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Article

Revolutionizing plant health with machine learning for disease detection and diagnosis

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Abstract: The use of artificial intelligence (AI) in the detection and diagnosis of plant diseases has gained significant interest in modern agriculture. The appeal of AI arises from its ability to rapidly and precisely analyze extensive and complex information, allowing farmers and agricultural experts to quickly identify plant diseases. The use of artificial intelligence (AI) in the detection and diagnosis of plant diseases has gained significant attention in the world of agriculture and agronomy. By harnessing the power of AI to identify and diagnose plant diseases, it is expected that farmers and agricultural experts will have improved capabilities to tackle the challenges posed by these diseases. This will lead to increased effectiveness and efficiency, ultimately resulting in higher agricultural productivity and reduced losses caused by plant diseases. The use of artificial intelligence (AI) in the detection and diagnosis of plant diseases has resulted in significant benefits in the field of agriculture. By using AI technology, farmers and agricultural professionals can quickly and accurately identify illnesses affecting their crops. This allows for the prompt adoption of appropriate preventative and corrective actions, therefore reducing losses caused by plant diseases.

Keywords: artificial intelligence (AI); identification; diagnosis; and plant disease detection technology

1. Introduction

The utilization of artificial intelligence (AI) in identifying and diagnosing plant diseases has garnered significant attention in contemporary agriculture. This increased interest is attributed to AI's ability to rapidly and accurately process extensive and intricate data, enabling farmers and agricultural specialists to effectively discern plant diseases. AI technology enables farmers to readily identify disease indications in plants and promptly adopt suitable actions to mitigate future propagation. Moreover, AI aids in classifying plant illnesses according to their distinctive features, simplifying the process of diagnosing and treating them. The use of AI in plant disease detection and diagnosis is anticipated to have a significant impact on improving agricultural output and reducing losses related to plant diseases.

The examination of applying artificial intelligence (AI) to identify and diagnose plant diseases holds significant importance in modern agriculture. With technology progressing rapidly, AI proves instrumental in accurately detecting various plant

diseases, empowering farmers to promptly address issues. Through an AI system proficient in automating data processing and plant image analysis, the identification of plant diseases can be carried out with enhanced efficiency and precision. Furthermore, AI utilization extends to predicting the progression of future plant diseases, enabling farmers to proactively implement preventive measures. Hence, this research presents substantial promise in boosting agricultural productivity and minimizing losses stemming from plant diseases.

In recent years, there has been a significant focus on using artificial intelligence (AI) to identify and diagnose plant diseases. Scientists have investigated various artificial intelligence methods, such as machine learning and deep learning, to create systems that can efficiently identify and diagnose plant illnesses by analyzing visual symptoms obtained through image processing techniques (Nigam and Jain, 2020; Patel and Patel, 2022; Yang and Guo, 2017). AI-powered systems have several benefits, including rapid and precise identification of diseases, evaluation of disease severity, and the ability to analyze disease resistance characteristics of crop cultivars (Patel and Patel, 2022).

One prominent example is the use of deep learning models for the detection of banana diseases and pests. Researchers have demonstrated the ability of AI to mimic human behavior in identifying plant diseases based on visual symptoms, enabling accurate and efficient disease recognition (Selvaraj et al., 2019). Similarly, deep learning-based computer vision techniques have been employed for the automatic detection of various plant diseases, such as potato plant diseases, showcasing the potential of these advanced AI methods in enhancing the precision and speed of the identification process (Saidani and Ghodhbani, 2022).

Furthermore, machine learning algorithms have been instrumental in plant disease research, aiding in the discovery of plant resistance genes and the classification of different plant diseases (Sinshaw et al., 2022). For instance, researchers have leveraged machine learning techniques to develop automated systems for the detection of potato plant diseases, achieving enhanced accuracy and efficiency in the identification process (Saidani and Ghodhbani, 2022).

