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DETECTION AND CLASSIFICATION OF PLANT LEAF DISEASES USING DIGTAL IMAGE PROCESSING METHODS: A REVIEW

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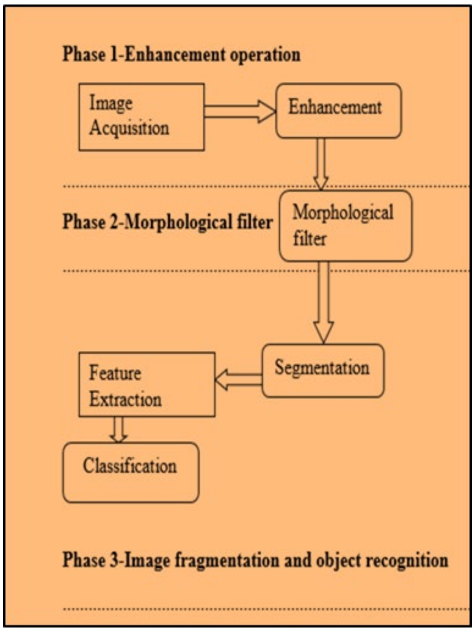
Graphical abstract



Abstract

Prediction and classification of plant leaf illnesses by farmers using conventional approaches can be unexciting and erroneous. Problems may occur while trying to predict the sort of illnesses manually. Inability to detect diseases of plants promptly could lead to the destruction of crop plants and this can cause serious decline in the yield. Losses can be prevented and yield be maximized when farmers adopt computerized image processing approaches in their farms. Numerous techniques have been proposed and used in the prediction of diseases of crop plants based on the images of the infected leaves. Researchers have in the past achieved a lot in the aspect of plant illnesses identification by exploring several techniques and models. However, improvement needs to be provided on account of reviews, new advancements and discussions. Deploying technology can greatly enhance crop production across the globe. Different approaches and models can be trained with huge data to identify new improved methods for uncovering diseases of plants to tackle problem of low yield. Previous works have determined the robustness of various image processing techniques such as; K-means clustering, Naive Bayes, Feed forward neutral network (FFNN), Support Vector Machine (SVM), K-nearest neighbor (KNN) classifier, Fuzzy logic, Genetic Algorithm (GA), Artificial Neural Network (ANN), Convolutional Neural Network (CNN) etc. This paper provides a critical review and results of different types of approaches and methods used previously to detect and classify various types of plant leaf illnesses using image processing approaches.

Keywords: Classification, Computerized, Image Processing, Plant Diseases, CNN.

1.0 INTRODUCTION

One of the main problems of rice production is plant leaf disease. The disease can destroy the crop and this could lead to decrease in the yield [1]. Farmers find it difficult to classify and detect plant leaf diseases. The old method of detecting diseases by means of physical observation is not always accurate and therefore could lead to serious decline in agricultural production [2]. Plant diseases temper with the leaf first before it infects the entire plant thereby decreasing the quality and quantity of the yield [3]. Recent advancements in deep learning have brought about numerous methods that can be used to identify and classify illnesses of plants using images of the infected plants [4]. Prompt identification of plant diseases is significant to achieving better crop yield [5]. Plant diseases affect the yield of crop plants due to its destructive effect on the crop [6].

In agriculture, identification of plant diseases is a major challenge for both farmers and experts [7]. Agricultural losses can be stopped by using digital image processing techniques to detect and classify diseases [8]. Artificial intelligence improves crop yield by identifying plant leaf diseases at an early stage before destruction spreads to other plants in the farm [9]. Accurate classification of plant diseases will not only increase crop yield but can also provide support for various cultivation methods [10]. Every country needs farming for production of crop for her needs and also for its economic strength. If crop plants are attacked by diseases the country's production and its economy is also affected [11]. Selecting an effective approach for image processing is always a difficult task owing to the disparities in data. Large datasets demands sophisticated techniques like CNN to produce better result. Larger datasets produce higher accuracy rate [12]. Image processing can be applied in areas such as Biology, Agriculture, Medicine etc. Nigeria is a farming society. Over 80% of the country's population engage in small scale farming [13]. Agriculture has offered jobs to more than 35% of the Nigeria's population [14]. Swift growth in the population has made lands for farming so scarce. As a result of this, crop production has declined in Nigeria and the world over [15].

