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Smart Horticulture: Its Prospects And Future Scope

[1]Anchal Meher, [2]Shantanu Bhattacharyya, [3]Pratibha Rani Deep

[1,2,3]School of Applied Sciences,

[1,2,3]Centurion University of Technology and Management, Odisha, India

Abstract: This study has been undertaken to investigate the prospects and future scope of smart horticulture**.** As the world population grows, smart sustainable agriculture practices are a necessity to accommodate growing global food demands. Dijk et al. (2021) predict that between 2010 and 2050, the global food demand will increase by about one-third to nearly three-fifths—from -91% up to +8% of hunger risk—and so on. The traditional horticulture also confronts lots of devastating challenges like desertification, climate change, and environmental pollution which significantly reduces the productivity and food security as well. These challenges require the implementation of smart agriculture technologies such as precision farming, data analytics, IoT (Internet of Things), AI and robotics. Various interventions have been implemented to facilitate resource management, automate agricultural practices and enhance crop health and yield while reducing environmental footprint. Horticulture can be optimized by using technologies like computer vision, nanotechnology, biosensors and protected cultivation to advance the primary processes & bio-processes in horticultural science.

Keywords: *smart agriculture technologies, data analytics, internet of things, AI and robotics, biosensors*

I. INTRODUCTION

Smart sustainable agriculture practices plays major role to meet the rising food demands along with exponentially growing global population. Dijk et al., 2021 reported 35% to 56% increase global food demand between 2010 and 2050, while risk of hunger will be −91% to +8% during that period. Planting, watering, pest management, harvesting, and handling of post-harvest crops are major agricultural practices in protected cultivation. Mismanagement of these practices results in loss of productivity. Precision farming practices are viable response to this problem. Smart horticulture technology uses data analytics, iot, al cloud computing, wireless communication, computational algorithms etc to automate the common agricultural practices. It results minimum utilization of natural resources as well as monitor crop health. It helps to improve the resources of agriculture, save labour and improve the quality and yield of the different product (Rayhana et. al., 2021).

A smart farm is an advanced agriculture system which having multiple advanced technologies used for sustainable cultivation such as fully automatic machinery and systems for maximum productivity. This farm can easily control and monitored remotely due to their IOT, WOT, OR MOT connectivity. smart farm helps to maximise productivity and can include a variety of activities, such as animal husbandry and plant cultivation. Along with increasing productivity, a smart farm also acts as automatically maintaining high productivity levels, even in the problem with the crop (Nguyen et. al., 2019).

Challenges in traditional horticulture practices

Due to advancement in agriculture technology, the yield and quality of agricultural crops have been improved in 21st century. But the advancement is still not enough to satisfy the population increasing need. Serious challenges like desertification, climate change, and environmental pollution threaten agricultural land and food security. These issues are exacerbating, leading to a decrease in available land for cultivation and making it harder to ensure an adequate food supply. Traditional techniques like mutation and crossing are common for perennial fruit trees, but they are labour-intensive and time-consuming. Horticultural crops face challenges due to their diverse species, long growth cycles, susceptibility to pests and diseases, and the need for controlled environments like greenhouses. Postharvest losses are significant, leading to decreased flavour and overall quality (Jiang et.al.,2022). In traditional horticulture, seedling transplantation is common, but the industry faces challenges such as poor production due to low-quality seeds and improper cultivation methods. Consumers prefer ripe, nutritious, and visually appealing fruits and vegetables, which require careful handling from harvest to storage and transportation to maintain their quality. The excessive use of agrochemicals has negatively impacted crop quality and food safety, posing risks to the environment and human health (Zhang et.al.,2023).

To address these challenges, modern agricultural technology, sustainable land management methods, and global collaboration are essential. technological developments like genetically engineered crops resistant to environmental pressures and precision agriculture are crucial for this problem. the horticulture industry should integrate smart technologies for rapid advancement, focusing on breeding, cultivation, transportation, and sales. By adopting innovative approaches, we can produce healthy fruits and vegetables in an environmentally friendly manner while reducing the reliance on harmful.

II.TECHNOLOGY USED IN SMART HORTICULTURE

Innovative technologies contribution to horticulture:

2.1. Sensor Development:

Digital sensors help in automated data collection and leading to better decision-making through software platforms. Advancements in computer vision technology are also revolutionizing greenhouse horticulture by enabling the measurement of internal and external plant parameters.

