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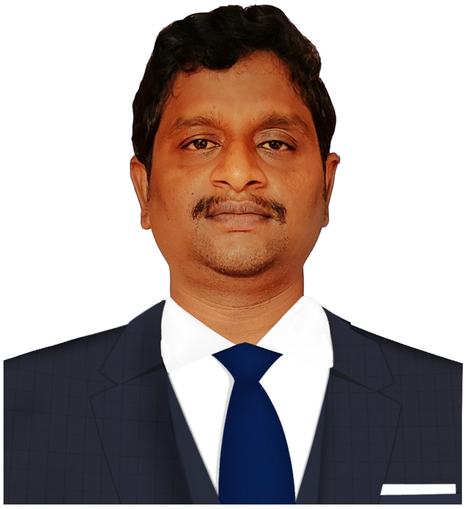
From the Desk of Editor-in-Chief

With immense humbleness and anticipation, I seek it's my pleasure to launch the April 2026 issue of the **"Krishi Netra"** a monthly e-Magazine subtitled "Invisible Vision on Farming" published by **GRN Creatives**. On behalf of the Krishi Netra Editorial Team, I would like to take this opportunity to thank our authors, editors, reviewers and all of them who have volunteered to contribute to the successful release of the first (December) issue of the e-Magazine.



The magazine aims to provide a common platform for the scientific community, research scholars and other readers to publish their ideas, new inventions, research findings etc., to provide the invisible insights for betterment of the farming community. Krishi Netra magazine is primarily focused on the areas of Agriculture, Horticulture, Precision Farming, Fisheries & Animal Sciences, Agriculture Engineering, Agribusiness Management, Food & Dairy Technology, Bio-Sciences/ Life-Sciences, Biotechnology & Biochemistry, Environmental Science &Forestry, Organic Farming, Sericulture and Home Science.

As we turn the pages of Krishi Netra, let us celebrate the unsung heroes, the farmers, the agri-entrepreneurs, the scientists, and the agri scholars. Together, we delve into the realms of sustainable practices, agro ecology, and the transformative power of technology, ensuring that the seeds we sow today yield a bountiful harvest for generations to come.

May this magazine be a source of inspiration, knowledge, and appreciation for the remarkable journey from seed to harvest. Join us on this exploration of the fields that bind us all, as we cultivate a deeper understanding and appreciation for the intricate dance of life on the farm.

I warmly welcome the authors with their contributions that can meet the practical appliances with an integrated/ convergent approach. I wish, with all your support I could see a very bright prospects for Krishi Netra magazine as an eye opener in serving the needs of the farming community.

We look forward for your valuable feedback!
For any questions/ suggestions/ concerns, please contact us: krishinetra@gmail.com
Thank you.

Editor-in-Chief
Gangisetty Srikanth Kumar

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Blockchain in Agricultural Supply Chains: Enhancing Traceability, Food Safety, and Digital Agricultural Governance

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Abstract

Agricultural supply chains in India are characterized by fragmentation, information asymmetry, and weak traceability systems, which collectively reduce farmer income realization and compromise food safety assurance. Blockchain technology, with its decentralized and immutable ledger structure, offers a transformative solution for enhancing transparency, traceability, and trust across agri-food systems. This paper examines the role of blockchain in Indian agriculture with emphasis on supply chain integration, food safety governance, and farmer inclusion. It further analyses select pilot implementations in India and proposes a conceptual framework for scalable adoption. Evidence suggests that while blockchain adoption remains in early stages, sector-specific pilots in export-oriented and high-value crops demonstrate measurable improvements in traceability efficiency, buyer confidence, and compliance systems.

Keywords: Blockchain, Agriculture, Traceability, Food Safety, Supply Chain, FPOs

1. Introduction

India's agricultural marketing system continues to operate through multi-layered intermediaries, often resulting in limited visibility of product origin, quality standards, and price transmission. This lack of transparency affects both producers and consumers, particularly in perishable and export-sensitive commodities.Food safety incidents and export rejections in horticultural products highlight the urgent need for robust traceability systems. Traditional databases are centralized and vulnerable to tampering, whereas blockchain introduces a **decentralized, cryptographically secured ledger system** that records every transaction in a supply chain in real time.Globally, blockchain has been recognized as a key enabler of "farm-to-fork" traceability, especially in agri-food governance systems. Issues such as food adulteration, pesticide residue contamination, and mislabelling of origin continue to affect consumer trust and public health. Strengthening food safety systems has therefore become a key policy priority for institutions such as the Food Safety and Standards Authority of India (FSSAI).In recent years, digital transformation in agriculture has accelerated through initiatives such as e-NAM and digital crop monitoring systems. Among emerging technologies, blockchain has gained attention for its ability to ensure transparency, traceability, and data integrity in agricultural supply chains. Its decentralized structure allows all stakeholders to access verified and tamper-proof records, thereby reducing dependency on manual documentation and intermediaries.

2. Understanding Blockchain Technology

Blockchain operates as a distributed ledger architecture where transactions are recorded in sequential blocks

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and validated through network consensus mechanisms, ensuring data integrity and resistance to unauthorized modification.

In agriculture, blockchain can store:

- Farmer identity and farm location
- Input usage such as seeds, fertilizers, and pesticides
- Harvesting details including time and quantity
- Storage and transportation conditions
- Processing, certification, and retail information

This creates an end-to-end digital trail of agricultural products from farm to fork, ensuring complete visibility across the supply chain.

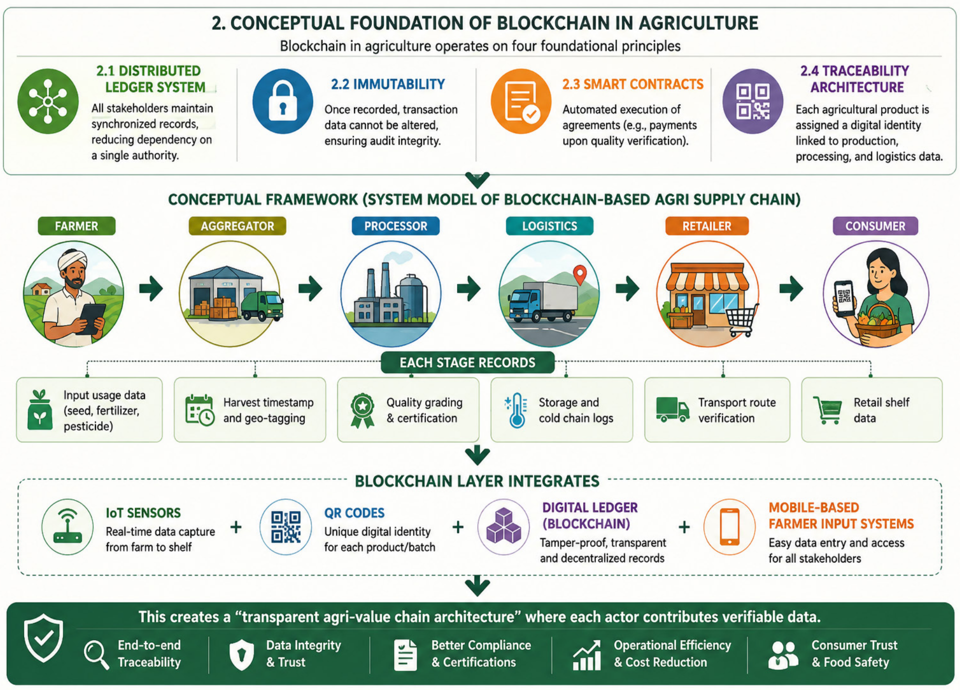

Figure1- Infographics illustrating the Conceptual Framework of Block chain technology

(The figure is an original conceptual illustration prepared by the authors to synthesize information from the reviewed literature).

3. Blockchain for Agricultural Traceability

Traceability refers to the ability to track the movement and history of agricultural products across all stages of production and distribution.At the production stage, blockchain enables the creation of a unique digital identity for each batch of farm produce by securely recording key details such as crop type, cultivation practices, and input usage. As the produce moves through the supply chain, additional information related to grading, sorting, storage conditions, and packaging is continuously added, ensuring quality integrity during post-harvest processing. During logistics and distribution, parameters such as transportation temperature,

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handling practices, and transit duration can be monitored and stored in real time, strengthening traceability. At the retail level, consumers can access the complete history of the product through QR codes, which enhances transparency, trust, and awareness of food origin and quality. Overall, blockchain significantly improves food safety by enabling rapid identification of contamination sources and affected batches, thereby reducing response time during food safety incidents. It also helps prevent food fraud by reducing risks of adulteration, mislabeling, and counterfeit products due to its immutable record system. Furthermore, certification and inspection records can be securely verified across stakeholders, while the requirement for every actor to record accurate data strengthens accountability throughout the entire agricultural supply chain.

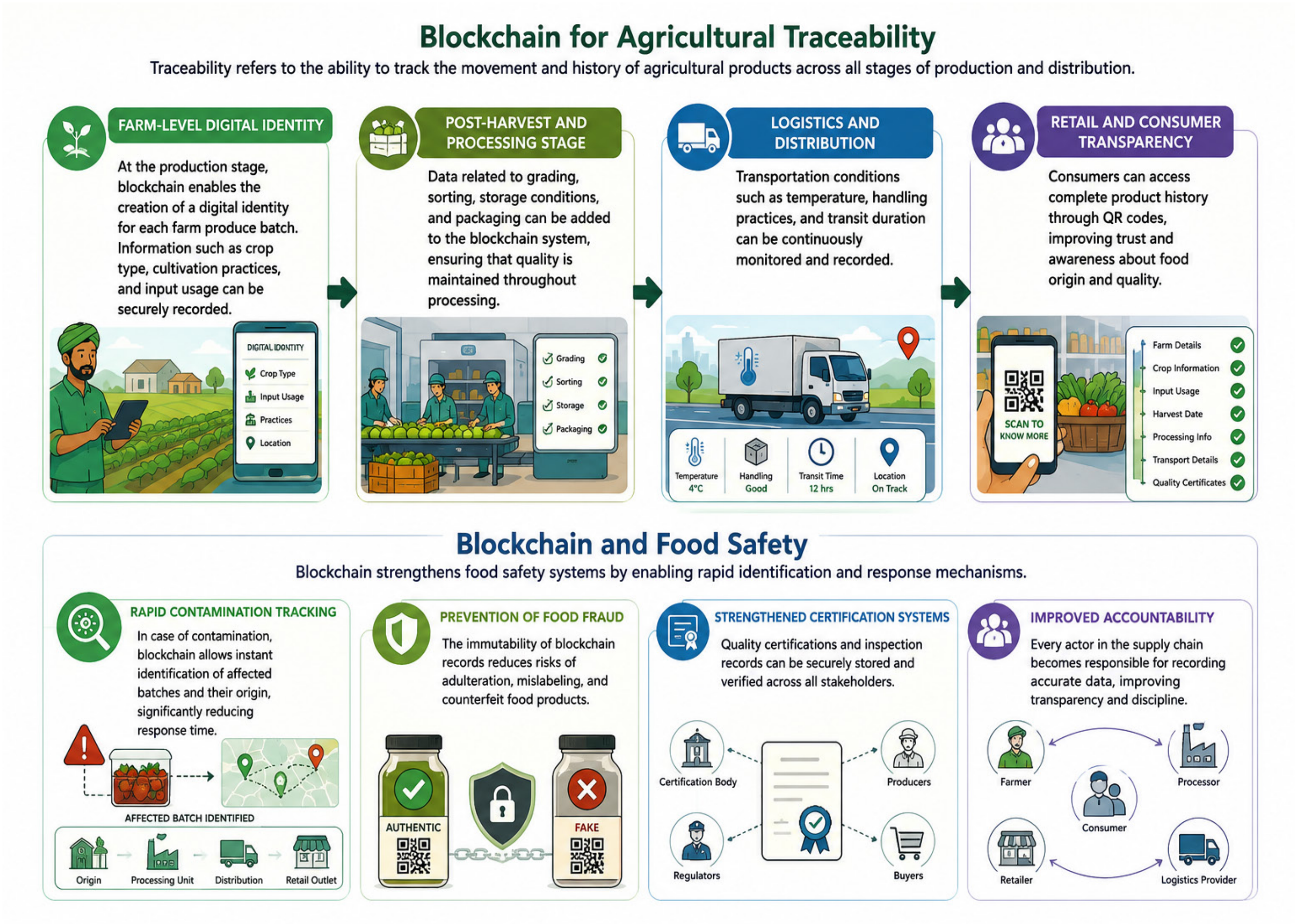

Figure 2- Infographics illustrating traceability of blockchain technology

(The figure is an original conceptual illustration prepared by the authors to synthesize information from the reviewed literature).

4. Case Studies and Practical Evidence

Case Study 1: Walmart–IBM Food Trust Blockchain System (Global Retail Supply Chain)

The Walmart–IBM Food Trust system is one of the most widely documented global implementations of blockchain in food supply chain management. It was designed to enhance end-to-end traceability of food products from farm production to retail shelves, ensuring faster response during food safety incidents.

System Components

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- Blockchain-based shared ledger across suppliers, processors, and retailers
- Digital recording of farm origin, batch details, and processing history
- Integration with retail inventory and supply chain databases
- QR-based product traceability systems
- Real-time data sharing among supply chain actors

Impact on Supply Chain

- Reduced food traceability time from several days to a few seconds (e.g., mango traceability pilot)
- Improved speed of contamination identification and recall management
- Enhanced transparency across multinational food supply chains
- Strengthened consumer confidence in food safety standards

Key Insight

This case demonstrates how blockchain significantly reduces information asymmetry and improves crisis response efficiency in large-scale global food supply chains.

Case Study 2: Andhra Pradesh Seafood Blockchain Traceability System (India Export Supply Chain)

A notable India-linked implementation of blockchain technology is the shrimp and seafood traceability initiative in Andhra Pradesh, developed in collaboration with global food retailers and technology partners.

System Components

- Digital recording of shrimp farming practices at the aquaculture stage
- Blockchain-based tracking from hatchery to export processing units
- Quality checks integrated at processing and packaging stages
- Cold-chain monitoring during transportation
- Compliance-linked export documentation system

Impact on Supply Chain

- Enabled end-to-end traceability of seafood exports
- Improved compliance with international food safety and import standards
- Strengthened India's reputation in global seafood markets
- Reduced rejection risks in export shipments due to better transparency

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Key Insight

This case highlights how blockchain can strengthen export-oriented agricultural value chains by aligning domestic production systems with global traceability requirements.

