Chapter 2
Literature Review

2.1 Introduction

Food security is a major concern in a modern society. Plant disease is greatly affecting the yield of agricultural crops and it is an immense threat to food security. Early identification of plant disease can decrease the effect of disease on crop yield. Agriculture has become much more than simply a means to feed ever growing populations. Plants have become an important source of energy, and are a fundamental piece in the puzzle to solve the problem of global warming (Barbedo et al., 2013). There are several diseases that distress plants with the latent to cause devastating economical, social and ecological losses. Therefore, detecting diseases in an accurate and timely way is of the most importance task. In tropical countries like India, yields of agricultural crops are immensely affected by various plant diseases. Early identification of these diseases can be useful to abolish the effect of disease on crop yield.

Empirical techniques of identification is time consuming and lengthy. It is noteworthy that most of the plant dieses produce different symptoms on the surface of the leaves. Most diseases, however, generate some kind of manifestation in the visible spectrum. In the vast majority of the cases, the diagnosis, or at least a first guess about the disease, is performed visually by humans. Farmers can take and upload image using smart phones. Trained raters may be efficient in recognizing and quantifying diseases, however they have associated some disadvantages that may harm the efforts in many cases (Barbedo et al., 2013). Bock et al. (Bock et al., 2010) list some of those disadvantages. However, these symptoms can be identified using various digital image analysis techniques. Image analysis techniques can be useful to resolve this problem. A relationship between digital numbers in various pixels can be identified from the image. Pixel wise classification techniques can be applied to identify disease symptoms on the leaves of plant.

The literature review is based on classifier used for the respective research study. The main classifiers used in this review are Support Vector Machine (SVM), Artificial Neural Network (ANN), Convolutional Neural Network (CNN), Principal

Component Analysis (PCA), K-means clustering, Neural Networks and some other common classifiers.

2.2 Literature Review based on SVM

Authors (Bhimte et al., 2018) proposed a system using SVM classifier for identification of cotton leaf diseases such as Bacterial blight and Magnesium Deficiency.

In this study researcher (Hussein & Abbas, 2019) proposed model for leaf diseases detection. SVM classifier used over dataset of 799 images and achieved 88.1% overall accuracy.

In this study authors (Biswas et al., 2016) propose a system for classifying three diseases affecting grapes – Anthracnose, Powdery Mildew and Downy Mildew – and identifying the severity of these diseases using image processing and machine learning algorithms(PNN, BPNN, SVM, random forest) and achieved 86% of accuracy.

In this research 2000 images of maize leaves were obtained from the open access PlantVillage image database by Arvind et al. 2018 and using SVM achieved an average of 83.7% accuracy.

Using this model authors (kumar et al. 2019) predict the best suitable crop to the farmer and detect the pest that may affect as well as suggest the pest control techniques using SVM and Decision Tree.

Authors (Meunkaewjinda et al., 2008) proposed a technique to identify and classify diseases that affect grape-vines. The colors present on the leaves are then clustered by means of an unsupervised and untrained self-organizing map, diseased and healthy regions are then separated by a Support Vector Machine (SVM).

In this study researchers (Youwen et al., 2008) proposed a technique to recognize two diseases that can apparent in cucumber leaves, some color, shape and texture features are extracted. Those features feed an SVM, which performs the final classification. The

authors stated that the results provided by the SVM are far better than those achieved using neural networks.

Authors (Rajiv et al., 2020) proposed method for classification of leaf diseases using SVM, gray-level co-occurrence matrix (GLCM) and compare with KNN. The achieved accuracy range from 92.44 to 96.65% which is more than accuracy results obtained by KNN.

The system proposed by authors (Yao et al., 2009) aimed to identify and classify three types of diseases that affect rice crops. Color, shape and texture features are extracted, the latter one from the HSV color space. Finally, the features are submitted to a Support Vector Machine, which performs the final classification.

Authors (Jian and Wei, 2010) proposed a technique to identify three types of cucumber leaf diseases.

