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Use of Internet of Things (IoT) in Vegetable Crops

Priyanka Paul

Abstract: -

The Internet of Things (IoT) has become an important component of precision agriculture by enabling real-time monitoring and automated management of crop production. In vegetable cultivation, IoT integrates sensors, wireless communication, cloud computing, and data analytics to monitor soil moisture, temperature, humidity, nutrient status, and crop health. This technology supports efficient irrigation, nutrient management, protected cultivation, and timely pest and disease detection, leading to higher productivity and improved resource-use efficiency. IoT also helps reduce labour requirements, production costs, and environmental impacts while improving vegetable quality. Although challenges such as high installation costs, poor internet connectivity, and limited technical knowledge remain, continuous advances in artificial intelligence (AI), machine learning, and sensor technologies are making IoT increasingly accessible. Therefore, IoT has significant potential to promote sustainable and climate-smart vegetable production in the future.

Keywords: Internet of Things (IoT), Precision Agriculture, Vegetable Crops, Smart Irrigation, Sensors, Sustainable Agriculture, Protected Cultivation.

Introduction:

Vegetables are an essential component of human nutrition and contribute significantly to food security and farmers' income. However, vegetable production is highly sensitive to variations in climate, water availability, nutrient management, and pest incidence. Traditional farming practices often depend on manual observations, which may lead to inefficient use of water, fertilizers, and pesticides (Zhang *et al*.,2024).

The Internet of Things (IoT) has emerged as an innovative technology that connects sensors, communication networks,

Priyanka Paul
Research Scholar, Department of Vegetable and Spice Crop
Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal-736165

and cloud-based platforms to collect and analyse field data in real time. Farmers can continuously monitor crop and environmental conditions and make timely management decisions. The integration of IoT with artificial intelligence (AI), machine learning (ML), drones, and remote sensing has further improved precision farming by enabling automated irrigation, fertigation, greenhouse management, and disease monitoring. Consequently, IoT has become a valuable tool for improving vegetable productivity, reducing input costs, and ensuring sustainable agricultural production (Wang et al.,2024).

1. IoT Concept in Vegetable Crops

The Internet of Things (IoT) refers to a network of interconnected devices that communicate through the internet to collect, process, and exchange agricultural information. In vegetable farming, IoT systems include soil moisture sensors, temperature and humidity sensors, weather stations, wireless communication devices, cloud servers, and mobile applications (Zhang *et al*.,2024).

The basic components of an IoT system include:

- Sensors for field data collection
- Wireless communication technologies (Wi-Fi, LoRaWAN, GSM, NB-IoT)
- Cloud storage and data processing
- Decision support systems
- Automated irrigation and fertigation controllers

These components continuously monitor field conditions and assist farmers in making accurate decisions based on real-time information, thereby increasing productivity while reducing unnecessary resource use.

2. IoT-Based Soil and Nutrient Management

Soil fertility is one of the most important factors determining vegetable yield and quality. IoT-based soil monitoring systems continuously measure soil moisture, temperature, pH, electrical conductivity (EC), and nutrient availability.

Real-time monitoring enables farmers to apply fertilizers according to crop requirements rather than following fixed schedules. This improves nutrient-use efficiency, minimizes nutrient losses through leaching, and reduces fertilizer costs. Smart fertigation systems integrated with IoT automatically regulate fertilizer application based on sensor readings (Vedantam *et al*.,2024).

Nutrient sensors also help detect nutrient deficiencies at early stages, allowing timely corrective measures that improve crop growth and fruit quality. Such precision nutrient management enhances productivity while minimizing environmental pollution caused by excessive fertilizer application.

3. Smart Irrigation and Water Management

Water scarcity has become a major challenge in vegetable production. IoT-based smart irrigation systems use soil moisture sensors, weather forecasts, and evapotranspiration data to determine the exact water requirement of crops (Fauziah *et al.*,2024).

When soil moisture falls below a predetermined level, irrigation is automatically activated and stopped once the required moisture level is reached. This prevents both over-irrigation and water stress.

Studies have reported that IoT-based irrigation systems significantly improve water-use efficiency while maintaining optimum soil moisture for crop growth. Integration with drip irrigation further reduces water losses and enhances vegetable yield and quality.

4. IoT in Protected Cultivation

Protected cultivation systems such as greenhouses and polyhouses require continuous monitoring of environmental conditions. IoT sensors record temperature, relative humidity, light intensity, carbon dioxide concentration, and soil moisture in real time.

Based on sensor data, automated systems regulate fans, cooling pads, foggers, irrigation systems, and ventilation units to maintain optimum growing conditions. Such automation improves crop growth, increases productivity, reduces labour requirements, and ensures uniform vegetable quality throughout the growing season. IoT-based greenhouse management has become an important component of modern protected vegetable cultivation (Wang *et al.*,2024).

5. Future Prospects

Rapid advances in artificial intelligence, machine learning, robotics, drones, remote sensing, and cloud computing are expected to further strengthen IoT applications in vegetable farming. Future IoT systems will provide more accurate disease prediction, automated harvesting, yield forecasting, and farm management recommendations.

Low-cost sensors, improved internet connectivity, and user-friendly mobile applications will increase the adoption of IoT among small and marginal farmers. Integration of blockchain technology with IoT may also improve traceability and food safety in vegetable supply chains. Government support, digital infrastructure, and farmer training programmes will play an important role in accelerating IoT adoption for sustainable vegetable production.

Conclusion

The Internet of Things has transformed vegetable production by enabling precision management of irrigation, nutrient application, and protected cultivation. Continuous monitoring through sensors and cloud-based decision support systems improves crop productivity, input-use efficiency, and environmental sustainability. Although challenges such as high investment costs, technical complexity, and connectivity issues remain, ongoing technological advancements are making IoT more practical and affordable. With increasing integration of AI, machine learning, and smart sensing technologies, IoT is expected to become a key component of sustainable and climate-smart vegetable production systems worldwide.

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