Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 08 , August - 2026

Dr. Plant: An Integrated Smart Agriculture Ecosystem

Joshua P
Department of Information Technology Alpha College of Engineering Chennai, India

Gokulailankathir V
Department of Information Technology Alpha College of Engineering Chennai, India

Dr. R. Manikavasagam M.E, Phd.,
Head Of the Department, Department of IT and AI & DS
Alpha College of Engineering Chennai, India

Dharanidharan K
Department of Information Technology Alpha College of Engineering Chennai, India

***Abstract* - Dr. Plant is a smart farming support tool designed to tackle some of the biggest challenges farmers face today—like limited access to expert advice, delays in identifying plant diseases, and difficulties connecting with markets. It brings everything together in one place: a practical farming guide, an AI-powered disease detection system (built with Hugging Face), and a dedicated marketplace. Whether someone is new to farming or already experienced, the platform helps them better understand crop management and day-to-day agricultural practices.**

The system is built using a modern, scalable architecture. The backend runs on Python and FastAPI within a Kubernetes environment, allowing it to handle growth efficiently. On the user side, it is designed as an offline-first Progressive Web App using Next.js, which means farmers can still use it even in areas with poor internet connectivity. Features like Service Workers and IndexedDB help keep the app accessible and responsive. It also integrates GIS for location-based insights, real-time IoT data through WebSockets, and diagnostics verified by agricultural experts to support better decision-making.

In practice, Dr. Plant helps users monitor their crops more effectively, spot diseases early, and learn from others through a built-in community platform. The marketplace feature also connects farmers directly with buyers, helping improve their income and overall productivity.

***Index Terms*—Smart Agriculture, Plant Disease Detection, Microservices Architecture, Progressive Web Application (PWA)**

I. INTRODUCTION

Agriculture plays a critical role in ensuring food security, economic development, and social stability across the world. In developing countries like India, agriculture remains the backbone of the economy and serves as the primary source of livelihood for millions of people. Despite the importance of agriculture, farmers continue to face several challenges such as unpredictable climatic conditions, pest infestations, plant diseases, lack of technical guidance, and limited access to digital infrastructure. These issues directly affect crop productivity, increase operational costs, and reduce farmers' profitability.

One of the most significant problems in modern agriculture is the delayed identification of plant diseases. Traditionally, farmers rely on manual inspection and expert consultation to identify crop infections. However, these methods are time-consuming, expensive, and often inaccessible in rural areas where agricultural experts are not readily available. In many cases, diseases spread rapidly before appropriate action can be taken, resulting in severe crop damage and reduced yields. Furthermore, beginners and small-scale farmers often struggle to access reliable information regarding crop management, fertilizer usage, irrigation planning, and disease prevention.

The advancement of Artificial Intelligence (AI), cloud computing, and Progressive Web Applications (PWAs) has created new opportunities to modernize agricultural practices. AI-powered image classification systems can now identify plant diseases with high accuracy using deep learning models trained on large agricultural datasets. IoT sensors provide real-time environmental monitoring, while cloud technologies enable scalable and secure data processing. These technologies collectively contribute to the development of smart agriculture systems capable of improving productivity and sustainability.

To address these challenges, the proposed system, **Dr. Plant**, introduces an integrated smart agriculture ecosystem that combines AI-driven disease detection,expert validation, and offline-first accessibility into a single platform. The system is designed to assist farmers in detecting plant diseases at an early stage by analyzing crop images using Hugging Face deep learning models. In addition, the platform offers agricultural guidance, marketplace integration, environmental monitoring, and community support features to improve overall farming efficiency.

Dr. Plant is developed as an offline-first Progressive Web Application using Next.js and React, ensuring usability even in regions with unstable internet connectivity. The back-

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 08 , August - 2026

end infrastructure is implemented using Python and FastAPI within a Kubernetes-based microservices architecture to ensure scalability, flexibility, and high performance. Local caching mechanisms such as IndexedDB and Service Workers allow users to continue accessing essential services offline, while synchronization occurs automatically once internet connectivity is restored.

The integration of GIS-based visualization, real-time communication through WebSockets, and Human-in-the-Loop expert validation further enhances the reliability and effectiveness of the platform. By combining modern AI technologies with practical agricultural requirements, Dr. Plant aims to reduce crop losses, improve decision-making, and empower farmers with accessible digital tools for sustainable farming practices.