As in most approaches, the separation between healthy and diseased regions is made by a simple Thresholding procedure (Barbedo , 2013). In the following, a variety of color, shape and texture features are extracted. Those features are submitted to an SVM with Radial Basis Function (RBF) as kernel, which performs the final classification.

Authors (Arivazhagan et al., 2013) proposed software solution for plant leaf diseases detection and classification and texture analysis that can classify and also recognize leaf diseases with slight computational effort.

In this paper authors (Dhaware et al., 2017) discusses techniques for image pre-processing, image segmentation algorithm used for automatic recognition and research on various plant leaf disease classification algorithms that may be used for leaves disease classification.

In this presented paper researchers (Pantazi et al., 2019) demonstrates an automated way of crop disease identification on various leaf sample and achieved success rate of 95%.

In this study authors (Gavhale et al., 2014) proposed image analysis and classification techniques for extraction and classification of plant leaf diseases. Used K-mean clustering leaf severity areas, feature extraction and classification. Classification achieved using SVM.

Authors (Ganatra and Patel, 2020) proposed model for plane leaf diseases detection using machine learning. In the experiment random forest achieved 73.38%, SVM achieved 67.27, ANN achieved 65.68 and KNN achieved 63.20 % of accuracy.

2.3 Literature Review based on ANN/CNN

Authors (Hiary et al., 2011) developed a software for automatic recognition and classification of plant leaf diseases. The indulgence system comprises of four main phases. The applications of K-means clustering and Neural Networks (NNs) was articulated for classification of diseases on plant leaves.

In this papers authors (Singh et al., 2017) developed an algorithm which is used for automatic classification and detection of plant leaf diseases and also covers various diseases classification techniques survey using ANN, Bayes classifier, Fuzzy Logic.

Authors (Kulkarni et. al., 2012) proposed methodology for detection of plant diseases, using diverse image processing techniques and ANN and achieved success rate up to 91%.

Authors (Ranjan et al., 2015) describes a diagnosis process Image is captured and Color HSV features are extracted as a result of segmentation. ANN classification performance is 80% better in accuracy.

In this paper researcher (Jagtap et al., 2014) proposed system to help inspection of leaf batches and identify the disease that includes 4 stages which are Image enhancement, Image segmentation, Feature extraction, & classification.

In this approach one can classify detected spot diseases using Feed Forward Networks (FFNN), learning vector quantization (LVQ) and radial basis function network (RBF) and for performance measurement Accuracy, Precision, Recall ratio and F_measure classification parameters were used by the authors (Muthukannan et al., 2015)

Huang (Huang. 2007) projected a system to sense and classify three kind of diseases that affect Phalaenopsis orchid seedlings

Authors (Hidayatuloh et al., 2018) uses CNN method to detect 6 types of diseases in Tomato plant leaves and achieved an average accuracy of 86.92%.

In this paper researchers (Gandhi et al., 2018)presents an image-based classification system for identification of plant diseases using Generative Adversarial Networks (GANs) to augment the limited number of local images available and the classification is done by a Convolutional Neural Network (CNN) model deployed in a smart phone app.

54,306 images of diseased and healthy plant leaves collected using public dataset of 14 crops and 26 diseases have been identified using convolutional neural network and unsupervised methods by the researchers (Li et al., 2018) and 89.83% accuracy is achieved.

In this presented research paper authors (Nardari et al., 2018) compares various convolutional neural network based methods, evaluating model complexity and performance based on multiple metrics for the binary classification task of segmenting trees from the environment and according to authors convolutional neural networks can be a viable method even when a small amount of data is available provided.

In this presented paper researchers (Suryawati et al., 2018) evaluate several Neural Network namely VGGNet, AlexNet, GoogleNet and CNN as Baseline for the tasks of tomato plant diseases identification, using a subset of the PlantVillage dataset and concluded with the results shows that VGGNet achieves the highest accuracy among the evaluated architectures.

Mobile app has been developed by the author (Singh, 2018) to identify affected plant parts using CNN model of AI and achieved 95% disease identification of accuracy.

In this paper, author (Kulkarni, 2018) formulated the applications of Deep Convolutional Neural Networks with the goal of classifying both crop species and identity of disease on images.

