A Comprehensive Review of Research on Disease Prediction in Plant Leaves

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***Abstract*— In agriculture, plant disease detection at an early stage is significant. Plant leaves are an important factor in plant disease detection. Early disease prevention in-line harvest loss benefit is given to plant growers. The odd leaves can be visible after getting infected, and if the software can tell accurately the disease infestation result. Forecasting plant leaf disease works better for an early disease warning. The infected leaf needs to be permanently removed, or it will affect the plant. As leaves are a significant part and produce food from the sun, the infected leaves show different patterns. Many proposing such AI and ML models have forecasted the infected leaves of many plants. This document focuses on forecasting diseases in plant leaves mainly for four types of plants: tomato, potato, apple & grape. Diseases in plant leaves can cause significant damage to plants and can have a detrimental effect on both the quantity and quality of production whether we consider a lower scale kitchen gardening or a high scale agriculture farming. The research begins with an overview of the common plant leaf diseases found in each of these four plants, along with their symptoms and causes. It then discusses the importance of early detection and management of these diseases to ensure healthy growth. This helps a naïve gardener as well as an experienced farmer to prevent a plant or a whole field from getting infected or diseased. Plant disease detection approaches are crucial for prevention and management. Various techniques in plant disease detection using AI-based machine learning and deep learning methods are reviewed comprehensively.**

Keywords— Agriculture farming, Kitchen Garden, Plant leaf diseases, Forecasting diseases.

I. INTRODUCTION

Forecasting diseases in plant leaf is a significant challenge for farmers and naïve gardeners, and early detection is crucial to prevent yield losses. Diagnosing plant diseases by observing symptoms on plant leaves optically is highly complex. Even experienced agronomists and plant pathologists often struggle to accurately diagnose specific diseases due to this complexity and the vast number of cultivated plants with their associated Phyto-pathological issues. For a kitchen Gardeners, it is even more difficult due to lack of knowledge in the field of planting and pests. As a result, they frequently reach mistaken conclusions and administer incorrect treatments. With advancements in deep learning, computer vision-based techniques have shown great potential in detecting and predicting diseases in plant leaf. An automated computational system for detecting and diagnosing plant diseases would be immensely valuable, providing assistance to agronomists tasked with diagnosing diseases through optical leaf observation. The study involves the use of data from four different types of plants, namely Tomato, Potato, Apple, and Grape.

The dataset needed for this study comprises images of healthy and diseased leaves of respective plants. The images should be collected from different sources and pre-processed before being analyse variation in diseases for generalised and plant specific symptoms.

Fig 1. Leaves of Diseased Plant [1]

The study focuses on evaluating dataset used for the study comprises images of healthy and diseased leaves of four different types of crops, namely Tomato, Potato, Apple and Grape. By using multiple architectures, we aim to identify the best-performing model for each crop and compare their performance against each other.

The motivation behind suggesting such model is to make it easily accessible for farmers and gardeners to get predictions on whether the leaf is healthy or diseased. This would enable both the categories, Gardner and Farmer to an early identification of disease in plants, make decisions, and take the necessary actions to prevent further damage.

If the suggested model forecast diseases accurately and efficiently in plants leaf that can further spread and contamination major growth, thereby helping farmers in making informed decisions, preventive measures at early detection and reduces yield losses.

Now a days, Deep learning methods have emerged as effective tools for plant disease detection, offering high accuracy. The study suggests a theory to compare different DL architectures and compare their performances in identifying disease in plant leaf accurately. This study will help finding the best AI machine learning model, with the highest accuracy will be considered the best model for crop leaf disease prediction. The project aims to provide a useful tool for a naïve Kitchen Gardner as well as for an agile farmers to identify disease in plant leaf early and take appropriate measures to prevent the spread of the disease and minimize yield losses.