Plant disease is a big challenge faced by agricultural sector. In India, for instance crop yield is affected by Plant diseases due to its devastating effect on plants [16]. Prompt uncovering or identification of illnesses can help greatly in tackling the problem of poor crop production. Manual prediction of the diseases is time consuming and may not be accurate. With deployment of technology, precision agriculture could be achieved. This can boost crop production across the world. The process of classifying plant leaf illnesses can be digitalized by adopting different models and algorithms.

Computerized image processing techniques are key to identifying plant diseases at an early stage before damage is done to the entire crops. In Asia, most especially India, 70% of its population depend on farming. Adopting computerized image processing methods in the field can help boost the economy of India and the world at large [17]. Deep learning techniques can be used to promote agricultural businesses. This paper focuses on analysis of over 100 literatures in the areas of classification of crop plant illnesses using different computerized image processing approaches. Identifying a robust technique to be used is paramount in achieving better yield.

2.0 LITERATURE REVIEW

This section presents and reviews different techniques and methods used in image processing. Table 1 below, summarizes various literatures in artificial intelligence, Machine learning and deep learning.

The authors in [18] give a summary of various techniques used in detecting and classifying plant leaves disease. The research established that image processing techniques can provide efficient and accurate way of classifying plant leaves disease. Authors in [19] carried out a research by using GLCM, K-means and SVM techniques to classify diseases on the images of citrus leaves. The research yielded a classification accuracy of 90% by using their proposed method. The authors in [20] developed a system to detect diseases on wheat crops using image processing technique. This work has contributed significantly in the automation of agricultural methods and processes.

A computer aided image processing model that can detect plant leaf diseases has been developed in [21]. The authors used K-means clustering and SVM classifier to classify cucumber leaves diseases. Uncovering plant illnesses at an early stage is key to maximizing yield [22]. The researchers in [23] carried out a research to study five different modern models of deep learning. ResNet101V2 produce the best result with an accuracy of 86.799%. The authors in [24] proposed a model for identification of paddy leaf diseases. The authors combined SVM classifier and deep CNN techniques to achieve 97.5% recognition accuracy.

Authors in [25] proposed a model to detect groundnut leaf disease using KNN algorithm. Fungi, bacteria, virus, etc. can cause plant diseases. Image processing methods can be used to recognize plant diseases based on the images of the affected leaves [26]. The authors in [26] used SVM and K-means clustering to achieve an accuracy of 88.89%. Decline in the volume of crop production is as the result of crop plant diseases that affect farmlands. Early detection of the illnesses controls the disease and stops it from spreading across the farm [27]. Computerized method for classification of soybean plants has been used to develop a decision support system that offers advice to users. Authors in [27] achieve a classification accuracy of 93.79%. A new architecture called Plant Disease Detection Neural Network (PDDNN) for successful detection of plant diseases using CNN model has been used to classify diseases of plants [28].

Farmers cannot accurately identify plant diseases with naked eyes and if the illness is not uncovered on time it may affect the entire farmland or even a neighboring farm. For an efficient and early detection of disease modern computer technology must be used. AlexNet and GoogleNet architecture of CNN were used to achieve overall classification accuracy of 86.00% [28]. The economic fortune of every country depends on the quality and quantity of its crop production. The production can be significantly enhanced by classifying the diseases at an early stage. Mere observation by naked eyes waste time and resources. Technology ensures success through quicker and accurate identification of plant leaf diseases [29].

Deep Convolutional Neural Network (Deep-CNN) had been used in [29] to detect cotton leaf disease. The authors in [29] use MATLAB to implement their method and confusion matrix to classify categories of diseases. Their result yielded 96% average accuracy. Anand et al. [30] propose a method for detecting diseases of brinjal leaf plant using image processing and artificial neural techniques. The authors in [30] used K-means clustering algorithm for segmentation and Artificial Neural network (ANN) for classification. Authors in [31] have conducted a research using deep learning to detect tomato leaves diseases. They used an algorithm that run in real time on robot to detect diseases of tomato plants. The researchers in [32] have conducted a research on tomato leaf disease using CNN. The authors in [32] have achieved a classification accuracy of 97%.

Monitoring large farms with automatic techniques can be beneficial to farmers because it reduces tedious work of close observation by experts which needs a lot of money. Automatic techniques use algorithm for image segmentation in classifying plant leaf disease [33]. The authors in [33] used MATLAB to conduct their experimentation.