Case Study 3: TraceX Technologies and FPO-Based Blockchain Adoption (India Agri-Tech Startups)

In India, agri-tech startups such as TraceX Technologies are working with Farmer Producer Organizations (FPOs) to implement blockchain-based traceability systems for high-value horticultural crops and export commodities.

System Components

- Blockchain-enabled digital farm records maintained at FPO level
- Recording of input usage, cultivation practices, and harvest details
- Batch-level traceability for fruits, vegetables, and export crops
- Integration with certification and quality assurance systems
- QR code-based consumer-facing traceability tools

Impact on Supply Chain

- Improved market access for small and marginal farmers through verified quality data
- Enhanced export readiness for FPO-linked produce
- Reduced information gaps between farmers, aggregators, and buyers
- Increased trust in product authenticity and origin verification

Key Insight

This case demonstrates that FPOs act as effective aggregation nodes for blockchain adoption in India's highly fragmented agricultural structure, making scalability more feasible.

Case Study 4: NDDB Dairy Blockchain and Digital Traceability Ecosystem (India)

The National Dairy Development Board (NDDB) has developed advanced digital traceability systems under broader livestock digitization initiatives such as the National Digital Livestock Mission (NDLM) and "Bharat Pashudhan" framework. These systems incorporate blockchain-aligned principles to improve transparency in India's dairy value chain.

System Components

- Unique animal identification and livestock health history database
- Digital milk procurement records at collection centers
- Batch-wise milk quality testing and grading systems

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- Cold-chain and transport monitoring systems
- Integration with dairy cooperatives and federations
- QR-linked product identification for processed dairy products

Impact on Supply Chain

- Improved milk quality assurance and adulteration detection
- Enhanced transparency in farmer payments based on quality parameters (fat/SNF)
- Better disease traceability and livestock health monitoring
- Increased consumer trust in branded dairy products

Key Insight

NDDB's model represents a hybrid blockchain-inspired governance system, where decentralized data integration and tamper-resistant digital records achieve blockchain-like traceability without fully relying on public blockchain infrastructure, making it suitable for large-scale public deployment.

5. India Policy Linkage: FPO Scheme, NDLM, and AgriStack Relevance

Blockchain-based traceability systems in Indian agriculture align closely with ongoing government digital and institutional reforms. The **10,000 Farmer Producer Organizations (FPO) Scheme** provides a critical institutional foundation by aggregating small and marginal farmers into structured collectives, which makes data standardization and digital traceability more operationally feasible in fragmented agricultural markets. Similarly, the **National Digital Livestock Mission (NDLM)** is advancing a unified livestock data ecosystem through digital animal identification, health records, and procurement-linked databases, which indirectly supports blockchain-compatible traceability frameworks in the dairy and animal husbandry sectors. In parallel, **AgriStack**, the Government of India's emerging digital agriculture infrastructure initiative, aims to build a federated farmer database and enable interoperable digital services across the agricultural value chain. Together, these initiatives create an enabling policy environment where blockchain can function as a trust layer on top of government-backed digital databases, improving data integrity, interoperability, and transparency across production, procurement, processing, and marketing systems.

6. Conclusion

Blockchain technology represents a promising innovation for improving traceability and food safety in agriculture. By enabling secure, transparent, and tamper-proof record systems, it strengthens trust across agricultural supply chains and enhances efficiency from farm to consumer.In the Indian context, the greatest potential of blockchain lies in its integration with existing digital platforms and institutional structures such as e-NAM, AgriStack, and Farmer Producer Organizations. While challenges related to infrastructure, cost, and digital literacy remain significant, gradual adoption supported by policy interventions and institutional collaboration can enable meaningful transformation.Ultimately, blockchain should be viewed not as a standalone solution but as an enabling technology that complements broader agricultural digitalization efforts aimed at building a safer, more transparent, and efficient food system.

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References

1.Food and Agriculture Organization (FAO). (2022). Digital Technologies in Agriculture and Food Systems. Rome.

2. Government of India. (2020). e-NAM Operational Guidelines. Ministry of Agriculture & Farmers Welfare.

3. National Bank for Agriculture and Rural Development (NABARD). (2023). Digital Agriculture and Farmer Institutions in India. Mumbai.

4. World Bank. (2021). Blockchain Technology in Agriculture: Opportunities for Developing Economies. Washington, DC.

5. Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID and blockchain technology. Proceedings of the 13th International Conference on Service Systems and Service Management. https://doi.org/10.1109/ICSSSM.2016.7538424

6. Kamilaris, A., Fonts, A., & Prenafeta-Boldú, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. Trends in Food Science & Technology, 91, 640–652. https://doi.org/10.1016/j.tifs.2019.07.034

7.Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. Telematics and Informatics, 36, 55–81. https://doi.org/10.1016/j.tele.2018.11.006

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Importance of Plant Growth Regulators (PGRs) in Cucurbits

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Abstract:

Plant growth regulators (PGRs) play a crucial role in improving growth, flowering, and yield in cucurbit crops.They help regulate sex expression, enhance fruit set, and improve overall productivity. Proper use of PGRs leads to better quality fruits and efficient crop management.

Introduction: Cucurbits are an important group of vegetable crops belonging to the family Cucurbitaceae, including cucumber, pumpkin, bottle gourd, and bitter gourd. These crops are highly sensitive to environmental conditions, particularly temperature and photoperiod, which influence flowering and sex expression. Plant growth regulators (PGRs) are organic substances that modify physiological processes at low concentrations and are widely used to enhance crop performance. In cucurbits, PGRs such as auxins, gibberellins, ethylene, and growth retardants play a vital role in regulating vine growth, inducing female flowers, improving fruit set, and reducing flower drop. Their application helps in increasing yield, improving fruit quality, and ensuring uniform growth, making them essential tools in modern cucurbit cultivation.

Importance of Plant Growth Regulators (PGRs) in Cucurbits

- Plant growth regulators (PGRs) are chemical substances that influence plant physiological processes at very low concentrations. In cucurbits, which are monoecious crops bearing separate male and female flowers, PGRs play a decisive role in modifying growth, flowering behavior, and yield potential.

Regulation of Sex Expression:

- Cucurbit crops naturally produce more male flowers than female flowers, which limits yield. Application of ethylene-releasing compounds like ethephon and auxins increases the proportion of female flowers (gynoecy), thereby significantly enhancing fruit production. Conversely, gibberellins promote maleness, which can be useful in hybrid seed production.

Improvement in Flowering Behavior:

- PGRs help in early initiation of flowering and reduce the node number at which first female flowers appear. This leads to early fruiting and shortens the crop duration. Uniform flowering also helps in synchronized harvesting.

Enhanced Fruit Set and Reduced Flower Drop:

- Auxins such as NAA and 2,4-D improve fruit set by preventing premature abscission of flowers and young fruits. They strengthen the fruit retention capacity of plants, reducing losses during critical stages.

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Induction of Parthenocarpy:

- Certain PGRs like auxins and gibberellins induce parthenocarpy (development of fruits without fertilization), especially in cucumber. This results in seedless fruits with better market preference and higher economic value.

Control of Vegetative Growth:

- Excessive vegetative growth in cucurbits can reduce yield. Growth retardants such as CCC (Cycocel) and MH (Maleic hydrazide) help control vine elongation and divert plant energy toward reproductive growth, improving yield efficiency.

Increase in Yield and Productivity:

- Through better sex expression, improved fruit set, and reduced drop, PGRs significantly increase the number of marketable fruits per plant, leading to higher overall yield.

Improvement in Fruit Quality:

- PGRs enhance fruit size, shape, color, and uniformity. They also improve internal quality parameters such as total soluble solids (TSS), sugar content, and texture, which increases consumer acceptance.

Early Harvesting and Market Advantage:

- Application of PGRs can advance flowering and fruit maturity, enabling farmers to harvest earlier and capture better market prices.

Stress Management:

- PGRs help cucurbit plants tolerate abiotic stresses such as drought, salinity, and temperature extremes by regulating physiological processes like stomatal activity and water balance.

Better Nutrient Utilization:

- PGRs improve enzyme activity and metabolic efficiency, enhancing nutrient uptake and assimilation, which supports overall plant vigor and productivity.

Role in Hybrid Seed Production:

- Gibberellins are used to increase male flower production, while ethylene-releasing compounds promote female flowers. This manipulation is essential for controlled pollination in hybrid seed production programs.

Economic Benefits:

- Efficient use of PGRs reduces crop losses, improves yield and quality, and ultimately increases farmers' income with relatively low investment.

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REFRENCE:

Taiz, L., Zeiger, E., Møller, I.M., and Murphy, A. (2015). Plant Physiology and Development (6th ed.). Sinauer Associates, USA.

Plant Growth and Development by Lalit M. Srivastava

Srivastava, L.M. (2002). Plant Growth and Development: Hormones and Environment. Academic Press.

Vegetable Crops by T.K. Bose

Bose, T.K., Kabir, J., Maity, T.K., Parthasarathy, V.A., and Som, M.G. (2002). Vegetable Crops. Naya Udyog, Kolkata.

Handbook of Horticulture by K.L. Chadha

Chadha, K.L. (2012). Handbook of Horticulture.

Vegetable Science by H.S. Choudhury

Choudhury, H.S. (1996). Vegetable Science. Oxford & IBH Publishing Co.

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Harnessing IoT and Smart Sensors for Climate-Resilient Precision Farming Applications

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ABSTRACT

Global agriculture is in jeopardy due to climate change, with food and nutritional security being threatened by a rising human population. This demands an intelligent and adaptive farming practices alongside resilient and smart solutions. This study presents an innovative framework integrating advanced IoT sensor networks with adaptive smart applications to support climate-resilient and precision-based agriculture. These smart app incorporates machine-learning-driven climate risk alerts, crop stage-specific advisories and predictive yield analytics tailored to local agro-ecological zones. IoT integration in agriculture revolutionizes resource use and climate resilience through precision technologies. This approach shifts farming from traditional methods to data-driven systems, minimizing waste and enhancing sustainability. The aggregate data of shared dashboards from various farm networks, provide community-level insights into weather patterns and soil health for collective decision-making. Early-warning systems analyse sensor data alongside forecasts to alert on droughts, heat waves, or outbreaks, helping farmers pre-emptively adjust practices like shading or masking, growing of resistant varieties. This paper highlights new opportunities, system architecture, and application pathways for building climate adaptive precision farming systems and identifies key challenges in interoperability, sensor calibration, and data reliability.

INTRODUCTION :

Agriculture faces escalating challenges due to unpredictable climate change, declining soil health, rising input costs and the need for higher productivity with limited resources. Traditional manual methods fall short against intensifying droughts, heatwaves and erratic rainfall, necessitating innovative tools for early sensing and real-time insights. In this context, sensor-based precision agriculture is the need of the hour. IoT sensors now can monitor soil moisture, nutrients, micro-climates, pests and crop growth, feeding data into mobile smart apps that deliver dynamic irrigation schedules, fertilizer alerts and weather risk warnings.

This IoT-smart app convergence shifts precision farming from input optimization to climate-resilient and proactive management *via* machine learning predictions of stress conditions. Affordable sensors, low-power connectivity and user-friendly dashboards in local languages empower smallholder farmers, enabling early detection of issues, holistic data fusion for tailored recommendations and community-level climate intelligence. Ultimately, these technologies foster sustainable, data-driven agriculture, enhancing yields, efficiency and global food security amid climate uncertainty.

APPLICATIONS OF SENSOR BASED PRECISION AGRICULTURE

1. Early Warning Systems

One of the most significant applications of IoT in modern agriculture is enhancing farmers' capacity to withstand climate variability. IoT sensors measure critical environmental parameters—temperature, humidity, soil moisture, wind speed, rainfall, solar radiation—at high frequency. Smart apps integrated with climate-prediction models analyze these data streams to detect early signs of extreme conditions such as drought, heat waves, cold waves, heavy rainfall, and storms.

These warnings help farmers make timely decisions such as advancing irrigation, applying protective mulches, adjusting planting schedules or harvesting early to avoid losses. In regions prone to drought, soil moisture-based alerts help farmers manage scarce water resources. In areas exposed to sudden storms or monsoonal changes, sensors predict them and alerts the farmers. Thus, IoT-enabled systems shift farming from reactive decision-making to preventive climate-adaptive management. (Research and Markets)

2. **Efficient Water Resource Management**

Water scarcity remains a global challenge, especially in semi-arid and arid agricultural regions. IoT-based precision irrigation systems use soil moisture probes, tensiometers, flow meters, and smart irrigation controllers to determine the exact water needs of crops at specific growth stages. Smart applications analyze real-time data to decide: When irrigation is required How much water should be applied Which irrigation method is optimal (drip/sprinkler/furrow irrigation methods *etc*).

This avoids under- or over-irrigation and improves water efficiency. Automated drip irrigation systems connected to IoT nodes can start or stop water flow without human intervention. Energy consumption is also reduced as pumps operate only when needed. Over time, these systems increase water productivity, ensure sustainable groundwater use, and reduce irrigation-related stress during climate extremes. (Saha G, Shahrin F, Khan FH, Meshkat MM, Azad AAM)

3. Smart Nutrient Management

Nutrient imbalance—whether deficiency or excess—can severely limit crop yield. IoT-based nutrient management systems employ NPK sensors, soil organic carbon sensors, and electrochemical probes to continuously monitor soil nutrient levels. Drone-mounted crop sensors can even detect nutrient stress through multispectral imaging. These IoT inputs feed into smart apps that recommend:

A. Site-specific nutrient management

B. Fertilizer types, doses, timing and schedules for drip system,

C. Organic substitute recommendation

Site-specific nutrient management

SSNM is a modern nutrient management approach developed to match fertilizer application to the specific needs of crops, specific soil conditions, and specific field variability at different times in the season. Instead of applying blanket fertilizer recommendations for an entire region, SSNM focuses on delivering the right nutrient, at the right rate, at the right time, and in the right place, based on real-time field data. It aims to

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increase crop productivity, improve nutrient-use efficiency, and reduce environmental losses. SSNM was widely promoted by IRRI (International Rice Research Institute) and later adapted for various crops like maize, wheat, sugarcane, and vegetables.