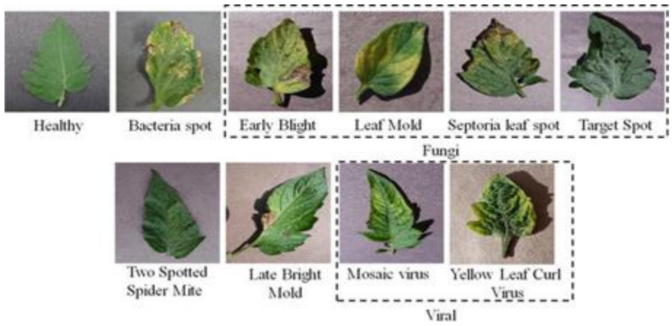

FIG 5. TOMATO HEALTHY AND TYPES OF DISEASE [2]

Fig 4. Potato Healthy and Types of Disease [3]

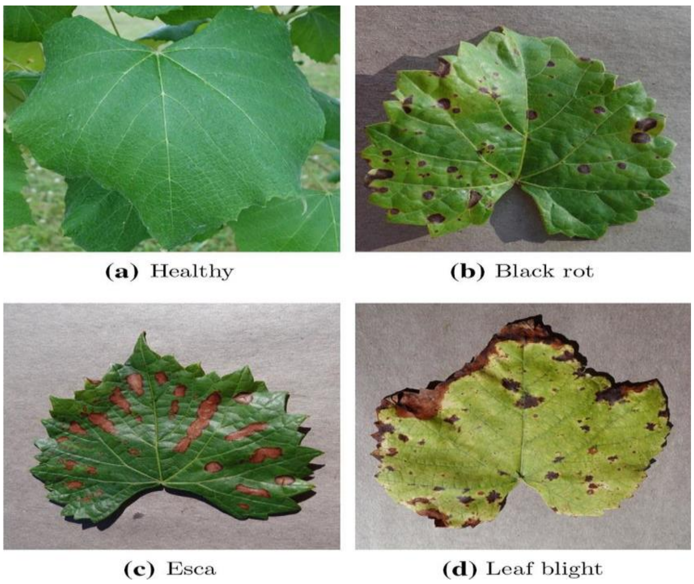

Fig 3. Grape Healthy and Types of Disease [4]

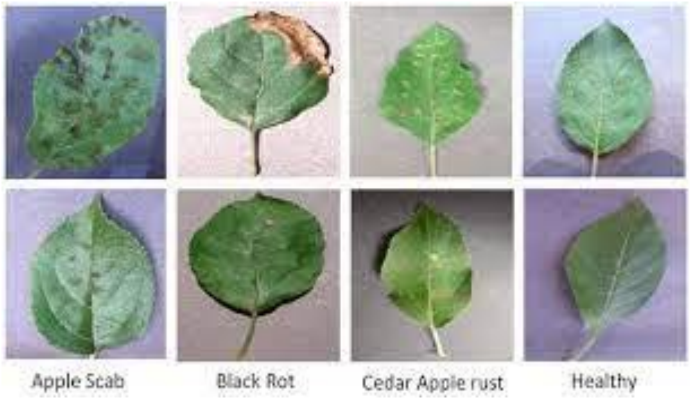

Fig 2. Apple Healthy and Types of Disease [5]

II. LITERATURE REVIEW

Agriculture is a vital sector for ensuring food security and economic development worldwide. Crop diseases are one of the most significant threats to agricultural production, resulting in significant yield losses, reduced food availability, and increased use of chemical pesticides. The early detection and diagnosis of crop diseases are crucial for timely and effective management.

Recent advances in deep learning and computer vision have shown promising results in detecting and classifying plant diseases from images. Several studies have explored the use of deep learning algorithms for crop disease identification, including convolutional neural networks (CNNs) and transfer learning approaches.

Experts from different domains have suggested a range of algorithms and architectures to fine-tune the functionality of different suggested models, aiming to boost the current scenario in field of agriculture that can help in increasing the efficiency and improve overall farming and gardening sector.

However, few studies have explored the performance of multiple deep-learning architectures for detecting crop diseases across multiple crop types. Therefore, this thesis aims to investigate the performance of five different deep-learning architectures for detecting crop diseases across four different crop types: Apple, Grape, Potato, and Tomato.