A new image recognition system based on multiple linear regressions using improved histogram segmentation method has been proposed in [34]. Their method was effective because appropriate threshold can be found automatically. Vision based automatic prediction of crop plant diseases using digital image processing is important [35]. The research used K-mean algorithm for color segmentation and GLCM for classification. Superb result and promising performance were achieved. The authors in [35] propose that their system reduces time of detection and labor cost. Early discovery and identification of plant leaf disease using computerized imaging approaches can help in increasing agricultural production [36]. The authors in [36] have reviewed various methods of leaf plant diseases detection used by various researchers in the past. Their paper presents a critical review of various classification strategies in image processing.

Reddy et al. [37] have conducted a comprehensive review of different methods and approaches used in identifying plant diseases. They have provided a review on various recognition methods that can be employed to detect and predict plant diseases. The authors in [37] examined that K-nearest neighbor (KNN) method is the simplest approach for prediction of diseases, but it is constrained by time complexity. The study further revealed that neural networks are tolerant to noisy input but complex to comprehend the arrangement of the algorithm. SVM is the best available machine learning algorithm in recognizing high dimensional datasets [37].

Different disease recognition approaches can be adopted to identify diseases of crop plants. To improve the recognition rate in classifying diseases; various techniques should be used [38]. Farmers have limited knowledge when it comes to accurate identification of plant diseases. Recent research has revealed that computerized image classification systems based on CNN structure can help in tackling the problem of inaccurate identification. Dataset for rice plant disease is not easily available [39]. The authors in [39] have developed their own small dataset to achieve an accuracy of 92.46%.

Devaraj et al. [40] write a paper that highlighted the importance of using image processing techniques to detect plant diseases based on the images of the infected leaves. The researchers in [40] developed a software system solution that detect and classify images mechanically. They discussed the steps involved in the process of classification from loading the image to classifying its illness. MATLAB could be used to add images and process them automatically based on SVM [41].

Farmers lack full knowledge of leaf plant diseases and so they need to be guided on how to use computerized image processing methods [42]. The researchers in [42] proposed system that supports android app. The model offers efficient way to detect and classify plant diseases. The system uses CNN to classify plant leaf diseases.

Future trends in plants and pests' diseases detection based on deep learning hold a number of challenges. However, possible solutions and general suggestions can be obtained in practical application of various methods of plant leaf disease detection [43]. Tackling issue of recognizing and analyzing plant illnesses involves adopting technology [44]. The authors in [44] proposed method of processing and classifying potato leaf disease image using several Classifier algorithms to achieve a classification accuracy of 97.00%.

Kowshik B. et al. [45] have developed a methodology that aimed to develop CNN-based strategy for detecting and identifying plant leaf disease. CNN and Deep Neural Network can be used to identify crop diseases and their symptoms efficiently and accurately. Authors in [46] designed a system that used Deep-CNN approach to classify guava leaf diseases. Their method used AlexNet strategy based on Deep-CNN model to achieve 98.74% accuracy. A research has been carried out in [47] to study different types of crop plant diseases.

A. R., Bhagat, et al. [48] develop a model using Inception v3. The model has been evaluated based on three classification metrics. The authors have carried out a review on detection of plant illnesses. They also established that CNN has greater capacity to produce accurate result. A CNN method of detecting plant diseases has been developed in [49] using 14 plants species and 26 illnesses. The model in [49] has achieved a testing accuracy of 99.35% by using AlexNet and GoogleNet. Authors in [50] used ANN to develop a model that produced a classification accuracy of 80% on cotton leaf. ANN has been used by several researchers to classify plant leaf diseases. In [51] a research has been conducted on 169 images using ANN. Their method in [51] yields an accuracy of 92%. Another comparative study has been carried out in [52]. Various neural networks that have been used previously by different researchers have been studied and reviewed. The authors in [52] have established that ANN and CNN are the most widely used neural networks.

Deep learning methods play significant role in identification and recognition of plant leaf illnesses [53]. Deep learning approaches are reliable in classifying diseases of plants. The authors in [53] use CNN to identify diseases of different crop plants to achieve an accuracy of 98%. Malti K. et al [54] perform a research on automatic classification of plant leaf diseases using MATLAB. The authors in [54] carried out an experiment on beans and tea leaves to achieve an accuracy of 98.2% and 98.4% respectively.

