PLANT MONITORING SYSTEM USING IOT AND AI

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Abstract - This paper presents a Plant Monitoring System Using IoT and AI for real-time monitoring of plant health. The system uses an ESP32, soil moisture sensor, DHT11, and LDR to monitor environmental conditions. An ESP32-CAM captures plant leaf images, which are analyzed using AI for disease detection. The system also provides automatic irrigation based on soil moisture and displays plant information through the Plant Guard AI application. The proposed system reduces manual effort, saves water, and supports healthy plant growth.

Index Terms— IoT, AI, Plant Monitoring, ESP32, ESP32-CAM, CNN, Disease Detection, Automatic Irrigation, Plant Guard AI.

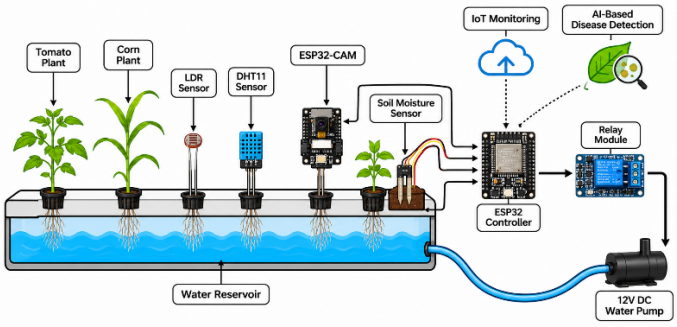
I.INTRODUCTION

Agriculture plays a vital role in food production and economic development. Traditional plant monitoring methods require continuous manual supervision, which can lead to inefficient irrigation, increased labor, and reduced plant growth. Monitoring soil moisture, temperature, humidity, and light intensity regularly can be difficult, especially when plants need continuous care. Improper irrigation and delayed identification of plant diseases can affect plant health and reduce crop productivity. Therefore, there is a need for intelligent systems that can monitor plant conditions accurately and efficiently.

The Internet of Things (IoT) enables sensors and devices to collect and exchange data in real time. In agriculture, IoT can be used for continuous environmental monitoring and automatic control, reducing the need for manual intervention. By connecting sensors with wireless communication, users can remotely monitor plant conditions through a mobile application.

This paper presents a Plant Monitoring System Using IoT and AI that monitors soil moisture, temperature, humidity, and light intensity using sensors connected to an ESP32 microcontroller. The collected information is transmitted through Wi-Fi to the Plant Guard AI application, allowing users to monitor plant conditions remotely.

The system also uses an ESP32-CAM to capture plant leaf images for AI-based disease detection using Convolutional Neural Networks (CNN). When the soil moisture falls below a predefined level, the system automatically activates a water pump through a relay module.



The proposed system provides an intelligent and user-friendly solution for plant monitoring. It reduces manual effort, minimizes water wastage, supports early disease detection, and helps maintain healthy plant growth through the integration of IoT, AI, and automatic irrigation.

Artificial Intelligence (AI) further enhances smart agricultural systems by enabling intelligent data analysis and automated decision-making. Machine learning and deep

learning techniques can analyze plant images and identify patterns associated with different diseases. Among these techniques, Convolutional Neural Networks (CNNs) are widely used for image classification and visual recognition due to their ability to extract relevant features from images. AI-based plant disease detection can help identify potential infections at an early stage, allowing users to take preventive measures and minimize the risk of disease spread.

Furthermore, the system incorporates an ESP32-CAM module to capture plant leaf images for AI-based disease detection using a trained Convolutional Neural Network (CNN) model. The captured images are analyzed to identify potential plant diseases based on learned visual features. This integration of image acquisition and deep learning provides an additional layer of intelligent monitoring beyond conventional sensor-based agricultural systems.