Additionally, the integration of AI with Internet of Things (IoT) technologies has enabled the development of smart agriculture practices, allowing for real-time monitoring and early detection of plant diseases in crop fields (Balram and Kumar, 2022). By leveraging large datasets and sophisticated deep learning models, researchers have made significant progress in automating the detection and classification of plant diseases, contributing to precision farming and increased agricultural productivity (Anitha and Saranya, 2022). The aim of this research was to identify the factors influencing the relationship between Community-Based Total Sanitation and the prevalence of diarrhoea in toddlers residing in riverine areas(Indah et al., 2022).

This study aims to explore the implementation of artificial intelligence (AI) in identifying and diagnosing plant diseases. The growing interest in using AI in agriculture, driven by technological advancements, is due to its potential to improve efficiency and accuracy in detecting plant health issues. By integrating AI technology, there is an expectation of speeding up the plant disease identification process, enabling farmers to promptly take appropriate measures to prevent disease spread and

subsequent losses. Additionally, this research aims to identify obstacles and complexities that may arise in applying AI to plant disease identification, as well as finding solutions to enhance the effectiveness and efficiency of AI technology adoption in agriculture. Therefore, the findings of this study are expected to make a significant contribution to the advancement of AI technology in agriculture, particularly in the field of plant disease identification and diagnosis.

2. Materials and methods

Figure 1 below are some methodologies frequently used in applying artificial intelligence (AI) to detect and diagnose plant diseases:

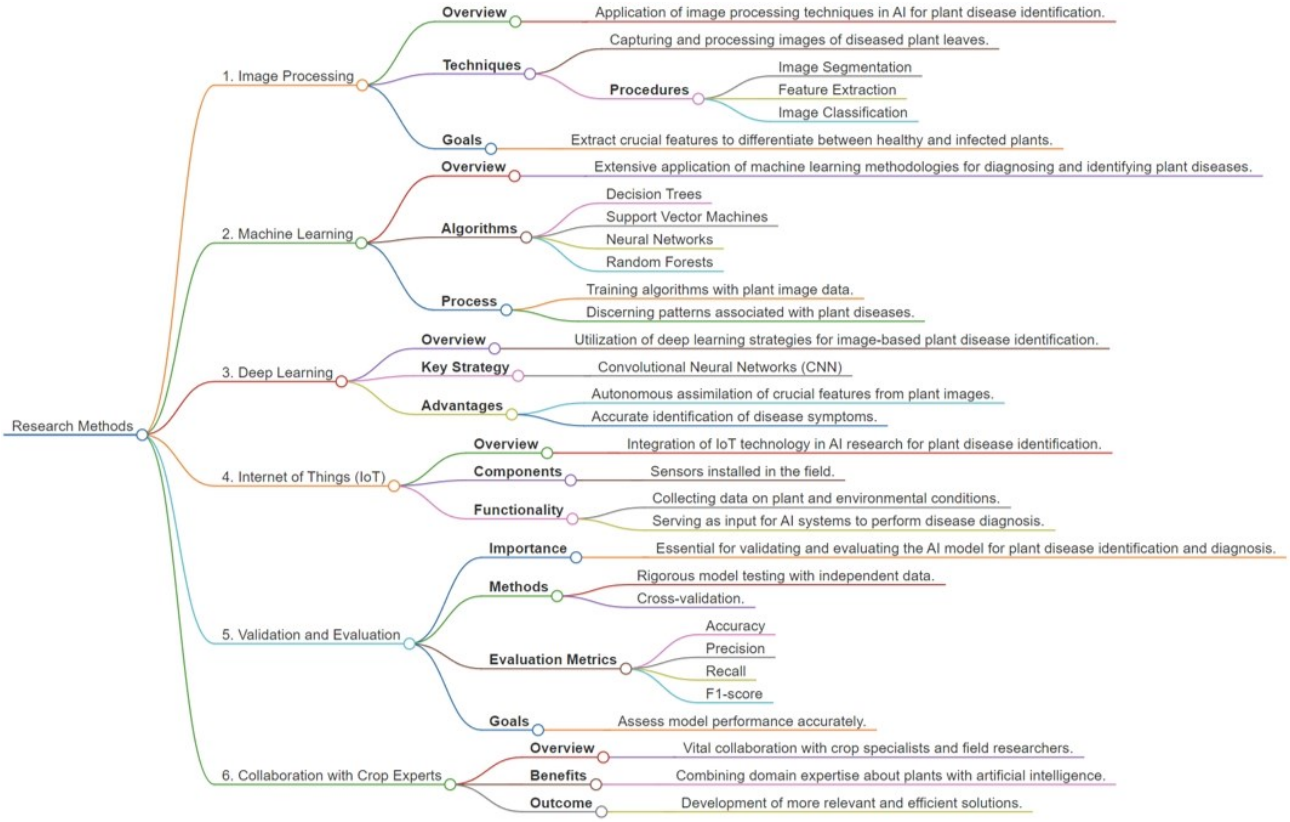


Figure 1. Research methods.

Integrating these diverse research methodologies in the exploration of employing AI for plant disease identification and diagnosis can pave the way for innovative and advantageous contributions to the agricultural sector.

3. Results and discussion

The integration of artificial intelligence (AI) in the field of plant disease identification and diagnosis has produced positive results within the agricultural sector. With AI technology, farmers and agricultural experts can quickly and accurately identify diseases affecting their crops. AI systems are able to analyze visual data from images of diseased plants, providing prompt and accurate diagnoses. This allows farmers to take immediate preventive or remedial measures, reducing losses caused by plant diseases. Additionally, the use of AI helps researchers develop more effective

and precise models for predicting plant diseases, supporting future efforts in disease prevention and management. As a result, the incorporation of AI in plant disease identification and diagnosis has the potential to greatly increase agricultural productivity and enhance food security in different regions.

1) AI helps in promptly and accurately identifying plant diseases by analyzing collected data or images. By leveraging AI technology, farmers can efficiently pinpoint plant diseases without solely relying on limited expert knowledge.
2) AI can predict the spread of plant diseases by considering factors such as weather patterns, crop varieties, and population density. Consequently, farmers can proactively implement measures to curb disease propagation before significant crop damage occurs.
3) After identifying and diagnosing plant diseases, AI can provide tailored treatment suggestions to mitigate the issue. These recommendations may include applying specific pesticides, crop treatments, or other preventive strategies.
4) Through the integration of AI in plant disease identification and diagnosis, farmers can reduce losses caused by plant diseases, increase agricultural productivity, and optimize resource utilization, such as water, fertilizers, and pesticides.

PlantifyDr exemplifies a mobile application that harnesses artificial intelligence (AI) to aid farmers and plant enthusiasts in pinpointing plant diseases. The app allows individuals to capture an image of a diseased plant. Following that, the app conducts an analysis of the image and provides a diagnosis accompanied by treatment suggestions.

The PlantifyDr application is expected to yield several outcomes, which include:

1) Through image analysis carried out by the AI system, PlantifyDr can accurately identify plant diseases, offering users a prompt and accurate diagnosis without needing expert knowledge.
2) Following the diagnosis of the disease, PlantifyDr provides appropriate treatment recommendations to address plant-related issues. These recommendations are formulated based on gathered data, information, and the knowledge of the AI system.
3) Using the PlantifyDr app allows farmers to quickly and easily identify crop diseases, enabling them to promptly implement necessary preventive or treatment measures. This proactive approach can help minimize losses from plant diseases and enhance agricultural productivity.
4) PlantifyDr also serves as a tool for regular crop monitoring, issuing early warnings when disease symptoms are detected. Consequently, farmers can take preventive action preemptively before the disease spreads.

Given the array of advantages presented by the PlantifyDr application can be seen in **Figure 2**, there is an expectation that it will assist farmers and plant enthusiasts in enhancing the effective and efficient management of crops. Additionally, it aims to raise awareness about the significance of vigilantly monitoring and addressing plant diseases.

