become one of the standard tools in molecular biology and have taken as commanding approach for the analysis of genome wide transcriptional response by studying the expression of all the expressed genes in a single experiment.

The complete transcriptome at a given time point allow us to detect any stress-inducible genes which can suggest the specific biological processes and/or the regulation of transcriptional and translational machineries that are induced. In rice, EST based cDNA arrays and oligonucleotide microarrays have been used to understand the underlying biological meaning by studying and comparing the global gene expression patterns. In the recent past, stress (including salinity)- inducible transcripts in rice were identified by using microarray technology (Kumari *et al*., 2009).

The capability to evaluate the expression levels of whole genome in a single experiment by microarray technique allows biologists to see what are the genes induced or repressed under specific environmental extremes. The constraint is that in addition to the actual genes that control the stress response, it detects enormous number of related genes which might be involved in secondary or irrelevant downstream functions. Beside the challenge of recognizing the relevant target genes, the transcriptomic approach offers an efficient tool of identifying the gene(s) involved in specific stress tolerance mechanism.

Conclusion:

- There is a need for developing new rice varieties with higher and stable yield across environments, climates and geographic locations.
- Mechanisms studied in rice have focused on Na^+ exclusion of Cl^-, $NO_3{}^-$and their location in the pathway from roots to shoots are yet to be addressed.
- The ideal salinity tolerant variety should possess tolerance to high amount of Na^+, control the uptake of Na^+ and keep high uptake of K^+, good initial vigour, agronomically superior with high yield potential.
- Last but not the least, the salt tolerant transgenic rice should be in the hand of final user i.e., farmer.

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HORTICULTURAL BIOSTIMULANTS

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Summary:

The horticultural industry is currently facing a significant challenge in enhancing productivity to meet the needs of a growing global population. It is crucial to maintain nutritional security while improving resource efficiency to minimize the environmental impact on ecosystems and human health. In this context fertilizers and insecticides play a vital role by enabling farmers to enhance output and ensure year-round productivity regardless of weather conditions. Over the past three decades various innovative technological advancements have emerged with the aim of promoting sustainability in horticultural production systems. These advancements primarily focus on reducing the reliance on synthetic agrochemicals such as pesticides and fertilizers. The utilization of natural plant bio-stimulants (PBs) represents an innovative approach that can foster environmental sustainability while offering a range of advantages. These bio-stimulants effectively promote flowering, enhance plant growth, fruit development, bolster crop production and improve nutrient usage efficiency (NUE). Moreover, they exhibit the ability to enhance resistance against various abiotic stresses. By harnessing the potential of PBs we can foster both environmental well-being and take significant strides towards achieving sustainability goals [1].

Introduction:

Plant biostimulants also referred to as agricultural biostimulants encompass a wide range of compounds that can be applied to the plant's surrounding environment with the aim of enhancing growth, nutrition and resilience to various abiotic and biotic pressures. While the primary purpose of most plant biostimulants is to facilitate nutrient uptake in the rhizosphere many of these substances also offer protective effects against environmental challenges such as limited water availability, soil salinity and unfavorable temperature conditions for growth. It is important to note that biostimulants themselves do not function as nutrients instead they assist in nutrient absorption and contribute beneficially to stimulate growth and confer resistance against stressors. In an online publication dedicated to turf care experts called Ground Maintenance the term "biostimulants" made its debut to describe substances that when used in small amounts encourage plant growth. Within the agricultural field a consensus was reached in 2012 regarding the definition of biostimulants. According to this definition biostimulants refer to substances and/or micro-organisms that when applied to plants or the rhizosphere (the root zone) activate natural processes aimed at enhancing nutrient absorption, nutrient efficiency, tolerance to environmental stresses and overall crop quality. Biostimulants possess extensive applicability across various agricultural techniques encompassing hydroponics, soil-based systems as well as field and greenhouse-grown crops, conventional and organic farming. The global market value of Biostimulants amounted to USD 3.5 billion in 2022 and is projected to soar to USD 6.2 billion by the year 2027 (marketsandmarkets.com, 2023).

Types of biostimulants

Plant bio-stimulants are classified into two main categories: microbial and non-microbial. A microbial plant bio-stimulant comprises either a single microorganism or a cluster of microorganisms primarily belonging to four distinct genera: *Azotobacter spp*., Mycorrhizal fungi, *Rhizobium spp*. and *Azospirillum spp*. The advantageous bacteria and fungi that inhabit plants can confer enduring and advantageous impacts on plant growth and overall health. Additionally, microbial bio-stimulants play a crucial role in extending the shelf life of produce during the retailing process and enhancing the landscape performance for individuals [2]. These bio-stimulants contribute to the improved performance of crops by enhancing various cellular and morphological metabolic processes within the plant system [3].

Non-microbial biostimulants encompass a wide range of bioactive compounds including humic acid, fulvic acid, protein hydrolysates and seaweed extracts *etc*. Protein hydrolysates can be derived from both plants and animals. Humic and fulvic acids are formed through the degradation of organic matter leading to the formation of acid compounds containing carboxyl and phenolate groups. Fulvic acids belong to the category of humic acids however, they distinguish themselves from humic acid by exhibiting a higher oxygen concentration and a lower molecular weight.

Characteristics of biostimulants

1. Bio stimulants can be formulated using either a solitary ingredient or a combination of multiple components.
2. They may be based on animals or plants.
3. They possess multitude of diverse physiological functions.

Biostimulants sources

Biostimulants are primarily derived from natural sources with one example being rosemary, which is an extract obtained from the plant. Rosemary oil aids in nutrient absorption and enhances nutrient uptake leading to increased growth and development. The fresh weight of roots is determined by employing hydrolysis techniques, utilizing chemicals or enzymes to generate different kinds of plant and animal biostimulants. This hydrolysis process yields a mixture of peptides and amino acids. To produce animal-based biostimulants from materials like bird feathers, casein (derived from cow's milk), collagen, bones, animal tissues or fish waste it is necessary to carry out acid or alkaline hydrolysis. Given that plant-based biostimulants require hydrolysis using different enzymes for their production and various organic materials can be utilized. These materials include straw, legumes, vegetable or fruit waste all of which can be employed in the production of plant biostimulants [4]. Additionally, marine algae-derived biopreparations and symbiotic groups of beneficial fungi or bacteria are also significant sources of biostimulants.

Ways of using bio stimulants

Biostimulants can be utilized in diverse manners depending on their types and forms. They can be employed through different applications such as soil preparations (powders, pellets, or solutions mixed into the soil) or as liquid foliar applications directly on the leaves. Another approach is fertigation where biostimulants are administered alongside water allowing plants to absorb them similarly to how they take up water. Non-microbial biostimulants including humic acids, fulvic acids and nitrogen-containing compounds are commonly administered to the soil directly. Additionally, plant and seaweed extracts of different kinds are applied as foliar sprays to the leaves of plants. To enhance the nutrient content of the soil it is customary to apply organic matter or bone meal directly to the soil several weeks before planting. Agricultural techniques such as ploughing are employed to incorporate biomass or meal into the topsoil for proper mixing. Stimulants typically come in various forms but the most common ones are preparations or powders that can be mixed with water or any other solvent to create a solution. The optimal time to administer biostimulants is in the morning as this is when stomata are open and the absorption rate is at its highest.

Role of biostimulants in horticulture

1. **Enhances plants ability to withstand abiotic stress**

Under the current circumstances of climate change it is expected that environmental pressures will exert a stronger negative impact. This has raised significant concerns about agricultural productivity and global food security. In order to address this challenge both non-microbial and microbial plant boosters (PBs) have been suggested as effective and cost-efficient means to enhance yield stability. In controlled experiments, the application of a legume-based plant booster containing amino acids and soluble peptides was found to alleviate the harmful effects of drought on tomato growth by improving transpiration use efficiency [8]. This was observed when the plant booster was used as a foliar spray or applied to the soil as a drench substrate. *Hartmannibacter diazotrophicus* E19 (T) has the ability to effectively establish itself in the roots of barley even in saline environments. When the roots were inoculated with this bacterium in saline soil a significant increase in both root and shoot mass was observed with a respective growth of 308 and 189 per cent. The relative water content of the inoculated roots was more than three and a half times higher compared to the control plants. Researchers found that treating wheat with the thermotolerant *Pseudomonas putida* strain AKMP7 led to a remarkable improvement in heat tolerance. Plants treated with this inoculum exhibited enhanced root and shoot length as well as seed size [9]. Furthermore, a short-term trial demonstrated the effectiveness of a protein hydrolysates-based biostimulant in mitigating the harmful effects of single stresses (such as hypoxia, salinity or nutrient deficiency) and multiple stresses (such as nutrient stress combined with hypoxia or salinity) on hydroponically grown maize [10]. The significant enhancement of root development encompassing biomass and architecture (length and density) was profoundly influenced by protein hydrolysates leading to the upregulation of crucial genes associated with nitrate transport and detoxification of reactive oxygen species. Consequently, this substantial improvement in root development contributed to a remarkable surge in shoot biomass [11].

2. Enhancing agronomic traits in horticultural crops

Biostimulants have been found to exert positive effects on a range of agronomic characteristics including fruit size, shape, plant height, root length, shoot weight, root weight and leaf number. In one study when a concentration of 3g/l of humic acids was sprayed alongside other biostimulants it resulted in an increase in cucumber plant height as well as a higher number of leaves and stems per plant. Moreover, the application of biostimulants to cherry trees was observed to enhance fruit weight. Additionally, when the bio stimulant salicylic acid was used together with calcium it demonstrated its bio stimulatory properties by increasing the yield of tart cherries. These findings underscore the potential of biostimulants in improving various agronomic traits and productivity in agricultural practices. A lettuce greenhouse experiment was conducted to assess the impacts of three distinct plant biostimulants (PBs): vegetal-derived PH, vegetal-derived PH enriched with copper and an additional PB. The application of a tropical plant extract on plant development and the epiphytic bacterial community was investigated. In the study three commercial plant boosters (PBs) were tested and they all showed an increase in the fresh weight of the shoot. However, there were no statistically significant differences observed between the three organic PBs [5]. Moreover, the utilization of biostimulants which consist of vermicomposting, malt, dust, organic herbs demonstrated the ability to enhance plant performance and growth by altering the microbial composition on the plants and in the surrounding environment. When *Prunus armeniaca* (apricot) was treated with biostimulants containing humic and fulvic acids along with carboxylic acids the fruit exhibited a remarkable tenfold increase in size compared to its original size. This suggests that the biostimulants had a profound impact on fruit development and growth. Based on the research findings it was discovered that carboxylic acids exerted the most significant impact on fruit size and leading to an average increase in fruit width of 2.6 mm during the second growing season. Additionally, the color of the fruit plays a crucial role in assessing its quality [6]. Another noteworthy attribute of silicon is its ability to stimulate biological processes. A study examined the effect of silicon-containing *Ascophyllum nodosum* extract on strawberry anthocyanin levels. The fruits treated with the bio-stimulant exhibited higher anthocyanin content during the early fruiting stage resulting in a more vibrant red color compared to the control group [7].

3. Enhance the antioxidant properties of fruits and vegetables

Extensive research has shown that fruits and vegetables possess inherent antioxidant properties. Moreover, the application of biostimulants has been found to amplify the antioxidant potential in various horticultural crops. For instance, when tomato plants were treated with a combination of earthworm-grazed substrate and *Trichoderma harzianum*-biofortified mushroom substrate (SMS) notable enhancements were observed in multiple aspects. These included increased antioxidant capacity, higher levels of total soluble sugars, carotenoids, total polyphenols, flavonoids contents and improved mineral composition (P, K, Ca, Mg, Fe, Mn, and

Zn) [12]. In another study sunflower seeds (*Helianthus annuus* L.) were soaked in a 3 per cent corn seed extract solution and subsequently sprayed with 1 mM of Magnesium. The result was a notable enhancement in the sunflower's antioxidant system. Specifically, the activity of superoxide dismutase, catalase and peroxidase increased by 65.5 per cent, 77.8 per cent and 84.6 per cent respectively, when compared to the control plants.