This approach minimizes fertilizer wastage, lowers production costs, and reduces environmental contamination caused by nutrient runoff. With precision nutrient management, farmers can apply fertilizers only when required and in appropriate quantities, leading to higher crop uptake efficiency and improved soil health over the long term.

1. **Early Detection of Pests and Diseases**

IoT-based pest and disease management is an emerging field with tremendous applications. Smart pheromone traps equipped with cameras, insect sensors, and wireless modules can monitor pest populations automatically. Similarly, leaf wetness sensors, humidity sensors, and micro-climate modules can predict fungal disease outbreaks before symptoms appear on leaves.

Smart apps combine sensor data with AI-enabled models to: Identify pest activity, Track pest population dynamics, predict disease Incidence, Recommend targeted chemical or biological control. This early detection system prevents major outbreaks, reduces pesticide dependency, lowers production costs, and supports eco-friendly pest management. Farmers gain the ability to take preventive actions instead of struggling with severe infestations that lead to substantial yield loss. (Research Article Ferentinos, K. (2018)

Fig 1. Pest and disease detection using…….

2. Automatic Greenhouse and Controlled Environment

Greenhouses, polyhouses, and hydroponic farms rely on accurate environmental control. IoT systems play a major role by regulating:

a) Temperature
b) Relative humidity
c) Nutrient solution concentration
d) CO_2 levels
e) Light intensity

Smart apps connect with actuators such as foggers, heaters, ventilation fans, and nutrient pumps to manage the environment automatically. This leads to optimal growth conditions regardless of external climate variations.

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Fruits, vegetables, and high-value crops grown under IoT-enabled controlled environments achieve higher yields and quality. Automation also reduces labor needs and human error.

3. **Yield Prediction, Harvest Optimization and Crop Forecasting**

IoT-enabled data analytics combined with machine learning creates accurate yield models. Sensors collect continuous data on crop physiology, soil conditions, and environmental factors, which are analyzed to estimate yield potential. These predictions help farmers plan harvesting, labor requirements, storage arrangements, and market sales.

TYPES OF SENSORS

1. Ultrasonic Sensors

Working Principle: Use high-frequency sound waves to measure distance based on echo time.

Agriculture Applications:

a) Crop height measurement (wheat, maize, rice)

b) Water level in tanks & ponds

c) Obstacle detection in agricultural robots

d) Seed level sensing in seed hoppers

e) Fertilizer bin level monitoring

f) Drone altitude measurement

Advantages:

a) Low cost

b) Works in dust/fog

c) No physical contact required

2. Optoelectronic Sensor

Optoelectronic sensors use light—such as lasers, LEDs, infrared light, or visible light—to detect changes in the environment. They include RGB cameras, NDVI sensors, multispectral and hyperspectral sensors, PAR sensors, and laser-based LiDAR. These sensors are important in smart and precision agriculture because they can detect plant stress, nutrient deficiency, disease symptoms, leaf area, canopy cover, and growth rate. They are essential for drone-based imaging and automated plant monitoring systems.

3. Electromagnetic Sensor

Electromagnetic sensors operate by sending electrical or magnetic signals into the soil and measuring how they are altered. The changes indicate soil electrical conductivity (EC), salinity levels, soil moisture variations, and nutrient-related properties. Devices like EM38 and EM31 are commonly used for large-area soil mapping.

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These sensors help farmers understand soil variability, create management zones, and apply fertilizers or irrigation water more accurately.

4. Mechanical Sensor

Mechanical sensors measure physical properties such as pressure, force, load, and vibration. They are commonly used in agricultural machinery, such as load cells in yield monitors, pressure sensors in irrigation systems, and vibration sensors to detect machine faults early. Mechanical sensors also help measure fruit firmness, soil compaction, and the tension in plant stems or roots. They are simple, reliable, and widely used in field operations.

5. Eddy Covariance Sensor

The eddy covariance system is an advanced sensing method used to

measure the exchange of gases (like CO_2), water vapor, and heat between plants and the atmosphere. It uses a combination of instruments like sonic anemometers and infrared gas analyzers. This system helps to understand evaporation, transpiration, crop water use efficiency, and greenhouse gas emissions. It is highly valuable in climate-resilient agriculture and environmental monitoring because it provides real-time micrometeorological data.

6. Electrochemical Sensor

Electrochemical sensors detect chemical properties using electrodes that react with ions in soil or water. Examples include pH sensors, electrical conductivity (EC) sensors, nitrate sensors, ammonia sensors, and dissolved oxygen sensors. These sensors help evaluate soil fertility, water quality, nutrient availability, and fertilizer management in both field crops and hydroponic systems. They are crucial for precise nutrient management and maintaining healthy crop environments.

7. Radiometric Sensor

Radiometric sensors detect electromagnetic radiation emitted or reflected by plants and soil. This includes thermal infrared sensors, canopy temperature sensors, and remote radiometers. These sensors help farmers identify drought stress, early disease symptoms, water stress. (Patil, K.A.,& Kale,N.R.)

SMART APPS IN AGRICULTURE

1. **PLANTIX**

Plantix is a smartphone app developed by PEAT (Progressive Environmental & Agricultural Technologies). It helps farmers identify plant diseases, pests, and nutrient deficiencies just by taking a photo of the affected plant. The app uses artificial intelligence to analyze the image and instantly tells the farmer what problem the plant has. Along with diagnosis, it gives clear solutions such as suitable pesticides, organic treatments, nutrient recommendations, and preventive measures. The app also provides weather updates, fertilizer schedules, and a farmer community section where users can ask questions and learn from others. Because it works in many Indian languages and gives fast and accurate results, Plantix has become one of the most popular digital tools in agriculture. (Plantix (PEAT GmbH))

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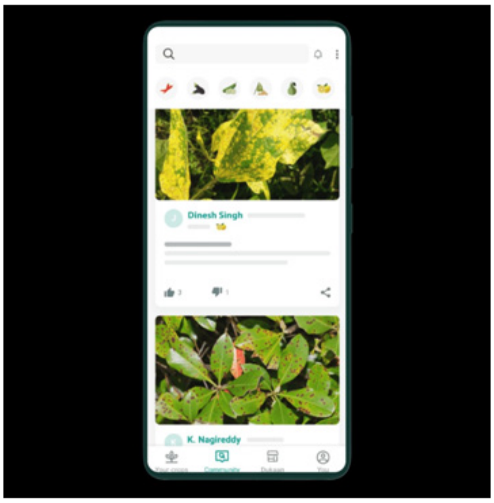

Fig 2. Plantix App Interface

2. Crop plan

There is an app called "Crop Plan – Microgreens / Growers" on Google Play / iOS which helps farmers or growers schedule crop production so that a crop is ready by a target harvest date. You can add crops, set a target harvest date (or event/pre-order date), and get notifications ahead of the harvest. There is also a desktop cross-platform software for gardeners/farmers on GitHub called cropplanning which allows users to create, duplicate, delete crops and plantings; reuse data from prior plantings; and auto-calculate dates/data for scheduling. This is open-source and free. Another product named CropPLAN is a more advanced farm-management / planning system (fertiliser application, crop protection, crop rotations, cost and profitability analysis per field/crop).

3. AgroStar

AgroStar is a mobile app that provides farmers with expert agronomic advice, crop management guidance, weather updates, and access to quality seeds, fertilizers, and crop protection products. It also allows farmers to connect with a community for knowledge sharing, helping them improve productivity and adopt climate-resilient practices.

3. BharatAgri app

BharatAgri is a farm-advisory + agri-input e-commerce platform. Through the app, farmers get: a personalized crop calendar (when to sow, fertilize, spray etc.), pest/disease alerts and advice (with "Agri-Doctor" support), input marketplace for seeds, fertilizers, crop-protection products, and home delivery of inputs. The service covers many crops, supports decision-making, and aims to reduce cost and increase yield for farmers.

4. IFFCO Kisan Agriculture App

IFFCO Kisan App provides farmers with crop-specific advice, weather updates, market prices, and fertilizer recommendations. It also allows farmers to interact with experts and access information on soil testing and government schemes, helping improve productivity and decision-making.

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Advantages of Sensor-based Precision Agriculture

a) **Enhanced Climate Resilience:** Maintains productivity under extreme weather, drought, floods, and heat stress.

b) **Higher Crop Yield:** Optimized resource management and timely interventions lead to improved yields.

c) **Early Warning & Risk Management:** Sensors and apps detect pests, diseases, and nutrient deficiencies early.

d) **Efficient Water Use:** IoT-enabled irrigation reduces wastage through precision watering.

e) **Optimized Fertilizer & Pesticide Use:** Reduces input costs and environmental impact.

f) **Data-Driven Decision Making:** Real-time data supports crop management and yield prediction.

g) **Access to Expert Knowledge:** Smart apps provide advisory, market information, and best practices.

h) **Sustainability & Soil Health:** Reduced chemical overuse and better soil management practices.

i) **Improved Market Access:** Apps help farmers track market prices and connect with buyers.

j) **Time-Saving & Labor Efficiency:** Automation, sensors, and smart tools reduce manual labor.

k) **Better Planning & Forecasting:** Weather predictions and analytics help schedule sowing, irrigation, and harvesting.

l) **Support for Crop Diversification:** Advisories encourage planting climate-resilient and suitable crops.

m) **Community Knowledge Sharing:** Communities allow farmers to share experiences and solutions.

n) **Resource Conservation:** Less water, energy, and chemicals are needed due to precise monitoring.

Disadvantages of Sensor-based Precision Agriculture

a) **High Initial Investment:** Cost of IoT sensors, drones, smart apps, and precision tools can be prohibitive.

b) **Technical Knowledge Required:** Farmers must be trained to use technology effectively.

c) **Internet & Connectivity Dependence:** Poor network limits app and IoT functionality in remote areas.

d) **Maintenance Challenges:** Sensors, devices, and drones require upkeep and calibration.

e) **Data Accuracy Issues:** Faulty sensors or low-quality inputs can lead to wrong decisions.

f) **Partial Crop Coverage:** Some minor or local crops may not be supported by apps or systems.

g) **Over-Reliance on Technology:** Too much dependence may reduce traditional knowledge use.

h) **Privacy & Data Security Risks:** Digital systems may expose farm data if not secure.

i) **Adaptation Resistance:** Some farmers may be reluctant to adopt new tools or practices.

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j) **Power/Energy Requirements:** IoT devices and drones need electricity or batteries.

Conclusion

Harnessing IoT and smart sensors for climate-resilient precision farming represents a transformative shift from traditional agriculture to intelligent, data-driven systems. By integrating real-time field monitoring with predictive analytics and smart advisory applications, farmers can respond proactively to climate variability, resource scarcity, and crop stress. For farmers, this approach offers clear practical benefits: timely early-warning alerts for droughts, pests, and diseases; optimized irrigation and fertilizer use to reduce costs; improved crop yields and quality through precise interventions; better planning of sowing and harvesting; and access to expert guidance and market information via mobile apps. Additionally, community data sharing strengthens collective decision-making and enhances resilience at the regional level. Overall, IoT-enabled precision agriculture improves productivity, conserves natural resources, reduces risk, and supports sustainable farming-making it a powerful tool for ensuring long-term food security under changing climatic conditions.

References

Saha, G., et al. (2025). "Smart IoT-driven precision agriculture: Land mapping, crop prediction, and irrigation system." PLOS ONE, 20(3),

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0319268&hl=enUS#:~:text=Citation%3A%20Saha%20G%2C%20Shahrin%20F,10.1371%2Fjournal.pone.0319268

Wang, X., et al. (2025). "Real-Time IoT-Driven Crop Yield Prediction Using Adaptive Ensemble Machine Learning." SciTePress.

Masupha, T. E., et al. (2024/2026). "A transformative framework reshaping sustainable drought risk management through advanced early warning systems." iScience, 27, 110066.

https://www.hashstudioz.com/blog/building-climate-resilient-farming-solutions-with-iot-sensors/?hl=en-US#:~:text=Additionally%2C%20early%20warnings%20from%20IoT,logistics%20for%20harvesting%20and%20storage

Patil, K. A., & Kale, N. R. (2026). "Applications of Internet of Things (IoT) in agriculture: A review." ResearchGate.

https://www.researchgate.net/publication/403759538_Applications_of_Internet_of_Things_IoT_in_agriculture_A_review?hl=en-US

Shin, Y.-S., et al. (2025). "Establishment and Operation of an Early Warning Service for Agrometeorological Disasters Customized for Farmers and Extension Workers at Metropolitan-Scale." Atmosphere, 16(3), 291.

Research and Markets (2026). "Internet of Things (IoT) in Precision Agriculture Market Report 2026."

https://www.researchandmarkets.com/reports/6103741/internet-things-iot-in-precision-agriculture?hl=en-US#:~:text=Major%20trends%20in%20the%20forecast,equipment%20integration%2C%20remote%20

Krishi Netra
ISSN : 3048-5207

field%20management.

FAO (Food and Agriculture Organization). Climate-Smart Agriculture: Building Resilience and Sustainability. Available at: https://www.fao.org/climate-smart-agriculture

IPCC (Intergovernmental Panel on Climate Change). Climate Change and Land: Agriculture and Food Security. Available at: https://www.ipcc.ch

World Bank. Climate-Smart Agriculture Overview. Available at: https://www.worldbank.org/en/topic/climate-smart-agriculture

CGIAR Research Program. Climate-Smart Villages & Climate-Resilient Agriculture. Available at: https://www.cgiar.org

ICAR (Indian Council of Agricultural Research). Precision Farming and Smart Agriculture Technologies in India. Available at: https://icar.org.in

NITI Aayog. Artificial Intelligence and Digital Agriculture Report. Available at: https://www.niti.gov.in

IEEE Xplore Digital Library. IoT-Based Smart Agriculture Systems. Available at: https://ieeexplore.ieee.org

Springer Nature. Advances in Precision Agriculture and IoT Applications. Available at: https://link.springer.com

Plantix (PEAT GmbH). About Plantix – AI Crop Diagnosis App. Available at: https://plantix.net

Research Article Ferentinos, K. (2018). Deep learning models for plant disease detection using Plantix. Computers and Electronics in Agriculture.