II. BACKGROUND

The Plant Monitoring System Using IoT and AI is an intelligent agricultural solution that integrates IoT, Artificial Intelligence (AI), image processing, and mobile application technology to improve plant monitoring and irrigation management. The system continuously monitors important environmental parameters such as soil moisture, temperature, humidity, and light intensity. It also uses AI-based image analysis for plant disease detection, enabling real-time monitoring and early identification of plant health problems.

The Internet of Things (IoT) connects physical devices, sensors, and communication networks to collect and exchange data automatically. In the proposed system, IoT enables the sensors to collect plant and environmental information and transmit the data through Wi-Fi. The monitored information is displayed in the Plant Guard AI application, allowing users to check plant conditions remotely.

The ESP32 microcontroller acts as the central processing unit of the system. It collects data from the soil moisture sensor, DHT11 temperature and humidity sensor, and LDR sensor. The ESP32 processes the sensor readings and communicates the information to the Plant Guard AI application through Wi-Fi. An ESP32-CAM is also used to capture plant leaf images, which are analyzed using AI-based Convolutional Neural Network (CNN) techniques for disease detection.

The relay module and water pump form the automatic irrigation unit. When the soil moisture level falls below the predefined threshold, the ESP32 activates the relay and switches on the water pump. When sufficient moisture is detected, the pump is switched off automatically. This helps reduce manual effort, avoid overwatering, and improve water utilization...

I. LITERATURE REVIEW

As shown in Fig. 3, the rapid advancement of theInternet of Things (IoT), Artificial Intelligence (AI),and wireless sensor technologies has significantly improved modern agriculture. Smart agriculture systems help monitor environmental conditions, automate irrigation, detect plant diseases, and reduce manual effort.

These technologies enable continuous data collection and intelligent analysis, allowing farmers to make better decisions regarding plant care and crop management. The integration of IoT and AI also improves resource utilization by reducing water wastage and supporting early identification of plant health issues. Such advancements contribute to the development of efficient, reliable, and sustainable agricultural practices.

Several researchers have proposed IoT-based plant monitoring and AI-based disease detection systems using sensors, image processing, machine learning, and mobile applications.

However, many existing systems focus only on individual functionalities such as irrigation control or disease detection and do not provide a complete intelligent plant monitoring solution.

K. Pradheep et al. proposed an IoT-Based Intelligent Plant Monitoring System that uses an ESP32 microcontroller, soil moisture sensor, relay module, water pump, and ESP32-CAM for plant monitoring and automated irrigation. The system monitors soil moisture levels, controls water supply automatically, and enables remote plant monitoring. However, it

mainly focuses on soil moisture monitoring and automated watering, with limited emphasis on AI-based plant disease detection and comprehensive environmental monitoring.

K. Sumithra Devi et al. proposed an AI-Driven Gardening Assistant that uses Artificial Intelligence, Deep Learning, and YOLO algorithms for plant disease detection and gardening assistance. The system provides disease identification, plant care suggestions, and chatbot-based interaction. However, it mainly focuses on AI-based disease diagnosis and does not provide IoT-based environmental monitoring or automatic irrigation.

Vinoparkavi D et al. developed an AI-Based Detection and Analysis System for Red-Brown Sesame Leaf Diseases using deep learning and image processing techniques. The system identifies disease symptoms from leaf images using trained neural network models. However, the system is mainly limited to sesame plants and does not provide environmental monitoring or automatic plant maintenance.

Rohit Chandra Joshi et al. presented a Real-Time Plant Leaf Disease Detection System using Convolutional Neural Networks (CNN) integrated with an Android application. The system detects diseases from leaf images and provide ssuitable cure suggestions. However, it mainly focuses on image-based disease detection and does not include IoT sensors or automatic irrigation. The CNN model analyzes the captured leaf images and identifies disease symptoms based on the trained dataset. The Android application displays the detection results, making it easier for users to understand the condition of their plants. This approach helps improve disease identification and provides useful information for taking appropriate treatment measures. However, the absence of environmental monitoring and automated watering limits its functionality as a complete smart plant management system.