According to [55] digital image processing methods are needed in the field of agriculture. The authors in [55] carried out a comprehensive review of various past researches on plant leaf diseases identification using image processing techniques. In [56] a review on detection of plant leaf diseases using digital image processing methods have been conducted. The efficiency of various methods of image processing has been highlighted. The authors in [56] establish that most researches prefer neural networks to other methods. Authors in [57] conducted a research on groundnut leaf disease using back propagation method to classify four classes of illnesses. Their work yielded 97% accuracy.

Authors in [58] conducted a thorough survey of recent works on plant leaf disease classification using digital image processing approaches. The authors in [58] establish that deep learning methods are superior to other approaches provided huge data is made available. Neural network classifiers produce better output and efficiency when it comes to plant leaf illnesses [59]. The authors in [59] carried out a research on Phyllanthus Elegans wall using multi-layer perceptron (MLP) and Radial Basis Function (RBF). Their methods produce an accuracy of 90.15% and 98.85% respectively. The authors in [60] performed an experiment using cotton and soybeans leaves on four different diseases; Angular leaf spot, bacterial pustule, bacterial gummosis and bacterial blight. They achieved accuracy of 83%, 80%, 80% and 70% respectively.

In [61] a research has been performed on plant leaf illnesses recognition using CNN with Bayesian algorithm. The authors in [61] used over 20,000 images of potato, tomato and pepper bell to achieve an overall accuracy of 98.9%. Authors in [62] examine four diseases; leaf blight, black rot, stable and black measles grape plants diseases. The authors used hybrid CNN with feature reduction to achieve total accuracy of 98.7%. Automatic recognition of plant leaf disease using leaves of plants is crucial in the aspect of farming. Prompt identification and early control of plant diseases are significant in enhancing production [63].

CNN has produced reliable result in the aspect of image processing [64]. Gurleen K. et al. [65] undertake a review on the efficiency of some methods used in classification of plant leaf diseases. The authors summarize different methods of classifying plant illnesses using image processing. Ehsan K. et al [66] conducted a research on strawberry leaf diseases using soft-computing. The authors in [66] have achieved a total accuracy of 96%. Disease of Solanum trilobatum plant leaf has been identified in [67] using Graythresh in MATLAB. Researchers in [68] proposed a sophisticated method for crop disease identification using computer vision and machine learning algorithms.

The system developed in [68] produced an accuracy of 93% on 20 different plant illnesses. In another work, conducted in [69], an efficient approach for identification of plant illness in Malus Domestica using K-means clustering has been proposed. Authors in [70] have provided a software solution in the aspect of plant leaf illness classification by using Genetic Algorithm (GA). Researchers in [71] have achieved an accuracy of 90% in the classification of apple leaf illness using pattern recognition. In [72] an android model has been developed using SVM and GA to classify cotton leaf illness.

Authors in [73] have proposed an automated model using machine learning and evolutionary approaches to identify paddy leaves diseases. The model can be used on android platform for quick identification of diseases. Authors in [74] achieve an overall accuracy of 98.39% to classify and analyze unhealthy leaves of grapes plant using G.A.

A survey has been carried out in [75] to analyze different methods of image classification that can be used to identify illnesses of plant leaf diseases. Authors in [76] have conducted a research on different deep learning methods that are used in the classification of plant leaf illnesses. The authors used weka tool to present a comprehensive analysis on several methods. K. Mohanapriya et. al [77] have developed a model that can identify unhealthy section of plant leaves using Naïve Bayes classification algorithm to obtain an overall accuracy of 97%. Authors in [78] have studied plant leaf classification using Naïve Bayes algorithm. The authors used shape and texture of the leaves to serve as an input to the classifier.

CNN model performs better than other classifiers such as KNN, RF, SVM, and Decision Tree [79]. The authors in [79] have achieved an accuracy of 99.58% and 97.66% for identification of paddy and potato leaves diseases respectively. Authors in [80] develop a system that provides report in detecting banana leaf diseases using CNN. A.S.M Farhan et. al. [81] proposed a model to identify Guava leaves disease using three CNN models. An overall accuracy of 95.61% has been produced by the third model. Another work in [82] has proposed a model to detect and identify potato leaf disease using machine learning methods. The model produced an overall accuracy of 95.99%.