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Hydroponics: A Climate-Resilient Food Production System

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Abstract

Climate change, water scarcity, shrinking arable land, and increasing food demand have created an urgent need for innovative and sustainable agricultural production systems. Hydroponics, a soilless cultivation technique, has emerged as a promising climate-resilient approach capable of producing high-quality crops with greater resource-use efficiency. By delivering nutrients directly to plant roots in a controlled environment, hydroponic systems optimize plant growth while significantly reducing water consumption and minimizing nutrient losses. The technology enables year-round cultivation independent of soil quality and adverse weather conditions, making it particularly suitable for regions vulnerable to drought, salinity, and climate variability. The integration of hydroponics with protected cultivation, automation, and precision agriculture technologies further enhances productivity and crop quality. As urban populations continue to grow and pressure on natural resources intensifies, hydroponic farming offers a practical solution for local food production, improved food security, and climate adaptation. This article highlights the role of hydroponics as a resilient agricultural system and discusses its potential to support sustainable crop production under future environmental and resource constraints.

Keywords: Hydroponics, climate resilience, sustainable agriculture, water use efficiency, controlled environment agriculture

Introduction:

Hydroponic cultivation is rapidly gaining global attention as an efficient method of resource utilization and high-quality food production. Conventional soil-based agriculture is increasingly challenged by urbanization, climate change, natural disasters, and the indiscriminate use of chemical fertilizers and pesticides, all of which contribute to declining soil fertility and reduced agricultural sustainability. Hydroponics offers a viable alternative through soilless cultivation systems, including wick, ebb and flow, drip, deep water culture, and Nutrient Film Technique (NFT). Each system differs in its operational mechanism, advantages, and limitations, allowing growers to select appropriate methods based on crop type and production scale. Additionally, operations such as weeding, spraying, and excessive irrigation are largely eliminated, resulting in improved efficiency. Among these systems, NFT has been widely adopted for the commercial production of leafy vegetables and other crops, offering water savings of up to 70-90%. Countries such as the Netherlands, Australia, France, England, Israel, Canada, and the United States are leading in the advancement and application of hydroponic technologies. For successful commercialization, there is a critical need to develop low-cost hydroponic systems that are simple to operate and maintain, require minimal labor, and reduce both initial setup and operational costs, thereby making the technology more accessible and scalable.

Reason to follow hydroponic cultivation:

Hydroponic cultivation is gaining popularity due to its efficient use of water, nutrients, and space while

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reducing dependence on soil and arable land. It promotes faster plant growth and higher yields by supplying balanced nutrients directly to plant roots. The system enables year-round crop production under controlled environments, minimizing the effects of seasonal changes and adverse weather conditions. Hydroponics can save up to 70–90% of water compared to conventional farming through water recirculation. It also reduces the incidence of soil-borne diseases, weeds, and pests, lowering the need for chemical pesticides and herbicides. Additionally, it ensures uniform crop quality, better nutrient management, and higher productivity per unit area. These advantages make hydroponics a promising and sustainable approach for modern commercial agriculture and urban farming.

Suitable Crops:

Hydroponics can support a wide range of crops, but it works best for plants that have relatively fast growth cycles, shallow to moderate root systems, and high market value. Here are the main categories:

- **Leafy vegetables (most suitable and widely grown)**

These are the easiest and most profitable in hydroponics the important crops are lettuce, spinach, kale, swiss chard, amaranth (leafy types), mustard greens, coriander, basil and other culinary herbs (mint, parsley, dill).

- **Fruiting vegetables**

These crops require more nutrients and support systems but perform well. In this category included tomato, cucumber, capsicum , chilli and eggplant.

- **Herbs**

Some herbs also grown in hydroponic system such as basil (very popular in hydroponics), mint, oregano, thyme, rosemary and sage.

- **Fruits**

Some fruit crops required special facility such as strawberry (one of the most successful hydroponic fruits globally) and melons (cantaloupe, watermelon-mostly commercial systems).

Hydroponic systems commonly used

Hydroponic cultivation uses different systems depending on crop type, scale, climate, and investment level. The most commonly used hydroponic systems are:

1. Nutrient Film Technique (NFT)

Thin film of nutrient solutions continuously flows over plant roots in a sloped channel. This system is best for Lettuce, Spinach and Herbs (basil, mint). The advantages of this method is high water-efficient, High oxygen availability to roots and Ideal for leafy greens. However, this is Sensitive to pump failure (roots can dry quickly) and not suitable for large fruiting crops

Figure:1. Successful cultivation of mint in Framed vertical NFT hydroponic system

2. Deep Water Culture (DWC)

Plant roots are suspended in oxygenated nutrient-rich water. Seedling are placed in net pots with roots

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submerged in oxygenated nutrient solution. This method is suited to lettuce, basil and leafy vegetables. The relative advantages are simple and low-cost, fast plant growth and easy for beginners. However, the limitations of this system are requirement of constant aeration (air pump) and water temperature control needed in hot climates like Rajasthan.

3. Drip System (Recirculating or Run-to-Waste)

In the drip hydroponic system, the nutrient solution is supplied directly to the root zone of each plant through emitters, delivering water and nutrients drop by drop via tubes. It is particularly suitable for fruiting crops such as tomato, capsicum, cucumber, and chili. This system is highly flexible, easily scalable for commercial production, performs efficiently in greenhouse conditions, and allows precise control of nutrient delivery, although careful nutrient management is essential for optimal plant growth.

4. Wick System (Passive hydroponics)

In the wick hydroponic system, nutrients are transported from a reservoir to the growing medium through a wick by capillary action, allowing plant roots to absorb water and nutrients passively. It is best suited for herbs, small leafy greens, and home gardening setups. The system is inexpensive, simple to operate, and requires no electricity, but it is not suitable for large or fast-growing crops due to its limited nutrient delivery capacity.

5. Ebb and Flow (Flood and Drain)

In the Ebb and Flow (Flood and Drain) system, the growing tray is periodically flooded with nutrient solution and then drained back to the reservoir. It is suitable for leafy greens, herbs, and small fruiting plants, providing good root oxygenation and supporting a wide range of crops. However, it requires a pump and timer, and system failure can occur if these components malfunction.

6. Aeroponics (Advanced system)

Roots are suspended in air and misted with nutrient solutions (Roots are suspended in air and misted with nutrient solution). This is best for seed production Potatoes (special systems) and high-value crops. Advantages of this system maximum oxygen exposure, very fast growth rates and very water efficient. Some limitations also include high cost and requires precise control and backup systems

Nutrient Application in Hydroponics:

Nutrient management is the core of hydroponics, because plants depend entirely on the nutrient solution for growth. Unlike soil, there is no buffer-so precision in concentration, pH, and timing is essential. Hydroponic nutrient application is a precise balance of nutrient composition, pH, EC, delivery method and small errors can significantly affect yield.

Figure:2. Methods and demonstration of hydroponic cultivation

Prospects:

Hydroponics, or soilless cultivation, is emerging as an important component of future agriculture due to its efficient use of water, nutrients, and space. It is expected to play a major role in Controlled Environment

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Agriculture (CEA), enabling precise management of growing conditions and year-round crop production. With rapid urbanization, hydroponic farming in rooftops, greenhouses, vertical farms, and container systems is likely to expand. The technology can reduce water consumption by up to 80–90%, making it highly suitable for water-scarce regions. Hydroponics also supports higher productivity, consistent crop quality, and reduced environmental impact. Its integration with advanced technologies will further improve efficiency and sustainability. Overall, hydroponics has strong potential to enhance food security, climate resilience, and sustainable agricultural development in the future.

Conclusion:

In conclusion, hydroponic farming in India represents a promising and sustainable agricultural approach that can significantly contribute to future food security, especially in the context of shrinking arable land, water scarcity, and climate change. By enabling efficient use of resources, higher productivity per unit area, and year-round cultivation of high-value crops, it offers a viable alternative to conventional farming systems. With increasing technological advancements, government support, and growing awareness among farmers and entrepreneurs, hydroponics has strong potential to transform Indian agriculture into a more resilient, profitable, and environmentally sustainable system.

References:

Wang, S., Kleiner, Y., Clark, S. M., Raghavan, V. & Tartakovsky, B. (2024). Review of current hydroponic food production practices and the potential role of bioelectrochemical systems.Reviews in Environmental Science and Bio/Technology, 23, 897-921.

Palmitessa, O. D., Signore, A. & Santamaria, P. (2024). Advancements and future perspectives in nutrient film technique hydroponic system: A comprehensive review and bibliometric analysis. Frontiers in Plant Science, 15, 1504792.

Wang, S., Kleiner, Y., Clark, S. M., Raghavan, V., & Tartakovsky, B. (2024). Review of current hydroponic food production practices and the potential role of bioelectrochemical systems. Environmental Science and Bio-Technology, 23, 897-921.

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Bugs to Protein: The Future of Sustainable Nutrition

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Agriculture is an age old practice and main stay of human civilization. It is the major economy driven activity in India where, 60-70% of the population depends on cultivation of crops directly or indirectly. As the population increases day by day, there is a sustainable pressure on farming escalates, and the efficiency of natural resources has dwindled relative to expected yields. In the surge of increased population, the demand for food protein would increase significantly. Insect farming is a viable and essentially alternative for producing insect-based proteins to supplement human and livestock diets. Edible insects are rich in proteins (50-82%), calcium, iron, zinc and other minerals. Wild gathering is also better option over insect farming, but cultivation of insects always provides sustainable yield and income. East Africa is the largest insect protein producing continent.

The global edible insect market is projected to reach approximately $5.6 billion in 2026 growing at a rate of 25%. All over the world, nearly 2000 species are eaten. Among the insects, A*cheta domesticus* is the common cricket species which is processed into protein powders used as snacks in beverage shops. Mealworms (*Tenebrio molitor*) also popular in Europe, frequently used in pastas and as a whole-snack topping. For the livestock and aqauaculture, the best protein feed can be obtained from the black soldier fly larvae (*Hermetia illucens*). This species having a capability to convert waste to wealth.


Acheta domesticus
(Entomology today, 2026)

Tenebrio molitor
(Anterground, 2026)


Hermetia illucens
(Mispeces, 2026)

The insect protein consists of all 9 essential amino acids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine) which are highly suitable to the humans growth compared to beef or soya. The iron and zinc are easily absorbed by the human body than those found in plant based sources. The insects are the richest source of chitin which acts as a pre biotic fiber that can improve the human gut health and also enhance the immune system. East Africa is the largest supplier of edible insects having more than 1000 black soldier fly and cricket farms.

Processing the insects for edible food is the most important step. First, harvest the desired insect (crickets, bugs, mealworms, black soldier flies, *etc*.). Initially separate the dead insects and use clean containers

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to prevent contamination. Keep the insects without food for 24-48 hours so that they can empty their gut. Rinse thoroughly with clean water; remove dirt, feed residues, and waste, if any. Later, we have to kill the insect by freezing or blanching. Then go for boiling or steaming insects for 3-10 minutes. This step helps to kill bacteria or any other parasites and improves the shelf life. Then go for drying, either oven drying (60-90°C) or sun drying (low cost). After processing, the insects go for roasting or frying. Add salt, spices, or flavors, and then use them as snacks. We can also go for protein powders by grinding the dried ones.

If we examine the nutritional composition of the insects, the final processed form contains 40-70% of protein, 10-40% of healthy fat (unsaturated fatty acids like Omega 3 and 6), low in carbohydrates, but contain chitin (exoskeleton), which acts as a dietary fiber, and also have minerals like iron, zinc, calcium, magnesium, phosphorus and vitamins like B12, B2, B3, A & E. Among all the insects crickets are having balanced diet for all the above components.

Edible insects offer several advantages over conventional foods, including sustainability and eco-friendliness, high nutritional value, efficient feed conversion, cost-effectiveness, and versatility in food applications. However, despite these benefits, they also present certain challenges such as limited cultural acceptance, potential allergy risks, food safety concerns, regulatory issues, difficulties in large-scale processing, and variability in nutritional composition.

Conclusion

Though the insects are rich in proteins and other essential elements which will supplement human nutrition, India is still emerging to organize insect farming for the production of edible insects. So far, northeastern states like Nagaland, Manipur and Assam are producing bamboo worms, silkworm pupae, fried crickets, grasshoppers and red ants (chutneys), but these productions depend on local ecosystems and traditional knowledge, which may limit scalability and commercial viability in other regions of India.

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Carbon Farming and Green Agriculture: A Sustainable Pathway for Future Farming

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Introduction

The present situation in agriculture finds itself at a crucial crossroads. Though it has been the cornerstone of human existence, agriculture has also become a significant source of greenhouse gas emissions. Rising temperatures, unpredictable precipitation cycles, and poor soil fertility have compelled agriculturalists and researchers to consider new farming techniques. Against this backdrop, carbon farming and green agriculture have proven to be viable ways of solving the problem.

Carbon farming is a form of agriculture where carbon dioxide from the atmosphere is captured and stored in the soil and plant matter. Green agriculture emphasizes the use of sustainable methods in farming without harming the environment.

Understanding Carbon Farming

The concept behind carbon farming revolves around one main idea. Namely, an increase in the level of carbon that gets into the soil. Plants breathe in carbon dioxide as part of their photosynthesis process and release it back into the soil where it can stay for a significant period if specific agricultural practices are employed.

Among them are:

Cover cropping, which implies planting certain plants such as legumes or grasses during idle seasons. Reduced tillage or no tillage at all, thus avoiding destruction of the topsoil layer. Agroforestry, where planting trees alongside regular crops or cattle is used. Various organic additives such as compost and manure. Notably, apart from helping the environment by decreasing carbon dioxide levels in the atmosphere, these practices lead to improved soil quality and increased fertility.

Green Agriculture: Concept and Importance

Green agriculture emphasizes sustainability, environmental protection, and efficient use of natural resources. It promotes practices that reduce chemical inputs, conserve water, and maintain ecological balance.

Key components of green agriculture include:

- **Organic farming**
- **Integrated pest management (IPM)**

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- **Efficient irrigation methods like drip and sprinkler systems**
- **Use of renewable energy in farming operations**

Green agriculture ensures long-term productivity without degrading natural resources. It also aligns with global sustainable development goals, particularly those related to climate action and responsible consumption.

Carbon Sequestration in Soil: The Science Behind It : Soil acts as a major carbon sink. It contains more carbon than the atmosphere and vegetation combined. When organic matter such as crop residues and manure decomposes, it contributes to soil organic carbon (SOC).