The elevated levels of antioxidant enzymes were attributed to the foliar application of magnesium ions which not only improved the speed of the photosynthesis process but also promoted overall plant health. Similarly, the application of bio stimulants to apricot trees has demonstrated the ability to enhance the antioxidant properties of the fruits. In the initial season following the utilization of these stimulants the antioxidant capacity of the fruit increased significantly, averaging at 76.8 mg/100 g. However, in the subsequent season where the stimulants were not employed the average antioxidant capacity decreased to 66.5 mg/100 g. Notably, a noteworthy discovery was made in the realm of olive trees wherein the foliar application of selenium (Se) led to notable advancements in the functional and nutritional qualities of Extra Virgin Olive Oil (EVOO). This improvement was attributed not only to the biofortification effect of Se but also to the observed accumulation of antioxidant molecules [13]. The introduction of *Rhizophagus intraradices* into soilless-grown saffron along with a mixture of *R. intraradices* and *Funneliformis mosseae* to a lesser extent resulted in a significant enhancement of the synthesis and accumulation of beneficial compounds such as anthocyanins, polyphenols and vitamin C. Additionally, this inoculation led to increased antioxidant activity and the presence of important bioactive components like crocin II, quercitrin and picrocrocin. Furthermore, compost possesses biostimulatory properties revealing a diverse array of constituents depending on the raw materials used and the composting procedures employed. These constituents may include polysaccharides, amino acids, nitrogen and various other substances. According to a study [14], during the autumn season lettuce leaves cultivated in compost exhibited 1.5 times greater antioxidant activity compared to lettuce cultivated in compost during the summer season. Additionally, the autumn-grown compost lettuce demonstrated significantly higher antioxidant activity than lettuce grown in peat during the same season.

4. Enhance Nutrient Use Efficiency (NUE)

The utilization of biostimulants is an incredibly advantageous approach to enhance soil nutrient levels and facilitate their absorption by plants. A significant portion of nitrogen and phosphorus present in soils remains unavailable in their current form under scoring the importance of converting them into accessible forms for plant utilization. Biostimulants offer a highly effective means to achieve this objective. Numerous studies have demonstrated the remarkable efficacy of these bioactive substances in enhancing plant nutrient use efficiency (NUE). The utilization of biostimulants derived from *Ecklonia maxima* (algae) and a range of tropical plants has demonstrated remarkable enhancements in lettuce production within greenhouse environments. These biostimulants have effectively enhanced nutrient utilization efficiency leading to improved overall plant growth. Moreover, they have been found to enhance chlorophyll synthesis thereby augmenting the photosynthetic activity of the plants. The combined effect of these improvements ultimately results in higher lettuce yields [15].

Conclusion:

Biostimulants, derived from natural sources are utilized to enhance the growth and yield of vegetables and fruits while prioritizing environmental sustainability. Despite the widely recognized advantages of biostimulants they are seldom incorporated into conventional farming practices. This lack of integration stems from farmer's limited knowledge regarding the functions and applications of biostimulants giving rise to concerns about increased cultivation costs and compromised plant quality and quantity. Such repercussions could ultimately harm crop profitability. Consequently, raising awareness among farmers is of paramount importance to promote the widespread adoption of biostimulants and their numerous benefits.

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ROLE OF JASMONIC ACID IN PLANT DEVELOPMENT AND DEFENSE RESPONSE

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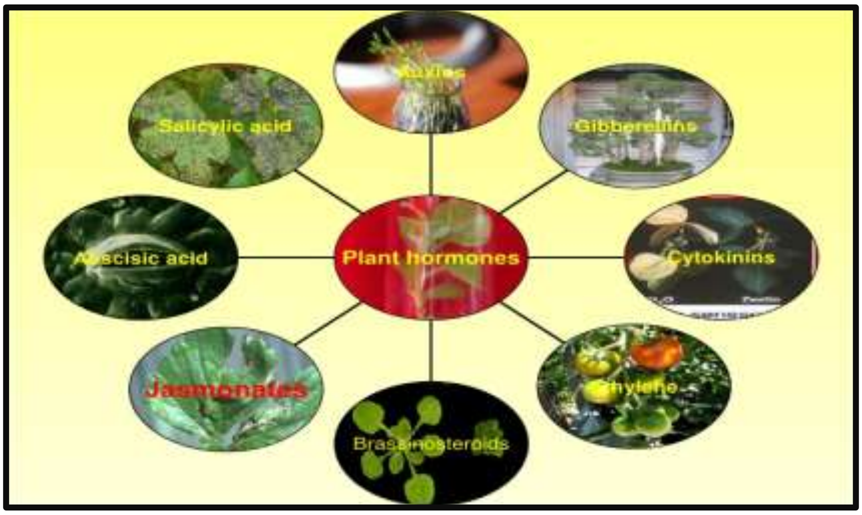
Introduction:

Hormones are chemical messenger, which plays a vital role in controlling the entire life process and other activities in the plants -like seed germination, ripening, growth, and flowering. The term "hormone" is derived from a Greek word meaning “to stimulate or to enhance an activity" Plant growth regulators are usually defined as organic compounds other than nutrients that in smaller concentration, affects the physiological processes of plants.



Jasmonates are cyclo pentanone compounds or Novel plant immune hormones which is derived from α- linolenic acid by the octadecanoid pathway. It includes group of oxygenated fatty acids which are collectively called as oxylipins. Methyl jasmonate was first isolated from the essential oil of *Jasmoinum grandiflorum.*

First isolated in culture filtrate of fungi *Lasiodiplodia theobroma*. Jasmonic acid initial discovery of metyl jasmonates (MeJA) as secondary metabolite in essential oil of jasmine. Role of plant defense was first shown by Farmer and Ryan (1990) who demonstrated the induction of proteinase inhibitors by MeJA and JA as part of the defense respone against herbivorous insects.

Jasmonate (JA) and its derivatives are lipid-based plant hormones that regulate a wide range of processes in plants, ranging from growth and photosynthesis to reproductive development. In particular, JAs are critical for plant defense against herbivory and plant responses to poor environmental conditions and other kinds of abiotic and biotic challenges. Some JAs can also be released as volatile organic compounds (VOCs) to permit communication between plants in anticipation of mutual dangers.

Synthesis is initiated with the conversion of linolenic acid to 12-oxo-phytodienoic acid (OPDA), which then undergoes a reduction and three rounds of β oxidation to form (+)-7-iso-JA, jasmonic acid. Only the conversion of linolenic acid to OPDA occurs in the chloroplast; all subsequent reactions occur in the peroxisoxysome.

Jasmoinum grandiflorum **(JASMINE)** **Jasmonic acid**

Properties

- Chemical formula: $C_{12}H_{18}O_3$
- Molecular mass: 210.27 g/mol
- Density: 1.1 g/cm^3
- Boiling point: 160 °C

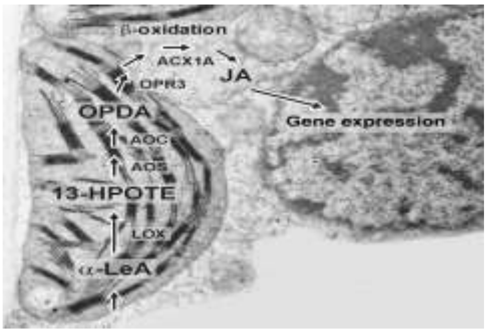
Functions of Jasmonic acid

- JA and MeJA inhibit the germination of nondormant seeds and stimulate the germination of dormant seeds.
- JA, MeJA, ABA, and ethylene inhibit the germination of the recalcitrant seeds of Quercus robur. When these desiccation-sensitive seeds were dried, the concentrations of MeJA and JA increased prior to the loss in seed viability.
- The increase in jasmonate was correlated with lipid peroxidation, suggesting that the production of jasmonate may not regulate germination but rather is a consequence of membrane damage.
- The seeds of the Arabidopsis mutants show increased sensitivity to ABA suggesting that JA may stimulate seed germination by decreasing sensitivity to ABA.
- JA strongly inhibits root growth by a mechanism that is not mediated by ethylene (Berger *et al*., 1995).
- JA also inhibits indole acetic acid-stimulated coleoptile elongation, possibly by blocking the incorporation of glucose into cell wall Polysaccharides.
- JA activates the differential growth involved in tendril coiling in pea, a response that does not directly involve ethylene or indole acetic acid (IAA).
- That JA may play a role in the formation of flowers, fruit, and seed is suggested by the relatively high levels of this compound in developing plant reproductive tissues. The presence of jasmonate and related volatile fatty acid derivatives in the flower may indicate a function in insect attraction and thus pollen dispersal.

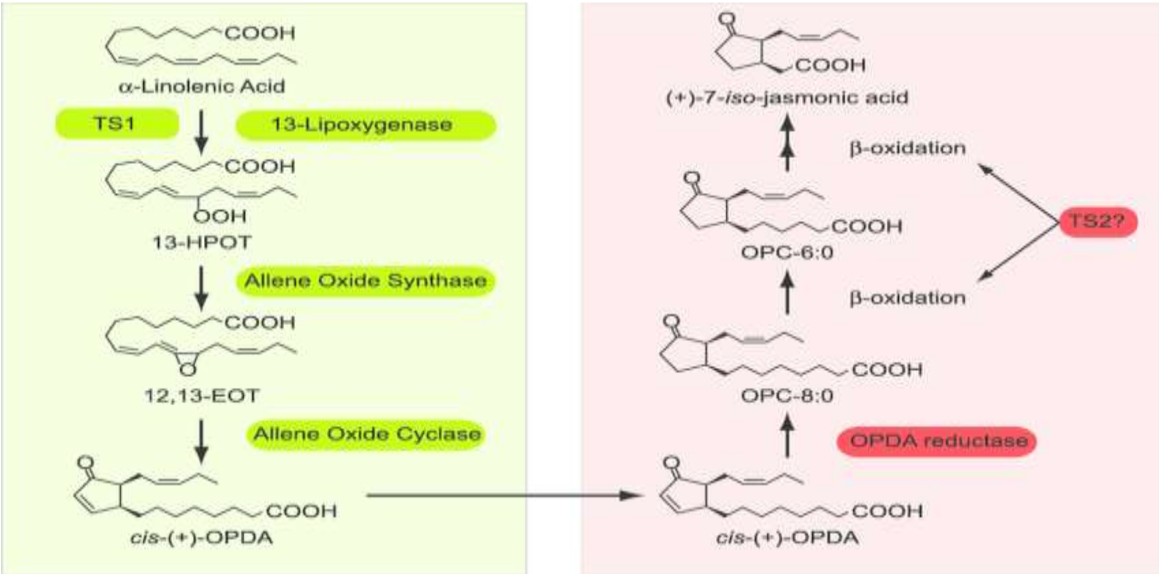
- Other aspects of flower, fruit, and seed development that can be modulated by jasmonate include fruit ripening, fruit carotenoid composition and the expression of genes encoding seed and vegetative storage proteins (VSPs).
- By contrast to the effects of JA on root growth, jasmonate-stimulated tomato and apple fruit ripening most likely occurs through the activation of ethylene-forming enzyme and the production of ethylene.
- A role for JA in mediating the accumulation of secondary plant products has also been proposed. Exogenous JA causes the accumulation of paclitaxel and related taxanes in *Taxus*, alkaloids in Cantharanthus and Cinchona, anthocyanins in soybean and rosmarinic acid in Litbospermum.
- JA levels are high in vegetative sink tissues, such as soybean axes, plumules, and the hypocotyl hook, suggesting that JA may be involved in the regulation of protein storage in plants.
- In six-week-old soybean seedlings, JA levels are higher in young growing leaves that are importing carbon and nitrogen than they are in older, fully expanded leaves.
- High levels of JA are also present in developing reproductive structures, especially pods, with lower levels in seeds. JA or a derivative tuberonic acid has been proposed to play a role in the formation of tubers, a specialized vegetative sink.
- Jasmonates play an important role in protein storage during plant development derives from the discovery that genes encoding VSPs are regulated by JA. VSPs accumulate in the vacuoles of paraveinal mesophyll and bundle sheath cells in soybean leaves.
- The Plant Cell JA is not essential for the production of viable ovules in Arabidopsis. However, the fad3-2 fad7-2 fad8 and *coil* mutants fail to produce viable pollen unless supplied with JA.
- Application of JA to leaves decreases expression of nuclear and chloroplast genes involved in photosynthesis. JA treatments also cause a loss of chlorophyll from leaves and cell cultures. The ability of JA to cause chlorosis led to the suggestion that this compound plays a role in plant senescence.