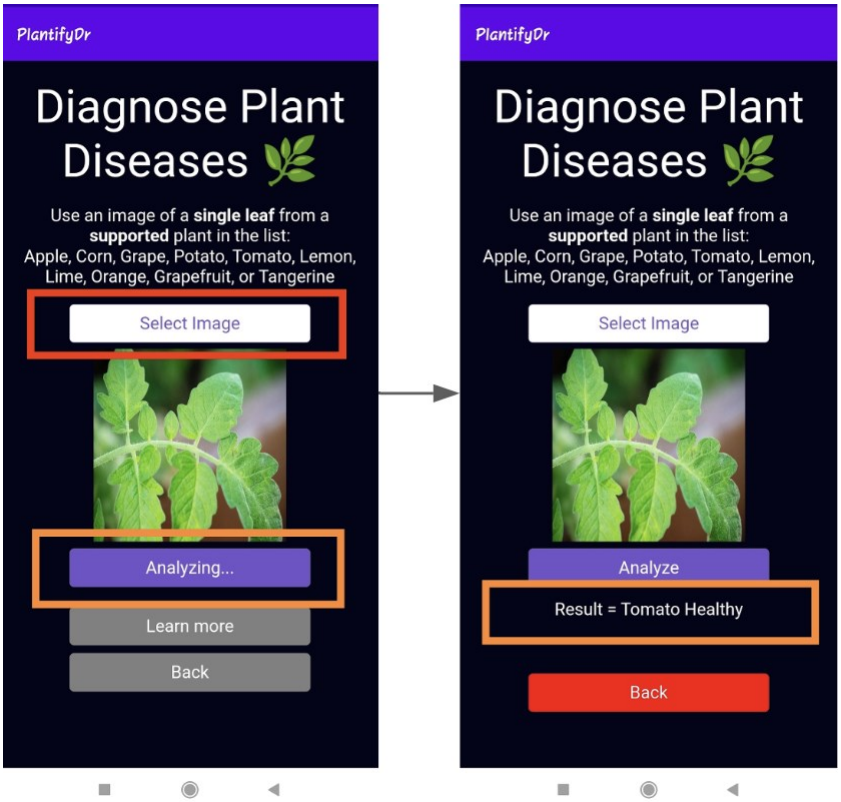


Figure 2. Plant identification with PlantifyDr.

The use of artificial intelligence (AI) for identifying and diagnosing plant diseases has garnered significant interest within the realm of contemporary agriculture. AI offers effective and precise solutions for recognizing plant diseases that pose potential threats to crop yields. By leveraging AI technology, farmers can swiftly discern disease symptoms, enabling timely implementation of preventative or remedial measures. Furthermore, AI aids in pinpointing the specific type of plant disease present, equipping farmers to undertake suitable actions to curb disease spread. Consequently, integrating AI into plant disease identification and diagnosis can enhance agricultural efficiency and mitigate losses stemming from plant diseases. However, additional research is essential to enhance the sophistication and accessibility of AI technology for farmers worldwide.

1) Image analysis is a commonly used method for detecting plant illnesses, where AI technologies like deep learning and computer vision allow the system to acquire knowledge of patterns and traits from photographs of damaged plants. This feature enables accurate identification of diseases and accelerates the diagnostic procedure.
2) AI can play a role in amalgamating data from plant sensors and the Internet of Things (IoT) to detect plant diseases at an early stage. Data collected from sensors, such as temperature, humidity, and soil moisture levels, can be leveraged to anticipate the likelihood of disease and implement appropriate preventive measures.
3) AI can facilitate the creation of expert systems capable of offering diagnostic and treatment recommendations for plant diseases based on observable symptoms.

These systems can aid farmers and agricultural experts in making informed decisions regarding disease management.

4) Ensuring the accuracy of plant disease identification and diagnosis requires proficient training of an AI model. This process involves collecting image data of diseased plants, tagging the data, and developing an AI model that is skilled in recognizing diseases.
5) Various mobile applications have been designed to utilize AI technology in supporting farmers with plant disease identification. Through these apps, farmers can capture images of diseased plants using their smartphone cameras and receive direct diagnoses through the applications.