The process involves:

1. **Photosynthesis**: Plants absorb CO_2 from the atmosphere
2. **Carbon transfer**: Carbon moves into roots and soil microorganisms
3. **Stabilization**: Carbon becomes part of soil organic matter

Healthy soils with high organic carbon content are more fertile, retain more water, and support better crop growth. This makes carbon farming both an environmental and agricultural strategy.

Economic Opportunities: Carbon Credits for Farmers

Carbon credits are another thrilling element of carbon farming. Farmers can accumulate carbon credits by using techniques that facilitate carbon sequestration. These credits can then be traded on carbon markets for companies seeking carbon offsets. Such possibilities would provide additional sources of income:

Extra source of income for farmers

Motivation to engage in sustainable practices

Encouragement of environmental farming

Yet, carbon markets are still in their nascent stages in countries such as India, and many farmers are unaware of them. Under the right conditions, they could be economically significant.

Benefits of Carbon Farming and Green Agriculture

1. Environmental Benefits

- Reduction in greenhouse gas emissions
- Improved biodiversity

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- Better soil and water conservation

2. Agricultural Benefits

- Increased soil fertility
- Higher crop yields in the long term
- Improved resilience to drought and climate stress

3. Economic Benefits

- Reduced input costs (fertilizers, pesticides)
- Potential earnings through carbon credits
- Long-term sustainability of farming system

Challenges and Limitations

Despite its benefits, carbon farming and green agriculture face several challenges:

- Lack of awareness among farmers
- Initial transition costs
- Limited access to carbon markets
- Policy and institutional gaps

In addition, measuring and verifying carbon sequestration is complex and requires scientific tools and monitoring systems. Small and marginal farmers may find it difficult to adopt these practices without external support.

Scope in India

Carbon farming has great possibilities in India owing to its vast agricultural land and varying agro-climatic zones. Various practices such as agroforestry, organic farming, and conservation agriculture have already been encouraged by several governmental schemes. Some of the schemes are:

National Mission for Sustainable Agriculture (NMSA)

Paramparagat Krishi Vikas Yojana (PKVY)

Soil Health Card Scheme

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Given that climate change is becoming an issue of great importance, carbon farming may prove helpful in making the Indian agricultural sector sustainable and resilient to the changes.

Future Prospects

The future of agriculture lies in balancing productivity with sustainability. Carbon farming and green agriculture are not just trends but necessities in the face of climate change.

Technological advancements such as remote sensing, AI-based soil analysis, and digital carbon tracking systems will further enhance the effectiveness of these practices. Moreover, global demand for sustainably produced food is increasing, which can benefit farmers adopting green practices.

Conclusion : The concept of carbon farming and green agriculture marks a new approach to agriculture. Rather than seeing farming as an activity that contributes to global warming, it sees farming as an answer.

Through its efforts at improving the soil condition, fostering biodiversity, and cutting greenhouse gas emission, carbon farming ensures that the farmer reaps profits while protecting the environment. However, awareness, policies, and incentives would have to be put in place for its widespread adoption.

India, being one of the most populous nations, would benefit immensely from the practice of carbon farming as a path to more sustainable agriculture. Though there would be some hard work, it would surely prove rewarding.

References

1. *Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. Science, 304(5677), 1623–1627.*
2. *FAO (2021). Recarbonizing global soils: A technical manual of recommended management practices. Food and Agriculture Organization.*
3. *IPCC (2022). Climate Change and Land Report. Intergovernmental Panel on Climate Change.*
4. *Ministry of Agriculture & Farmers Welfare, Government of India (2023). Sustainable Agriculture Initiatives.*
5. *Smith, P. et al. (2020). How much land-based greenhouse gas mitigation can be achieved without compromising food security? Global Change Biology.*
6. *World Bank (2022). Carbon Markets and Agriculture: Opportunities for Developing Countries.*

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Major Diseases of Rubber (Hevea brasiliensis): Symptomatology, Diagnosis, and Integrated Management Strategies.

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1. Introduction

Rubber (*Hevea brasiliensis* Müll. Arg.) is the principal source of natural rubber and one of the most economically important plantation crops cultivated in tropical regions worldwide. The productivity and sustainability of rubber plantations are frequently challenged by a range of fungal diseases that affect leaves, stems, branches, and roots. These diseases can cause severe defoliation, dieback, root decay, reduced latex production, and — in advanced cases — complete tree mortality.

Favorable environmental conditions, particularly high humidity and persistent rainfall, accelerate pathogen proliferation and disease spread across plantations. Early and accurate diagnosis is therefore critical. Timely identification enables growers to implement targeted management interventions before losses escalate. This chapter provides a comprehensive overview of the seven major diseases affecting *Hevea brasiliensis*, emphasizing symptomology, causal organisms, and integrated management strategies encompassing cultural, biological, and chemical approaches.

2. Foliar Diseases

2.1 Abnormal leaf fall

Causal Organisms: ***Phytophthora palmivora& P. nicotianae var. parasitica***

Symptoms:

Abnormal leaf fall is one of the most economically damaging foliar diseases of rubber, typically occurring between June and August — distinctly different from the natural leaf fall that occurs in December. Infected leaves develop dull grey, circular spots that gradually enlarge and become irregular in outline. The petioles display characteristic sunken lesions, and affected fruits undergo rapid rotting. Leaves are shed prematurely, either while still green or after turning coppery red. The accumulation of fallen foliage on the plantation floor forms a thick, malodorous carpet of rotting leaves, which serves as a primary source of secondary infection.

Management:

- Apply prophylactic sprays of Bordeaux mixture (1%) before the onset of the south-west monsoon season.
- Supplement spray solutions with zinc sulphate ($ZnSO_4$) at 0.2% to enhance fungicidal efficacy.
- Repeat applications at regular intervals throughout the monsoon period for sustained protection.

Abnormal leaf fall Fruit rot

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2.2 Birds eye spot

Causal Organisms: ***Drechslera heveae***

Symptoms:

Bird's eye spot derives its name from the distinctive appearance of the lesions it produces: small, circular spots with a grey centre surrounded by a sharp brown border, giving the impression of a stylized eye. These spots occur in large numbers, particularly on nursery plants and young field-established trees. High lesion density can significantly impair photosynthetic efficiency and weaken juvenile plants during the critical establishment phase.


Circular spots with grey centre

Management:

- Spray with Bordeaux mixture (1%) at first appearance of symptoms.
- Repeat applications every 10–15 days during periods of high humidity.
- Ensure adequate spacing in nurseries to improve air circulation and reduce leaf wetness duration.

2.3 Corynespora leaf spot

Causal Organism: ***Corynespora cossicol***

Symptoms:

Corynespora leaf spot predominantly infects young, expanding leaves. The characteristic lesions are circular, featuring a brown to papery necrotic centre encircled by a dark brown ring, outside which a prominent yellow halo develops. As the disease progresses, small shot-holes may form within necrotic areas as dead tissue disintegrates. Heavily affected leaves desiccate completely and abscise prematurely, contributing to significant defoliation and canopy reduction.


Infected leaf

Management:

- Spray with Bordeaux mixture (1%) at regular intervals during the flush period.
- Monitor susceptible clones closely, as genetic variation in susceptibility is well-documented.
- Remove and destroy heavily infected leaf debris to reduce inoculum sources.

2.4 Powdery Mildew

Causal Organism: *Oidium heveae*

Symptoms

Powdery mildew is readily recognizable by the white, powdery fungal growth (conidial masses) that colonizes both young and mature leaf surfaces. Infected leaves curl, crinkle, and roll inwards before abscising, while the petiole remains attached to the branch — giving affected shoots a distinctive "broomstick" appearance. The pathogen also infects flowers and tender fruits, causing extensive shedding. Epidemic outbreaks during the refoliation period can result

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in severe loss of new leaf growth.

Management

- Apply sulphur-based fungicides 3–5 times at 15-day intervals during the refoliation season.
- Use Carbendazim (0.1%) or Tridemorph (1.5%) alternated with sulphur dust (70%) for resistance management.
- Carbendazim combined with wettable sulphur or Micro-Sul (52% EC) provides effective systemic and protectant action.

2.5 Colletotrichum Lea

Infected plant

Powdery fungal growth on leaves

Causal Organisms: *Colletotric*

Symptoms : Colletotrichum le ;, with infections commonly initiating at the leaf tip region. yellow halo. As the disease advances, numerous spots coale gressive defoliation. Infected leaves frequently exhibit crinkl ing the refoliation flush can cause almost complete defoliation, substantially reducing photosynthetic capacity and delaying canopy recovery.

Management

- Spray with Bordeaux mixture (1%) at 10–15 day intervals during susceptible flush stages.
- Alternative fungicides include copper oxychloride (0.125%), Mancozeb (0.2%), and
- Carbendazim (0.05%).
- Integrate fungicide rotations to delay resistance development in pathogen populations.

Infected Leaf tips

3. Stem and Branch Diseases

3.1 Pink disease

Causal Organism : *Corticium salminicolor*

Symptoms:

Prevalent in wet areas. Young twigs and branches are mostly affected. The fungal growth encircles the stem, penetrates the bark and cortical tissues which eventually decay. The bark splits and peals off. If the infection in not recognized early the tree dies after the rainy season.

Management:

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Affected parts should be pasted with Bordeaux paste or painting tar. Copper fungicides should not be used in rubber because they will contaminate the latex.


Infected twigs


Splited bark

4. Root Diseases

4.1 Brown root diseases

Causal Organism: ***Fomes noxius***

Symptoms:

The affected roots are encrusted with mass of soil and small stones held by network of mycelium. The affected tap root becomes rotted and the entire tree is killed.

Management:

Removal and destruction of the infected trees. Apply lime @ 2.5t/ha**.** In the area of dead tree apply additional dose of lime @ 25 kg/dead tree. Wash the partially affected root with Emisan or Aretan 0.1%.


Affected root

5. Conclusion

Diseases represent a significant challenge to the productivity and longevity of rubber (*Hevea brasiliensis*) plantations. Effective disease management relies on accurate diagnosis, regular monitoring, and the timely implementation of appropriate control measures. Integrating preventive practices with suitable cultural and chemical interventions can substantially reduce disease incidence and associated losses. A comprehensive understanding of disease symptoms and management strategies is therefore essential for maintaining plantation health, enhancing latex production, and promoting the sustainable cultivation of rubber.

Reference

1. *Déon, M., Fumanal, B., Gimenez, S., Bieysse, D., Oliveira, R.R., Shuib, S.S., ... Dussert, S. (2014). Diversity of the cassiicolin gene in Corynespora cassiicola and relation to pathogenicity in Hevea brasiliensis. Fungal Biology, 118(1), 32–47.* DOI: 10.1016/j.funbio.2013.10.011

Krishi Netra
ISSN : 3048-5207

2. *Lopez, D., Ribeiro, S., Label, P., Fumanal, B., Venisse, J.S., Kohler, A., ... Duplessis, S. (2018). Genome-wide analysis of Corynespora cassiicola leaf fall disease putative effectors. Frontiers in Microbiology, 9, 276. DOI: 10.3389/fmicb.2018.00276*

3. *Limkaisang, S., Kom-un, S., Furtado, E.L., Liew, K.W., Salleh, B., Sato, Y., & Takamatsu, S. (2006). Molecular phylogenetic and morphological analyses of powdery mildews on rubber. Mycoscience, 47(4), 220–226. DOI: 10.1007/S10267-006-0298-3*

4. *Nandris, D., Nicole, M., & Geiger, J.P. (1987). Root rot diseases of rubber. Plant Disease, 71(4), 298–306. DOI: 10.1094/PD-71-0298*

5. *Ali, S.S., Shao, J., Lary, D.J., Kronmiller, B.A., Shen, D., Strem, M.D., & Meinhardt, L.W. (2017). Phytophthora palmivora and cocoa black pod disease: A comprehensive review. Frontiers in Microbiology, 8, 2022. DOI: 10.3389/fmicb.2017.02022*

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Paddy Straw Management Strategies

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Abstract

Rice straw is a major organic residue produced during paddy cultivation and ranks as the third-largest agricultural residue after sugarcane bagasse and maize straw. Southeast Asian countries contribute nearly 80% of global rice production, resulting in large quantities of straw each year. Managing this surplus is a significant challenge due to storage issues, complete removal from fields and limited time between successive crops. As a result, farmers often resort to stubble burning, which is a quick, low-cost method for land preparation. However, rice straw is rich in nutrients and energy. At crop maturity, it retains about 40% nitrogen, 30–35% phosphorus, 80–85% potassium, and 40–50% sulphur absorbed by the plant. Despite its value, burning straw damages soil health by destroying beneficial microorganisms and contributes to environmental pollution by releasing harmful gases such as SO_2, NO_2, CH_4, N_2O, carbon monoxide and particulate matter. To address this issue, eco-friendly alternatives should be adopted.

Introduction

Rice crop or paddy is a type of grass (Gramineae) and belongs to the genus Oryza. The rice *Oryza glaberrima* and rice *Oryza sativa* were domesticated in Africa and Asia respectively. Many other places have been proposed for the origin of *O. sativa* such as northern Thailand and India. The *O. sativa* is cultivated in a wide range of environments. It is cultivated from lowland paddy fields to high altitude terraces, equatorial tropics to sub-tropical mid-latitude, and from swamps to upland rice. The maximum yield of paddy is obtained in the dry season, because of less cloud cover. With lesser cloud cover, the photosynthetic active radiations (PAR) are more as compared to the wet season.

Paddy straw management in agriculture:

1. Incorporation of paddy straw in the field.

The burning of crop residues leads to soil degradation, for that the conversion of waste paddy straw into organically rich nutrients for the soil. In agriculture, the use of compost improves crop yield problems by 4-9 % To accelerate the breakdown process, some special fungus is added and it gives successful results just in 3 months. The addition of cow dung also provides the required environment for enzymes and microbes. .

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2..Paddy straw uses as bedding material

Farmer has to use the paddy straw as bedding material in winter for cattle. Rice straw provides a dry, clean, comfortable, non-slippary, and hygienic environment which prevents the chances of lameness and injury. Healthy legs ensure better milk production and reproductive efficiency of animals Navneet *et al*., (2012), rice straw as bedding material as a shown in figure 2

Paddy straw for mushroom cultivation

Cultivation of mushroom requires paddy straw with some specific moisture, length and temperature the factors required for the proper growth of mushrooms are relative humidity of about 75-85% and 35ºC temperature. The production cycle of paddy straw mushrooms is 15 days only Ahlawat et al.,2007 and Chang and Hayes, 1978, paddy straw for mushroom as shown in figure 3.

straw for mushroom cultivation.