Panchareddy Nishitha et al. introduced a Smart Agriculture System for early detection of plant diseases and pests using CNN and Artificial Intelligence techniques. The system improves disease identification through image analysis. However, it provides limited automation and doesnot combine continuous environmental monitoring with intelligent irrigation.

Anita Shrotriya et al. developed an Automated Plant Disease Detection System using deep learning models suchas CNN, YOLOv5, Grad-CAM, and VGG16. The system improves plant disease recognition under different conditions. However, its primary focus is disease detection and it does not integrate IoT sensors, automatic irrigation, or a complete plant monitoring platform.

Abhijit Kulkarni et al. proposed Plant Care AI, an AI-powered plant diagnosis and assistance system. It identifies plant diseases from images and provides plant care recommendations. However, it lacks real-time environmental monitoring, sensor integration, and automatic watering.

Saiful Islam et al. presented a Smart Agriculture System using IoT and Machine Learning for irrigation management and plant disease monitoring. The system combines environmental sensors, machine learning, and IoT communication. However, its hardware architecture can be complex and may increase implementation cost for small-scale users.

Aminu Musa et al. proposed an Intelligent Plant Disease Detection System for Smart Hydroponics using Convolutional Neural Networks (CNN). The system uses camera modules and deep learning algorithms to identify plant diseases from leaf images. However, the system mainly focuses on disease detection in hydroponic environments and does not provide a complete low-cos tplant monitoring solution.

Existing research in smart agriculture has demonstrated the importance of integrating modern technologies to improve plant monitoring and agricultural practices. Various studies have explored sensor-based monitoring techniques to measure environmental parameters, while other research has focused on artificial intelligence and deep learning methods for identifying plant diseases through image analysis. IoT-based systems help monitor plant conditions and automate irrigation, whereas AI-based approaches assist in detecting plant health issues and providing useful information. However, implementing these technologies separately may limit their overall effectiveness in providing complete plant care.

From the above literature survey, it can be observed that existing systems generally focus on either AI-based plant disease detection or IoT-based environmental monitoring and irrigation. Only a limited number of systems combine these functions into a single user-friendly platform. Therefore, the proposed Plant Monitoring System Using IoT and AI integrates ESP32, ESP32-CAM, soil moisture sensor, DHT11 sensor, LDR sensor, CNN-based disease detection, automatic irrigation, and the Plant Guard AI application. This integrated approach provides real-time plant monitoring, early disease detection, automatic watering, and remote access through a single platform. It reduces manual effort, helps conserve water, and supports healthier plant growth.

II. METHODOLOGY

The proposed Plant Monitoring System Using IoT and AI integrates Internet of Things(IoT), Artificial Intelligence(AI), image processing, and automation to provide an intelligent solution for plant health monitoring and irrigation management. The system continuously monitors important environmental parameters and detects plant diseases from leaf images with minimal human intervention.

The proposed system consists of five major stages: Sensing, Image Acquisition, Processing, Decision and Actuation, and Communication. The sensing stage collects environmental information using different sensors.

A soil moisture sensor measures the moisture level of the soil and helps determine whether the plant requires additional water. The DHT11 sensor measures temperature and humidity, providing information about the surrounding environmental conditions. The LDR sensor measures light intensity and helps identify the amount of light available for plant growth. These parameters help in understanding the environmental conditions affecting plant growth and maintaining suitable conditions for healthy plant development.

The sensors are connected to the ESP32 microcontroller, which collects and processes the readings at regular intervals. The collected information helps identify changes in soil moisture, temperature, humidity, and light intensity that may influence plant health. Based on the soil moisture readings, the controller can determine whether irrigation is required and activate or deactivate the water pump accordingly. The temperature, humidity, and light intensity readings provide additional information about the plant's surrounding environment. Furthermore, the collected sensor data are transmitted through Wi-Fi to the Plant Guard AI application, allowing users to monitor environmental conditions remotely.