2.2. Computer Vision of 2D and 3D Geometric Features:

Computer vision technology in horticulture does a lot of things, like identifying plants, measuring growth, spotting pests and diseases, and even controlling machinery. Cameras, especially in smartphones, are being used more for these tasks. Soon, smartphone apps could use this tech to identify plant problems from pictures. This could help farmers and gardeners manage issues better. For example, there's an app developed by Wageningen UR that measures the size of Anthurium cut-flowers using cameras. Also, lasers are used to improve quality assessment in sorting lines, and 3D sensors help robots pick fruits accurately (Pekkeriet et. al., 2015).

2.3. Precision Agriculture

Precision agriculture refers to the use of technology and data-driven approaches to optimize farming practices, maximizing efficiency and minimizing waste. It involves techniques like GPS, sensors, drones, and AI to precisely manage variables such as water, fertilizers, and pesticides. This allows farmers to tailor their interventions to specific areas of their fields, improving yields, reducing environmental impact, and lowering costs.

2.4. Nanotechnology, genetic engineering and biotechnology

Nanotechnology, genetic engineering, biofortification, and protective farming are new technologies in agriculture. Nanotechnology deals with very small particles and has promising uses in medicine, food, and agriculture. In cities where more people are living, there's a greater need for fruits, vegetables, and flowers. Nanotechnology can help manage diseases, improve nutrient absorption in plants, and increase crop yields and nutritional value. Nanobiotechnology, especially, has potential for boosting agricultural production with tiny devices and materials. Genetic engineering and biotechnology offer solutions to emerging agricultural challenges by exploiting wild species and integrating genes into cultivated crops. Traditional breeding methods have limitations, but biotechnology can overcome them, providing genomic resources like genome sequences, gene expression profiles, and molecular markers. These resources enable molecular breeding and genetic engineering of horticultural crops, enhancing their tolerance to stress and improving production.

2.5. Biosensors

Nanosensors are tiny devices equipped with bioreceptors that can specifically detect certain substances like urea, glucose, and pesticides. They're used for various purposes such as monitoring metabolites, detecting pathogens like bacteria and viruses, and even determining the optimal time for crop harvesting. By providing accurate data, these smart sensors help farmers make informed decisions, ultimately enhancing agricultural productivity. Additionally, they play a crucial role in combating crop diseases and ensuring food safety.

2.6. Protected Cultivation

Growing horticultural crops in protected structures, like greenhouses covered with transparent sheets or synthetic materials, is becoming increasingly popular among farmers worldwide. This method shields crops from pests, diseases, and harsh weather conditions, allowing for better control over growing conditions. It also enables year-round farming, leading to increased profits for farmers. Additionally, these structures provide a more comfortable working environment for growers (Kumar et.al., 2019).

III. COMPUTER VISION INTERNAL FEATURES

3.1. X-Ray

Computer vision technology allows for the measurement of internal features using various techniques such as X-ray, microwave, hyperspectral imaging, and fluorescence. Sorting machines equipped with X-ray technology are commonly used to grade flower bulbs, tulip flowers, and Alstroemeria. Additionally, successful research has been conducted to detect long-horned beetles in small imported trees using this technology.

3.2. Hyper Spectral Imaging

Cameras can capture more than just what's visible to the human eye by using a broader spectrum of light. Multispectral cameras, for example, can detect wavelengths beyond the visible spectrum, providing insights into the internal properties of plants and flowers. These cameras can contain numerous spectral bands, from far-infrared to far-UV, allowing for detailed analysis. NIR-spectrometry involves directing white light towards an object and examining the transmitted or reflected light to identify substances present and their quantities. This technology enables quality assessment, such as measuring lycopene in tomatoes for sorting purposes, as well as evaluating nutritional content for optimal fertilizer application.

3.3. Fluorescence Techniques

Chlorophyll fluorescence involves directing a red laser beam at an object, causing chlorophyll to emit fluorescence. A camera captures the fluorescent image, which reflects the object's photosynthetic activity. By subtracting images taken with and without the red laser, software generates an image indicating the product's photosynthetic capacity. This technique is used to assess plant health, ripeness, shelf life, and fruit, vegetable, and flower quality, as well as to detect stress and diseases. Advancements include transitioning from laser beams to high-power LEDs, making measurements more robust, cost-effective, and faster (Pekkeriet et.al., 2015).