By employing AI for the identification and diagnosis of plant diseases, there is an optimistic outlook that it will assist farmers and agricultural professionals in resolving plant disease issues with enhanced effectiveness and efficiency. This, in turn, aims to amplify agricultural productivity and mitigate losses stemming from plant diseases.

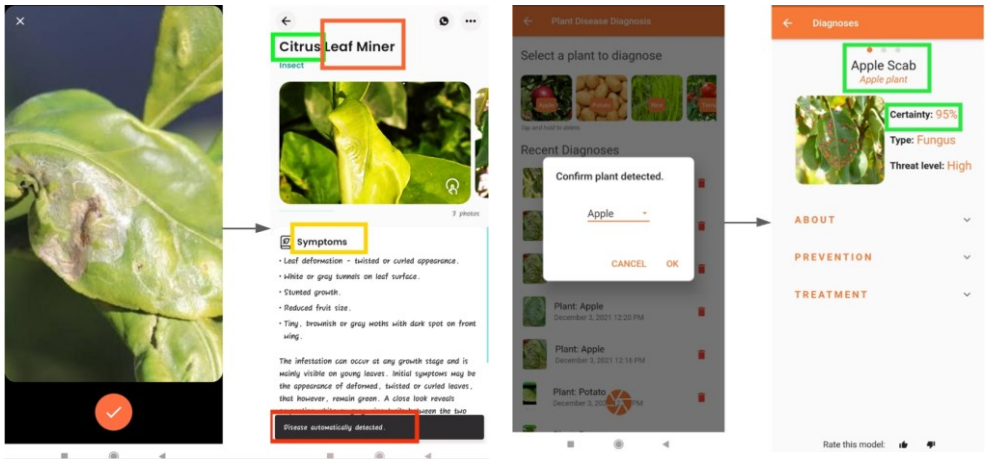
The innovative PlantifyDr application leverages artificial intelligence (AI) to aid in the identification and treatment of plant diseases. The following discussions pertain to the functionalities of the PlantifyDr app:

1) PlantifyDr employs AI technology to scrutinize images of plants afflicted with diseases. By training the AI system with image data of diseased plants, the app can accurately discern disease symptoms, facilitating prompt and precise diagnoses for users, such as farmers or plant enthusiasts.
2) PlantifyDr is designed with user-friendliness in mind, catering to individuals without extensive technical expertise. Users simply need to capture a photo of the target plant for analysis, after which the app undertakes the identification process and delivers diagnostic outcomes along with treatment recommendations. This simplicity is particularly beneficial for farmers lacking specialized agricultural knowledge.
3) Beyond diagnosis, PlantifyDr provides tailored treatment recommendations to tackle identified plant diseases. Drawing upon collated data, information, and the AI expertise embedded within the app, users can take relevant measures to effectively address plant infections.
4) By using the PlantifyDr app, farmers can quickly identify crop diseases and take timely preventive or treatment measures. This proactive approach helps reduce losses caused by plant diseases, increase farm productivity, and enhance crop yields.
5) PlantifyDr facilitates the routine monitoring of crop health and issues timely alerts upon detecting disease symptoms. This early notification system empowers farmers to preemptively safeguard against disease spread and uphold crop well-being.

The PlantifyDr app, with its diverse advantages and functionalities, has the potential to serve as a highly beneficial instrument for farmers and plant enthusiasts seeking to enhance crop management efficacy and efficiency. The integration of AI technology within this app is anticipated to foster awareness about the significance of plant disease monitoring and treatment, thereby aiding in the promotion of sustainable agricultural practices.