Straw bales as cattle feed.

Bale making

Paddy straw bale making converts agricultural waste into compact, transportable and high-density blocks. The process involves drying, raking, compressing and binding, primarily using a tractor-operated baler. It reduces the need for burning, aids in sustainable waste management and prepares the straw for biofuel, fodder or industrial applications. Paddy straw bales are a cost-effective, high-fiber roughage for ruminants (cattle, buffalo, sheep).

Compost making

Composting paddy (rice) straw involves breaking down nutrient-rich, carbon-heavy straw using nitrogen sources like cow dung or urea, creating a nutrient-dense organic fertilizer that improves soil structure, enhances moisture retention, and increases crop yields while avoiding burning. The process takes 4-8 weeks and turns 70% straw mixtures into valuable, nutrient-rich soil amendment.

PADDY STRAW FOR ENERGY PRODUCTION

Biogas from paddy straw

For the production of biogas from rice straw, underground containers usually have 2.5 m width, 4 m height, with a dome shape on top, and constructed with cement and bricks at the top of the container, a way for the gas outlet is provided and at the bottom, there is a way for the water inlet shown in the figure 6. A half-meter thick layer of rice straw and a layer of cow dung are placed alternately on the straw layer. These steps are repeated continuously till the complete filling of the plant. Later the plant is filled with water, and the fermentation process begins and production of biogas starts.

Figure 6: Production of biogas from paddy straw

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Bio ethanol from paddy straw

Bioethanol production from rice straw involves pre-treating the ligno cellulosic biomass (32-47% cellulose) with acid or alkali (NaOH) to remove lignin, followed by enzymatic hydrolysis and fermentation (e.g., using Saccharomyces cerevisiae) to produce ethanol. Effective pretreatments increase sugar yield, with optimized processes yielding around 0.40 g/g ethanol from fermented material. Bioethanol is a renewable fuel derived from agricultural products (paddy straw) primarily used as a sustainable transport fuel additive to reduce greenhouse gas emissions, Binod *et al*., (2010).

Bio char from paddy straw

Bio char is a type of charcoal that is derived biologically with thermo chemical pyrolysis of rice straw (biomass) shown in figure 7. Pyrolysis is a thermo chemical decomposition of organic materials at an elevated temperature in absence of oxygen. In the pyrolysis process, larger molecules break down into small molecules Gong *et al*., (2018). Although bio char can never add nutrients itself in soil, it increases the pH value in an area that is acidic in nature. So, with the help of bio char, there may be a reduction in greenhouse gases, increase in crop yield, and the soil is provided with more fertility.

Figure 7: Biocha

Paddy straw for generation of power

Currently, bio energy is the largest renewable energy source globally and accounts for more than 2/3rd of the renewable energy mix. In the overall energy scenario, bio energy accounts for 13% –14% of the total energy consumption Chandra *et al*., (2017). Crop residues, in particular, are one of the largest biomass resources globally and the best options for use to produce bio energy. The thermal efficiency of rice straw is approximately 60-75 % which may further depend on the technology used in its combustion.

Paddy straw management in industries

Paddy straw - cement bricks Rice straw is also being used for the production of lightweight cement bricks that are used as fillers in the construction of buildings (skeleton types). The burned product ofbiomass power plant left behind contains high silica contents and is used in the manufacturing of bricks. the straw used in the production of bricks also provides thermal insulation to it.

Figure 9: Paddy straw cement bricks

Mixing with plastic for 3 D objects

Recently a company in China invented an eco-friendly material- straw-based plastic - made from rice and wheat stalks and can be used in 3 D printing. It is prepared from the dried straw of crops like rice straw, wheat straw, corn stalk, etc., mixed with plastic and plastic additives. .

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Paddy straw for paper making

Collection & Cleaning: Raw paddy straw is collected, washed to remove soil, and cut into small pieces. Pre-treatment/Cooking: The straw is treated (often with NaOH or enzymes) at high temperatures to remove lignin and silica. This breaks down the fibers into a pulpy consistency.

Packaging materials from paddy straw

Conclusion

Proper utilization of rice straw is not only the responsibility of farmers; government should have to make proper laws and regulations to check stubble burning. There must be public awareness regarding rice straw management and compulsory training must be given to farmers related to rice straw management. Uses of rice straw also provide some financial support to farmers. Rice straw can be used for different purposes as a fuel that may reduce greenhouse and other harmful gases. In this way, the environment can be protected from the future critical situation of pollution. The technology should be such that rice straw can be transported from the field to industry with minimum effort otherwise all efforts are a failure.

Reference

https://agricoop.nic.in/sites/default/files/Mushroom%20Cultivation.pdf. *Ministry of Agriculture & Farmers Welfare, India. Mushroom cultivation manual.*

https://icar.org.in/content/crop-residue-management. *ICAR (Indian Council of Agricultural Research). Crop residue management.*

https://www.fao.org/3/t4470e/t4470e0b.htm. *FAO. Rice straw utilization in paper and board making.*

https://www.fao.org/3/y5031e/y5031e0h.htm.*FAO (Food and Agriculture Organization). Rice straw management and soil fertility.*

https://www.ieabioenergy.com/wp-content/uploads/2018/01/biogas-from-agriculture.pdf. *IEA Bioenergy. Biogas production from agricultural residues.*https://www.unep.org/resources/report/single-use-plastics-roadmap-sustainabilility.

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Seed Sector Reforms and Agribusiness Growth: A Public–Private Partnership Perspective

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1. Introduction

Agriculture remains a cornerstone of the Indian economy, supporting livelihoods, food security, and rural development. Within agriculture, the horticulture sector has emerged as one of the fastest-growing and most commercially vibrant subsectors. India ranks among the world's leading producers of fruits, vegetables, spices, flowers, and plantation crops, with horticultural production exceeding food grain production in recent years. The sector contributes substantially to agricultural gross value added (GVA), employment generation, nutritional security, and export earnings.

The success of horticultural production depends heavily on the availability of quality seeds and planting materials. Unlike cereal crops, horticultural crops are characterized by high market value, quality sensitivity, perishability, and intensive input requirements. Farmers increasingly demand hybrid seeds, disease-resistant cultivars, climate-resilient varieties, and planting materials capable of meeting evolving market and consumer preferences. Consequently, seed systems have become a critical determinant of productivity, profitability, and competitiveness within horticultural value chains.

Traditionally, seed systems in India focused primarily on the multiplication and distribution of improved varieties developed by public research institutions. However, rapid commercialization, technological advancement, and globalization have transformed seed systems into complex market-driven ecosystems involving multiple stakeholders, including research organizations, seed companies, nurseries, farmer producer organizations (FPOs), agri-startups, distributors, retailers, and regulatory agencies. This transition reflects a broader shift from input-centric approaches toward integrated value chain models that emphasize efficiency, innovation, market responsiveness, and farmer empowerment.

Market-driven seed systems operate through coordinated networks that connect research, seed production, processing, quality assurance, marketing, distribution, and end-user adoption. Such systems encourage innovation, facilitate investment, improve access to quality planting materials, and strengthen linkages among actors across the value chain. Public-private partnerships (PPPs) have emerged as a particularly important mechanism for promoting these objectives by combining public-sector research capabilities with private-sector efficiency, investment, and market expertise.

The increasing adoption of digital technologies is further accelerating the transformation of seed systems. Mobile-based advisory platforms, artificial intelligence-driven forecasting tools, blockchain-enabled traceability systems, and e-commerce marketplaces are reshaping how seeds are produced, distributed, and marketed. These innovations are improving transparency, reducing transaction costs, and enhancing market access for farmers and agribusiness enterprises.

Despite significant progress, several challenges continue to constrain the effectiveness of horticultural seed systems. High seed costs, counterfeit products, climate-related risks, inadequate storage infrastructure, fragmented markets, and regulatory bottlenecks remain persistent concerns. Addressing these issues requires coordinated efforts involving policymakers, research institutions, private enterprises, farmer organizations, and development agencies.

This paper examines the evolution of market-oriented seed systems in India's horticulture sector, with particular emphasis on value chain integration and public-private partnerships. It explores emerging business models,

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technological innovations, institutional arrangements, and policy interventions that are shaping the future of horticultural seed systems. The study also identifies key challenges and opportunities for strengthening sustainable and inclusive

Indicator	Value
Horticulture Production	~351 Million Tonnes
Area Under Horticulture	~28 Million Hectares
Share in Agricultural GDP	~30%
Global Rank in Fruits Production	2nd
Global Rank in Vegetables Production	2nd

2. Literature Review

The development of efficient seed systems has long been recognized as a critical factor influencing agricultural productivity, food security, and rural economic development. According to Almekinders and Louwaars (2002), a well-functioning seed sector requires strong linkages among research institutions, seed producers, regulatory agencies, and farmers to ensure the continuous availability of quality planting materials. Their work emphasized the importance of integrating formal and informal seed systems to improve accessibility and sustainability.

Tripp and Rohrbach (2001) highlighted the role of policy and institutional frameworks in promoting seed enterprise development. Their study demonstrated that market-oriented seed systems perform more effectively when supported by enabling regulations, private-sector participation, and investment in seed infrastructure. The authors argued that liberalization of seed markets can stimulate innovation and improve the dissemination of improved varieties among farmers.

In the Indian context, Singh (2014) observed that seed systems play a strategic role in enhancing food security and agricultural competitiveness. The study emphasized that access to quality seeds significantly influences productivity growth, particularly in high-value agricultural sectors such as horticulture. Similarly, Chand (2017) identified improved seed adoption as a key component of strategies aimed at increasing farmers' income and strengthening agricultural value chains.

The expansion of horticulture has created new opportunities and challenges for seed system development. Birthal et al. (2005) reported that increasing market integration and vertical coordination in high-value agricultural commodities have encouraged the adoption of improved technologies, including hybrid seeds. Their findings indicated that stronger market linkages improve efficiency, reduce transaction costs, and enhance farmer participation in commercial agriculture.

Recent studies have highlighted the growing importance of public-private partnerships in seed sector development. Spielman and Kennedy (2016) argued that collaborative approaches involving public research institutions and private enterprises accelerate varietal development, technology transfer, and commercialization. Public institutions contribute scientific expertise and germplasm resources, while private companies provide investment, marketing capabilities, and distribution networks.

Digital transformation has emerged as another significant theme in contemporary seed system literature. The World Bank (2019) emphasized the potential of digital technologies to improve transparency, traceability, and efficiency across agricultural value chains. Technologies such as mobile advisory platforms, artificial intelligence, blockchain systems, and e-commerce marketplaces are increasingly facilitating information exchange and market access for farmers.

Despite considerable progress, several studies continue to identify persistent constraints within seed systems, including high input costs, counterfeit products, regulatory bottlenecks, climate-related risks, and inadequate infrastructure. These challenges are particularly pronounced in developing countries where smallholder farmers often face limitations in accessing quality seeds, financial resources, and technical support.

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Overall, existing literature suggests that sustainable seed systems require a combination of technological innovation, institutional coordination, market integration, and supportive policy interventions. The growing emphasis on public-private partnerships, digital agriculture, and value chain approaches reflects an evolving understanding of seed systems as dynamic agribusiness ecosystems rather than merely input delivery mechanisms. This study builds upon these perspectives by examining the role of market-driven seed systems in strengthening horticultural agribusiness value chains in India.

3. Importance of Seed Systems in Horticultural Development

Seeds and planting materials constitute the foundation of agricultural productivity and represent one of the most critical inputs in horticultural production systems. The quality of seeds directly influences crop establishment, yield potential, pest and disease resistance, product quality, shelf life, and marketability. In horticultural crops such as tomato, chilli, cabbage, cauliflower, cucumber, watermelon, onion, papaya, and various floriculture species, the adoption of improved varieties and hybrid seeds has significantly enhanced productivity and farm profitability.

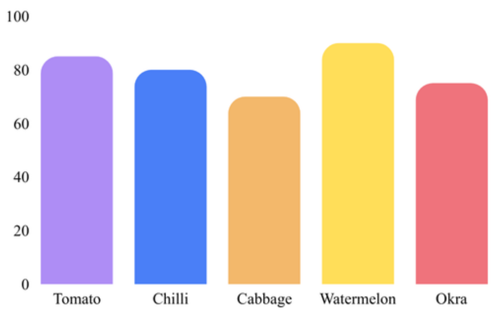
The role of quality seed extends beyond productivity enhancement. Improved genetic material enables farmers to respond effectively to changing climatic conditions, emerging pest and disease pressures, and evolving consumer preferences. Climate-resilient varieties help reduce production risks associated with drought, heat stress, flooding, and erratic weather patterns. Similarly, disease-resistant hybrids contribute to lower pesticide use, reduced production costs, and improved environmental sustainability.

Horticultural markets increasingly demand uniformity, appearance, nutritional quality, and extended shelf life. These characteristics are largely determined by seed quality and varietal selection. Export-oriented horticulture enterprises, in particular, rely heavily on high-performance seeds capable of meeting stringent international quality standards. As a result, investment in improved seed systems has become an essential component of competitiveness in domestic and global markets.

Quality seed systems also contribute to rural economic development by generating employment opportunities across seed production, nursery management, processing, packaging, logistics, retailing, and extension services. Seed enterprises support entrepreneurship among youth, women, and farmer producer organizations, creating additional income streams within rural economies. Furthermore, reliable access to quality seeds enhances farmers' confidence in adopting modern technologies and participating in commercial agriculture.

From a food and nutritional security perspective, improved horticultural seeds play a crucial role in increasing the availability and accessibility of fruits and vegetables. Enhanced production contributes to dietary diversification and supports public health objectives related to nutrition and food quality. As demand for horticultural products continues to rise due to urbanization, income growth, and changing consumption patterns, efficient seed systems become increasingly important for sustaining agricultural growth and meeting consumer needs.

Therefore, strengthening horticultural seed systems is not merely a technical requirement but a strategic necessity for achieving broader goals related to agricultural transformation, rural development, food security, and economic growth.