Based on the study of numerous authors' work, the following information is gained regarding the Plant Disease. These proposed permutations of different models can help in analysing the most efficient algorithm to opt and improvise.

Shima Ramesh ET. Al. [6] proposed a method to distinguish the illness introduce in a plant by watching its morphology by picture handling and machine learning. They used Random Forest algorithmin to differentiate between healthy and diseased leaf from the data sets created. For extracting features of an image they used Histogram of an Oriented Gradient (HOG). The objective of their proposed algorithm is to recognize abnormalities that occur on plants in their greenhouses or natural environment. Modern approaches such as machine learning and deep learning algorithm increases the recognition rate and the accuracy of the results over various Laboratory based approaches or techniques that have been employed for disease identification. Random forest classifier, the model was trained using 160 images of papaya leaves. The model could classify with approximate 70 percent accuracy.

Khirde ET. Al. [7] reviewed different segmentation and feature extraction algorithms that may be used to diagnose plant illnesses using images of their leaves in their literature survey. Manually detecting plant illnesses is extremely tough due to time, understanding of plant diseases, and labour. As a result, the author has divided the entire process of identifying plant leaf diseases into five steps, which are as follows: a) Image acquisition; b) Pre-processing; c) Segmentation; d) Feature extraction; e) Disease classification. For RGB leaf image capture, the transformation structure was utilized. The picture is then pre-processed to reduce noise and improve contrast. Next, segmentation separates an image into multiple feature parts using K-means clustering, outs filters, and other techniques. This segmented picture is then utilized to extract features before being classified using a variety of classification techniques.

Singh ET. Al. [8] proposed an algorithm for image segmentation technique which is used for automatic detection and classification of plant leaf diseases. The numbers of leaf disease samples that were classified into five classes of leaf disease those are, bacterial leaf spot, Frog eye leaf spot, Sun burn disease, fungal disease, early scorch by using proposed algorithm. The leaves of banana, beans, lemon and rose plants are used to train and test the model. The detection accuracy is 95.71% with proposed algorithm.

To classify the Downey Mildew and Anthracnose watermelon leaf diseases, Kutty ET. Al. [9] used a neural network-based technique. This classification is based on the RGB colour model's extraction of colour features from identified pixels in the region of interest which involves the process of diseases classification using Statistical Package for the Social Sciences (SPSS) and Neural Network Pattern Recognition Toolbox in MATLAB. Determinations in this work have shown that the type of leaf diseases achieved 75.9% of accuracy based on its RGB mean colour component.

Sannakki ET. Al. [10] proposed methodology to diagnose the disease using image processing and artificial intelligence techniques on images of grape plant leaf. They developed a feed-forward back-propagation Neural Network-based approach to identify and categorize illnesses in grape leaves. Best results were observed when Feed forward Back Propagation Neural Network was trained for classification. The results were tested on downy mildew and powdery mildew matrices, with actual positive and false-positive para-author claims to have an accuracy of about 100% when using the colour characteristic alone.

Zhang ET. Al. [11] proposed a new approach to automatically detecting citrus canker from citrus leaf images captured in field. A hierarchical detection strategy was introduced to segment lesion leaf images captured in field from background, which is different from previous research based on images collected in a laboratory environment. The experimental results demonstrated that the proposed approach leaded to a higher classification accuracy than other methods. However, the proposed method aims to work from a remote place and to quickly obtain an initial detection result. It can be used as an early detection/warning system to detect canker disease at their very early stage or as a server-based remote pre-detection method using images transmitted through internet

The major aim of Rao ET. Al. [12] was to generate an automated process to introduce a low-cost and high accuracy solution for disease detection using digital signal processing methods over manual and microscopy inspections. Image signal processing is carried out in 3 phases: First, illumination and noise related issues are solved using image enhancement techniques. Subsequently, we developed a combined feature extraction technique by using GLCM, Complex Gabor filter, Curvelet and image moments. Lastly, using the extracted features, Neuro-Fuzzy Logic classifier was trained. The average classification accuracy using proposed feature extraction and combined form of shape, colour and texture gives 91.74% & 93.18%.