Authors (Krishnaswamy et al., 2018) used tomato foliage leaves and achieved 97.29% of classification accuracy.

Authors (Biswas et al., 2014) used Fuzzy C-mean clustering and neural network based approach to detect and quantify the severity for late blight disease of potato and achieves an accuracy of 93%.

In this presented paper, authors (Golhani et al., 2018) reviews Neural Network (mechanism, types, models, and classifiers) techniques available to process hyperspectral data, with a special emphasis on plant disease detection.

Researchers (Majid et. al., 2013) Developed android application for paddy plant disease identification system using fuzzy logic and PNN. According to experiment results, the fuzzy entropy has a good performance for identifying the paddy diseases with 91.46% accuracy.

Authors (Francis et al., 2016) proposed an image processing algorithm to find the disease detection and identification in pepper plant leaves and get succeeded with identifying the presence of diseases.

An initial effort to monitor plant health was supported by authors (Hetzroni et al., 1994). Their scheme tried to recognize iron, zinc and nitrogen deficits by monitoring lettuce leaves. Those strictures are finally nourished to neural networks and statistical classifiers, which are used to recognize the plant condition

Authors (Pydipati et al., 2005) likened two dissimilar methods to sense and classify three types of citrus ailments. The primary method was based on a Mahalanobis

minimum distance classifier, using the nearest neighbor value. The second tactic castoff radial basis functions (RBF) neural network classifiers skilled with the back propagation algorithm. Conferring to the authors, both the classification methods performed alike, by means of the finest of the four subsets, which contained ten hue and saturation texture features.

The scheme projected by the authors (Abdullah et al., 2007) attempted to discriminate a plant disease of rubber tree leaves, Principal Component Analysis (PCA) is applied straight to the RGB values of a low resolution image of the leaves. The first two principal components are then nourished to a Multilayer Perceptron (MLP) Neural Network with one hidden layer, whose output reveals if the sample is diseased or not.

2.4 Literature Review based on PCA/ K-means clustering and Neural Networks

Authors (Pujari et al., 2013) describes detection and classification of symptoms of plant leaves affected by disease using discrete wavelet transform (DWT) and Principal component analysis (PCA).

In this study authors (Harini et al., 2011) propose a methodology for detection and identification of diseased leaves based on Wavelets and PCA for Tomato leaves.

Researchers (Wang et al., 2012) concluded that, K – Mean classification is better for image recognition of two kinds of wheat (wheat stripe rust and wheat leaf rust) and grape (grape downy mildew and grape powdery mildew) diseases.

Authors (Sannakki et al., 2011) takes grape leaf image and use K-means clustering for disease segmentation and achieved training accuracies of 100%.

In this study researchers (Goel et al., 2018) proposed a method to detect leaf disease in a pomegranate plant using K-Means algorithm and provides useful estimation.

Researchers (Narmadha et al., 2017) design the methodology to remove the noise automatic, error by human and minimizing the time taken to mensurate the effect of paddy leaf disease using K-means techniques.

Authors (Sridhathan & kumar, 2018) established an algorithm for recognition of disease using image processing. For color separation K – Mean is suitable while GLCM classification achieved 98.27% accuracy.

In this study authors (Arti et al., 2013)provides different methods to study detection of leaf disease using image processing and also provides the survey of different techniques. (k-means & neural network)

Authors (Naikwadi et al., 2013) proposed software solution for detection and classification of leaf diseases that compares leaf with healthy and diseased leaves and displays comparison result that is the testing sample has disease or not.

Authora (Bashish and Braik, 2010) suggested an image processing program used for leaf and stem disease recognition by means of K – Mean classification. That covers 5 diseases; Early scorch, Cottony mold, ashen mold, late scorch, tiny whiteness.\

2.5 Literature Review based on Common classifiers

Authors (Barbedo & Gracia, 2013) represents a survey on methods of image processing to detect, classify and quantify plant diseases in the visible range.

Authors (Barbedo & Gracia, 2014) presents a method to identify and quantify plant leaves symptoms using conventional color images with a limitation or constraint that is “the background must be as close to white or black as possible”.