Hybrid Seed Adoption in Major Vegetable Crops

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4. Characteristics of Market-Driven Horticultural Seed Systems

Horticultural seed systems differ substantially from conventional seed systems associated with cereal crops due to their commercial orientation, technological complexity, and quality sensitivity. The increasing integration of horticulture into domestic and international markets has accelerated the development of sophisticated seed supply networks designed to meet the evolving requirements of producers, processors, retailers, and consumers.

One of the defining characteristics of horticultural seed systems is the dominance of hybrid varieties. Crops such as tomato, chilli, brinjal, okra, cabbage, cauliflower, watermelon, and cucumber are largely cultivated using hybrid seeds because of their superior yield potential, uniformity, disease resistance, and market acceptance. The development and commercialization of hybrid technologies have created significant opportunities for private-sector participation, resulting in a highly competitive and innovation-driven seed industry.

Horticultural seed systems are also characterized by intensive technological requirements. Seed production often involves controlled pollination, maintenance of genetic purity, isolation protocols, nursery management, and specialized post-harvest handling procedures. These activities require technical expertise, infrastructure investments, and strict quality control mechanisms to ensure seed viability and performance.

Another important feature is the high economic value associated with horticultural seeds. Although seed costs constitute a relatively small proportion of total cultivation expenses, they have a substantial influence on crop performance and profitability. Consequently, farmers are generally willing to invest in premium-quality seeds when they perceive clear economic benefits. This market behavior encourages continuous innovation and product differentiation among seed companies.

The perishability of horticultural produce further increases the importance of seed quality. Poor-quality seeds can result in reduced germination rates, uneven crop establishment, inferior product quality, and significant post-harvest losses. Therefore, efficient seed systems play a critical role in ensuring consistency, reliability, and competitiveness throughout horticultural value chains.

Furthermore, horticultural seed systems increasingly rely on market intelligence and consumer-driven innovation. Seed companies continuously develop new varieties based on changing preferences related to appearance, taste, nutritional value, shelf life, and processing characteristics. This close alignment between seed development and market demand distinguishes horticultural seed systems from many traditional agricultural sectors.

5. Seed Value Chain Framework in the Indian Horticulture Sector

The horticultural seed industry functions through an interconnected value chain that links research institutions, seed producers, processing units, distributors, retailers, and farmers. The effectiveness of this value chain significantly influences the availability, affordability, and quality of seeds supplied to producers across diverse agro-climatic regions.

The value chain begins with research and varietal development. Public-sector institutions, including the Indian Council of Agricultural Research (ICAR), the Indian Institute of Horticultural Research (IIHR), and State Agricultural Universities (SAUs), play a critical role in developing improved varieties adapted to regional conditions. These institutions focus on enhancing productivity, disease resistance, climate resilience, and nutritional quality through conventional breeding and advanced biotechnological approaches.

Alongside public research organizations, private seed companies invest heavily in hybrid breeding programs and product innovation. Their efforts are primarily directed toward developing commercially viable hybrids that satisfy market demands and generate competitive advantages. The collaboration between public research institutions and private enterprises has become increasingly important in accelerating the commercialization of improved genetic materials.

Seed production represents the second major stage of the value chain. India has emerged as a global hub for hybrid vegetable seed production due to favorable agro-climatic conditions, skilled labor availability, and relatively low production costs. States such as Telangana, Andhra Pradesh, Karnataka, Maharashtra, Gujarat, and Tamil Nadu serve as major centers for seed multiplication activities.

Contract farming has become a widely adopted model for horticultural seed production. Under this arrangement, seed companies provide parent lines, technical guidance, quality standards, and assured procurement agreements, while farmers undertake seed multiplication activities. This model reduces market risk for producers while ensuring a stable supply of quality seeds for companies.

Following production, seeds undergo processing and quality assurance procedures. Activities such as cleaning, grading, drying, treatment, packaging, and germination testing are essential for maintaining seed quality and meeting regulatory standards. Seed certification agencies and quality control laboratories play a vital role in verifying compliance with prescribed standards and protecting farmers from substandard products.

The final stages of the value chain involve marketing, distribution, and retailing. Traditional distribution networks consisting of agri-input dealers and seed retailers continue to dominate seed sales. However, digital marketplaces, farmer producer organizations, franchise networks, and specialized horticultural nurseries are increasingly expanding market access and improving supply chain efficiency. The growing adoption of e-commerce platforms has further transformed distribution systems by enabling direct interaction between seed suppliers and end-users.

An efficient seed value chain ensures timely availability of quality planting materials, reduces transaction costs, facilitates innovation diffusion, and enhances the overall competitiveness of the horticulture sector. Strengthening linkages among value chain actors remains essential for achieving sustainable growth and improving farmer welfare.

Indicator	Value
Total Horticulture Production (India)	~351 Million Tonnes
Area Under Horticulture	~28 Million Hectares
Share in Agricultural GDP	~30%
Vegetable Seed Market Controlled by Private Sector	>75%
Hybrid Seed Adoption in Major Vegetables	70-90%
Seed Replacement Rate in Vegetables	>90%

State	Major Seed Activities
Telangana	Hybrid vegetable seed production
Andhra Pradesh	Chilli, Tomato, Cucurbit Seeds
Karnataka	Hybrid vegetable seed production
Maharashtra	Onion & Vegetable Seeds
Gujarat	Contract Seed Farming
Tamil Nadu	Nursery & Seedling Enterprises

6. Public-Private Partnerships in Horticultural Seed Systems

Public-private partnerships (PPPs) have emerged as a critical mechanism for strengthening horticultural seed systems in India. The increasing complexity of agricultural markets, rapid technological advancement, and growing demand for high-quality planting materials have necessitated collaborative approaches that leverage the strengths of both public and private institutions. PPPs facilitate resource sharing, risk mitigation, technology transfer, and market expansion, thereby contributing to the development of efficient and sustainable seed ecosystems.

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Public-sector institutions continue to play a foundational role in seed system development through germplasm conservation, breeding research, varietal development, quality regulation, and extension services. Organizations such as the Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs), National Seeds Corporation (NSC), and State Seed Corporations have historically contributed to the development and dissemination of improved crop varieties. These institutions provide the scientific knowledge and regulatory framework necessary for maintaining the integrity and reliability of seed markets.

The private sector complements these efforts through investments in research and development, hybrid seed technology, product commercialization, branding, logistics, and market expansion. Private seed companies possess the financial resources and operational flexibility required to rapidly respond to changing market demands and consumer preferences. Their participation has significantly accelerated the adoption of hybrid technologies and improved access to quality seeds across diverse production environments.

Several successful PPP models have emerged within India's horticulture sector. Contract seed production represents one of the most widely adopted models, wherein seed companies collaborate directly with farmers for the multiplication of hybrid seeds. Under these arrangements, companies provide parent materials, technical guidance, quality standards, and assured procurement mechanisms. This model creates stable income opportunities for farmers while ensuring a reliable supply of quality seeds for the industry.

Licensing agreements constitute another important form of partnership. Public research institutions increasingly license improved varieties and hybrids to private companies for commercial multiplication and distribution. Such collaborations accelerate technology dissemination and enhance the accessibility of publicly developed innovations to farming communities.

Farmer Producer Organizations (FPOs) are also emerging as significant partners within seed systems. By engaging in seed production, aggregation, processing, and marketing activities, FPOs strengthen local seed availability while improving bargaining power and reducing transaction costs for member farmers. Their participation contributes to greater inclusiveness and equity within seed value chains.

Overall, PPPs facilitate innovation, enhance investment flows, improve market efficiency, and support the development of resilient seed systems capable of addressing emerging agricultural challenges. Strengthening institutional collaboration remains essential for ensuring long-term sustainability and competitiveness within the horticulture sector.

PPP Model	Benefits
Contract Seed Production	Assured farmer income
Licensing Agreements	Faster commercialization
Seed Village Programs	Local seed availability
FPO-led Enterprises	Better bargaining power
Nursery Partnerships	Quality seedlings

7. Digital Technologies and Agribusiness Innovation in Seed Systems

Digital transformation is rapidly reshaping agricultural value chains worldwide, and the horticulture seed sector is no exception. The integration of advanced digital technologies is improving operational efficiency, enhancing market transparency, and facilitating data-driven decision-making across seed production and distribution networks.

Mobile-based advisory platforms have become an important tool for delivering real-time information to farmers. These platforms provide recommendations on varietal selection, pest and disease management, irrigation scheduling, nutrient management, and weather forecasting. By improving access to timely information, digital advisory services help farmers make informed production decisions and optimize resource utilization.

Artificial intelligence (AI) and data analytics are increasingly being utilized for demand forecasting, inventory

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management, market intelligence, and production planning. Predictive analytics enables seed companies to anticipate market demand more accurately, reduce inventory costs, and improve supply chain responsiveness. Data-driven decision-making also supports the identification of emerging market opportunities and consumer preferences.

Blockchain technology is gaining attention as a potential solution for enhancing traceability and transparency within seed supply chains. By creating immutable records of seed production, processing, certification, and distribution activities, blockchain systems can improve accountability and reduce the prevalence of counterfeit seeds. Enhanced traceability also strengthens consumer confidence and facilitates compliance with regulatory standards.

E-commerce platforms are transforming traditional distribution channels by enabling direct interactions between seed suppliers and farmers. Online marketplaces provide greater product visibility, expanded market reach, and improved price transparency. Farmers benefit from access to a wider range of seed products, while companies gain opportunities to serve geographically dispersed markets more efficiently.

The emergence of agri-startups has further accelerated innovation within the seed sector. Startups are developing digital marketplaces, precision agriculture solutions, smart nursery technologies, remote sensing applications, and traceability systems that address specific challenges across horticultural value chains. These entrepreneurial ventures are contributing to increased competitiveness and modernization within the agribusiness landscape.

Despite their potential, the adoption of digital technologies remains uneven across regions and farmer categories. Limited digital literacy, inadequate internet connectivity, and affordability constraints continue to restrict technology adoption among smallholder farmers. Therefore, investments in digital infrastructure, capacity building, and inclusive innovation strategies are essential for maximizing the benefits of digital transformation.

As digital agriculture continues to evolve, the integration of emerging technologies will play an increasingly important role in strengthening seed systems, improving market efficiency, and supporting sustainable horticultural development in India.

PPP Model	Key Features	Major Benefits
Contract Seed Production	Company-farmer agreements for seed multiplication	Assured buy-back, stable income
Licensing Agreements	Public varieties licensed to private firms	Faster commercialization
Seed Village Programmes	Cluster-based seed production	Local seed availability
FPO-led Enterprises	Collective production and marketing	Better bargaining power
Nursery Partnerships	Protected nursery development	Quality planting material

8. Market Analysis and Emerging Agribusiness Models

The Indian horticulture seed industry has experienced substantial growth over the past two decades, driven by rising demand for high-value crops, increasing adoption of hybrid technologies, urbanization, and changing dietary preferences. The growing commercialization of agriculture has transformed seeds from a basic production input into a strategic component of agribusiness development and value chain competitiveness.

India's seed market is estimated to be among the largest in Asia, with vegetable seeds representing one of the fastest-growing segments. Private sector participation accounts for a significant share of the horticultural seed market, particularly in hybrid vegetables where adoption rates exceed those observed in traditional cereal crops. The increasing demand for superior quality produce, climate-resilient varieties, and export-oriented cultivation has further stimulated investment in research, breeding, and seed production activities.

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Several innovative agribusiness models are reshaping the horticulture seed ecosystem. Protected nursery enterprises have emerged as an important business opportunity, supplying plug-tray seedlings, grafted plants, and disease-free planting materials to commercial growers. These enterprises improve crop establishment, reduce seed wastage, and enhance production efficiency while creating employment opportunities in rural areas.

Digital seed marketplaces represent another significant innovation. Online platforms enable farmers to access a wide range of seed products, compare prices, obtain technical information, and place orders directly from suppliers. Such platforms reduce information asymmetry, improve market transparency, and strengthen linkages between producers and consumers.

Community seed enterprises and farmer-led seed businesses are also gaining importance in promoting localized seed security and strengthening rural entrepreneurship. These initiatives facilitate decentralized seed production and distribution while preserving locally adapted genetic resources. In many regions, farmer producer organizations have successfully integrated seed business operations into broader agricultural value chains, enhancing income generation and collective bargaining power.

Export-oriented seed production has emerged as a promising area of growth. Favorable agro-climatic conditions, skilled labor availability, and competitive production costs have positioned India as an attractive destination for global seed production. International demand for hybrid vegetable seeds offers substantial opportunities for expanding seed exports and strengthening India’s presence in global agricultural markets.

The convergence of technological innovation, institutional support, and market expansion is creating a dynamic environment for agribusiness entrepreneurship within the seed sector. Continued investment in innovation, infrastructure, and market development will be essential for sustaining long-term growth and competitiveness.

Year	Trend
1990	Low private participation
2000	Moderate growth
2010	Expansion of hybrid seeds
2020+	Digital and startup-led growth

9. Challenges and Constraints in Horticultural Seed Systems

Despite significant advancements, several challenges continue to impede the development of efficient and inclusive horticultural seed systems in India. Addressing these constraints is critical for ensuring long-term sustainability and maximizing the benefits of market-driven approaches.

One of the most significant challenges is the high cost of hybrid seeds. Although hybrid varieties offer substantial productivity advantages, their affordability remains a concern for many small and marginal farmers. Limited access to institutional credit further restricts the adoption of improved planting materials, particularly among resource-constrained households.

The proliferation of counterfeit and substandard seeds represents another major concern. Fake seeds not only reduce agricultural productivity but also undermine farmer confidence in formal seed markets. Weak enforcement mechanisms and inadequate monitoring systems often allow counterfeit products to enter supply chains, resulting in economic losses for both farmers and legitimate seed companies.

Climate change poses additional challenges to seed production and crop performance. Rising temperatures, erratic rainfall patterns, droughts, floods, and emerging pest and disease pressures affect both seed multiplication activities and field-level productivity. Developing climate-resilient varieties and strengthening adaptive capacity have therefore become strategic priorities for the seed industry.

Infrastructure deficiencies continue to constrain value chain efficiency. Inadequate storage facilities, limited cold-chain infrastructure, and poor transportation networks negatively affect seed quality and viability. These

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challenges are particularly pronounced in remote and underserved regions where access to markets and support services remains limited.