A. Sensor Data Collection .

The ESP32 microcontroller acts as the central controller of the system. It receives readings from the soil moisture, DHT11, and LDR sensors. The collected values are processed and compared with predefined conditions to determine the current status of the plant environment.

B. Plant Disease Detection

The ESP32-CAM captures images of plant leaves. The captured images are processed and analyzed using Artificial Intelligence and Convolutional Neural Networks (CNN). Image preprocessing techniques such as resizing and normalization can be applied before classification. The CNN model analyzes visual characteristics of the leaf, such as color, texture, edges, and disease patterns, to identify whether the plant is healthy or affected by a disease.

The disease detection result is then provided to the user through the Plant Guard AI application, along with suitable plant-care information or recommendations where available.

C. Automatic Irrigation

The automatic irrigation mechanism is controlled according to the soil moisture level. When the moisture level falls below the predefined threshold, the ESP32 activates the relay module, which switches ON the water pump. When sufficient soil moisture is reached, the relay switches OFF the pump automatically. This reduces manual effort and helps prevent unnecessary water usage.

The CNN model is trained using a plant leaf image dataset containing healthy and diseased plant samples. During training, the network learns important visual features such as leaf color, texture, edges, and disease patterns.

Sensor Parameter	Tomato Plant	Corn Plant
Temperature (DHT11)	28.5°C	29.2°C
Humidity (DHT11)	65%	61%
Soil Moisture	42%	35%
LDR (Light Intensity)	1850	2200

D. Communication and Monitoring

The ESP32 uses its built-in Wi-Fi capability to transmit sensor information to the Plant Guard AI application. The application provides a user-friendly interface for monitoring soil moisture, temperature, humidity, light intensity, watering status, and plant disease detection results.

The collected sensor readings are periodically updated in the application, allowing users to observe changes in environmental conditions without physically checking the plants. The displayed information helps users understand the current condition of each plant and determine whether suitable growing conditions are maintained. The application also provides information about the automatic irrigation process, including the water pump status, enabling users to know whether the pump is operating or switched off.

The complete working procedure of the proposed system can be summarized as follows:

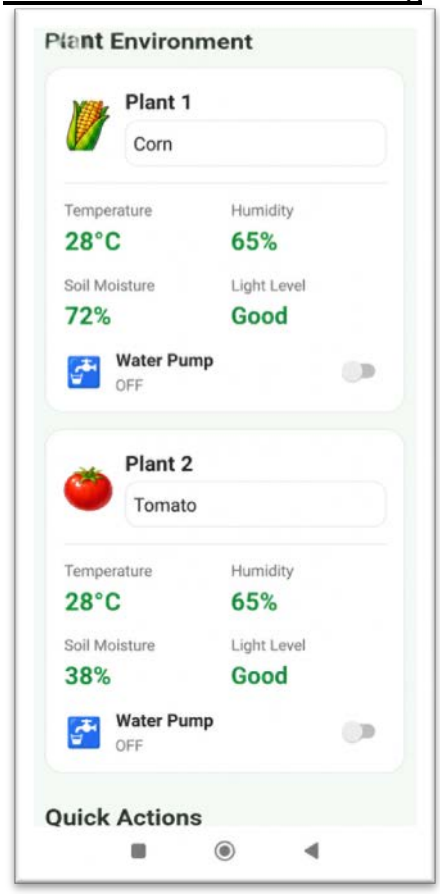
1. The soil moisture, DHT11, and LDR sensors continuously collect environmental data.
2. The ESP32 receives and processes the sensor readings.
3. The ESP32-CAM captures plant leaf images for disease analysis.
4. The captured images are analyzed using CNN-based AI techniques.
5. If the soil moisture falls below the required level, the ESP32activatestherelayandwaterpump.
6. When sufficient moisture is detected, the water pump is switched OFF automatically.
7. Sensor readings, plant status, irrigation status, and disease detection results are displayed through the Plant Guard AI application.