Authors (Chaudhary et al., 2012) implemented an algorithm for identify disease spot. This paper saws a comparison of disease spot detection using the effect of CIELAB, HSI and YCbCr color space. Median filter is used for image smoothing and for calculation of threshold by Otsu method.The experiment carried out on “Monocot” and

"Dicot" plant with white and noise background.With the help of CIELAB color model noise which is because of background, vein and camera flash can be wiped out as an experimental result .

Authors (Pujari et al., 2013) proposed a technique for quantitative detection and classifying disease on Mango, Pomegranate and Grape and achieved 76.6% of accuracy.

In this study researcher (Saradhambal et al., 2018) proposed k-mean clustering algorithm to predict the infected area, and a color-based segmentation model is used to segment the infected area.

Author (Singh & Singh, 2015) take high resolution quality images of paddy crop with maximum detail of the leaf color and to get rid of illumination conditions differs a lot adjustable user defined thresholding and making necessary adjustments to the shades of LCC.

Authors (Malathi et al., 2015) provides survey on plant leaf disease identification using image processing techniques that can detect diseased leaf and in the other section this papers present various automated methods for disease detection and classification.

Authors (Gupta et al., 2018) focus on various types of sesame disease such as Sesame phyllody ,fungal diseases, Alternaria leaf blights, Phytophthora leaf spot, Cercospora leaf spot Macrophomina root /stem rot, Powdery Mildew, Bacterial leaf spot and Bacterial blight on plants and their treatment management.

Authors (Baquero et al., 2014) chiefly focus on identification of defected regions and classification using Content Based Image Retrieval (CBIR) systems and claims that proposed approach can partially finds several diseases, such as, chlorosis, sooty moulds and early blight.

In this study researchers (Devraj et al., 2019) proposed a software system that find and classify disease such as Alternaria Alternata, Antracnose, Bacterial Blight and Cercospora Leaf Spot.

Authors (Pillil et al., 2015) developed a prototype of a ground base robot eAGROBOT that provides reliable platform and automatically graphing farmland, detect diseases in that farmland and spray the pesticide for groundnut and cotton. This experiment is done manually without GPS; therefore its accuracy is not computed.

Authors (Pujari et al., 2014) focuses on early detection and classification of fungal disease and its related symptoms on horticulture and agriculture crops using Feature extraction and classification based algorithms with image processing techniques.

Author (Soni & Chahar , 2016) proposed a hybrid method to identify the existence of disease in plant leafs using ring project based segmentation model and PNN classifier and achieved effective results.

In this proposed study the robot has been designed and simulated in an open source software known as Virtual Robot Experimental Platform (V-REP) with experimental field of 40 crops by the authors (Arvind et al., 2016)

Hough transform algorithm is used to identify Crop line by authors (Diao et al., 2017) for Wheat disease identification and spraying algorithm in robot system have been investigated in this paper to reduce the waste of pesticides and obtain the disease information through machine vision effectively.

Adaptive Thresholding is used by the author (Aparajita et al., 2017) in proposed method for segmentation of disease affected area from leaf image and achieved 96% accuracy.

In this study authors (Suresha et al., 2017) proposed method works on identification of blast and brown spot diseases in rice plant using global threshold method and KNN classifier classification method and attained 76.59% accuracy using this method.

Authors (Sukmana & Rehmanti, 2017) used segmentation process for detection of leaf blight in corn.

Authors (Ganeshan et al., 2017) proposed fuzzy based method for the early identification and segmentation of affected plant leaves efficiently.

In this research plant diseases detected using remote sensing images by the authors (Shanmugam et al., 2017).

In this project researcher (Kamble, 2018) develop Mobile app for automatically detecting plant disease through image processing technique with the objective of providing fast, accurate, ease of use and inexpensive solutions to farmers.

In this paper, researchers (Verma et al., 2018) present a survey on detection and prediction models for tomato plant diseases, based on Image processing and IoT (Internet of Things) sensors for identification, detection as well as quantification of Tomato plant diseases.

In this presented paper researchers (Gupta et al., 2018) proposed a system that was developed to giving an optimized performance to meet the expected requiremens.