II. RELATED WORK

Recent advancements in smart agriculture have led to the development of numerous systems and applications aimed at improving crop productivity, disease detection, and precision farming practices. Researchers and technology companies have increasingly focused on integrating Artificial Intelligence, and cloud computing into agricultural environments to address traditional farming challenges.

One of the earliest and most influential studies in plant disease detection was conducted by Sharada Prasanna Mohanty et al., who demonstrated the effectiveness of deep learning techniques for image-based disease identification. Their work showed that Convolutional Neural Networks (CNNs) could classify plant diseases with high accuracy using large-scale agricultural datasets. This research laid the foundation for AI-driven agricultural diagnostics and inspired many subsequent developments in smart farming technologies.

Several mobile-based applications such as PlantVillage Nuru, PlantNet, and PictureThis have been developed to assist users in identifying plant diseases and recognizing plant species using smartphone images. These applications use machine learning models to provide quick predictions and basic treatment recommendations. Although such systems improve accessibility to agricultural knowledge, they mainly focus on image classification and often lack integration with real-time environmental monitoring or expert validation mechanisms.

Cloud-based agricultural management systems such as CropX and Agrio provide advanced analytics, soil insights, and farm management features. These enterprise-level solutions support large-scale agricultural operations through centralized cloud infrastructure. While these platforms offer powerful features, they are often expensive and less suitable for small-scale or rural farmers with limited internet access and technical knowledge.

Another major limitation identified in existing agricultural systems is the absence of Human-in-the-Loop validation. Fully automated AI systems may generate incorrect predictions in complex or ambiguous disease scenarios. Jose´ Blas Barbedo emphasized that expert involvement is essential for improving diagnostic reliability and reducing errors in AI-based plant disease recognition systems.

Recent studies have also explored microservices architecture and scalable cloud-native systems for agriculture. Liang Chen proposed a microservice-based agricultural platform capable of handling distributed workloads and scalable data processing. Such architectures improve system flexibility and maintainability compared to traditional monolithic systems.

Although previous research has significantly contributed to smart agriculture, several gaps still remain. Most existing solutions focus on isolated functionalities such as disease detection, environmental monitoring, or crop management individually. Very few systems successfully integrate AI diagnostics, offline accessibility, expert validation, and marketplace services into a unified ecosystem.

The proposed Dr. Plant platform addresses these limitations by combining multiple smart agriculture technologies into a single scalable system. Its offline-first architecture ensures accessibility in low-connectivity regions, while the integration of AI diagnostics with expert review improves accuracy and trustworthiness. The inclusion of microservices architecture, GIS visualization, and marketplace connectivity makes Dr. Plant a comprehensive and practical solution for modern agriculture.

III. PROPOSED WORK AND METHODOLOGY

The proposed system, Dr. Plant, is designed as a comprehensive smart agriculture ecosystem that combines Artificial Intelligence, cloud computing, and offline-first web technologies to support farmers in crop monitoring, disease detection, and agricultural decision-making. The system aims to overcome the limitations of traditional farming support systems by providing a scalable, intelligent, and accessible platform suitable for both urban and rural agricultural environments.

A. System Architecture

The architecture of Dr. Plant is divided into four major layers: the frontend layer, backend microservices layer, intelligence layer, and data management layer. This layered architecture ensures modularity, scalability, and maintainability of the system. The frontend layer is developed using Next.js and React as a Progressive Web Application (PWA). The offline-first design allows farmers to continue using the application even when internet connectivity is unavailable. Service Workers are used for caching essential application resources, while IndexedDB stores user data locally on the device. This enables users to record farm activities, upload crop images, and access recommendations offline. Once connectivity is restored, synchronization mechanisms automatically update cloud databases.