3.4. Internet of thing (IOT) and sensor network

The Internet of Things (IoT) is revolutionizing agriculture by using advanced sensors and wireless technology to make farming smarter and more efficient. By combining these technologies, farmers can greatly improve every aspect of their traditional operations. For example, precision farming, animal monitoring, and greenhouse monitoring are just a few examples of how IoT is being used in agriculture. With IoT, farmers can monitor factors like soil quality, pest presence, and irrigation needs more accurately and in real-time.

the wireless sensor network mainly focuses on the environmental monitoring system. Sensor networks offer a compelling solution for various monitoring needs, from agriculture and habitat protection to indoor living, greenhouse, climate, and forest monitoring. By combining low power consumption, affordability, and real-time capabilities, they provide efficient and cost-effective alternatives to traditional human-based monitoring methods. These networks enhance performance, robustness, and overall efficiency in monitoring systems, making them indispensable tools for environmental management and protection (Barrenetxea et.al., 2008).

3.5. Precision Agriculture

Precision agriculture is a farming approach that uses technology to optimize crop production by tailoring inputs such as water, fertilizers, and pesticides to specific conditions within a field, resulting in increased efficiency, productivity, and sustainability. precision agriculture offers significant benefits, it faces challenges that hinder its widespread adoption in practical farming. These challenges include small farm sizes, diverse crop systems, expensive technology, limited local expertise in computer analysis and decision-making, and farmers' reluctance due to technological gaps. However, overcoming these hurdles is crucial for harnessing the potential of precision farming to create environmentally sustainable agriculture. Ongoing developments, such as using GPS and GIS for mapping insect infestations and disease spread, implementing variable-rate spray technology, and introducing field robots for tasks like fleet management, show promise for the future of agriculture (Sahu et.al., 2019).

3.6. Artificial Intelligence (AI)

Artificial intelligence (AI) is how humans create smart machines. It's a part of computer science focused on making systems that act and think like people, doing tasks intelligently. AI is super useful in horticulture. It helps spot diseases, increase crop yields, control weeds, and figure out what nutrients' plants need, cutting down on unnecessary fertilizer use. Learning from past data and making quick decisions are key to AI. Machine learning, a part of AI, creates tools for this. For example, there's an AI-based method to pick out the ripest fruits and veggies. It uses computer vision and machine learning to do this. AI is great at solving problems fast and giving advice. It's transforming agriculture and horticulture, making farming smarter and more efficient. With digital tools, farmers and consumers have huge opportunities. The future of farming is going to be all about digital technology, making everything from growing crops to managing data much easier (Virk et al., 2020).

IV. ROBOTICS AND AUTOMATION

The shortage of skilled labor has become a significant challenge in crop cultivation, impacting food production across various crops and leading to permanent changes in cultivation practices. This shortage poses a major threat to sustainable food production. One of the primary reasons for the labour shortage is the attraction of higher wages in nearby urban areas. To address this issue and ensure sustainable food security, modern agriculture is turning to autonomous robots and labor. Robotics and Autonomous Systems (RAS) comprise electronic and mechanical equipment operated through software technology for specific purposes, with each set capable of performing one or more tasks. While RAS holds promise for enhancing efficiency and saving time in the future, it currently faces obstacles such as low operational efficiency in extreme weather conditions.

The migration of rural populations to urban areas is a key factor contributing to the labour shortage, alongside low incomes in rural villages. This trend, coupled with global population growth, has led to a reversal in traditional labour dynamics despite overall population increases. Developed nations have made significant strides in adopting robotic labor and automation technologies to address these challenges (Kumar et al., 2023).

V. APPLICATIONS OF SMART HORTICULTURE

The application of smart horticulture involves the integration of advanced technologies to optimize various aspects of plant cultivation, management, and monitoring. This approach utilizes innovations such as precision agriculture, data analytics, automation, and remote sensing to enhance efficiency, sustainability, and productivity in horticultural practices

Utilizing technology in horticulture brings about significant advantages, making gardening easier, more efficient, and environmentally friendly. Firstly, technological innovations streamline various processes involved in gardening, such as planting, harvesting, and post-harvest management. These advancements reduce the need for labor and save time, ultimately increasing productivity. Precision agriculture, enabled by technologies like GPS-guided tractors and drones, plays a crucial role in optimizing resource use. By precisely targeting planting, irrigation, and fertilization, farmers can minimize waste and maximize crop yields. Real-time data from sensors on soil conditions, moisture levels, and crop health further inform decision-making, ensuring optimal growing conditions.