In this research work identification of the nitrogen shortage in chilly is covered by the authors (Hampannavar et al., 2018)

In present research paper authors (Singh & Mishra, 2017) developed a technique for image segmentation, method used for automatic detection and classification and also includes survey on disease classification.

In this survey authors (Patil & Chandavale, 2013) studied and evaluated techniques for detection of plant disease in two phases' segmentation and classification and also include two types of plant family Monocot and Dicot family plant.

In this survey authors (Majumdar et al., 2014) has covered maximum research work that includes Image processing and ANN for detection of plant disease.

In this survey paper authors (Barbedo & Garcia, 2013) covers methods that use digital image processing techniques to detect, classify and quantify plant diseases from images in the visible band.

The method proposed by the authors (Tucker & Chakraborty, 1997) objects to enumerate and recognise infections in sunflower and oat foliage. The first step of the system is a separation whose threshold differs rendering to the disease being considered. The subsequent pixels are associated into gatherings, representing the unhealthy regions.

Authors (Sannakki et al., 2012) compared binary morphology and Sobel edge detector algorithms for detecting edge and proved that morphology is more efficient than other.

Authors (Auerunyawat et al., 2012) extract leaf edge from background using grey scale image and YCrCb color space image by applying adaptive threshold of mean.

Authors (Zheng & Wang, 2010) uses Gray-scale morphological methods for extracting leaf veins.

Researcher (Katyal, 2012) formulated a vein extraction method using Odd Gabor filters.

Authors (Wang et al., 2013) aimed a new algorithm that segment single leaf from real time video and achieved clear and accurate edges.

Authors (Prasad et al., 2011) have proposed an algorithm to detect fungal diseases in plants using block- based unsupervised color image segmentation.

Authors (M. Mukherjee et al., 2012) developed a method to detect Bacterial leaf Blight and Rice Tungro in paddy leaf at early stage.
Authors (Ambatkar et al., 2017) proposed algorithm for rose diseases detection and uses 8-connected boundary detection algorithm for edge detection.

In this study (Nisale et al., 2011) achieves 93% accuracy by extracting geometric features of a leaf for detecting various stages and deficiencies in plant.

Authors (Sudahrani & Priya Madhuri ,2021) used Convolutional neural networks to identify plant ailments on healthy and unhealthy leaves and achieved 95.83 % of overall accuracy.

Researchers (Pandian et al., 2022) proposed 14- layered deep convolutional neural network (DCNN) to identify leaf diseases. And DCNN achieved 99% of accuracy.

Authors (Kumari et al., 2022) performed survey on model efficiency of machine learning and deep learning. According to authors the rise of Neural Network techniques has a significant impact on disease detection

In this paper authors (Joshi et al., 2022) describes technique that can be used detection and classification of plant leaf diseases on various crops. Random Forest classification technique has been used and achieved 93.00% accuracy.

Authors (Chowdhury et al, 2021) proposed model to leaf diseases detection on tomato leaf. U-net and EfficientNet models were used. U-net achieved 98.66 % accuracy, EficientNet-B7 achieved 99.95 % accuracy and EfficientNet-B4 achieved an accuracy of 99.89%.

Author (Pawar et al., 2021) prepared review on different methods used for identification of leaf diseases. According to authors K-Mean clustering, CNN, SVM algorithms were used for segmentation for diseases identification in leaves which is more accurate than the existing methods.

Author (Chowdhury et al, 2021) studied the performance of the various convolutional neural networks (CNNs) classification network architectures to classify tomato diseases for six and ten class classification. InceptionV3 achieved accuracy of 99.2%. DenseNet201 achieved an accuracy of 97.99% for six class. DenseNet201 achieved an accuracy of 98.05% for ten-class classification.

In this paper Authors (Tiwari et al., 2020) proposed a model that uses VGG19 for fine-tuning to extract the relevant features from the dataset. And achieved classification accuracy of 97.8%.