A model for classification of beans leaf diseases has been developed in [83]. The authors in [83] have achieved an accuracy of 97% for training and 92% for testing. Similar work in [84] proposes a system that identify maize leaf disease using improved Deep-CNN. Authors in [85] have developed an approach to detect and classify purple blotch disease in onion using Deep-CNN. The model produced an accuracy of 85.47%. Several deep learning models have been developed to detect and identify plant leaf diseases. This field of research is made great by employing Deep learning approaches that produce better accuracy [86]. Machine learning and deep learning approaches have been applied in the field of agriculture with the aim of increasing production and tackling challenges [87].

Authors in [88] have proposed an approach called Attention Based Depth-wise Neural Network with Bayesian Optimization (ADSNN-BO) to classify plant leaf diseases. In [88] an accuracy of 94.65% has been achieved. Researchers in [89] have developed a model that can detect and classify maize diseases detection using Random Forest algorithm. The authors in [88] compared their model with other methods to achieve an overall accuracy of 80.68%. In [90], an automatic system for classification of plant diseases using RF algorithm has been developed. The model has achieved an accuracy of 95%. A hybrid learning model for plant leaf classification has also been developed in [91]. The model uses K-Means clustering and CNN algorithms to identify plant leaf diseases. The model yielded an accuracy of 92.6% to outperform SVM and CNN.

Classification of plant leaf diseases is a significant field of research in agriculture [92]. Authors in [93] conducted a research to identify sugarcane leaf illness using image SVM to obtain a classification accuracy of 95%. Deployment of image processing technologies can be beneficial in enhancing crop production through early identification of the disease [94]. Image processing methods can be used reliably to classify plant diseases [95].

Classification of plant diseases has to be carried out effectively so as to enhance crop production. Generally, leaves are the major sources of diseases in most plants [96]. Jennifer R. et. al. [97] developed a model to detect and classify cassava leaf disease using ANN and K-nearest neighbor techniques. The model in [97] has produced a classification accuracy of over 90%.

3.0 LITERATURE DISCUSSION

To improve the quality and quantity of crop production, image processing techniques must be used. Image processing is divided into two stages. Pre-processing and Post-processing. Pre-processing stage involves enhancement, morphological operation, and segmentation while post-processing includes feature extraction and classification. Figure 1 below depicts the entire process. Various techniques and algorithms such as GLCM could be used for feature extraction, K-means clustering for segmentation and SVM or CNN for classification of image.

While feature extraction could be done separately or manually and feed them into models like SVM for classification, CNN has an automatic feature extraction property that can extract the features from the image automatically. This work reviews and compares various techniques that had been used by researchers in the aspect of detection and classification of plant diseases. The paper also identifies the best techniques that could be used for better result.

4.0 FRAMEWORK

The framework for the classification system is represented in figure 1 below. The structure indicates the flow of activity as the image is being processed.

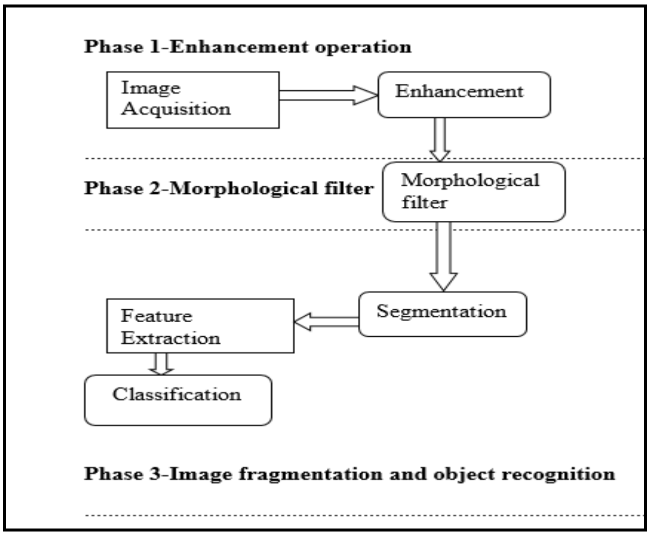


Figure 1: Plant Disease Classification Framework

Image acquisition

This is pre-processing step that involves acquisition or collection of image from database or using digital media devices like mobile phone, cameras etc. Images of plants are collected from a source for use [98].