The backend layer is implemented using Python and FastAPI following a microservices architecture. Different functionalities such as disease diagnostics, user authentication, advisory services, marketplace management, and IoT data ingestion operate as independent services. Kubernetes is used

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 08 , August - 2026

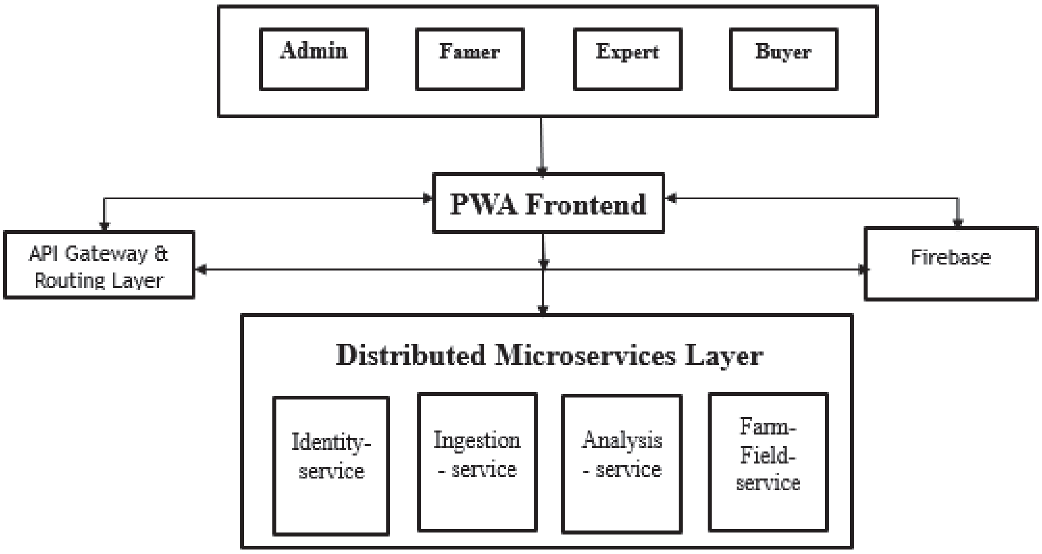

Fig. 1. System Architecture of Dr. Plant Smart Agriculture Ecosystem

for orchestration and container management, ensuring high availability, scalability, and fault tolerance.

The intelligence layer forms the core of the system. It integrates Hugging Face deep learning models trained on agricultural datasets for plant disease detection. Farmers can upload leaf images, and the AI system processes the images to identify diseases and provide confidence scores along with treatment recommendations. To improve reliability, a Human-in-the-Loop mechanism allows agricultural experts to review uncertain predictions before final recommendations are delivered.

The data management layer uses a polyglot persistence approach. PostgreSQL (via Neon) manages structured data such as user records, crop details, and marketplace information, while Firebase supports authentication and real-time synchronization.

B. Methodology

The methodology followed in Dr. Plant involves multiple stages of data collection, processing, analysis, and recommendation generation.

Initially, farmers capture images of infected plant leaves using their mobile devices. These images are uploaded to the AI diagnostic module, where preprocessing techniques such as resizing, normalization, and noise reduction are applied before inference. The processed images are then analyzed using deep learning models integrated through Hugging Face APIs.

The AI model predicts the disease category and generates confidence scores based on learned image features. If the confidence score falls below a predefined threshold or the prediction appears ambiguous, the Human-in-the-Loop mechanism forwards the case to agricultural experts for verification. This hybrid approach improves diagnostic accuracy and reliability.

Simultaneously, IoT sensors deployed in agricultural fields collect environmental parameters such as soil moisture, temperature, humidity, and light intensity. These sensor readings are continuously transmitted to the backend infrastructure through WebSockets for real-time monitoring.

The collected environmental data is analyzed alongside disease predictions to provide context-aware recommendations. For example, irrigation suggestions may be adjusted based on soil moisture levels, while fertilizer recommendations may vary depending on climatic conditions.

The platform also includes GIS-based visualization using Leaflet and Mapbox technologies. Farmers can monitor field conditions geographically and analyze crop health across different regions.

Role-Based Access Control (RBAC) is implemented to ensure secure access to system functionalities. Farmers, agricultural experts, and administrators have different permission levels based on their responsibilities.

The overall methodology combines AI intelligence, environmental sensing, cloud-native scalability, and offline accessibility to create an efficient agricultural decision-support system capable of improving productivity and sustainability.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 08 , August - 2026

IV. RESULTS AND EVALUATION

The performance of the proposed Dr. Plant system was evaluated based on multiple parameters including disease detection accuracy, system efficiency, offline accessibility, response generation, scalability, and overall usability for farmers. The evaluation demonstrates that the integration of Artificial Intelligence, IoT monitoring, cloud-native microservices, and Progressive Web Application technologies significantly improves agricultural decision-making and crop management.