Regulatory bottlenecks also affect sectoral growth. Lengthy approval procedures for new varieties and hybrids can delay commercialization and discourage innovation. While regulatory oversight is essential for maintaining quality standards, excessive procedural complexity may reduce the competitiveness of the seed sector.

Furthermore, digital and informational inequalities restrict the adoption of emerging technologies among smallholder farmers. Limited access to digital tools, technical training, and market information can exacerbate existing disparities and reduce the inclusiveness of market-driven seed systems.

Addressing these challenges requires coordinated interventions involving policymakers, research institutions, private enterprises, farmer organizations, and development agencies. A holistic approach that combines technological innovation, institutional strengthening, infrastructure development, and regulatory reform is essential for building resilient and inclusive seed ecosystems.

10. Policy Recommendations and Conclusion

Policy Recommendations

The sustainable development of market-driven horticultural seed systems requires a comprehensive policy framework that promotes innovation, competitiveness, inclusiveness, and environmental sustainability. Several strategic interventions can accelerate progress toward these objectives.

First, investments in research and development should be increased to support the development of climate-resilient, disease-resistant, and market-oriented varieties. Strengthening collaboration between public research institutions and private companies can accelerate innovation and improve technology dissemination.

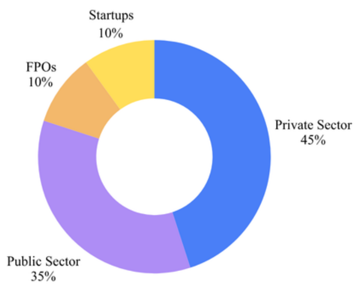
Second, public-private partnership frameworks should be expanded to facilitate investment, risk sharing, and knowledge exchange across the seed value chain. Supportive policies that encourage collaboration among research organizations, seed companies, farmer producer organizations, and agri-startups can enhance system efficiency and scalability.

Third, regulatory processes governing varietal approval, seed certification, and quality assurance should be streamlined while maintaining rigorous standards. Simplified procedures can reduce delays, encourage innovation, and improve market responsiveness.

Fourth, investments in digital infrastructure and farmer capacity building should be prioritized. Expanding access to digital advisory services, e-commerce platforms, and traceability systems can enhance market transparency and strengthen farmer participation in modern value chains.

Fifth, targeted support should be provided to women entrepreneurs, youth-led enterprises, and farmer producer organizations engaged in seed production and marketing activities. Inclusive business models can contribute significantly to rural employment generation and economic empowerment.

Finally, strengthening anti-counterfeit measures, improving seed quality monitoring systems, and expanding storage and logistics infrastructure will be essential for maintaining farmer confidence and ensuring the integrity of seed markets.



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Conclusion

The transformation of horticultural seed systems from traditional input delivery mechanisms into integrated agribusiness ecosystems represents a significant opportunity for advancing agricultural development in India. Market-oriented seed systems supported by strong value chain linkages, technological innovation, and institutional collaboration can substantially improve productivity, profitability, and sustainability across the horticulture sector.

Public-private partnerships have emerged as a powerful instrument for combining scientific expertise, entrepreneurial capacity, financial investment, and market knowledge. These partnerships facilitate innovation, accelerate technology transfer, and strengthen the commercialization of improved varieties and planting materials. At the same time, digital technologies are creating new possibilities for enhancing transparency, efficiency, and market access throughout seed value chains.

Although challenges related to affordability, quality assurance, climate change, infrastructure, and regulation persist, strategic investments and policy reforms can significantly improve sector performance. A coordinated market systems approach that promotes innovation, inclusiveness, and resilience will be critical for realizing the full potential of India's horticulture seed industry.

As demand for high-quality horticultural products continues to grow domestically and internationally, strengthening seed systems will remain central to achieving food security, nutritional well-being, rural prosperity, and sustainable agribusiness development. With appropriate institutional support and stakeholder collaboration, India is well positioned to emerge as a global leader in horticultural seed production, innovation, and value chain development.

References

Almekinders, C. J. M., & Louwaars, N. P. (2002). The importance of the farmers' seed systems in a functional national seed sector. Journal of New Seeds, 4(1-2), 15-33.

Birthal, P. S., Joshi, P. K., & Gulati, A. (2005). Vertical coordination in high-value food commodities: Implications for smallholders. International Food Policy Research Institute (IFPRI), MTID Discussion Paper No. 85.

Chand, R. (2017). Doubling farmers' income: Rationale, strategy, prospects and action plan. NITI Aayog, Government of India.

Food and Agriculture Organization (FAO). (2023). FAOSTAT statistical database. FAO.

Food and Agriculture Organization (FAO). (2024). The state of food and agriculture 2024. FAO.

Government of India. (2002). National seed policy. Ministry of Agriculture and Farmers Welfare, New Delhi.

Government of India. (2024). Agricultural statistics at a glance 2024. Ministry of Agriculture and Farmers Welfare, New Delhi.

Indian Council of Agricultural Research (ICAR). (2024). Annual report 2023-24. ICAR, New Delhi.

International Seed Federation (ISF). (2024). Global seed industry performance report. International Seed Federation.

National Bank for Agriculture and Rural Development (NABARD). (2024). Status of Indian agriculture and rural economy report. NABARD, Mumbai.

National Horticulture Board (NHB). (2024). Indian horticulture database 2023-24. Ministry of Agriculture and Farmers Welfare, Government of India.

Krishi Netra
ISSN : 3048-5207

Organisation for Economic Co-operation and Development (OECD). (2023). Innovation, productivity and sustainability in agriculture and food systems. OECD Publishing, Paris.

Seed Association of India. (2024). Indian seed industry outlook 2024. Seed Association of India, New Delhi.

Singh, R. B. (2014). Seed systems and food security in India. Indian Journal of Agricultural Economics, 69(3), 289-302.

Spielman, D. J., & Kennedy, A. (2016). Towards better metrics and policymaking for seed system development. Agricultural Systems, 147, 8-13.

Tripp, R., & Rohrbach, D. (2001). Policies for African seed enterprise development. Food Policy, 26(2), 147-161. United Nations Development Programme (UNDP). (2023). Digital transformation in agriculture: Opportunities for sustainable development. UNDP.

World Bank. (2019). Future of food: Harnessing digital technologies to improve food system outcomes. World Bank, Washington, DC.

World Bank. (2024). Transforming agrifood systems for resilience and sustainability. World Bank, Washington, DC.

Yadav, S., Kumar, R., & Sharma, P. (2023). Public-private partnerships in seed systems: Emerging opportunities for Indian agriculture. Journal of Agribusiness Development and Emerging Economies, 13(4), 521-538.

Zhang, X., & Fan, S. (2022). Digital agriculture and rural transformation in developing economies. Food Policy, 108, 102233

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Major Insect Pests of Bottle Gourd and Their Integrated Management

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Abstract

Bottle gourd is an important cucurbit vegetable crop widely cultivated in tropical and subtropical regions for its nutritious and easily digestible fruits. However, its production is greatly affected by several insect pests such as melon fruit fly, red pumpkin beetle, hadda beetle, aphids, whiteflies, and squash bug, which cause serious damage to leaves, flowers, and fruits, resulting in reduced yield and poor market quality. Effective management of these pests requires an integrated pest management (IPM) approach that combines cultural, biological, botanical, and chemical methods. Practices such as field sanitation, crop rotation, trap crops, reflective mulches, and regular monitoring help reduce pest incidence. Natural enemies, entomopathogenic fungi, neem-based products, and plant extracts provide eco-friendly pest suppression. Need-based application of safer insecticides further helps in controlling severe infestations. Adoption of IPM practices ensures sustainable bottle gourd production while minimizing environmental pollution and pesticide hazards.

Introduction : Bottle gourd belongs to the family Cucurbitaceae and is one of the important vegetable crops widely cultivated in tropical and subtropical regions, especially in India. It is grown mainly for its tender and nutritious fruits, which are commonly used in daily cooking and preparation of different food items. The crop is popular among farmers due to its good yield potential and adaptability to different climatic conditions.

Bottle gourd is considered beneficial for human health because it is easy to digest, rich in water content, and helps in maintaining body hydration. Regular consumption also supports digestion and helps reduce constipation. In addition, the crop contains important phytochemicals and medicinal compounds that are useful for maintaining good health.

Despite its importance, bottle gourd cultivation is seriously affected by several insect pests and diseases that reduce both yield and fruit quality. Therefore, adopting proper management practices such as field sanitation, regular monitoring, biological control, use of botanicals, and safe chemical methods is essential for sustainable production and higher productivity of bottle gourd.

Major pest and there integrated management

Melon Fruit Fly

Bactrocera cucurbitae is a serious pest of bottle gourd. The female lays eggs inside tender fruits, and maggots feed on the pulp causing rotting and fruit drop. Infested fruits become deformed and unfit for market. Severe infestation leads to heavy yield loss.

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Cultural Management : Regular collection and destruction of infested fruits help reduce pest population. Bagging young fruits with paper covers prevents egg laying. Growing maize as a trap crop also helps in reducing fruit fly damage.

Biological Control : Parasitoids such as *Opius fletcheri* and *Fopius arisanus* help control fruit fly naturally. Beneficial fungi and nematodes reduce maggot and adult population. These biological agents help maintain ecological balance.

Chemical Control : Bait sprays prepared with malathion and jaggery attract and kill adult flies. Insecticides like quinalphos and diflubenzuron are effective under severe infestation. Chemical sprays should be used carefully due to frequent harvesting.

Red Pumpkin Beetle : Aulacophora foveicollis attacks seedlings, leaves, flowers, and tender plant parts. Both grubs and adults feed on plants and cause severe damage during early growth stages. Heavy infestation weakens plants and reduces yield. The pest is common in many cucurbit-growing regions.

Cultural Management : Regular field inspection helps in early detection of infestation. Hand collection and destruction of beetles reduce pest population. Deep ploughing and early sowing also help in minimizing damage. Clean cultivation prevents pest carryover.

Botanicals : Neem cake and neem-based products help control grubs and adults. *Beauveria bassiana* effectively reduces beetle infestation and increases yield. Plant extracts like *Parthenium* also show repellent action. Botanical methods are safe for the environment.

Chemical Control : Sprays of malathion or carbaryl control beetles effectively during seedling stage. Synthetic pyrethroids such as cypermethrin and deltamethrin suppress pest population quickly. Dusting with permethrin also gives good protection. Chemical control is mainly used during severe attack.

Hadda Beetle : Epilachna vigintioctopunctata feeds on green leaf tissues and causes skeletonization of leaves. Both larvae and adults damage foliage and reduce photosynthesis. Severe infestation dries leaves and affects fruit quality. Young plants may be completely destroyed.

Cultural Methods : Regular field inspection and hand picking of beetles help reduce infestation. Crop rotation and removal of crop residues decrease pest population. Row covers also protect young plants from attack. These methods are simple and economical.

Chemical Control : Sprays of malathion, spinosad, pyrethrin, and lambda-cyhalothrin effectively manage severe infestation. Timely spraying helps protect leaves and fruits from damage. Chemical control should be used only when necessary. Proper dosage should always be followed.

Aphids : Aphis gossypii and Myzus persicae suck sap from tender plant parts. Infested plants show curling, yellowing, wilting, and stunted growth. Aphids also produce honeydew that promotes sooty mould growth. They spread several viral diseases in bottle gourd crops.

Cultural Methods : Regular checking of lower leaf surfaces helps detect aphids early. Yellow sticky traps and reflective mulches reduce aphid infestation. Floating row covers help prevent virus transmission. Proper field sanitation also minimizes pest spread.

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Biological Control : Ladybird beetles, lacewings, and syrphid flies naturally feed on aphids. Parasitoids and entomopathogenic fungi help suppress pest population. Biological control methods are eco-friendly and safe. They help maintain natural balance in the field.

Chemical Control : Sprays of acetamiprid, cypermethrin, potassium soap, and malathion effectively control severe aphid attack. Proper timing of spray improves effectiveness. Excessive use of chemicals should be avoided. Safer insecticides are preferred for sustainable management.

Whitefly : Bemisia tabaci sucks sap from leaves and weakens bottle gourd plants. Infested plants show yellowing, curling, and reduced growth. Whiteflies produce honeydew that encourages sooty mould growth. They also transmit several viral diseases.

Cultural Management : Crop rotation, healthy seedlings, mulching, and field sanitation reduce whitefly infestation. Reflective mulches repel adult whiteflies from plants. Removal of weeds and crop residues helps prevent pest carryover. These methods reduce virus spread in the field.

Biological Control : Natural enemies like ladybird beetles, lacewings, spiders, and parasitoids help manage whiteflies. Fungi such as *Beauveria bassiana* and *Verticillium lecanii* are also effective. Biological agents reduce pest population naturally. They are suitable for eco-friendly pest management.

Chemical Control : Soil application of imidacloprid or thiamethoxam effectively controls whiteflies. Foliar sprays of acetamiprid and spiromesifen manage immature stages. Repeated use of the same insecticide should be avoided. Proper spray timing improves control efficiency.

Squash Bug : Anasa tristis damages bottle gourd by sucking sap from leaves and injecting toxic saliva. Infested plants show wilting, blackening, and drying of foliage. The pest also damages fruits and reduces quality. Severe infestation leads to poor plant growth and yield loss.

Cultural Management : Row covers and straw mulch help reduce squash bug infestation. Squash can be grown as a trap crop around bottle gourd fields. Removal of infested plant material also helps lower pest population. These methods are useful during early crop growth.

Biological Control : Parasitoids belonging to Encyrtidae and Scelionidae families naturally suppress squash bugs. *Trichopoda pennipes* is an important parasitoid attacking both nymphs and adults. Biological control helps reduce pest multiplication. It also minimizes chemical pesticide use.

Chemical Control : Timely insecticide application is important for effective control of squash bug. Foliar sprays are more effective against young nymphs. Dinotefuran and pyrethrin are commonly recommended insecticides. Proper management helps protect crop yield and quality.

Reference:

Cabrera, A., Celis, R. and Hermosín, M. C. (2016). Imazamox-clay complexes with chitosan and iron (III)-modified smectites and their use in nanoformulations. Pest Management Science, 72: 1285-1294.

Cabrera, A., Celis, R. and Hermosín, M. C. (2016). Imazamox-clay complexes with chitosan and iron (III)-modified smectites and their use in nanoformulations. Pest Management Science, 72: 1285-1294.