Enhancement

This process entails detailing and bringing out features of interest like contrast in an image. Enhancement simplifies image representation by highlighting features that are obscured. It is used basically to enhance perception of information in images for presentation of better input [99].

Morphological filters

This is the process of using operations like dilation and erosion to remove imperfections in the structure of image [100].

Segmentation

In this stage, images are simplified and made more valid and easier to examine [101]. Various methods like k-means clustering, thresholding and Otsu's algorithm can be used to segment images for classification [102].

Feature extraction

In this phase features that are needed are extracted. These features could be based on texture, shape or color [103]. Models like CNN have automatic feature property that can extract the desirable qualities of the image automatically for better output.

Classification

This is the last phase of the image processing where object recognition takes place. Inputs are classified as either healthy or unhealthy (diseased). This task of classification can be accomplished by classifiers such as SVM, ANN, CNN, Naive Bayes and RFC.

5.0 COMPARISON ACCURACY

Accuracy of some selected image processing methods have been presented in table 1 below for comparison purposes. The table reveals different results obtained from various researches carried out in the past. Figure 2 below depicts a chart showing performance accuracy of some selected methods.

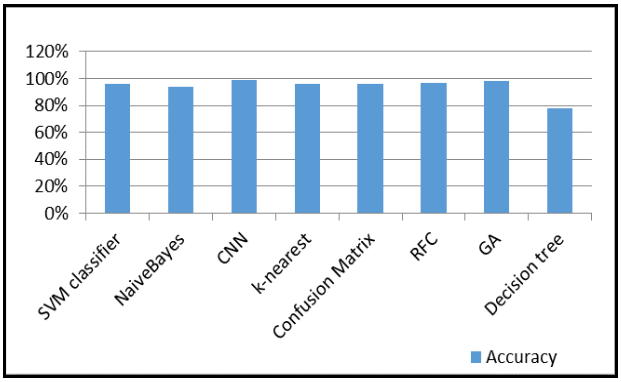


Figure 2: Comparison Accuracy Chart

6.0 REVIEW TABLE

Table 1 below is the review table which presents a comprehensive comparison data and results of various methods and techniques used in previous researches.

Table 1: Review Table

Authors	Plant Types	Techniques	Accuracy
[1]	Rice	ResNet 50 ResNet101 DenseNet161 DenseNet169	91.68% 92.50% 95.74% 94.98%
[2]	Tomato	Principal Component Analysis (PCA), Linear SVM	88.67%
[3]	Potato, Tomato, Strawberry, Corn, Grape, Apple	Logistic Regression, KNN, CNN, SVM	66.4% 54.5% 53.4% 98.0%
[4]	Tomato,Sugarcane, Potato,Grapes, Corn, Apple	CNN	96.5%
[5]	Tomato	CNN, Vector Quantization Algorithm (LQV)	86%
[6]	Pomegranate	Canny Edge Detection Technique	NA
[7]	Chili, Coconut, Cotton, Tomato, Brinjal, Papaya, Maize.	ANN,K-means, CNN,SVM	NA
[9]	Turmeric	VGG-16	96.24%
[10]	NA	SVM	92.4%
[11]	Tomato, Pepper, Potato	CNN	98.029%
[16]	Vegetables	k-means clustering	95.1613%
[17]	Weed	Histogram analysis, SIFT	95% 99%
[18]	NA	SVM, Naive Bayes.	87% 78%
[19]	Citrus	GLCM, k-means, SVM	90%
[20]	Wheat	OpenCV	NA
Authors	**Plant Types**	**Techniques/Methods**	**Accuracy**
[21]	Salad cucumber	K-means, SVM,GLCM	NA
[23]	Rice	Vgg16,	70.42%