The AgroAI-Plant application is a cutting-edge tool that employs artificial intelligence (AI) to enhance farmers' farm management capabilities. Below is a dialogue concerning the AgroAI-Plant application:

1) A fundamental aspect of the AgroAI-Plant application is its capacity to identify ailments in plants. By capturing an image of an afflicted leaf or plant, the app can scrutinize disease symptoms and provide details regarding potential disease types. This functionality aids farmers in swiftly recognizing issues in their crops and taking essential measures.
2) After detecting diseases in crops, AgroAI-Plant offers relevant treatment suggestions. By leveraging AI analysis and accumulated data, the app can propose appropriate medications or treatments to address plant diseases. This guidance assists farmers in making informed decisions to effectively address their agricultural challenges.
3) AgroAI-Plant also facilitates the routine monitoring of plant health. With this feature, farmers can monitor the progression of crop conditions over time and detect any alterations that may occur. Such monitoring enables farmers to implement necessary precautions or treatments to prevent worsening crop conditions.
4) Furthermore, AgroAI-Plant provides insights into weather forecasts and offers advice on utilizing fertilizers suitable for prevailing soil and crop conditions. Armed with this information, farmers can adeptly plan their farming operations and ensure optimal nutrient supply for robust crop growth.
5) By utilizing the AgroAI-Plant app, farmers can streamline farm management with efficiency. Spanning from disease detection to plant health supervision, this application aids farmers in safeguarding crop vitality and productivity. Consequently, this can foster heightened farm productivity and improve crop yields.



(a) **(b)**

Figure 3. (a) Uploaded picture of a Automated plant leaf showing signs of recognition and disease sickness diagnosis Plantix is an agricultural application that serves as a virtual crop doctor; **(b)** Personally choose the The illness was plant/crop by manual automatically selection detected AgroAI is a platform for diagnosing plant diseases, currently at the early.

The AgroAI-Plant app **Figure 3**, with its array of functionalities, has the potential to serve as a highly beneficial tool for farmers in farm management. It is anticipated that the integration of artificial intelligence technology within this application will enhance farmers' understanding of the significance of plant disease monitoring and treatment, ultimately supporting more effective, efficient, and sustainable agricultural practices.