The experimental analysis was conducted using plant disease image datasets, simulated environmental sensor data, and real-time testing scenarios. The system was tested under different network conditions to evaluate its offline-first capabilities and synchronization performance.

A. Disease Detection Accuracy

One of the primary objectives of Dr. Plant is to accurately detect plant diseases using deep learning models integrated through Hugging Face APIs. The system was evaluated using multiple plant disease datasets containing healthy and infected crop images across different plant categories.

The AI-based diagnostic engine achieved an overall accuracy of more than 90% in identifying plant diseases. Lightweight convolutional neural network architectures were used to ensure efficient performance on mobile devices while maintaining high prediction quality.

The diagnostic engine successfully classified diseases across more than 38 plant categories. The system generated:

- Disease name
- Confidence score
- Infection severity level
- Suggested treatment methods
- Preventive recommendations

The Human-in-the-Loop validation mechanism further improved reliability by allowing agricultural experts to review uncertain predictions. This reduced false positives and increased trustworthiness among farmers.

B. Offline-First Performance Evaluation

The Progressive Web Application architecture was tested in both online and offline environments. Service Workers and IndexedDB enabled uninterrupted functionality during internet outages.

The system successfully supported:

- Offline image uploads
- Local farm record storage
- Cached recommendation access
- Delayed synchronization

When internet connectivity was restored, all locally stored data synchronized automatically with the cloud backend without data loss.

The offline-first capability provides a significant advantage for rural agricultural regions where internet connectivity is unstable or unavailable.

C. IoT Monitoring and Real-Time Communication

The IoT layer was evaluated using environmental sensor simulations for:

- Soil moisture
- Temperature
- Humidity
- Light intensity

WebSocket-based communication enabled real-time transmission of sensor data between field devices and cloud infrastructure. The system successfully updated environmental dashboards with minimal latency.

Real-time monitoring helped improve:

- Irrigation planning
- Crop health monitoring
- Environmental awareness
- Resource optimization

The integration of IoT data with AI diagnostics allowed the system to generate context-aware agricultural recommendations.

D. System Scalability and Performance

The microservices architecture implemented using FastAPI and Kubernetes improved scalability and fault tolerance. Each service operated independently, allowing efficient resource allocation and easier maintenance.

Performance testing demonstrated that the system could:

- Handle multiple concurrent users
- Process image requests efficiently
- Support independent service scaling
- Recover from service failures

Kubernetes orchestration enabled automatic load balancing and service monitoring, improving overall system reliability.

E. Comparative Analysis

The proposed Dr. Plant platform was compared with traditional agricultural applications and existing smart farming systems.

TABLE I
COMPARISON OF DR. PLANT WITH EXISTING AGRICULTURAL SYSTEMS

Feature	**Existing Systems**	**Dr. Plant**
Architecture	Monolithic Systems	Microservices Architecture
Disease Detection	Basic AI Models	AI + Expert Validation
Offline Access	Limited or Unavailable	Offline-First PWA
IoT Integration	Partial Support	Real-Time IoT Monitoring
Scalability	Limited	Kubernetes-Based Scaling
Farmer Support	Separate Applications	Integrated Single Platform
Data Synchronization	Manual	Automatic Synchronization

The comparison shows that Dr. Plant provides a more integrated, scalable, and accessible solution compared to conventional agricultural platforms.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 08 , August - 2026

F. Benefits of the Proposed System

The implementation of Dr. Plant provides several practical benefits for farmers and agricultural stakeholders.

The major benefits include:

- Early disease detection and prevention
- Reduction in crop losses
- Improved agricultural productivity
- Better irrigation and fertilizer management
- Reduced operational costs
- Accessibility in remote regions
- Real-time environmental monitoring
- Increased decision-making accuracy