The proposed methodology combines IoT sensing, wireless communication, AI-based disease detection, and automatic irrigation into a single plant monitoring system. This approach reduces manual monitoring, supports early disease identification, improves irrigation management, and helps maintain healthy plant growth.

Furthermore, the proposed system performs continuous monitoring of environmental conditions at regular time intervals. The ESP32 periodically collects data from all connected sensors and verifies whether the measured values lie within the predefined threshold range. If any parameter exceeds or falls below the acceptable limit, the controller immediately generates an alert and transmits the information to the IoT platform. This real-time monitoring mechanism enables users to respond quickly to unfavorable environmental conditions before they affect plant growth ese pixels represent a specific portion of the image, when The disease detection module plays an important role in improving the intelligence of the proposed system. The ESP32-CAM captures high-quality images of plant leaves under suitable lighting conditions. Before classification, the captured images undergo preprocessing operations such as image resizing, normalization, contrast enhancement, and noise removal to improve image quality. These preprocessing techniques reduce unwanted variations and improve the accuracy of disease detection.

III. RESULTS AND DISCUSSION

6.1 Environmental Monitoring



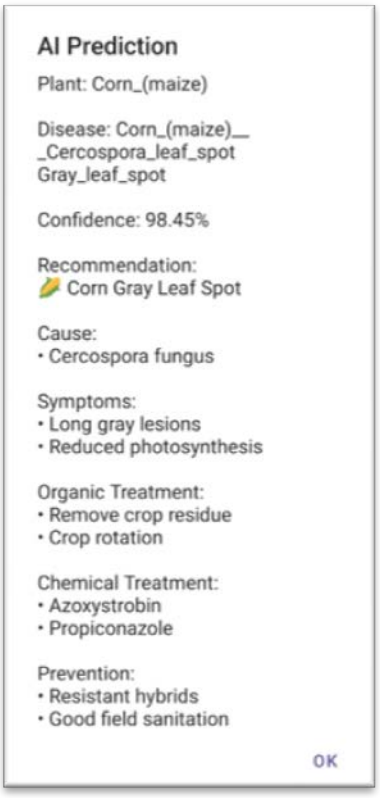
The soil moisture sensor continuously monitors the moisture content of the soil, while the DHT11 sensor measures temperature and humidity. The LDR sensor detects the intensity of surrounding light. The collected sensor data

are processed by the ESP32 to monitor environmental conditions and identify situations that may affect plant growth.

6.2 Plant Disease Detection

The ESP32-CAM captures images of plant leaves for disease identification. The trained Convolutional Neural Network (CNN) model processes the images and classifies them into corresponding disease categories. The integration of image-based analysis helps identify visible symptoms of plant diseases and supports early detection.

The detection results help users understand the possible health conditions of their plants and take necessary preventive measures. This feature reduces dependence on manual leaf inspection and improves the overall plant monitoring process.



6.3 Automated Irrigation System

The automated irrigation system uses soil moisture readings to determine the watering requirements of the plant. When the soil moisture falls below a predefined threshold, the ESP32 activates the water pump through a relay module. Once the required moisture level is reached, the pump is switched off. This mechanism helps reduce unnecessary water consumption and supports efficient irrigation.

When the measured soil moisture level falls below a predefined threshold, the ESP32 activates the water pump through a relay module. The pump supplies water to the plant until the required moisture level is achieved. Once the soil reaches the specified moisture condition, the ESP32 automatically switches off the pump, preventing excessive watering and unnecessary water consumption.

The relay module acts as an electrically controlled switching mechanism between the microcontroller and the water pump. This enables the ESP32 to control the operation of the pump based on sensor readings. The system also supports manual control of the water pump through the Plant Guard AI application, allowing users to operate the irrigation mechanism whenever required.

The relay receives control signals from the ESP32 and switches the pump's power supply accordingly. This provides a safe and efficient way to control the pump without directly connecting it to the microcontroller.