Biosynthesis of JA

- Jasmonic acid synthesized from fatty acid (α-linolenicacid)
- Lipoxygenase (LOX), AOS, AOC are key enzymes of JA biosynthesis in Chloroplast, and they form OPDA.
- OPDA is transported to peroxisome through ABC transporter COMATOSE (CTS) Reduction of cyclopentanone ring of OPDA is catalyzed by peroxisomal OPR enzyme.
- Three cycles of β-oxidation occur to give finally Jasmonic Acid Enzymes involved are:
    - ACX1 (Acyl-CoA oxidase in tomato)
    - MFP (Multi-functional Protein)
    - KAT (L-3-keto acyl CoA thiolase)
- The JA and its metabolic derivatives are collectively called JASMONATE.



Intracellular locations of enzymes and intermediates in JA biosynthesis, illustrated on a SEM of a barley mesophyll cell showing the associated cellular compartments



Biosynthesis of jasmonic acid in Chloroplast and Peroxysomes.

Metabolic fate of JA

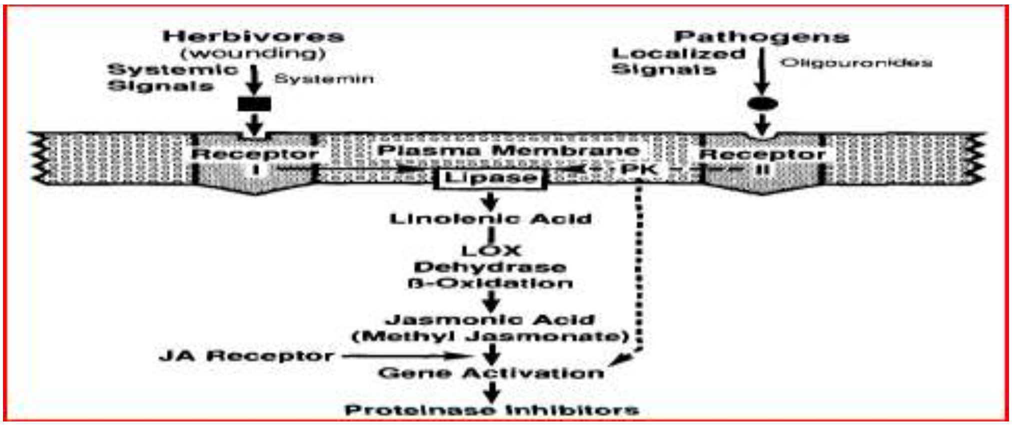
- Formation of amino acid conjugates by a JA conjugate synthase (JAR1) (Staswick and Tiryaki, 2004) upon adenylation at the carboxylic acid side-chain of JA by the AMP-transferase activity of JAR1.
- Methylation of JA by a JA-specific methyl transferase (Seo *et al*.,2001).
- Hydroxylation at C-11 or C-12 of the pentenyl side chain and subsequent O-glucosylation (Swiatek *et al*., 2004).
- Decarboxylation of JA to *cis-jasmone* (Koch *et al*., 1997).
- Formation of cucurbic acids by reduction of the keto group of the cyclo pentanone ring.
- Formation of jasmonoyl-1-b-glucose, jasmonoyl-1- b-gentiobiose and hydroxyjasmonoyl-1-b-glucose (Swiatek *et al*., 2004).
- Conjugation of the ethylene precursor ACC to JA (Staswick and Tiryaki, 2004).

Mechanism of signalling:

- The central feature of JA Signaling is the repression of JA responses JAZ (JASMONATE ZIM DOMAIN) protein family.
- JAZ proteins function to inhibit the activity of transcription factors responsible for driving the expression of JA responsive target genes.

- In the absence of JA, JAZ proteins bind to downstream transcription factors and limit their activity.
- However, in the presence of JA or its bioactive derivatives, JAZ proteins are degraded, freeing transcription factors for expression of genes needed in stress responses.

MECHANISM OF ACTION OF JA IN BIOTIC STRESS



Mechanism of herbivores and pathogen action in biotic stress

Role of Jasmonic Acid in Plant defense and development

1. Root Growth Inhibition
2. Lateral root formation
3. Adventitious root formation
4. Tuber formation
5. Trichome formation
6. Leaf movement
7. Senescence
8. Gravitropism
9. Development of reproductive organs of dicotyledonous plants
10. Development of reproductive organs of monocotyledonous plants
11. Seed germination

1. Root Growth Inhibition

Growth inhibition and senescence promotion were the first two physiological responses described for JA (Ueda and Kato, 1980; Dathe *et al*., 1981). Root growth inhibition by JA application has been used in mutant screens since the 1990s. The first mutant insensitive to JA was jar1 (Staswick *et al*., 1992). Subsequently, JAR1 was cloned as JA-Ile synthase (Staswick and Tiryaki, 2004). Root growth inhibition by JA was also strongly supported by short-root phenotype of mutants with constitutive elevation of JA levels, such as cev1 (Ellis *et al*., 2002), and reduced sensitivity to JA in coi1 and myc2 mutants (Xie *et al*., 1998; Lorenzo *et al*., 2004). For inhibition of root growth, JA requires COI1, as indicated by the JA-unresponsiveness of the coi1 mutant. However, ET and its precursor ACC, which occurs only in the light but not in the dark, are also known to inhibit root growth. The ACC/ET-induced root growth inhibition is light- and COI1-dependent, but JA-independent. However, JA-induced root growth inhibition needs to be analysed in relation to other factors controlling the complex process of root development (Petricka *et al*., 2012a; Ubeda-Toma´s *et al*., 2012). Initially, cell- and tissue-specific gene expression maps revealed non-overlapping areas of auxin-, GA- and JA-dependent gene expression. JA-induced gene expression appeared in outer layers of roots. But such expression data have to be taken into account cautiously, as the cellular proteome map of

Another example of auxin/JA cross-talk is given by the axr1 mutant defective in an SCF-complex component required for auxin signalling. Taken together, the JA-induced root growth inhibition seems to occur preferentially via modulation of the effects of auxin in root growth and development.

2. Lateral root formation

Most of the Arabidopsis lateral root mutants are affected in auxin homeostasis, signalling and transport and in PINs, thereby indicating the dominant role of auxin in lateral root formation (Petricka *et al*., 2012a). The various possibilities for cross-talk between JA and auxin as described above strongly suggest a role of JA in lateral root formation. The JA-insensitive mutant coi1-16 that produces fewer lateral roots lends further credence to this idea. Furthermore, the high promoter activities of AtAOC3 and AtAOC4 in emerging lateral roots suggest that JA is involved in lateral root formation. It has been shown that lateral root formation is induced by auxin, but is inhibited by the conjugate of JA with tryptophan.

3. Adventitious root formation

Adventitious roots are formed naturally or induced by environmental stimuli in aerial organs. Like root growth, adventitious root formation is a complex process regulated by hormones and environmental factors. Auxin is a positive regulator mediated by ARF6 and ARF8, which are targets of miR167 Interestingly, downstream of this auxin-induced adventitious root formation, there is a negative COI1- and MYC2-dependent regulation via altered JA/JA-Ile homeostasis. Whereas JAR1, which is the GH3.11 of the GH3 gene family of conjugating enzymes, generates JA-Ile, the other members (GH3.3, GH3.5, GH3.6) conjugate Asp, Met and Trp with JA. The triple-mutant of these genes has fewer adventitious roots and increased expression of JA biosynthesis genes, whereas mutants impaired in JA perception and signalling, such as coi1-16, myc2, myc3, myc4 and jar1 form far more adventitious roots than the wild-type. These data are in agreement with auxin–JA cross-talk that occurs during adventitious root formation. Here, the positive regulatory effects of ARF6 and ARF8 are increased by the GH3.3, GH3.5, GH3.6 module that attenuates the negative regulatory effect of JA/JA-lle via conjugation of JA to JA-Asp, JA-Met and JA-Trp. However, whether this increase in JA levels is essential for subsequent adventitious rooting remains to be elucidated.

4. Tuber formation

For a long time, tuber-inducing activities of jasmonates, particularly 12-OH-JA (TA) and its glucoside (TAG). StLOX-1 was shown to be involved in tuber yield and tuber formation and LOX-derived metabolites such as JA, TAand TAGaccumulate at low, tuber-inducing temperature. There were, however, only correlative data on the endogenous content of jasmonates in stolons and tuber formation. The cloning of a 12-OH-JA sulfotransferase from A. thaliana and tomato and the occurrence of 12-OH-JA, 12-HSO4-JA and 12-O-Glc-JA in different non-tuber-bearing plant species argue against a specific role of jasmonates in tuber formation. Possibly, tuber-inducing effects might be caused indirectly via cell expansion in stolons accompanied by changes in microtubule orientation (Abe *et al*., 1990), because JA biosynthesis may occur in developing stolons. Multiple pathways are involved in tuber formation. Besides hormonal control, tuberization in potato is strictly photoperiod-dependent. Low night temperature and a short-day photoperiod produce a systemic signal in leaves which induces tubers in roots. Tuberization depends on conserved function of the potato orthologue of CONSTANS (CO) and FLOWERING LOCUS T (FT). Both of them are key players in flower induction. Phytochrome B-mediated photoperiodic control of tuberization is well described. Identification of the BEL5 TF of potato shed new light on the regulation of tuber formation. StBEL5 binds together with the potato KNOX gene product POTH1 to promoter sequences of the gene encoding the GA-20 oxidase1, which leads to its repression and altered GA level that affect tuber formation and other aspects of vegetative development. Initiation of cell division in stolons by cytokinins is another hormonal control active in tuber formation (Xu *et al*., 1994).

5. Trichome formation

Glandular trichomes are multicellular and often involved in resistance to insects due to formation of terpenoids, flavonoids, alkaloids and defence proteins. They represent a useful tool for production of secondary metabolites. Genetic evidence for the involvement of JA in glandular trichome formation were obtained by characterizing the tomato homologue of COI1, the central component of JA perception. The corresponding tomato mutant jai1 is female sterile, but is impaired in grandular trichome formation, trichome monoterpene content and spider mite resistance. Further support for the link between trichome formation, JA and defence came from the recessive tomato mutant odorless-2 (od-2), which exhibits altered morphology, density and chemical composition of glandular trichomes. Under natural field conditions, od-2 plants were highly susceptible to Colorado potato beetle larvae and the solanaceous specialist Manduca sexta, indicating that trichome-borne compounds determine host plant selection under natural conditions. Recently, an antagonism between herbivore-induced plant volatiles and trichome formation has been observed in tomato. Using the JA-deficient spr2 mutant and the trichome-free JA-insensitive jai1 mutant, preferential oviposition that was observed on trichome-free JA-insensitive plants indicated a greater impact of trichomes over volatile emission in this tritrophic interaction. Furthermore, glandular and non-glandular trichomes are involved in defence against herbivores via trichome density and JA-inducible defence compounds, such as PI2, monoterpenes and sesquiterpenes. Consequently, the elevated JA level in cotton fibre activates downstream genes involved in Ca2+ signalling and ET biosynthesis. In Arabidopsis, targets of JAZ proteins are TFs such as MYB75, GL3 and EGL3, which are involved in anthocyanin biosynthesis and trichome initiation. JA regulates trichome initiation in a dose-dependent manner via the key TF in trichome formation GL3 and its interaction with JAZ proteins.