		Vgg19, ResNet50, ResNet50v2, ResNet101v2	73.60% 51.99% 61.60% 86.79%
[24]	Rice	SVM, Deep-CNN	97.5%
[25]	Groundnut	KNN classifier	NA
[26]	Grape	K-means &SVM	88.89%
[27]	Soybean	Scale Invariant Feature Transform (SIFT) & SVM	93.79%
[28]	Maize,Grape,Apple, Tomato	AlexNet, GoogleNet, CNN	86.00 %
[29]	Cotton	Deep-CNN	96.00%
[30]	Brinjal	K-means, ANN	NA
[31]	Tomato	AlexNet SqueezeNet	95.65% 94.30%
[32]	Tomato	CNN	97.00%
[33]	Lemon, Banana, Beans, Rose	SVM,K-means Clustering, Minimum Distance Criterion (MDC)	95.71%
[34]	NA	Multiple linear regression (Normal situation), Multiple linear regression (Random situation)	93.30% 90.00%
[36]	NA	KNN, Neural network, SVM	NA
[37]	NA	KNN, Probabilistic Neural Network, ANN, Fuzzy Logic, SVM, Principal Component Analysis	NA
[38]	Jute, Grape, Paddy, Okra	k-means, SVM, ANN,GLCM	NA
[39]	Rice	CNN	92.46%
[40]	NA	K-means, GLCM	NA
[41]	Corn, Peach	SVM	NA
[42]	Orange,Cherry, Grape,Blueberry, Apple, Pepper, Potato, Soy, Squash, Tomato, Strawberry, Peach	CNN	NA
[44]	Potato	Random Forest, Naive Bayes, Logistic Regression, Linear Discriminant Analysis, KNN, Decision Trees, SVM	97% 94% 91% 91% 84% 78% 37%
[45]	Potato, Banana Mango, Lemon Sapota,Jackfruit Beans	CNN	NA
[46]	Guava	Deep-CNN	98.74%
[47]	Citrus	K-means, SVM,GLCM	NA
[49]	NA	CNN	99.35%
[50]	Cotton	ANN	80.00%
[51]	NA	ANN	92.00%
[54]	Beans, Tea leaf	MATLAB	98.20% 98.40%
[57]	NA	Back propagation	97.00%
[59]	Phyllanthus Elegans	Multi-layer perceptron (MLP) Radial basis function (RBF)	90.15% 98.85%
[60]	Cotton Soybeans (Four diseases)	ANN	83.00%, 80.00%, 80.00%, 70.00%
[61]	Potato, Tomato, Pepper bell	CNN, Bayesian algorithm	98.90%
[62]	Grapes	Hybrid CNN	98.70%
[66]	Strawberry	Soft-computing	96.00%
[69]	Malus Domestica	K-Means clustering	NA
[70]	Pomegranate	Genetic algorithm (GA)	NA
[71]	Apple	Pattern recognition	90.00%
[72]	Cotton	SVM, GA	NA
[74]	Grapes	GA	98.39%
[77]	NA	Naïve Bayes Algorithm	97.00%
[79]	Rice , potato	CNN	99.58% 97.66%
[81]	Guava	CNN	95.61%
[82]	Potato	k-means and GLCM	95.99%
[83]	Beans	MobileNet	92.00%
[84]	Maize	GoogleNet, Cifa10	98.90% 98.80%
Authors	**Plant Types**	**Techniques/Methods**	**Accuracy**
[85]	Onion	Deep-CNN	85.47%
[88]	NA	Attention Based Depth-wise Neural Network	94.65%

		with Bayesian Optimization (ADSNN-BO)	
[89]	Maize	RF	80.68%
[90]	NA	RF	95.00%
[91]	NA	k-means clustering, CNN	92.60%
[93]	Sugarcane	SVM	95.00%
[97]	Cassava	ANN, K-nearest neighbor	90.00%

NA= Not Available

7.0 CONCLUSION

The review has presented and revealed various techniques that have been developed and made available to help in achieving tremendous success in the area of machine learning, deep learning and image processing. It has also been highlighted in the review that; the percentage accuracy can be improved upon by training and testing the models with more and more dataset so as to increase the accuracy of the recognition rate.

Basically, new and improved deep learning methods that can give higher accuracy in identifying and classifying crop plants disease must always be developed and used to tackle the problem of plant leaf disease. Several methods have been built and used in the past to classify plant leaf diseases. However, neural networks like CNN appears to be the best technique to classify plant diseases, because of its flexibility and feature extractor property that allows it to extract features automatically. Unlike other previous models like Naive Bayes, K-Nearest Neighbor, SVM, RFC etc. CNN can learn additional features from the images to give better output. Neural networks like CNN can be best suited for research work in the area of image processing, machine learning and deep learning by virtue of its sophistication in learning and extracting features from the images for reliable output.

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