Moreover, technology contributes to crop improvement through genetic engineering and breeding techniques. Scientists can develop plant varieties that are resistant to diseases, tolerant to droughts, and capable of higher yields, bolstering food security. Enhanced monitoring capabilities provided by sensors and data analytics enable farmers to make informed decisions about irrigation, pest control, and nutrient management. By closely monitoring environmental conditions, farmers can respond promptly to changes, minimizing risks and optimizing crop growth.

Sustainable horticulture practices are further supported by technology, with innovations like smart irrigation systems and eco-friendly pest control methods reducing water wastage and minimizing environmental impact. These practices ensure that gardening remains sustainable in the long term, preserving natural resources and ecosystems.

Furthermore, technology facilitates global collaboration among horticulturists, enabling the exchange of knowledge, best practices, and innovations. Digital platforms connect farmers worldwide, fostering a community where insights and expertise can be shared to improve crop management practices.

VI. CHALLENGES AND LIMITATIONS

The challenges facing the horticulture sector are multifaceted, unlike the support systems in place for food-grains such as the Minimum Support Price (MSP). Issues like inadequate cold chain storage and transport networks restrict the lifespan of perishable products. Furthermore, the sector lacks sufficient machinery and equipment, making it difficult to overcome time constraints. High input costs, coupled with minimal government support for smaller farmers, add to the difficulties, particularly for marginal farmers coping with price fluctuations. Limited market intelligence, especially for exports, exacerbates the situation. Additionally, challenges like the insufficient availability of quality seeds, imbalanced input use, and significant losses due to various stresses persist. The sector also suffers from poor market infrastructure and limited access to storage, processing, and packaging facilities, further impeding its progress (Singh et.al.,2023).

Organic farming, in particular, presents its own set of challenges. Transitioning from conventional methods may lead to lower yields during the transition period. It requires a deep understanding of local ecosystems and agroecological principles, which poses a steep learning curve. Adapting existing farming systems to organic approaches may also present challenges, along with the need for careful management to avoid issues such as excessive growth and pest management. Additionally, installing efficient irrigation systems may come with initial costs and ongoing maintenance requirements. Planning crop rotations to optimize benefits and aligning with market demands add to the complexity. Similarly, establishing agroforestry systems requires a long-term commitment, with initial competition between young trees and crops for resources being a notable challenge.(Narayana et.al.,2021)

VII. FUTURE SCOPE

As we know conventional farming practices are proving insufficient to meet our future demands and quality standards. To ensure nutritional security for the growing population, it is essential to adopt new technologies that enhance agricultural and horticultural production. Improving quality can be achieved through the application of biotechnological tools, the integration of nanotechnology, and the adoption of emerging technologies. These advancements will help sustain the agro-ecosystem and promote sustainable development (Jiang et.al., 2022).

Future scope of smart horticulture in India

The future of smart horticulture in India promising us with significant potential and development in agriculture sector and economy. India's horticulture sector can achieve global prominence through better resource management, improved infrastructure, technology upgrades, and effective policies. Key steps for future growth include bringing in new technologies to boost productivity and train workers, promoting organic farming for better environmental and economic outcomes, standardizing farming methods to help farmers improve their skills and production, encouraging private companies to increase efficiency and export opportunities, offering government incentives to support farms transitioning to organic farming, and promoting Good Agricultural Practices (GAP) to produce higher quality fruits and vegetables, boosting demand and exports (Kumar et.al., 2019).

Future projection

- The area under horticulture is projected to grow by 2.7% as compared to the previous one.
- Horticulture production is expected to increase by 5.8 million tons over the last financial year.
- The agriculture ministry has identified 10 globally popular fruit crops and 10 indigenous fruit crops for promotion.
- There is potential to boost productivity to meet the projected demand of 650 million tons of fruits and vegetables in India by 2050 (Singh et.al., 2023).

VIII. CONCLUSION

smart sustainable agriculture is necessary to fulfill the increasing global food demand due to growing population. Desertification, acid rain and climate change create issues that are more severe than those faced by traditional horticulture. The precision farming and smart horticulture technologies that use data, IoT, AI — assist with optimizing resource selection management to ensure crop health and operations. Sensors, computer vision and nanotechnology controls decision-making as well as quality of crop produce, biosensors help in early disease detection; while protected cultivation uplifts sustainability. Nevertheless, challenges like poor infrastructure, high input costs and limited market intelligence continue to plague our farmers. Transition is a major problem for organic farming from other methods. The future of smart horticulture, especially in India, is promising with potential for significant growth through better resource management, technology adoption, and effective policies. Embracing these innovations will ensure nutritional security and meet future food demands sustainably

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