6. Leaf movement

There are several types of leaf movements. Among them are the upward leaf movement (hyponastic growth) and the leaf movement of nyctinasty plants such as Albizzia. Both of them are altered by JA compounds. Hyponastic growth is induced by ET, heat and low light intensity and is stimulated by JA but inhibited by SA. Nyctinastic leaf movement depends on activity of motor cells. Here, TAGhas a role. Among the enantiomeric forms of TAG, only one mediates activity of motor cells of nyctinasty plants, such as Albizzia and Samanea saman in a COI1-independent manner.

7. Leaf senescence

Leaf senescence is a complex developmental programme that depends on light/dark conditions, nutrients, biotic and abiotic stresses, and several hormones including JA. Over the last few years, several reviews on leaf senescence in relation to JA have been published. Therefore, only a few aspects will be discussed here. In A. thaliana, comparative large-scale transcript profiling between environmentally and developmentally regulated leaf senescence revealed only limited similarities in early stages, but showed convergence and divergence of gene expression profiles. High-resolution transcript profiling of senescing leaves identified a distinct group of TFs that link metabolic pathways, leaf development and senescence. The JA-linked TFs identified to be active in leaf senescence are WRKY53, WRKY54 and WRKY70 and ANAC092/ORE1. The F-box protein ORE9 was initially identified from a screen of ABA-, JA- and ET-induced senescence mutants, but it was found to have different regulatory properties in photomorphogenesis, shoot branching and cell death. Leaf senescence is characterized by JA-inducible chlorophyll breakdown. In A. thaliana, between the two key enzymes involved in chlorophyll degradation, the gene encoding the CHLOROPHYLLASE1 is strongly induced by JA. Moreover, a mechanistic explanation for the senescence-promoting effects of JA in leaves was provided only recently. It has been shown that Rubisco-activase is downregulated by JA in aCOI1-dependent manner.

8. Gravitropism

Gravitropism is a well-studied, morphogenic response, in which intra- and intercellular communictation by auxin takes place. Traditionally, the Cholodny–Went hypothesis is used to explain the asymmetric growth as a consequence of auxin redistribution. Regarding the repeatedly discussed cross-talk between auxin and JA (see sections 4.7 and 9.2), it is not surprising that JA has a role in gravitropism. Using rice coleoptiles, the Cholodny–Went hypothesis was found to be true. In addition to an auxin gradient, gradients of JA and auxin responsiveness were found to be involved in gravitropism. A mechanistic framework 1046 Wasternack & Hause — Biosynthesis and action of jasmonates might be given by an interaction between auxin and JA signalling pathways. This became evident by identification of tryptophan conjugates of indolyl-3-acetic acid and JA as endogenous inhibitors of the gravitropic response, one of the most prominent auxin responses. In rice a gravitropismrelated gene, LAZY1, was identified that is required for gravity responses in leaf lamina, but not in roots. The function of its gene product remains unknown.

9. Development of reproductive organs of dicotyledonous plants

The most diagnostic phenotype of Arabidopsis mutants impaired in JA biosynthesis and perception, such as coi1, opr3, dde1, dde2, dad1, as and fad3-2fad7-2fad8, is male sterility. Three characteristic phenotypes were identified: (1) insufficient filament elongation, (2) non-viable pollen and (3) delayed anther dehiscence. In mutants impaired in JA biosynthesis, fertility can be restored by JA treatment when applied in stages 11 and 12 of floral development, but not by OPDA. Transcript profiling of JA-treated stamens of opr3 plants allowed detection of stamen- and JA-specific mRNAs preferentially regulating genes involved in metabolic pathways required for the synthesis of terpenoid volatiles, wax and pollen constituents. Most interestingly, new TFs required for stamen developmentwere identified in the stamen transcriptome of opr3 plants. Among them were MYB21 and MYB24. Subsequent genetic analysis identified MYB108, which, together with MYB24, is involved in JA-regulated stamen and pollen developments. MYB21 andMYB24 were further identified as targets of JAZ repressors. In the coi1 mutant, the overexpression of MYB21 could partially restore the delayed anther dehiscence, but not JA insensitivity in terms of root growth inhibition, anthocyanin formation and susceptibility to necrotrophic pathogens. These data suggest a dominant role of MYB21 in stamen and pollen development. The essential role of JA in stamen development is also obvious by DAD1, an Arabidopsis PLA1 involved in JA formation of flowers. DAD1 is expressed in flowers, and dad1 shows a phenotype similar to coi1. This gene is a target of the centralTFAGAMOUS, of all the JA cross-talks involving other hormones, the JA– auxin cross-talk is the most important in flower development. Recently, embryo development in tomato has been shown to be OPDA-specific, but JA-independent, implying the difference in flower development vis-a-vis fertility between Arabidopsis and tomato. Beside its role in stamen development in Arabidopsis, JA has a role in petal growth. The final stages of petal growth are largely dependent on cell proliferation and/or cell expansion. The bHLH TF BIGPETALp (BPEp), expression of which is controlled by JA, limits petal size by controlling cell expansion. Consequently, the opr3 bpe-1 mutants are characterized by a larger petal size that can be restored by JA treatment.

10. JA in development of reproductive organs of monocotyledonous plants

JA has a central role in sex determination of maize. In maize, sex organs are located on the same plant in the male tassel at the top and the female ear(s). Originating from a bisexual floral meristem, the pistil primordia are aborted undergoing a tassel seed-mediated cell death. There are two tassel seed genes in maize, namely ts1 and ts2. Whereas the ts2 gene encodes a short-chain dehydrogenase/reductase with broad substrate specificity, the ts1 gene has been identified recently by positional cloning and encodes a plastid-targeted 13-LOX. The homozygous ts1 mutant is characterized by a loss of 13-LOX activity and lower JA levels in inflorescences, but the mutant phenotype could be rescued by JA application. TS1 and TS2 are both required for sex determination. Possibly, TS2 plays a role similar to TS1 in JA biosynthesis by regulating b-oxidation steps of the carboxylic acid side chain of OPDA. Cytoplasmic male sterility (CMS), a maternally inherited phenomenon leading to pollen abortion, is associated with JA biosynthesis. In rice, proteins of mitochondrial complexes together with a sex-determining TASSELSEED2-like protein were found to be affected in a CMS line YuetaiB, leading to aberrant changes in JA biosynthesis during microspore development.

11. Seed germination

Inhibition of seed germination was described for JA. However, recent genetic and biochemical evidence has shown that OPDA is the inhibitory compound which acts together with ABA in a COI1-independent manner.

Application of JA:

- Jasmonic acid is also converted to a variety of derivatives including esters such as methyl jasmonate; it may also be conjugated to amino acids.
- According to an October 2008 BBC News report, Researchers at the UK's Lancaster University have signed a licensing deal with an American company (Plant Bioscience Limited) to market jasmonic acid as a seed treatment (EU Regulation).
- The company has rolled out the technology progressively, starting with soybean and peanut in the USA in 2010, and product sales have increased year after year.
- Field application of JA may enhance the efficacy of parasitoids and predators as biological control agents.
- JA seed treatment stimulates the natural anti-pest defences of the plants that germinate from the treated seeds, without harming plant growth.
- Exogenous application of JA on rice plants elicits the production of proteinase inhibitors, phytoalexins, PRs, and salt-induced and it may increase the emission of volatiles.
- Exogenous application of MeJA increases the release of volatile organic compounds, which enhances the mortality rates of the herbivores by attracting the natural enemies of herbivores.

Conclusion:

- Plant lacks an immune system like in animals but possess mechanism that recognizes potential pathogens and initiate defense responses. During their biochemical evolution, the plants are devised with certain magic molecules of defense (secondary metabolites) like JAs.
- Recent insights in to the Jas mediated plant defense cascade and knowledge of key regulators of this will help us to design future crops with increased biotic stress resistance and better adaptability.
- Higher crop yields might be achieved by increasing the pathogen/ insect resistance which can be achieved by manipulating the expression of the key genes involved in Ja’s biosynthesis and signalling cascades.

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SEED: THE SYMBOL OF BEGINNING; SEED PRODUCTION AND CERTIFICATION IN INDIA

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Abstract:

Seed, the symbol of beginning, is the most basic input for growing any plant. Certification of seeds is a vital stage in the manufacture and marketing of seeds. This is done in order to maintain high standards for seeds and to make them available to farmers so they may maintain good and quality output. Varieties of crops are typically produced in this system with the goal of evaluating the purity, viability, physical identity, and attributes of seeds. It is a regulated legal system for examining the status of the quality of seed production and its methods of multiplication. To achieve optimum crop output and optimal returns, high-quality seed is essential. The national seed sector, which is made up of both public and private companies, is crucial in ensuring that there is an adequate supply of high-quality seed by adhering to its quality standards and regulatory framework. The fundamental tenet of the seed laws in various nations is to prohibit dishonest practices in the seed supply chain while promoting breeding and variety development to satisfy the need for high-quality seeds of numerous superior variations of various crops suitable for varied agro-ecologies. Although the seed scenario, the availability of infrastructure, and the need for qualified human resources to manage the seed system are all taken into consideration when developing the mechanism for applying laws, operating procedures, categorization, and quality standards. It is also desired for all participating nations to align their domestic laws with international conventions and treaties that serve as a legal framework to direct and oversee the interests of breeders, seed producers, and consumers globally in light of the rapidly growing global seed trade. Equally crucial is that the aforementioned national regulatory frameworks make it easier for farmers to obtain the highest caliber seeds.

Keywords: Quality seed, Seed Certification, Seed Production, Tagging

Introduction:

Seed is considered as the symbol of beginning. Every farmer ought to have access to wholesome seeds that are genetically pure, have high seed vigour, and have a high germination rate. Farmers are guaranteed a nice harvest and a profit when high-quality seeds are readily available when they are needed. In agriculture, seeds are essential since they serve as a carrier of a variety's genetic potential. The expansion of our nation's food production is greatly aided by the manufacturing of high-quality seeds that adhere to effective certification processes. Through the Indian Seeds Act of 1966, the government established standards and introduced seed production methods, testing, certification, and marketing procedures.

The market is now significantly undersupplied when it comes to good quality certified seeds. This chapter includes information on the production and acquisition of high-quality seeds. Seed certification is a procedure created to preserve seed quality during seed production, post-harvest management, and seed distribution. Through this seed certification, the certifying body controls and inspects seeds destined for domestic and foreign markets to guarantee good seed quality for consumers.

Definition of seed

A basic agricultural input, seed is an embryo that is lodged in the tissue that stores food. A matured ovule that contains an embryonic plant with food storage and is encased in a protective seed coat is known as a **seed**.

Current scenario of seed industry in India

In India, the seed sector comprises of two types viz., formal and informal. Farmers that grow seeds without adhering to certification requirements and exchange them among themselves work in the informal sector. To manufacture a certain kind of seed, the formal type of seed industry adheres to certification procedures and criteria.

Major organizations involved in seed industry

One of the largest seed markets in the world is found in India, which also includes a number of institutions and businesses from the public and private sectors as well as university and government research facilities.

Major players in the seed industry include the Ministry of Agriculture and the Department of Seed Certification, Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAU), National Seeds Corporation (NSC), State Farm Corporation of India (SFCI), 15 State Seed Corporations (SSCs), 22 State Seed Certification Centres, and 104 notified Seed Testing Laboratories. The manufacturing of seeds is carried out countrywide by around 150 significant private seed enterprises.

Seed vs. Grain

No doubt both the terms are used most often simultaneously, but there is a mark-able difference between seed and grain; and so as seed production and crop production. When compared to the grains that are utilised as a source of seeds, seeds that are created scientifically are superior. Below are some of the differences between seed and grain:

SEED	GRAIN
1.Seeds are produced in accordance with a carefully thought-out seed programme.	1.There is no planned seed scheme for grain production.
2.The seed is genetically pure and can be distinguished from its breeder seed by its varietal purity.	2.The grain's seed variety purity is unknown.
3.Quality controls, such as the elimination of off-types, sickly plants, weed plants, and other crop plants, are carried out during the seed	3.The requirements for quality are not met.

production process.	
4.The physical cleanliness and germination of seeds are excellent.	4.Germination and physical purity are not guaranteed.
5.The techniques for processing, treating, packaging, and labelling seeds are used in scientific seed production.	5.Production of grains does not adhere to processing, labelling, and tagging procedures.
6.Seeds are dried under carefully regulated conditions.	6.Higher temperatures are used to dry the grains, which degrades the seeds' quality.
7.Seed vigour and viability are preserved while they are being stored.	7.Grain is protected during storage from pests and pathogens but not from vigour and viability.
8.Produced seeds have the appropriate certification and labelling.	8.No certification tags or labels will be present on grains used as seeds.
9.No seeds can ever be turned into grains unless the seed inspector authorises it.	9.Can be used for seed purposes and occasionally for commercial grain purposes.