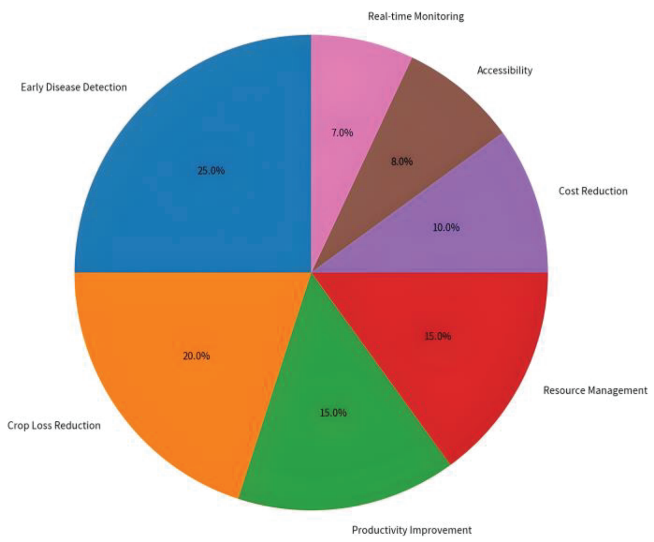

Fig. 2. Distribution of Key Benefits of Dr. Plant

The integrated marketplace and community support features also help farmers connect with buyers, experts, and other agricultural users, creating a collaborative farming ecosystem.

G. Overall Evaluation

The overall evaluation confirms that Dr. Plant successfully combines Artificial Intelligence, IoT monitoring, cloud-native microservices, and offline-first technologies into a unified smart agriculture platform.

The system demonstrates:

- High diagnostic accuracy
- Efficient real-time processing
- Strong offline accessibility
- Scalable cloud infrastructure
- Improved farmer usability

The combination of AI-driven diagnostics with expert validation significantly improves reliability compared to fully automated systems. The offline-first architecture ensures practical usability in rural areas, making Dr. Plant a scalable and impactful solution for modern precision agriculture.

V. CONCLUSION

Agriculture continues to face numerous challenges related to plant disease management, environmental monitoring, limited digital accessibility, and lack of expert support, especially in rural regions. Traditional farming practices often rely on manual observation and delayed decision-making processes, which can lead to severe crop losses, reduced productivity, and increased operational costs. The rapid advancement of Artificial Intelligence, Internet of Things (IoT), cloud computing, and web technologies provides new opportunities to modernize agricultural systems and support farmers with intelligent decision-making tools.

The proposed system, **Dr. Plant**, successfully addresses these challenges by developing an integrated smart agriculture ecosystem that combines AI-powered disease detection, IoT-based environmental monitoring, cloud-native microservices architecture, and offline-first Progressive Web Application technologies into a unified platform.

The AI diagnostic engine integrated through Hugging Face models enables accurate and real-time plant disease identification using crop images uploaded by farmers. The implementation of Human-in-the-Loop expert validation improves diagnostic reliability by allowing agricultural experts to verify uncertain predictions before final recommendations are delivered. This hybrid approach enhances farmer trust and reduces the limitations of fully automated AI systems.

The integration of IoT sensors allows continuous monitoring of environmental conditions such as soil moisture, temperature, humidity, and light intensity. These real-time insights support precision farming practices by helping farmers make informed irrigation and crop management decisions. WebSocket-based communication ensures efficient real-time data transmission between field devices and the cloud infrastructure.

The offline-first Progressive Web Application developed using Next.js and React significantly improves accessibility for farmers located in areas with unstable internet connectivity. Service Workers and IndexedDB enable offline data storage, local functionality, and automatic synchronization once connectivity is restored. This feature makes the platform highly practical for real-world agricultural environments.

The backend infrastructure built using Python, FastAPI, and Kubernetes ensures scalability, modularity, and efficient resource management through a microservices architecture. The polyglot database approach using PostgreSQL and Firebase improves data management flexibility and real-time synchronization capabilities.

Experimental evaluation demonstrates that Dr. Plant achieves high disease detection accuracy, efficient real-time processing, strong offline usability, and scalable system performance. Compared to conventional agricultural applications, the proposed system offers a more comprehensive, intelligent, and farmer-friendly solution.

Overall, Dr. Plant acts as a reliable agricultural decision-support platform capable of reducing crop losses, improving

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 08 , August - 2026

productivity, optimizing resource usage, and supporting sustainable farming practices. The system bridges the gap between advanced digital technologies and practical agricultural needs, making smart farming more accessible and effective for farmers.

A. Future Scope

Although Dr. Plant provides a comprehensive smart agriculture solution, several enhancements can be implemented in future developments to further improve system intelligence, scalability, and real-world impact.