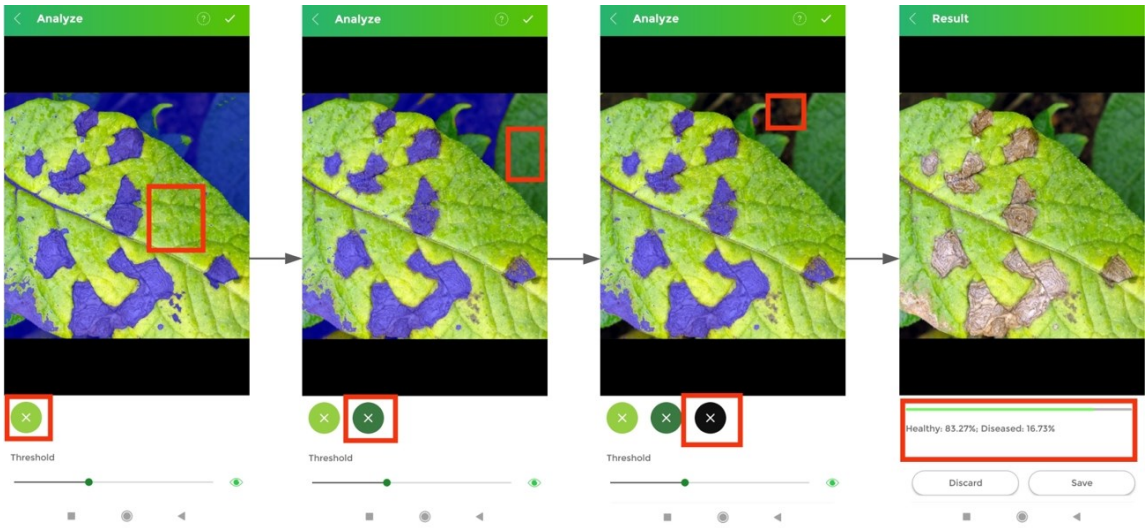


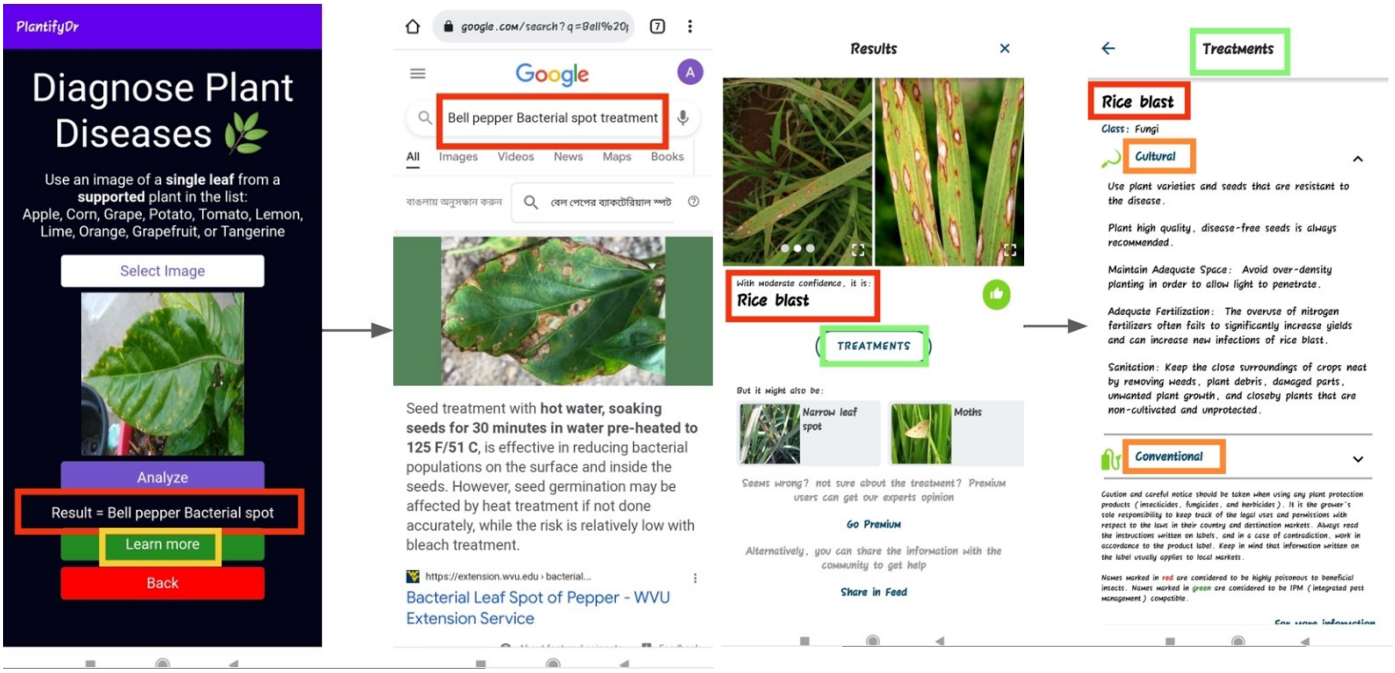
Figure 4. Identifying the severity and visualizing the affected region of the sick leaf by leaf doctor.

The Leaf Doctor application **Figure 4** presents an innovative approach to assessing the severity of diseases on plant leaves and visually representing the affected areas. The following discussion pertains to the functionalities of the Leaf Doctor app.

1) Leveraging artificial intelligence (AI) technology, Leaf Doctor can ascertain the extent of disease severity on plant leaves. By capturing photos of affected foliage, the app can scrutinize disease symptoms and offer insights into the plant's current condition. This enables farmers or plant enthusiasts to gauge the spread of the disease and respond accordingly.
2) A standout feature of the Leaf Doctor app is its capability to visualize areas affected by diseases on plant leaves. Through the utilization of augmented reality (AR) technology or visual overlays, users can visually discern disease-infected regions on plant foliage. This aids users in comprehending the plant's condition and pinpointing areas that warrant heightened attention.
3) Besides describing disease severity and visualizing affected areas, Leaf Doctor provides tailored treatment and care recommendations. Using AI analysis and accumulated data, the app provides guidance on remedial actions for treating infected plants and nurturing plant health to ensure vitality.
4) Empowered by the Leaf Doctor app, farmers can swiftly and easily detect disease symptoms in their crops. This proficiency can aid in mitigating losses stemming from plant diseases and enhance farmers' awareness of the significance of regular crop monitoring and upkeep. Consequently, this app can fortify productivity and sustainability in farming practices.