6.4 Discussion

The integration of Internet of Things (IoT) and Artificial Intelligence (AI) provides a practical and efficient approach to smart plant monitoring. Real-time environmental sensing enables continuous observation of plant conditions, while AI-based disease detection supports the identification of potential plant health issues through leaf image analysis. The combination of these technologies improves the efficiency of plant care and reduces dependence on traditional manual monitoring methods.

The use of multiple sensors, including soil moisture, temperature, humidity, and light intensity sensors, provides comprehensive information about the surrounding environmental conditions.

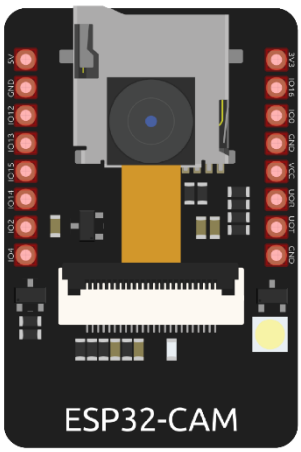
These parameters play an important role in understanding plant growth requirements and identifying conditions that may negatively affect plant health. The ESP32 microcontroller collects sensor data and processes it to support automated monitoring and decision-making.

The automatic irrigation mechanism is an important feature of the proposed system. By monitoring soil moisture levels and controlling the water pump through a relay module, the system supplies water whenever required. When the soil moisture level falls below a predefined

threshold, the ESP32 activates the relay, which switches on the water pump to irrigate the plant.

Once the soil reaches the required moisture level, the system automatically switches off the pump, preventing unnecessary water usage. This approach helps prevent excessive watering and water scarcity, promotes efficient water utilization, and reduces the need for continuous human supervision. Furthermore, automated irrigation minimizes manual effort and ensures timely water supply based on the actual moisture requirements of the soil rather than fixed watering schedules.

The integration of sensor-based monitoring and automatic water control improves irrigation efficiency and supports healthy plant growth. This mechanism is particularly beneficial in situations where regular manual watering is difficult, contributing to water conservation and sustainable agricultural practices.
The system ensures that water is supplied only when the soil moisture level falls below the predefined threshold, preventing unnecessary water usage. It also minimizes human intervention by automating the irrigation process based on real-time sensor readings. This approach helps maintain consistent soil moisture conditions and promotes efficient utilization of available water resources.



Furthermore, the integration of the ESP32-CAM with an AI-based plant disease detection model enables visual analysis of plant leaves. The Convolutional Neural Network (CNN) model identifies disease-related patterns from captured images and assists in recognizing potential plant diseases. This feature can support early detection and help users take appropriate preventive measures to maintain plant health.

The combined operation of IoT-based environmental monitoring, AI-based disease identification, and automated irrigation demonstrates the potential of intelligent agricultural systems. However, the performance of disease detection depends on image quality, lighting conditions, variations in leaf appearance, and the diversity of the training dataset. Further improvements in model training and testing under different environmental conditions can enhance detection accuracy and system reliability.
Overall, the proposed Plant Guard AI system offers a promising solution for smart agriculture by integrating real-time monitoring, intelligent disease identification, and automated irrigation into a unified framework. By reducing manual intervention and supporting efficient resource utilization, the system contributes to improved plant management and sustainable agricultural practices. The modular design of the system also provides flexibility for integrating additional sensors and functionalities according to agricultural requirements. The system can be further enhanced by incorporating cloud-based data storage, mobile notifications, historical data analysis, and advanced AI models to support scalable and precision-based agricultural applications. In addition, future integration of weather forecasting, remote monitoring, and predictive analytics could enable the system to make more effective decisions regarding irrigation scheduling and disease prevention, thereby improving adaptability and overall agricultural productivity.

REFERENCES

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K. Pradheep et al. proposed an *IoT-Based Intelligent Plant Monitoring System* using ESP32, soil moisture sensors, a relay module, a water pump, and ESP32-CAM. The system monitors soil moisture levels, automates irrigation, and enables remote plant monitoring. It helps reduce manual intervention and supports efficient water management. However, the system mainly focuses on soil moisture monitoring and automated watering, with limited emphasis on AI-based plant disease detection and comprehensive environmental monitoring.