Sujatha ET. Al. [13] aimed to classify citrus leaf disease using both methods ML (SGD, RF, SVM) & DL (Inception-v3, VGG-16, VGG-19) to find out which one of these is performing better in disease detection. We observed their work for comparison between ML and DL because we are proceeding with deep learning algorithms. ML is meant for parsing the data and learning from it. Based on the requirement they applied to get the decision. Several algorithms were developed to address the various tasks of classification, clustering, association rule mining, outlier detection, and so on. Deep Learning is part of the evolution of ML that addresses the various types of datasets in a compatible manner. For the task of image recognition, CNN is used in a great manner in the deep learning environment. It is conveyed that a DL classifier helps in a better understanding of the considered dataset along with the deployed architecture. The flow of work begins with the citrus leaf disease dataset and for the process of multi-class classification used the ML and DL classifiers to make the predictions.

C Jackulin ET. Al. [14], this paper adapts the artificial intelligence logic in order to identify the plant leaf disease and providing the appropriate alert to prevent plants from the diseases as well as avoiding the huge loss ahead. Though a great deal of noteworthy progress was noticed in recent years, there were still some research gaps that should be addressed and to implement effective techniques for plant disease detection.

Mitali V. Shewale ET. Al. [15] proposed a method to classify diseases with high precision by automatically extracting features thereby eliminating the feature engineering and threshold segmentation process. The proposed model is a feed-forward network eliminating the need of feature engineering and manual pre-processing. This helps to reduce the time computation and model complexity. By reviewing their work and results presented in their study which includes both the augmented and original dataset. Initially they performed the experimentation by varying the input image size to check which dimensions provide with highest accuracy. From the graphical representation it is clearly observed that higher image dimension has produced the highest accuracy as the model in this case is able to extract maximum information thereby increasing its learning capability. We also, evaluate all five models on the basis of accuracy, precision, recall and F1Score.

Konstantinos P. Ferentinos ET. Al. [16] suggested that CNNs constitute one of the most powerful techniques for modelling complex processes and performing pattern recognition in applications with large amount of data, like the one of pattern recognition in images. This implementation uses Torch7 machine learning computational framework, which uses the LuaJIT programming language, in Linux environment.

Pushkara Sharma ET. Al. [17] proposed AI-based automatic plant leaf disease detection and classification, aiming to enhance crop productivity. Methodology involves image collection, pre-processing, segmentation, and classification. Different machine learning and deep learning algorithms like logistic regression, KNN, SVM and CNN are trained and compared on the basis of accuracy. As we have already discussed in [15] focusing on one parameter is insufficient to evaluate different methodologies and algorithms.

Ravindra Jogekar ET. AL. [18] summarised that, different methods delve into larger and more diverse datasets, enabling the identification of subtle patterns indicative of disease. Still there exists confusion among system designers regarding the most effective combination of algorithms for disease classification. To address this, it's crucial to compare and objectively evaluate existing techniques, identifying the most effective fusion of algorithms for developing highly accurate disease classification systems.

By continuously refining and innovating these techniques, we can improve agricultural sustainability and ensure food security in the face of evolving disease threats in our work.

The proposed solution of Marko Arsenovic ET. Al. [19] included creation of a new dataset containing labeled images from real environments, an augmentation method based on GANs, and a two-stage algorithm for real-time disease detection. But the existing models often fall short in real-world conditions, prompting the proposal of a novel approach for plant disease detection. A new dataset was introduced, featuring images of leaves in real environments, labelled for classification and detection tasks, enhancing model accuracy and practical usability.

Objective of Maltesh I G ET. Al [20] was to reduce pesticide usage in agriculture and increase both the quality and quantity of production. Plant diseases can be detected using image processing techniques. The proposed method involves image processing techniques to identify and display the affected parts of leaves. Common signs of plant diseases include water-soaked spots and changes in leaf colour or texture. Neural networks and Otsu's algorithm are used to analyse the infected area of plant leaves and detect diseases.

