

Citripreneurship leaping ahead

Indian horticulture is likely to take the shape of organized industry with linkages with quality planting material production and distribution, value-addition and value chains, and export promotion of different horticultural crops and produces. Horticultural crops (F&Vs) with high nutritive value are also addressing the nutritional security of Indian population with affordable prices. As a driver of economic growth, the Indian horticulture sector with proper investment from state and private players in addition to R&D policy shift for selected advance digital technologies will be essential.

Scope of digital citriculture in India

In today's rapidly evolving agricultural landscape, the application of digital tools and the Internet of Things (IoT) is revolutionizing the entire agricultural value-chain from nursery management to post-harvest operations, and crop monitoring to supply chain management. This shift, commonly referred to as the 'Digital revolution' in agriculture, is driving changes across various crops, and citrus farming is no exception. In the citriculture sector, digital innovations are enabling farmers and agri-business to achieve higher productivity, enhance quality, conserve resource, reduce losses, and increase profitability by automating processes, improving decision-making, and facilitating real-time monitoring and tracking. A list of key areas, where digital technologies are being used or can be used in citriculture is discussed below.

GIS mapping

- Farm mapping and land-use planning.
- Spatial analysis for zoning, crop management, and monitoring disease or pest outbreaks.
- DSS for yield prediction and resource allocation.

Precision farming and resource management

- IoT-enabled sensors for soil health monitoring (moisture, nutrients, pH).
- AI, machine and smart apps learning for optimizing resource use and allocation (water, fertilizers, pesticides).
- Remote sensing via drones or satellites to assess plant health.
- Automated and smart irrigation systems (IoT-based drip and sprinkler systems).
- Digital tools for real-time monitoring and decision-making on fertilization schedules.
- Integrated systems and data-driven recommendations on irrigation and nutrient management.
- Digital platforms for monitoring greenhouse gas emissions.

Weather forecasting

- Real-time weather data and predictive analytics for planning agricultural activities.
- Climate forecasting tools to mitigate risks from extreme weather situations.

Insect-pest, and disease diagnostics and management

- Drones and remote sensing technologies for crop surveillance.
- AI and machine learning for early detection of disease and pest infestations.
- AI-driven disease diagnosis based on image recognition of plant symptoms.
- IoT sensors for detecting environmental conditions conducive to disease outbreaks.

Farm automation

- Automated machinery guided by GPS for precision planting and harvesting.
- Robotic systems for weeding, pruning, and fruit-picking.

Post-harvest management and processing

- Automated sorting and grading systems using computer vision.
- IoT-based cold chain monitoring (temperature, humidity and gaseous composition sensors).
- AI for optimizing post-harvest storage conditions.
- IoT-driven processing plants for monitoring and controlling operational parameters.
- Automated processing systems to improve quality and reduce losses.

Supply chain management, traceability and food safety

- GPS tracking of shipments for real-time logistics management.
- IoT devices, RFID and shipments for real-time inventory, produce quality and product flow monitoring throughout the supply chain.

- Blockchain for transparent supply chain and traceability from farm to consumer.
- Digital certificates for food safety and quality compliance.

Technology dissemination and market information

- Mobile apps offering farmer advisory services on best practices, crop care, and pest control.
- Digital platforms offering e-learning modules and tutorials for farmers.
- Virtual reality modules for training farmers in best practices and precision techniques.
- Virtual platforms for knowledge sharing, training, and consultancy.

Market information, credit linkage and e-Commerce

- Mobile apps providing real-time market prices, demand trends, and buyer connections.
- e-Commerce platforms to connect farmers directly with buyers and consumers.
- Digital platforms for crop insurance and credit linkage.

Digital citriculture holds the promise of making citrus farming more resilient and efficient. It has the potential to transform the way citrus is cultivated, with innovations that enhance productivity, sustainability and profitability. Collaborative efforts between stakeholders will be key to overcoming barriers and ensuring that the benefits of digital technology reach all citrus growers, regardless of their scale or location. The adoption of IoT, data analytics, and other digital technologies is enabling a new era of smart farming, where informed decisions drive better outcomes. As this revolution continues to unfold, the citrus industry will likely see more efficient, sustainable, and profitable farming practices, benefiting both farmers and consumers alike.

Precision tree fruit farming

Precision and automated production of tree fruits including citrus fruits, requires a few specific challenges in productions. Automation, particularly on selected mechanization with personal labour-force use in any of the field operations such as training, pruning, picking, selective harvesting for fresh fruit market need to be addressed.

The adoption of automation technologies for tree fruits may need a techno-economic analysis, including orchard, automation (purchasing cost, operation and maintenance) as well different systems to be used to offer different information. Good irrigation planning is the core in orchard automation system.

Since water is becoming critical input micro-irrigation management with fertigation system is gaining, prominence in integration with HDP. In several crops, standardization of micro-irrigation technique for better WUE and drought is already done.

Integrated pest & disease management (IPDM) is

another input needed for precision farmers. Monitoring of pest and disease symptoms to predict plant protection needs, could economically control the insect pests and diseases.

Robotic fruit harvesting septum for traditional canopy management structure and robotic harvesting system may not work in India in many tropical fruit crops. Automation of fruit farming where automation is through integration of agricultural equipment and precision agriculture management for harvesting maximum quality fruits is desirable. A proper techno-economic analysis for crop-based for irrigation practices should be done.

Major constraints

Small holder farming: About 86% farm households own and operate in less than 2.0 ha of land. These small holder famers do not have enough funding for undertaking farming properly, resulting in poor crop yield and low economic return. Of late, some programme of government in the form of projects are coming up with private investment in infrastructure and banking support. Private investment to promote horticultural crops, particularly long-term tree fruits and pro-poor agricultural value chain with participation of small holder famers are still very negligible.

Nutritionally rich horticultural crops, farmer-friendly MSP and procurement policy, land use planning including land capability and productivity will create an enabling environment for enhancing farmers income. Horticulture is slowly emerging as the driving force in boosting farm economy. Post-harvest technological R&D needs close linkage in food processing and export of fruits and vegetables. A policy shift towards integration of PHM activities in Horticulture sector, integration of processing varieties of horticulture crops and export of processed fruits & vegetables need more attention.

CONCLUSION

In the age of AI, Indian Horticulture cannot be a passive player. Fruits and vegetables are rich source of nutritive value, and India having climatic advantage of almost all types (tropical, sub-tropical, temperate fruits, coastal, arid *etc.*) of eco-system and rich natural resource is an ideal country for adopting advance technologies. Further, with the digital technology, knowledge products are available in wide range of crops, HVCs in particular. Also, for fruits, several horticulture technology in digital sector to be used in neighbouring countries can also be licensed with negotiable policy support. Some requirement on skill development for management of digital horticulture in the country is also needed.

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