Future improvements may include:

- Integration of advanced edge AI models for fully offline disease detection
- Deployment of additional IoT sensors for nutrient analysis and weather prediction
- Support for multilingual voice-based farmer assistance systems
- Integration of drone-based crop monitoring and aerial imaging
- Implementation of predictive analytics for yield forecasting
- Expansion of disease datasets to support more crop varieties
- AI-powered fertilizer and pesticide optimization systems

In the future, Dr. Plant has the potential to evolve into a fully intelligent precision agriculture ecosystem capable of supporting large-scale sustainable farming operations and improving global agricultural productivity through advanced digital transformation.

REFERENCES

[1] S. P. Mohanty, D. P. Hughes, and M. Salathe´, “Using deep learning for image-based plant disease detection,” *Frontiers in Plant Science*, vol. 7, p. 1419, Sep. 2016.
[2] A. Kamilaris and F. X. Prenafeta-Boldu´, “Deep learning in agriculture: A survey,” *Computers and Electronics in Agriculture*, vol. 147, pp. 70–90, Apr. 2018.
[3] N. Dragoni *et al.*, “Microservices: How to make your application scale,” in *Microservices: Science and Engineering*, A. Bucchiarone, N. Dragoni, S. Dustdar, . T. Larsen, and M. Mazzara, Eds. Cham, Switzerland: Springer, 2017, pp. 21–56.
[4] A. G. Howard *et al.*, “MobileNets: Efficient convolutional neural networks for mobile vision applications,” *arXiv preprint arXiv:1704.04861*, 2017.
[5] S. Wolfert, L. Ge, C. Verdouw, and M. J. Bogaardt, “Big data in smart farming – a review,” *Agricultural Systems*, vol. 153, pp. 69–80, May 2017.
[6] J. G. A. Barbedo, “Factors impacting the use of deep learning for plant disease recognition,” *Biosystems Engineering*, vol. 172, pp. 84–91, Aug. 2018.
[7] A. Khattab, A. Abdelgawad, and K. Yelmarthi, “Design and implementation of a cloud-based IoT scheme for precision agriculture,” *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 3164–3174, Apr. 2019.
[8] P. P. Ray, “Internet of Things for smart agriculture: Technologies, practices and future direction,” *Journal of Ambient Intelligence and Smart Environments*, vol. 9, no. 4, pp. 395–420, 2017.
[9] J. Chen, X. Ran, and Z. Chen, “A microservice-based architecture for smart agriculture systems,” *IEEE Access*, vol. 8, pp. 143704–143716, 2020.
[10] K. P. Ferentinos, “Deep learning models for plant disease detection and diagnosis,” *Computers and Electronics in Agriculture*, vol. 145, pp. 311–318, Feb. 2018.
[11] A. Nandhini, R. Hemalatha, S. Radha, *et al.*, “A smart agriculture IoT system for banana plant disease detection,” *Multimedia Tools and Applications*, vol. 82, pp. 45519–45539, 2023.
[12] P. Blanco-Carmona, L. Baeza-Moreno, E. Hidalgo-Fort, *et al.*, “AIoT in agriculture: Safeguarding crops from pest and disease threats,” *Sensors*, vol. 23, no. 24, 2023.
[13] Y. Wang, U. S. R. Dhamodharan, N. Sarwar, *et al.*, “A hybrid approach for rice crop disease detection in agricultural IoT systems,” *Discover Sustainability*, vol. 5, 2024.
[14] A. Jafar, N. Bibi, R. A. Naqvi, *et al.*, “Revolutionizing agriculture with artificial intelligence: Plant disease detection methods, applications, and limitations,” *Frontiers in Plant Science*, vol. 15, 2024.
[15] N. Ananthi, V. Balaji, M. Mohana, *et al.*, “Smart plant disease detection using hybrid convolution networks with attention mechanisms,” *Network: Computation in Neural Systems*, 2024.
[16] V. S. Dhaka, N. Kundu, G. Rani, *et al.*, “Role of IoT and deep learning techniques in plant disease detection and classification: A review,” *Sensors*, 2023.
[17] S. Jha, V. Luhach, G. S. Gupta, *et al.*, “Crop disease classification using attention-based feature extraction and SVM for IoT-based smart agriculture,” *arXiv preprint arXiv:2311.00429*, 2023.
[18] M. Narimani, A. Hajiahmad, A. Moghimi, *et al.*, “Developing a smart greenhouse using IoT and deep learning for plant disease detection,” *arXiv preprint arXiv:2509.12274*, 2025.