Sachin B. Jadhav ET. Al. [21] proposed a method for identifying soybean diseases using a transfer learning approach with pretrained AlexNet and GoogleNet convolutional neural networks (CNNs), and a classifier model for distinguishing between one non-disease class and three disease classes (bacterial blight, brown spot, and FLS).

Santhosh Kumar ET. Al [22] presented a survey of different plant diseases and advanced techniques for their detection. Biomedical methods, particularly image processing, are efficient and reliable for detecting plant diseases using leaf images. This literature survey emphasizes the importance of disease detection for both plants and humans. The author highlights the significance of image processing in agriculture and suggests further research on specific types of diseases.

Pruthvi P. Patel ET. Al. [23] proposed the method to detect both crop diseases and pests. The paper reviews deep learning techniques for disease and pest detection and proposes a deep learning model for automatic diagnosis of crop diseases and pests. A survey conducted in the agriculture field revealed that some existing works do not utilize images of every infected part of the crop, lack field-conditioned images, and do not combine disease and pest detection. Also, the proposed method processes images of all infected parts of the crop, including the upper and lower sides of leaves, stems, roots, and fruit images, hereby using fine-tuning technique for the CNN model to identify crop diseases and pests using deep learning.

Inzamam Mashood Nasir ET. Al. [24] proposed a hybrid classification method is proposed, combining a Deep Convolutional Neural Network (DCNN) model with Pyramid Histogram of Oriented Gradient (PHOG) features for fruit classification. Their final proposed approach combines a deep neural network (VGG19) with contour feature extraction using PHOG. The classification process utilizes 5G and cloud technology, where images captured on a smart device are transferred to the cloud via the 5G network. Looking at the present scenario, the proposed methodology has to overcome another technology barrier of high-speed internet and compatible devices those are not yet available in country sides or villages.

Prof. Parvaneh Basaligheh ET. Al. [25] proposed their theory for advancement in domain of precision agriculture through deep learning algorithms for accurate diagnosis and continuous monitoring of plant diseases. The proposed model is trained on an extensive dataset of plant photos depicting various illnesses, enabling it to identify subtle visual cues that may be overlooked by human observers. Combining state-of-the-art monitoring systems with powerful deep learning models like CNN and ResNet-50 allows for accurate and fast disease identification and control. ResNet-50, in particular, has shown outstanding performance in disease identification, exhibiting excellent F1 scores, recall, accuracy, and precision.

Suranjit Mandal ET. Al. [26] proposed a method for utilization of machine learning models for disease detection and classification. Emphasizes the importance of integrating computer vision, machine learning, and deep learning into automated devices like smartphones for modern agricultural practices. They also suggested for future research should focus on extending disease detection systems from lab to field conditions, maintaining high accuracy, and prioritizing the development of novel image processing algorithms to facilitate the segmentation and extraction of leaf lesion features, especially in complex scenarios.

Shivani S. Dagwale ET. Al. [27] proposed a Method for predicting leaf species and disease using artificial intelligence, which seems a useful tool for identifying plants and detecting disease in agriculture, forestry, etc. in comparison with current techniques those require time and resources for laboratory diagnosis. This review paper highlights the utilization of the PlantDoc dataset, Ice Vision framework, and YOLOv5 model across 13 plant varieties. This study contributes to the advancement of computer vision and machine learning in agricultural research. Machine learning models show great potential in plant disease detection, and early detection of plant diseases can prevent spread of infections, increase crop yields, and improve food security.

Ajay Kumar ET. Al. [28] proposed a research with a primary goal to develop a deep learning-based system for forecasting and classifying crop leaf diseases and the system's performance is expected to reach a new peak. Their work suggest a swift response to disease outbreaks in vegetable crops, particularly potatoes, is vital to prevent production losses, as signs of disease often appear first in leaves and stems. Recent advancements in deep learning allow leaf image-based disease classification. The study aims to develop a deep learning system using Inception V3 and classification algorithms (SGD, SVM, Logistic regression) for forecasting and categorizing crop leaf diseases, expecting peak performance.