Given the functionalities it provides, the Leaf Doctor app stands as a valuable asset for farmers and plant enthusiasts seeking to enhance crop management with

efficacy and efficiency. The aspiration is that the incorporation of AI and AR technologies within this platform will elevate awareness regarding the criticality of monitoring and addressing plant diseases, while bolstering sustainable and eco-conscious agricultural practices. The extension is a dynamic process necessitating interaction between the extension worker and the person to initiate a behaviour modification process (Sulandjari et al., 2022).



(a) PlantifyDr. **(b)** AgroAI–Plant.

Figure 5. Screenshots showing the therapy functionality in the app(s).

In recent years, there has been considerable interest in the use of artificial intelligence (AI) for the detection and diagnosis of plant diseases. As shown in **Figure 5** above, the use of the AI applications PlantifyDr and AgroAI-Plant is illustrated. Scientists have explored the use of deep learning models to identify and diagnose plant diseases (Ferentinos, 2018; Lee et al., 2020). These models harness AI technologies to automate and enhance the process of detecting and diagnosing plant diseases, thereby facilitating early intervention and effective disease management.

Studies have demonstrated that AI can play a pivotal role in transforming disease diagnosis across various sectors, including medicine and agriculture. AI has been likened to clinicians in disease diagnosis, underscoring its potential to offer precise and efficient diagnostic results (Shen et al., 2019). Moreover, the integration of AI into clinical workflows has been underscored, focusing on elements such as data sharing, privacy, algorithm transparency, and interoperability (He et al., 2019).

In the agricultural domain, AI applications have been pivotal in enhancing crop management and agricultural productivity. AI technologies empower swift diagnosis of plant diseases, effective application of agrochemicals, and the delivery of location-specific agronomic guidance to farmers (Tzachor et al., 2022). Additionally, the creation of AI-driven mobile systems for automating plant leaf disease diagnosis processes exemplifies the practical implementation of AI in agriculture (Ahmed and Reddy, 2021).

The importance of machine learning in plant disease research has been highlighted, especially in the detection of plant resistance genes and the classification of plant illnesses (Yang and Guo, 2017). Moreover, the integration of artificial intelligence (AI) and the Internet of Things (IoT) has led to the development of illness detection models for intelligent healthcare systems, emphasizing the capacity of AI to improve healthcare procedures (Mansour et al., 2021).

5. Conclusion

The use of artificial intelligence (AI) in the detection and diagnosis of plant diseases has provided substantial benefits for the agricultural industry. AI technology enables farmers and agricultural professionals to quickly and precisely identify illnesses affecting their crops, allowing them to promptly execute preventative and corrective actions to reduce losses caused by these diseases. Furthermore, artificial intelligence assists in predicting the advancement of illnesses using past data, enabling farmers to take proactive measures in dealing with plant diseases and improving agricultural output. However, using AI for the purpose of identifying and diagnosing plant diseases requires a significant investment in the development and training of a reliable AI system. Furthermore, it is crucial to give utmost importance to the concerns of data security and privacy for farmers who are using this AI technology. Ultimately, the use of AI in the detection and diagnosis of plant diseases has significant potential to improve agricultural performance. However, it is crucial to exercise careful management in order to mitigate risks and guarantee the long-term viability of its implementation.

Author contributions: Conceptualization, LJ and IWS; methodology, BSS; software, A; validation, A, S and BSS; formal analysis, S; investigation, ZW; resources, EAM; data curation, S; writing—original draft preparation, A; writing—review and editing, EAM; visualization, ZW; supervision, LJ; project administration, ZW. All authors have read and agreed to the published version of the manuscript.

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