[2] K. Sumithra Devi et al. (2025)
K. Sumithra Devi et al. proposed an AI-Driven Gardening Assistant for intelligent plant care and disease detection. The system utilizes YOLO, deep learning, and AI chatbot assistance to identify plant diseases and provide gardening recommendations. It supports users through disease identification and interactive plant care guidance. However, the system primarily focuses on AI-based assistance and lacks integrated IoT environmental monitoring and automated irrigation facilities.

[3] Vinoparkavi D. et al. (2025)
Vinoparkavi D. et al. developed an AI-Based Detection and Analysis System for Red-Brown Sesame Leaf Diseases using deep learning and image processing techniques. The system analyzes leaf images to identify disease symptoms and supports early disease diagnosis. However, its application is limited to specific sesame leaf diseases and depends on the quality and diversity of the training dataset.

[4] Rohit Chandra Joshi et al. (2025)
Rohit Chandra Joshi et al. proposed a Real-Time Plant Leaf Disease Detection System Using CNN and Android Application. The system employs Convolutional Neural Networks (CNN) and image processing for plant disease identification. It also provides disease-related information and recommendations through a mobile application. However, it mainly focuses on image-based disease detection without integrating environmental monitoring and automatic irrigation mechanisms.

[5] Pradeep Jha et al. (2025)
Pradeep Jha et al. developed a Plant Disease Detection and Classification System Using Convolutional Neural Networks. The system utilizes deep learning techniques to classify plant diseases based on leaf images. The study demonstrates the effectiveness of CNN models in automated plant disease classification. However, it primarily concentrates on disease identification and does not incorporate IoT-based environmental monitoring or automated plant care functionalities.

[6] Panchareddy Nishitha et al. (2024)
Panchareddy Nishitha et al. proposed a Smart Agriculture System for Early Detection and Diagnosis of Plant Diseases and Pests using CNN and AI techniques. The system analyzes plant images to identify diseases and pests at an early stage, supporting improved agricultural productivity. However, it provides limited real-time automation and lacks a comprehensive integration of environmental monitoring and automatic irrigation.

[7] Anita Shrotriya et al. (2024)
Anita Shrotriya et al. developed an Automated Plant Disease Detection System Using CNNs and YOLOv5. The system incorporates deep learning architectures and image analysis techniques for plant disease identification and classification. The use of advanced models improves disease recognition capabilities. However, the system primarily emphasizes disease detection and does not provide integrated IoT-based environmental monitoring or automatic irrigation facilities.

[8] Abhijit Kulkarni et al. (2024)
Abhijit Kulkarni et al. proposed Plant Care AI, an intelligent plant disease diagnosis and assistance system. The system uses AI-based image analysis to identify plant health problems and provide relevant plant care recommendations. It supports users in understanding plant diseases and their possible remedies. However, it lacks integrated sensor-based monitoring, automated irrigation, and real-time environmental data collection.

[9] Saiful Islam et al. (2023)
Saiful Islam et al. introduced a Smart Agriculture System Using IoT and Machine Learning for environmental monitoring and automated irrigation. The system utilizes IoT sensors and machine learning techniques to monitor agricultural parameters and improve irrigation efficiency. It reduces manual intervention and supports smart agricultural practices. However, the implementation may involve increased system complexity and does not fully integrate image-based plant disease identification with automated plant care.

[10] Aminu Musa et al. (2021)
Aminu Musa et al. proposed an Intelligent Plant Disease Detection System for Smart Hydroponics Using Convolutional Neural Networks (CNN). The system applies deep learning and image processing techniques to identify plant diseases in hydroponic environments. It demonstrates the effectiveness of CNN-based disease detection in intelligent agricultural applications. However, it mainly focuses on disease classification and lacks comprehensive IoT-based environmental monitoring and automated irrigation functionalities