Sandeep K H ET. Al. [29] proposed study to evaluate the disease-affected region of the leaf and assess the severity of the diseases, and illnesses are detected using K-means clustering with fuzzy logic in machine learning models for convolutional neural networks and K-nearest neighbours. India's sizable agricultural market provides the perfect conditions for cultivating a variety of products, including the tomato harvest. Detecting the transmission of diseases from unhealthy to healthy plants poses a severe threat to the agricultural industry because, if caught early enough, they can quickly spread and perhaps infest the entire farm. In terms of profit in good forming, early stage crop disease identification and severity monitoring is quite important. Finding diseases early helps farmers make more money and keep their crops healthy.

Ravi Kumar Gupta ET. Al. [30] suggested an automated system which could easily detect the plant diseases beforehand and could easily help in overcoming them by suggesting the measures and techniques to overcome them is required so that agricultural productivity could be increased, and agricultural production could be done properly with vast production of good quality crops which in turn help in growth of the authors' nation. Traditional methods of disease monitoring by experts are expensive. The suggested automated systems for disease identification could revolutionize crop monitoring. The studied research revolves around observing various diseases hamper plant growth and agricultural productivity. The necessity for developing an application to predict and manage diseases becomes paramount. Agriculture is vital for India's economy and it demands meticulous attention.

In today's agricultural environment, there's a critical demand for innovative solutions that can swiftly identify affected crops and provide effective remedies. This necessity is particularly significant for small-scale kitchen gardeners, plant and flower nursery owners, and most primarily, agriculture rural communities. Efficient disease management, achieved by reducing diagnosis time and preventing the spread of contagious infections, is vital for these stakeholders. In one survey on Random Forest classifiers [6], it was noted that while these classifiers can address the overfitting issue in their training dataset and are adept at handling both numerical and categorical data, the achieved classification accuracy in their study was approximately 70%, falling below the desired expectation. Restricting the identification to only five disease categories may not provide an effective solution. However, upon comparison with this study [8], we observed that our proposed dataset encompasses a wider range of diseases, offering a more comprehensive approach for diagnosing plant-specific illnesses. The symptoms obtained [12] lack precise information, including boundaries and tissue details, posing challenges in accurately defining the affected region. Furthermore, different diseases may exhibit symptoms in combined or hybrid forms. Despite utilizing proposed shape feature extraction and a combined approach incorporating shape, colour, and texture, the average classification accuracy only reaches 91.74% and 93.18%, respectively. This indicates that the current approach may not effectively meet the present requirements. The research presented in [21] examines only three types of diseases and the model solely distinguishes between diseased and non-diseased leaves. Conversely, our approach is geared towards identifying specific diseases affecting plants, empowering users to take early corrective measures.

III. CONCLUSION

The primary aim of this survey paper is to serve a wide range of audiences, encompassing kitchen gardeners, plant nursery owners, and agricultural farmers. Our objective is to design an automatic disease detection system capable of identifying a wide array of diseases in crops, thus providing valuable assistance to farmers and kitchen gardeners. Furthermore, we anticipate that this research will be beneficial to scientists actively involved in plant disease detection studies. After analysing multiple research studies, it's evident that introducing a deep convolutional neural network-based model for leaf image classification architecture is essential to address this need. Despite significant progress in recent years, there are still research gaps that need to be addressed to implement effective techniques for plant disease detection. Hereby we propose a CNN model for leaf disease identification and classification. Furthermore, the proposed study analyses five different CNN Algorithms to identify the most user-friendly solution that achieves high performance and accuracy and become foundation architecture for the implementation Model. Our objective is to contribute by identifying the most efficient model among these promising options. The study involves the use of data from four different types of plants, namely Tomato, Potato, Apple, and Grape.

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