Seed production

Characteristics of good quality seed

Seeds of good quality are the right of every farmer in the country. So as to produce good quality seeds, the criteria for quality seeds are of utmost importance.

1. **Seed health**

   Quality seeds are those that have a high rate of germination and seed vigour. Seeds should be free of bacterial and fungal contamination as well as insect damage.

2. **Physical purity**

   The seeds' physical purity needs to be kept between 96 and 98 percent, and they must be undamaged, uniform in size, and shape. The seeds must not contain any inert material, such as dust, stones, seeds from other crop varieties, broken seeds, weed seeds, etc. In order to maintain the physical integrity of the seeds after harvest, they should be separated from chaffy seeds and seeds that have been afflicted by insects or diseases.

3. **Genetic purity**

   To guarantee the quality of the seeds, the genetic purity of the seed should be preserved. Genetic purity is the preservation from generation to generation of the traditional and inherent qualities of the seed. The offspring should have traits that are identical to those of the mother plant.

4. **Moisture content**

   High moisture content seeds quickly lose their germination vigour and viability. In order to maintain optimum germination potential and viability, it is crucial to maintain the proper moisture content of the seeds. Additionally, it is crucial to safeguard the seeds from disease and pest attack. A safe moisture level for seeds to be stored at is between 9 and 13%. Using a digital moisture metre, the moisture content of the seeds is directly measured.

Reasons for crop deterioration

Producing high-quality, genetically pure seeds is the primary goal of seed production. However, during seed production, the genetic purity of the seed may be compromised for a variety of causes; this is referred to as degradation of a particular crop type. Following are some of the causes of crop deterioration:

1. **Developmental variation**

   Developmental variation may arise when a seed variety is cultivated for several successive generations in agroecological conditions that are different from those found in nature (i.e., a different habitat, different soil and fertility levels, and different elevations). To reduce developmental variance, each and every seed type should be grown in a location that is flexible. Nucleus and breeder seed multiplication should take place in an environment that is capable of accommodating the plant, if it is cultivated at all in non-adaptable regions.

2. **Mechanical mixtures**

   This form of degradation can occur at any point in the development process, from sowing to processing. It may occur as a result of volunteer seeds contaminating the field, using the same seed drill for two different types, growing various varieties next to one another, and employing an unclean threshing floor and processing equipment. The greatest care should be taken at all phases of seed preparation to prevent these kinds of combinations.

3. **Natural crossing**

   In the case of crops that are sexually reproduced, this is achievable. The breeding method of the variety, isolation distance, and its pollination agent all affect how much contamination there is. A greater separation distance reduces the amount of contamination brought about by natural crossing.

4. **Genetic drift**

   When a seed crop is raised across a vast region and only a limited amount of seed is saved for the following year's planting, all genotypes will not be present in the following generation. This is referred to as genetic drift. By growing the seed crop in a smaller area as needed, this kind of degradation can be minimised.

5. **Disease infestation**

   In order to prevent pest and disease infestation, the seed production field must maintain clear sanitation and adhere to appropriate plant protection measures.

6. **Mutations**

   Given the rarity of spontaneous mutations, its significance is minimal. Any obvious mutation symptom should be quickly rouged out of the field if it is found there.

Factors affecting seed production

There are some rules that must be followed when multiplying seeds; else, the seeds' quality would suffer.

a. Selection of suitable site

The soil in the field used for seed production should be rich, and there should be enough irrigation and drainage systems. High weed incidence and volunteer plants should not exist in the field (volunteer plants are undesirable plants that grew in the seed producing field from the previous season's harvest). The same crop variety that was grown in the field the previous season shouldn't be planted there again. For the successful management of pests and diseases, it should receive adequate sunlight and aeration.

b. Selection of seed source

Care should be made when choosing the seed variety to choose the types that the local farmers in that area favour. Choose healthy seeds of consistent size from a reputable provider. Breeder seeds are needed for the creation of foundation seeds, and foundation seeds are needed for the production of certified seeds, so seeds should be chosen based on the type of seed production. Selected seeds ought to have a high germination rate, be vigorous, and be genetically pure.

c. Field preparation

The soil in the chosen field needs to be suitable for the crop. The field must be fully ploughed without any lumps. In order to improve the soil's nutrient content, green manure crops might be grown there. To increase the fertility of the soil, organic manures such as compost, vermicompost, and farmyard manure can be employed. Within three days of seeding, the field should receive adequate irrigation to prevent soil hardening.

d. Selection of seed

Chaffy seeds can be separated from healthy seeds using salt solution. Place an egg in a container with some water in it. It will continue to receive slow additions of salt until the egg rises to the water's surface. The high-quality seeds will sink to the bottom of the water when the seeds are dropped into it. Eliminate the seeds that aren't viable from the water's surface. To eliminate the salt deposits, wash the chosen seeds twice or three times in clean water. The ability of the seeds to germinate will be impacted if this is not done. The unviable seeds can be fully eliminated with this technique. When there is more chaff, this approach should be used.

e. Seed testing

The viability of the chosen seeds, or seed germination, should be evaluated. It is only possible to produce and multiply seeds when the germination capability is great. In the end, higher seed multiplication is possible if the germination rate is high.

f. Seed germination

The ability of seeds in a seed lot to germinate normally, create all the elements of a healthy seedling, and flourish is referred to as the germination capability of the seed lot. Well-developed primary roots, a young pair of leaves, and one or two cotyledons are essential components of the seedling.

$$\%\ of\ germination = \frac{Number\ of\ normal\ seedlings}{Total\ number\ of\ seed\ germinated} \text{ x } 100$$

A high level of seed viability is indicated by a germination rate of 70 to 80%. Seed dormancy may also have an impact on germination.

g. Seed vigour

It varies from species to species, but generally speaking, seeds with good germination capacity and uniformity in size will have good vigour. Good vigour is the sum total of all the seed attributes that favours rapid and uniform standard establishment in the field under varying field conditions.

Weak seeds will not germinate well in the field and will eventually die; even if they do, they won't produce healthy seedlings. Therefore, it is essential to check the germination of the seeds before planting them in the main field. Small pots with moistened soil can be filled with a countable number of seeds, and they can be set in a sunny spot. The number of healthy seedlings in each container should be counted after a few days.

h. Seed dormancy

Seed dormancy is the temporary cessation of a viable seed's growth together with a decrease in internal metabolic activity. It is the stage of the seed when it is resting and it postpones germination. Seed dormancy is caused by unfavourable climatic factors such low temperatures, temperature fluctuation, and a lack of water. A hard seed coat, an underdeveloped embryo, as well as the presence of germination inhibitors in the seeds can all contribute to dormancy. The presence of chemical poisons in the seeds as well as excessive heat, light, or darkness exposure to the seeds may also be to blame. The seeds' dormancy can be broken using any of the following techniques:

i. Scarification – Removal of the hard seed coat by rubbing the seeds with sand paper. Eg. Pulses

ii. Hot water treatment – Soak the seeds in hot water at 45-50°C. Eg. Tree crops.

iii. Leaching – Soak the seeds in water for overnight to remove the germination inhibiting chemicals present in the seeds. Eg. Coriander

iv. Stratification – Subject the seeds to very low temperature of 0-5°C to break the embryo dormancy. Eg. Cole crops.

v. Light treatment – Some seeds do not germinate in dark and periodic exposure to light is essential to break the dormancy. Eg. Lettuce.

i. Sowing season

The ideal sowing season is influenced by the right temperature, amount of rain, wind speed, and photoperiod. Heavy rains should not fall during the seed crop's blossoming stage, and the maturation of the seed should take place throughout the summer months in order to produce quality seeds. The quality of seeds gathered during the dry season is always higher.

j. Planting density

The plant's field density has a direct impact on the seeds' quality. Diseases are more common in plantings that are more densely populated, while plantings that are less densely populated have more weed infestation and uneven ripening. Therefore, it's important to maintain the ideal plant density for each type of crop.

k. Weed management

Weeds should not be allowed to grow on the land that has been chosen for seed production. The purity of the seed crop will be lowered because weed seeds will remain dormant for a protracted amount of time, grow more quickly than the primary crop, and generate seeds. Maintaining the purity of the seeds requires weed removal at all phases of the seed producing field.

l. Disease and insect pest management

Insects will disperse pathogen-producing microorganisms and specifically harm the seeds. To keep the field free of pests and diseases, special care and attention should be given at every step of the seed development.

Other factors influencing seed production

1. **Seed Multiplication Ratio (SMR):** When a seed is sowed and harvested, it will generate a certain number of seeds.

$$SMR = \frac{Seed\ Yield}{Seed\ Rate}$$

2. **Seed Replacement Rate (SRR):** The percentage of crop grown in the season that was seeded with certified, high-quality seeds rather than farm-saved seeds is known as the seed replacement rate.

$$SRR = \frac{X}{Y} \text{ x } 100$$

Where, X = Quantity of seeds with the farmer

Y = Quantity of quality seeds of a particular variety to cover a given area.

This is necessary to preserve genetic purity and produce high-quality seeds. The rate of seed replacement provides information about the number and quality of seeds utilised by farmers.

Sl. No.	Name of the crop	SMR	SRR
1.	Paddy	17	1:80
2.	Bajra (Pearl Millet)	8	1:200
3.	Maize	6	1:80
4.	Redgram	6.1	1:100
5.	Blackgram	17.7	1:40
6.	Greengram	11.7	1:40
7.	Cowpea	14.2	1:40
8.	Groundnut	5	1:8
9.	Sunflower	50	1:50
10.	Sesame	15	1:250

Seed certification

Classes of Seed

The Association of Official Seed Certification Agency has established four primary categories of seeds. Those are:

1. Nucleus Seed
2. Breeder Seed
3. Foundation Seed

Certified seed

1. **Nucleus seed**

   The fundamental seed types for seed production are nucleus seeds. The breeder keeps track of these seeds for future reproduction. It is made directly under the direction of the responsible plant breeder. It is created using several crop multiplication techniques and procedures. The genetic purity of nucleus seeds is quite high (100%).

2. **Breeder seed**

   Under the direction of a breeder, breeder seeds are created utilising nucleus seeds in research facilities or universities. The National Seed Corporation's officials as well as the scientists and officers of the Seed Certification Department will keep an eye on the entire production process. The given tag for the breeder seed is golden yellow in colour and the breeder seeds are 100% genetically pure.

3. **Foundation seed**

   Breeder seeds are used to create foundation seeds. It is made either at government farms or by commercial seed companies. By obtaining the appropriate breeder seeds, farmers can also start producing it. The foundation seeds are 99.5% genetically pure, and their certification sticker is white in hue.

4. **Certified seed**

   Certified seeds are those that are grown from foundation seeds. The National and State Seed Corporation, private seed firms, and farmers all participate in the manufacture of certified seeds. The Department of Seed Certification's definitions of uniformity and purity should be met by the certified seeds. The given certification sticker is blue, and the certified seeds have 99% genetic purity.

5. **Truthfully labelled seed**

   It is accurate to say that there is another category of seeds. The Department of Seed Certification is not responsible for this category of seeds. These seeds are merely examined for germination and physical purity. By using this technique, any farmer can create seeds and sell them as seeds with accurate labels. Certification is optional but labelling is not.

Seed certification

The organisation with legal authority to oversee seed production, multiplication, and quality control is the Seed Certification Department. The Seed Act of 1966 stipulates that seed certification is optional. The term "certified seeds" refers to seeds that have received certification from the Seed Certification Agency and have met all applicable field and seed criteria. While seed certification procedures and costs vary from State to State, seed standards are set and standardised across the nation.

Steps involved in seed certification

Aim of seed certification

The primary goal of the Seed Certification Department is to produce good quality seeds of the crop varieties that have been announced by the Central and State Governments and make them available to farmers.

Steps in seed certification

1. Application for seed production
2. Registration of sowing report
3. Field inspection
4. Seed processing
5. Seed sample and seed analysis
6. Tagging and sealing

1. Application for seed production

A sowing report in triplicate along with the required certification fees and registration cost of Rs. 50/- (Rupees fifty only) should be submitted to the Assistant Director of Seed Certification by anyone wishing to start producing certified seeds. The cost is for a single crop variety, up to 25 acres, and a single growing season. The label of the seed source must be submitted along with this price for seed certification.

For different crop kinds, classes, and stages, separate sowing reports are necessary. If the seed production fields are more than 50 metres apart, the sowing or planting dates are more than 7 days apart, or the seed farm area is more than 25 acres, separate sowing reports for the same crop variety must be registered. Within 35 days after the sowing date or 15 days before to flowering, whichever comes first, the sowing report must be delivered to the appropriate Assistant Director of Seed Certification. The sowing report for a transplanted crop should be sent 15 days prior to flowering.

2. Registration of sowing report

The Assistant Director of Seed Certification examines and registers the seed farm after receiving the application for the sowing report, and then properly assigns a Seed certification number for each sowing report.

3. Field inspection

The goal of the field examination is to look for any elements that might compromise the seeds' genetic integrity and physical well-being. The Seed Certification Officer (SCO) assigned to the particular seed farm will carry out the field inspection. The Seed Certification Officer will send him a copy of the planting report together with information on the inspection date and the seed farm. Based on the crop's growth stages, the number of field inspections will vary from crop to crop. The following crop growth stages are often when field inspections are conducted.

i. Pre flowering stage
ii. Flowering stage
iii. Post flowering stage
iv. Pre harvest stage
v. Harvest stage

4. Seed processing

The seeds should be transported to the processing plant after being gathered from the seed farm in accordance with the necessary field standards. Only authorised seed processing facilities should be used for processing. Each seed lot in the unit is checked with this report, which should be included with each processing report. Cleaning, drying, grading, treatment, and other processes are included in processing to raise the seed quality. The processing facility will be inspected by a Seed Certification Officer to rule out any potential mechanical combinations. The estimated yield and the seed lot should be correlated. Lots of seeds should be properly labelled and have the required moisture level. For paddy, perform a float test (take 400 processed paddy seeds, place them in a water-filled tumbler, and count how many paddy seeds float). The maximum allowable float is 5%; if it is higher, additional processing must be done to ensure that it was done correctly. The seed lots in the processing facility must be processed within three months of the delivery date. Permission should be requested from the Assistant Director of Seed Certification in the event of processing delays. Seeds that have been processed need to be accurately weighed, packed, sealed, and labelled. At this point, lot numbers are assigned as follows:

E.g. DEC 22-03-01-25-209

Where, DEC 22 represents seed harvested in December 2022.

03 represent seed crop raised in Assam

01 represent seed processing unit number

25 represent seed produce code

209 represent bag number

Along with the Seed Certification Officer's signature, the processing label contains information on the S.C.No., kind, variety, class of seed, lot number, date of sampling, quantity in kgs, and number of bags/total bags.

5. Seed sample and seed analysis

Through the Assistant Director of Seed Certification, a seed sample shall be forwarded to the seed testing laboratory for examination. When registering a seed farm, the Rs. 30/- (Rupees

Thirty Only) charge for seed analysis must be paid. The producer must pay the Assistant Director of Seed Certification a fee of Rs. 200/- (Rupees just two hundred) in order for the Assistant Director to examine the genetic purity of the seed sample.

Only seed batches that are pure, devoid of inert materials, at a certain percentage of moisture, and capable of germination will be given the certification label. When purchasing certified seeds from the Assistant Director of Seed Certification, you should pay Rs. 3 for foundation seeds and Rs. 2 for certified seeds.

6. Tagging and sealing

Various types of tags used in certification of all the classes of seeds

Within two months of receiving the seed analysis result or within 30 days of the date of the genetic purity test being conducted, approved seed batches must be marked with a certification tag. The Seed Certification Officer verifies the seed tags after receiving them. The tag is filled out completely with all the required information. Along with the certification tag, the producer tag in green (10–15 cm in size) needs to be fastened to the seed lot. On the tags, avoid stitching them more than once. The Seed Certification Officer should be present for the entirety of the tagging procedures. With prior approval from the Assistant Director of Seed Certification, confirmation samples may be taken if tagging has not been completed within the specified time frame. In these situations, the seed lot's validity will be fixed as of the initial date of seed analysis and tagged. In these situations, there is a price of Rs. 50/- (Rupees fifty only) for the delayed tagging as well as a Rs. 30/- (Rupees thirty only) fee for the seed analysis.

Validity period

For all seed crops, the certified tagged seed is only valid for a short time, say nine months from the date of seed sample testing. If the specific seed lot is not sold out within this time frame, it may be revalidated for an additional six months, but only if it satisfies our required seed requirements.

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ORGANIC AGRICULTURE: PROMOTING HEALTH IN INDIA

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Organic farming, sometimes referred to as ecological farming or biological farming, is a type of agriculture that emphasizes crop rotation and companion planting while using organic fertilizers including compost manure, green manure, and bone meal. It began in the early 20th century as a response to rapidly evolving farming methods. Sustainability, openness, self-sufficiency, autonomy and independence, health, food security, and food safety are all argued to be benefits of organic farming.

Based in large part on the standards established by the International Federation of Organic Agriculture Movements (IFOAM), an international umbrella organization for organic farming organizations founded in 1972, organic agricultural practices are internationally regulated and legally enforced by many nations. An integrated farming system that priorities sustainability, improving soil fertility and biological diversity while, with very few exceptions, forbidding synthetic pesticides, antibiotics, synthetic fertilizers, genetically modified organisms, and growth hormones.

On a local level, organic farming can help to maintain the environment and biodiversity. But because organic farming produces lower yields than conventional farming, more agricultural land must be created elsewhere in the world, which requires converting natural area to agricultural land. The resulting biodiversity loss and unfavorable climate changes may overwhelm any local environmental improvements.

Agriculture has been practiced for thousands of years without the use of artificial chemicals. Man-made fertilizers were first developed in the mid-19th century. These early fertilizers were cheap, strong, and easy to transport in bulk. Similar advances occurred for chemical pesticides in the 1940s, leading to the decade known as the "age of pesticides". These new farming techniques, while beneficial in the short term, have serious long-term side effects such as soil compaction, erosion, and overall decrease in soil fertility, as well as other problems. Environmental health problems due to the entry of hazardous chemicals into the food supply. In the late 1800s and early 1900s, soil biologists began looking for ways to address these side effects while maintaining higher yields.

The growing environmental awareness of the general population in modern times has turned the original supply-driven organic movement into a demand-driven movement. High prices and some government subsidies have attracted farmers. In developing countries, many growers use traditional methods that are equivalent to organic farming, but are not certified and may not include the latest scientific advances in organic farming. In other cases, farmers in developing countries have converted to modern organic methods for economic reasons.

"Organic agriculture" is a production system that supports the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles that adapt to local conditions, instead of using inputs that have harmful effects. Organic agriculture combines tradition, innovation and science to benefit the common environment and promote equal relationships and quality of life.

Although organic farming is fundamentally different from conventional farming due to the use of carbon-based fertilizers versus highly soluble synthetic fertilizers and biological pest control instead of synthetic pesticides, organic farming and large-scale conventional farming are not entirely mutually exclusive. Many of the methods developed for organic farming have been borrowed by more conventional farming. For example, integrated pest management is a multifaceted strategy that uses as many biological pest control methods as possible, but in conventional agriculture, synthetic pesticides can only be used as a last resort. Examples of beneficial insects used in organic farming include ladybugs and beetles, both of which feed on aphids. The use of IPM reduces the likelihood that pests develop resistance to pesticides applied to crops.

Organic farming encourages crop diversity. The science of agroecology has revealed the benefits of polyculture (many crops grown in the same space), commonly used in organic farming. Growing a variety of vegetable crops supports a variety of beneficial insects, soil microorganisms and other factors that contribute to the overall health of the farm. Crop diversity helps the environment thrive and protects species from extinction.

Organic farming relies more on the natural breakdown of organic matter than the average conventional farm, using techniques such as green manure and composting, to replace nutrients taken from the soil of previous crops. This biological process, fueled by microorganisms such as mycorrhizae and earthworms, makes nutrients available to plants throughout the growing season. Farmers use a variety of methods to improve soil fertility, including crop rotation, mulching, reduced tillage, and organic fertilization. By reducing fuel-intensive land use, less soil organic matter is lost to the atmosphere. This has the added benefit of sequestering carbon, reducing greenhouse gases and helping to reverse climate change. Reducing tillage can also improve soil structure and reduce the likelihood of soil erosion.

Need of organic farming

- Excessive use of chemical fertilizers reduces soil fertility.
- The excessive use of chemicals has resulted in soil, water and air pollution.
- Ecosystem conservation.
- Promote sustainable development.
- Farming is inexpensive.
- Increased demand for organic products due to food safety.

Objectives of organic agriculture

- To increase genetic diversity.
- To encourage greater use of natural pesticides.
- To make sure to do the soil at the right time.

- To maintain and develop good soil structure and fertility.
- To fix nitrogen in the soil with legumes
- To control pests and weeds. Protect soil quality with organic matter and encourage biological activity
- To provide nutrients indirectly to plants by soil microorganisms
- To control weed and pest based on methods such as crop rotation, biodiversity, enemies, organic fertilizers and appropriate chemical, thermal and biological interventions.
- To encourage Animal husbandry, barn care, nutrition, health, breeding and reproduction.
- To Concern for the wider environment and conservation of natural habitats and wildlife.

Benefits of organic farming

Strong demand:

There is a huge demand for organic products in India and around the world, generating more revenue through exports.

Nutrition:

Compared to chemicals and fertilizers, organic products are more nutritious, tastier and better for your health.

Ecological:

Growing organic produce does not use chemicals and fertilizers, so it is not harmful to the environment.

Long term durability:

Many of the changes observed in the environment are long-term and occur slowly over time. Organic agriculture examines the medium and long-term effects of agricultural interventions on agro-ecosystems. It aims to produce food while at the same time establishing an ecological balance to prevent problems with soil fertility or pests. Organic farming takes a proactive approach instead of dealing with problems after they arise.

Soil:

Soil building practices such as crop rotation, intercropping, symbiotic associations, cover crops, organic fertilizers and minimal tillage are central to organic practice. These encourage soil flora and fauna, improve soil formation and structure, and create more stable systems. In turn, nutrient and energy cycles are increased and soil holding capacity for nutrients and water is improved, compensating for the absence of mineral fertilizers. These management techniques also play an important role in soil erosion control. The time the soil is exposed to the forces of erosion decreases, the biodiversity of the soil increases and the loss of nutrients, all of which help maintain and improve soil productivity. The export of plant nutrients is generally offset by renewable resources of agricultural origin, but sometimes additional soil organic matter with potassium, phosphate, calcium, magnesium and trace elements is required. In many agricultural areas, groundwater contamination by synthetic fertilizers and pesticides is a major problem. Since their use is prohibited in organic farming, they are being replaced by organic fertilizers (e.g. compost, animal manure, green manure) and through greater use of biodiversity (of cultivated species and permanent vegetation), improving soil structure and water infiltration.

Well-managed biological systems with better nutrient holding capacity will greatly reduce the risk of groundwater contamination. In some areas where pollution is a real problem, the transition to organic farming is strongly encouraged as a recovery measure (for example, by the French and German governments).

Atmosphere and climate change

Organic farming reduces the use of non-renewable energy by reducing the need for agrochemicals (these needs require the production of large amounts of fossil fuels). Organic farming contributes to greenhouse gas reduction and global warming through its ability to sequester carbon in the soil. Many management practices are used by organic agriculture (e.g., minimal tillage, return of crop residues to the soil, use of cover crops and rotations, and greater integration of legumes. nitrogen fixation), which increases the return of carbon to the soil, increases yield and promotes carbon storage. Several studies have found that soil organic carbon levels in organic farming are significantly higher. The more organic carbon is retained in the soil, the greater the agricultural potential to mitigate climate change. However, more research is still needed in this area. There is a lack of soil organic carbon data for developing countries, no comparative data from African and Latin American farming systems, and only limited data on soil organic carbon stocks, which is very important in determining carbon sequestration rates for agricultural activities.

Biodiversity

Organic farmers are both stewards and users of biodiversity at all levels. At the genetic level, traditional and adapted seeds and varieties are favored for their better disease resistance and resilience to climate stress. At the species level, different combinations of plants and animals optimize nutrient and energy cycling for agricultural production. At the ecosystem level, maintaining natural areas in and around biological fields and free of chemical inputs creates favorable habitats for wildlife. Regular use of underutilized species (usually crop rotation to increase soil fertility) reduces erosion of agro-biodiversity, creating a healthier genetic stock – the basis for adaptation in future. The provision of structures that provide food and shelter, and without the use of pesticides, attract new or recombinant species to the biosphere (permanent and migratory), including flora and fauna. wildlife (e.g. birds) and organisms beneficial to biological systems. as pollinators and predators of pests. The number of studies on organic agriculture and biodiversity has increased significantly in recent years. A recent study involving a meta-analysis of 766 scientific articles concluded that organic farming produces more biodiversity than other agricultural systems.

Ecological services

The impact of organic agriculture on natural resources promotes interactions in agro-ecosystems that are vital to both agricultural production and nature conservation. Derived ecological services include soil formation and conditioning, soil stabilization, waste recycling, carbon sequestration, nutrient cycling, predation, pollination and habitat. By choosing organic products, consumers through their purchasing power promote a less polluting agricultural system. The potential environmental costs of agriculture in terms of natural resource degradation are minimized.

Disadvantages of organic farming

Not enough ability:

The main problems with organic farming are lack of infrastructure and inadequate product marketing.

Less production:

The products obtained from organic farming are less in the first years than chemical products. Thus, it is difficult for farmers to adapt to large-scale production.

Shorter shelf life:

Biological products have more defects and shorter shelf life than chemical products.

Limited production:

Off-season crops are limited and less selective in organic farming.

Organic agriculture and food security

Persisting world hunger has demonstrated that agriculture alone (be it conventional or not) cannot alone solve food insecurity. Still, many questions are asked with regards to the ability of organic agriculture to provide food**:** and many speculations are made, without any comprehensive data basis. FAO held An International Conference on Organic Agriculture and Food Security in May 2007 to examine food security in terms of food availability, access to food, stability of food supply systems and food utilization; material and empirical experience discussed demonstrate that organic agriculture has the potential to feed the world, under the right circumstances.

What is a certified organic product?

Certified organic products are those that have been produced, stored, processed, handled and placed on the market to exact specifications (standards) and are certified "organic" by a certification body. Once compliance with organic standards has been verified by the certification body, the product will be issued a label. This label will vary depending on the certification body but can be seen as assurance that the essential elements constituting an "organic" product have been respected from farm to market. It is important to note that the organic label applies to the manufacturing process, ensuring that the product has been produced and handled in an environmentally friendly manner.

Organic agriculture in India:

- According to the World Organic Agriculture Report 2018, India is home to 30% of the total organic farmers in the world, but only 2.59% (1.5 million ha) of the total farming area. 57.8 million hectares of organic farming.
- At the same time, most organic farmers are struggling due to weak policy measures, rising input costs and limited markets, according to a study by the Association of Indian Chambers of Commerce and Industry. Degree (ASSOCHAM) and global consulting firm Ernst & Young.

Why does India need organic farming?

- The main reason farmers give to practice organic farming is that they are worried about the use of agrochemicals in traditional farming systems.
- Since many agrochemicals require energy-intensive production processes that are highly dependent on fossil fuels, there is an issue of the amount of energy used in agriculture. Organic farmers find their farming methods profitable and personally beneficial.

Indian organic market:

- India is the world's largest exporter of organic cotton.
- More than 30% of the world's organic producers are in India
- India exported 1.35 million tons of “certified organic” food in 2015-16.
- Oilseeds account for half of India's total organic food exports, followed by processed foods with 25%.

Conclusion:

Organic farming can be a viable alternative production method for farmers, but challenges remain.

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BIOCHAR MEDIATED HEAVY METAL REMEDIATION FROM SOIL

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Abstract:

Heavy metal soil degradation has risen to be a major worry due to heavy metals build up in the soil as a result of rising urbanization, agricultural inputs, and growing industry. Heavy metals are likely to infiltrate the food chain due to their non-degradable nature, speciation, and bioavailability to living species. Metals from the environment are removed using a variety of heavy metal remediation processes. Among the methods, the use of biochar, which is energy-efficient, inexpensive, and environmentally friendly, is developing as a new strategy for heavy metal remediation. A solid compound rich in carbon known as biochar is prepared by pyrolyzing waste biomass from forestry and agriculture. Biochar is a solid material with a porous structure that is produced when biomass is processed thermo-chemically in a sealed container with oxygen at a minimum. Numerous studies have shown how efficiently biochar works to immobilise metals in contaminated soils, and its potential application in soil remediation is growing. Biochar's attributes, such as its low cost of manufacture, high cation exchange capacity, pH, surface functional groups, and porosity, make it a viable option as an adsorbent for the removal of heavy metals from soil.

Keywords: Biochar, Heavy metals, Heavy metal remediation, Bioavailability

Introduction:

Chemicals that are more prevalent in one area of the environment than another are known as environmental contaminants. Numerous pollutants, including inorganic ions, organic pollutants, organometallic compounds, radioactive isotopes, gaseous pollutants, and nanoparticles, have severely harmed the ecosystem. One of them is pollution from heavy metals. Due to either their high atomic weight or their high density, they are classified as heavy metals (HM's). The term "heavy metal" is now used to refer to metallic chemical elements and metalloids that are harmful to both humans and the environment. Anthropogenic activity, which is the main cause of pollution, has led to the emergence of heavy metal contamination. Heavy metal use in agriculture, such as the use of pesticides, insecticides, fertilizers, and other chemicals, has been a secondary source of heavy metal pollution. The heavy metals bioaccumulate in our systems after being ingested or inhaled into them. As a result, they are considered dangerous.

To accomplish this goal, various approaches have been used in recent years, including physical remediation (washing, thermal desorption, solidification), chemical remediation (leaching, immobilisation and electrokinetic methods), and biological remediation (microorganisms and plants). However, each of these approaches has its own drawbacks, such as a difficult to master technique, low efficacy, poor viability, short duration, high cost, high secondary risk, and so on. Currently, one of the most promising remediation methods is adding amendments to heavy metal contaminated soil such as biochar which is often utilized soil additives (Derakhshan *et al*., 2018).

Because of eco-friendly nature, biochar has been effectively used to remove heavy metals from water and soil. Application of biochar is a less environmentally disruptive and less expensive, and hence potentially attractive as a future option.

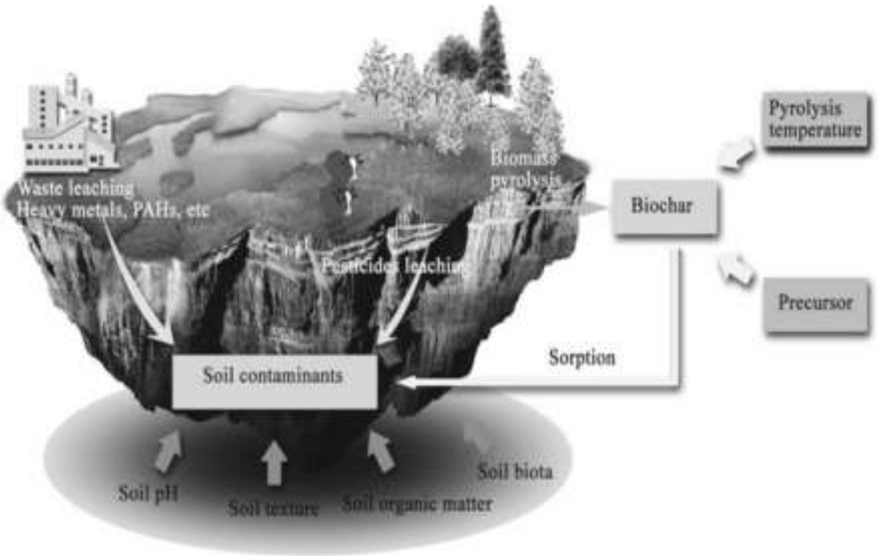

Figure 1: The remediation of contaminated soil by biochar derived from varied biomass sources

Biochar is a kind of carbon-rich, porous material has a neutral to alkaline pH value, large specific surface area, a negative surface charge, and an abundance of active organic functional groups and carbon aromatic structures (Cheng *et al*., 2020). Numerous studies show that adding biochars to HM-contaminated soil greatly boosted seed germination, plant growth, crop yields, and microbial activity and population. Meanwhile, numerous pot studies and field trials have validated the effects of biochar on the immobilization/mobilization for various types of HMs. Additionally, the creation of biochar is thought to be an effective management technique for getting rid of a lot of organic waste, which has some advantages in terms of feasibility and economic benefits.

Characterization of biochar

These are the characteristics of biochar, as described by Chen *et al*., (2014).

Index	Value	Index	Value
Specific surface area (m^2/g)	6.86	Ash (wt%)	42.25
Micropore area (m^2/g)	0.17	C (wt%)	48.45
Total pore volume (mm^3/g)	22.29	H (wt%)	1.78
Micropore volume (mm^3/g)	0.02	N (wt%)	1.47
pH	10.09	S (wt%)	0.78

Properties of biochar that affect HM remediation

Feedstock and pyrolysis: Almost any type of organic material, including crop residues, byproducts from forestry, industrial byproducts, animal manure, and sewage sludge, can be pyrolyzed to create biochar under a variety of circumstances. In general, biochars made from crop residues, manures, and seaweeds are more nutrient-rich, have a higher pH, and have less stable carbon than biochars made from lignocellulose-rich woody biomass. Various thermochemical processes, such as pyrolysis (slow and fast), can produce biochar. For slow pyrolysis, biomass is heated in the absence of air from ambient temperatures up to around 500 °C, with residence times ranging from minutes to hours. The properties of biochar made at lower pyrolysis temperatures are thought to be advantageous for the stability of heavy metals and the subsequent immobilisation of metals in soil.

Surface area and pore distribution: Highly porous structure allows biochar for physical sorption of metals. In general, biochar's surface area increases as pyrolysis temperature rises. For biochar's adsorption capacity, large surface area, highly porous structure, and high pore volume are regarded advantageous. The surface area of biochar is increased by the release of volatiles and the deformation of raw material components during pyrolysis, creating a porous structure resembling a honeycomb. Depending on the substance used to produce the biochar, the pore size varies.

Cation Exchange Capacity (CEC): The majority of biochars have an alkaline character, and as the pyrolysis temperature rises, the ash content rises as well, intensifying the biochar's alkaline nature and raising its pH. pH >7 is typically seen in biochar. According to reports, adding biochar raises soil pH, which lowers HM's mobility and bioavailability. The addition of biochar raises the pH of the soil, causing the precipitation of metal hydroxide and the adsorption of heavy metals.

Inorganic composition and pH: The majority of biochars have an alkaline character, and as the pyrolysis temperature rises, the ash content rises as well, intensifying the biochar's alkaline nature and raising its pH. The biochar's non-organic ash component is made up of elements including Mg, Ca, O, N, S, and K, among others. The pH of the biochars is greater when there are more alkaline salts, alkali metals (Na, K, Ca, and Mg), and $CaCO_3$. The phenomenon is referred to as the "liming effect" because the addition of biochar raises soil pH, which decreases the mobility and bioavailability of Cd, Zn, and Pb (Wu *et al*. 2017). The ash concentration and pH of biochar are primarily influenced by the type of source material and pyrolysis temperature. Biochar made from grass, grain husks, straw, and animal manure and sludge have a higher ash content than woody biochar.

Surface functional groups: Several functional groups, such as hydroxyl -OH, amino-NH_2, ketone -OR, ester -(C=O) OR, methyl -CH_3, nitro -NO_2, aldehyde -(C=O) H, and carboxyl -(C=O) OH, are formed on the surface of biochar as a result of the reformation and rearrangement of chemical bonds that occur during the thermal treatment of biomass. Biochars can have acidic, basic, hydrophobic, or hydrophilic qualities due to their nature as electron donors or acceptors. More oxygen-containing surface functional groups (-OH, -CO, -COOH) are present in biochar produced at lower pyrolysis temperatures (400 °C), and these groups form complexes with metal cations. Metal-ligand complex formation in soil may result in mineral precipitation on soil particle surfaces, changing soil porosity and altering the physical structure.

Soil type: The key soil characteristics influencing the development of metal-biochar complexes include soil organic matter, cation exchange capacity, pH, and mineral concentration. Due to their innate inability to store heavy metals, tropical soils are more easily phytotoxic than soils from temperate climates as they are extremely weathered, acidic, deficient in organic carbon, and predominately contain kaolinite and iron**:** or aluminum-oxyhydroxides.

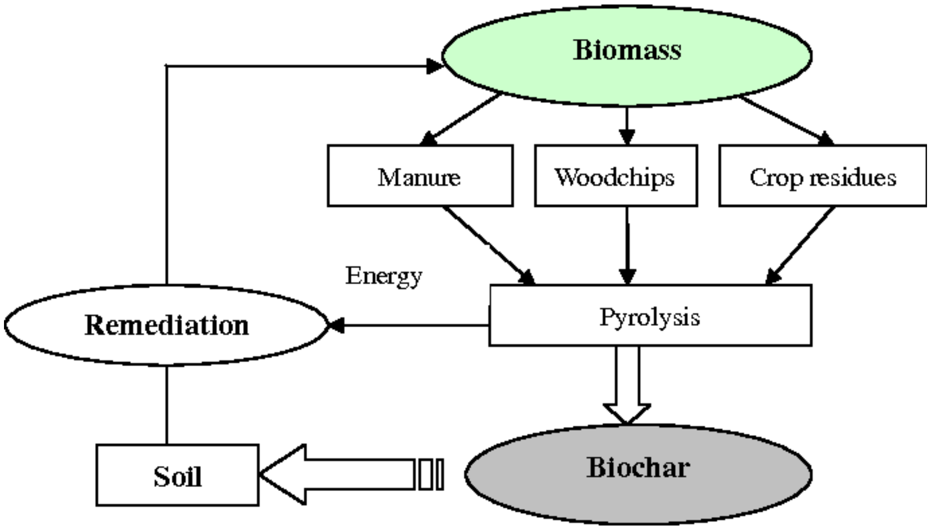

Figure 2: Biochar preparation process

Mechanism of heavy metal remediation

Adsorption, complexation, electrostatic attraction, ion exchange and precipitation processes, which cause the redistribution of HM's (Heavy metals) from soil liquid phases to solid phases, restrict their mobility and bioavailability, are the key techniques for capturing HM's.

- **Complexation:** Acidic functional groups (phenolic, carbonyl, carboxylic, phenolic, and hydroxyl) and basic functional groups found in biochar, which are abundant in oxygen, play a critical role in the complexation of heavy metals and metalloids on the surface and within the pores of biochar. Compared to biochar manufactured through higher temperature pyrolysis, low temperature biochar has more polar functional groups. Due to the development of inner and outer sphere complexes containing oxygenated (acid) functional groups, it effectively results in metal immobilisation. For metals with soluble nature, complexation is thought to be the most frequent route for adsorption with biochar.
- **Adsorption:** The removal of heavy metals through physical or surface adsorption entails the diffusion of metal ions into the pores of the sorbent. No chemical bond formation is connected to this technique. High surface areas and pore volumes in biochars will be preferred when carbonization temperatures rise (over 300 °C) for both animal and plant biochars. The heavy metal's radius is substantially smaller than biochar's typical particle size. In fact, smaller the radius of heavy metal, more it will penetrate into the pores of

biochar, and greater will be the inducement for adsorption (Shi *et al*. 2020). The characteristics and precise surface area of the biochar have a direct impact on the physical adsorption rate. Larger pores enable direct immobilisation of metal ions through diffusion and retention within the pore. In general, when pyrolysis temperature rises, the surface area and porosity of the biochar similarly rise, increasing its potential for adsorption.

- **Precipitation:** The most frequent processes for the immobilisation of heavy metals by biochar are thought to be precipitation. Precipitation is the creation of solid(s), either in solution or on a surface, during the sorption process. The pH of the soil is markedly raised by the addition of biochar (with pyrolysis temperature > 300 °C), and the heavy metal ions in the soil may react with the oxide, phosphate, and carbonate (OH, PO_4, CO_3, HCO_3) fractions of the biochar, reducing the mobilisation of heavy metals into the soil by precipitation.

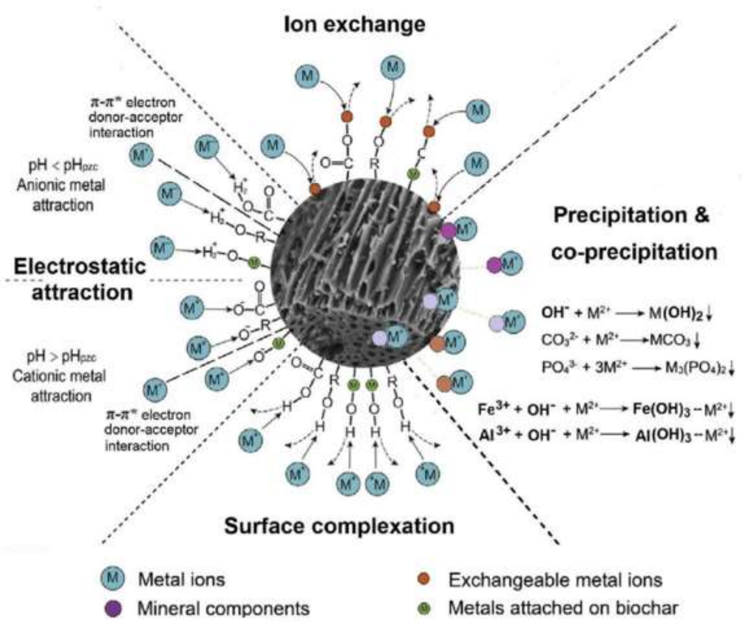

Figure 3: Mechanism of Heavy Metal remediation through Biochar (Guo *et al*. 2020)

- **Electrostatic attraction:** When biochar is produced at greater pyrolysis temperatures, its surface is negatively charged. Strong electrostatic interactions between negatively charged biochar surface and positively charged metal ions in soil reduce metal bioavailability.
- **Ion exchange:** The functional groups on the surface of biochar have a significant impact on CEC. These groups are abundant in low temperature biochars and bind with metal ions on the surface of the biochar. Metal ions may also combine with the inorganic minerals contained in the biochar matrix, such as Na, K, Mg, P, and Ca.

Effect of biochar on soil properties

- **Bulk density:** Because biochar has a relatively lower bulk density than soil, adding it to the soil caused the soil's bulk density to decrease and its porosity to increase. Additionally, biochar has significant porosity as a result of maintaining the biomass feedstock's cell wall integrity (Yadav *et al*. 2018) Being a porous material, it increases the soil's porosity and reduces bulk density when applied to the soil. According to Hseu *et al*. (2014), the creation of macropores and the rearranging of soil particles caused the change in porosity in soils that had been treated with biochar. It improves soil quality.

- **Water holding capacity:** Biochar typically has a water retention capacity of between 75.0% and 247% (Solaiman *et al*. 2012) The soil's moisture content rises after the application of biochar. This is due to enhanced aggregation that resulted in the formation of more pore spaces as a result of increased earthworm digging, or to biochar soils having more micropores to physically retain water. It is suggested that the rise in moisture content on increasing biochar rates is due to an increase in surface area that could absorb more moisture.
- **Cation exchange capacity:** The CEC and amount of exchangeable cations in the amended soils both rise significantly after the addition of biochar, indicating an improvement in soil fertility and nutrient retention. Biochar increases soil fertility by allowing extra nutrients to be retained in the soil and by preventing nutrient loss by holding them inside pores. The soil can now serve as a nutrition reservoir for plant roots owing to biochar. The observed CEC of biochar ranges from 8 to 40,000 c mol/kg, and as go by on, these values will rise following soil application.

  The CEC gets improved as a result of its porous nature. The biochar's delayed oxidation also led to a rise in carboxylic groups, which in turn raised the treated soil's CEC. In soil biochar can help the soil's exchangeable cation status, particularly calcium.
- **Anion exchange capacity:** oxonium functional groups support AEC independent of pH and can be helpful in lowering nitrate (NO_3) and phosphate leaching when applied to soils (Lawrinenko and Laird, 2015) observed that. Biochar may be able to absorb $PO_4^{3:}$ and NH_4^+ from wastes like dairy effluent, making it helpful as a waste recycling that might later be put to the soil as a nutrient amendment (Sarkhot *et al*. 2013).
- **pH:** Biochar can alter soil chemical characteristics by raising pH, CEC, nutrient utilisation efficiency, and nutrient concentrations (Lehmann and Joseph, 2015). While all these results lessen the demand for lime treatment and boost crop productivity in severely weathered, infertile tropical soils and decrease the availability of heavy metals in soil.
- **Biological properties:** Biochar with high high porosity would be the most favorable for microorganism habitat because the pore spaces in biochar provide a good habitat. Microbes can be protected from parasitism and desiccation by biochar, which also contains labile C and mineral nutrients that promote growth. The ability of biochar to enhance pH and the addition of labile organic C to the soil (Farrell *et al*. 2013), which results in wider C/N ratios, have both been linked to this shift in the microbial community.

Cons of biochar application

- The use of contaminated raw materials, municipal garbage, or sewage sludge might cause toxic metals to build up in the biochar. If applied to soil, this heightens the risk of phytotoxicity and soil pollution. During the pyrolysis process, biochar may produce dioxins, carbonaceous nanoparticles, volatile organic compounds (VOC), polyaromatic hydrocarbons (PAH), and VOCs. High molecular weight PAHs typically occur at high temperatures (>500 °C), whereas low molecular weight PAHs typically arise at low temperatures (500 °C).

- The ability of biochar to immobilise heavy metals may change over time when competing contaminants or native soil organic matter occupy the sorption sites.
- The biochar's ability to effectively immobilise heavy metals can also immobilise a number of essential micro and macronutrients, reducing soil fertility and decreasing the bioavailability of those nutrients to plants.
- Due to the source material or production process, metal buildup in biochar may leak into the soil or water, increasing their concentration in the environment and causing biomagnifications or bio-accumulation into the food chain.
- In order to fully grasp the impacts of biochar, which are still being investigated in the laboratory, field trials are required.

Conclusion:

Thus, it can be concluded that although the total amount of toxic metals in the soil did not decrease as a result of the addition of biochar, it did reduce the mobility of Pb, Cr, and Cd as well as the bioavailability of Zn, Pb, and Cd. Biochar has the potential to enhance the agronomic value and quality of soil while reducing the harmful effects of toxic metals. Biochar affects the physical characteristics of soil, which may subsequently have an ongoing effect on plant growth. Additionally, biochar increases the availability of nutrients for plants and decreases the bioavailability of harmful metals while reducing the leaching of soil resources.

For the treatment of water and soil contaminated with toxic metals, biochar is a viable and environmentally beneficial technique. The ability of biochar to effectively adsorb toxic metals and other pollutants in water and soil makes it a great, environmentally friendly, and economically viable method for reducing environmental contaminants in water and soil.

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