2.6 Conclusion

It is found from the study of previously done work that, a crop disease is one of the most key reasons to the devastation of a crop. Identifying the diseases at initial stages enable farmers to overcome and treat them correctly. This method needs an expert to recognize the disease, defines the methods of treatment and protection. Henceforth, farmers frequently depend on agricultural experts or consultants to offer the correct information for disease diagnosis and to advice methods of treatment.

Regrettably, numbers of agricultural experts are limited and they are not all the time presented when farmers need their assistance. Mung bean plant leaf crops have several diseases that can disturb productivity and their lifetime. In such conditions, computerized systems can help a great deal for classifying these diseases and offers the technique for treatment to be carried out. It is found form the literature study that researchers conducted the studies on crops such as Tomato, Orchid, Cucumber, Rice, Cotton, Pomegranate, Mango, Potato, Beans, Lemon, Citrus, Grape, and Paddy, for the calculation of leaf diseases. Amongst all, Mung bean was not considered by the researcher as an objective to evaluate the disease. Till today no disease diagnosis system developed for Mung bean plant leaves.

Though, the declination in mung bean's growth due to leaf disease, appeal agriculturist attention to it. With the growth of recent technology, the difficulty of precise calculation and assessment of the disease is reduced. In current era, essential features of image processing increase the demand in essential method for identification of diseased portion. Grounded on the concerns raised, the study gap for the current study is to identify the diseases on Mung bean plant leaf.

It is also found from the study of previous work that majority researchers have done their research work on various plant diseases identification in controlled environment

dataset. In controlled environment image is having single leaf as a main object and a plain background with it. Very few researcher has carried their work in an uncontrolled environment where background is not plain. In uncontrolled environment image contains leaves with soil and other plant organs as background. So it is difficult to work in uncontrolled environment. Since the leaf is not the only object present in image, more steps are required to classify the image like noise removal etc., compared to controlled environment image. So, research have thought to work for controlled, uncontrolled and combined environment for mung leaf bean plant.

Machine learning and deep learning techniques can be used to find possible diseases.

References

[1]. Abdullah, N. E., Rahim, A. A., Hashim, H., & Kamal, M. M. (2007, December). Classification of rubber tree leaf diseases using multilayer perceptron neural network. In 2007 5th student conference on research and development (pp. 1-6). IEEE.

[2]. Al-Hiary, H., Bani-Ahmad, S., Reyalat, M., Braik, M., & Alrahamneh, Z. (2011). Fast and accurate detection and classification of plant diseases. International Journal of Computer Applications, 17(1), 31-38.

[3]. Al Bashish, D., Braik, M., & Bani-Ahmad, S. (2010, December). A framework for detection and classification of plant leaf and stem diseases. In 2010 international conference on signal and image processing (pp. 113-118). IEEE.

[4]. Ambatkar, A., Bhandekar, A., Tawale, A., Vairagade, C., & Kotamkar, K. (2017, January). Leaf disease detection using image processing. In Proceedings of international conference on recent trends in engineering science and technology (Vol. 5, pp. 333-336).

[5]. Aravind, K. R., & Raja, P. (2016, December). Design and simulation of crop monitoring robot for green house. In 2016 International Conference on Robotics: Current Trends and Future Challenges (RCTFC) (pp. 1-6). IEEE.

[6]. Aravind, K. R., Raja, P., Mukesh, K. V., Aniirudh, R., Ashiwin, R., & Szczepanski, C. (2018, January). Disease classification in maize crop using bag of features and multiclass support vector machine. In 2018 2nd International Conference on Inventive Systems and Control (ICISC) (pp. 1191-1196). IEEE.

[7]. Arivazhagan, S., Shebiah, R. N., Ananthi, S., & Varthini, S. V. (2013). Detection of unhealthy region of plant leaves and classification of plant leaf diseases using texture features. Agricultural Engineering International: CIGR Journal, 15(1), 211-217.

[8]. Arnal Barbedo, J. G. (2013). Digital image processing techniques for detecting, quantifying and classifying plant diseases. SpringerPlus, 2(1), 1-12.

[9]. Auearunyawat, P., Kasetkasem, T., Wongmaneeroj, A., Nishihara, A., & Keinprasit, R. (2012, May). An automatic nitrogen estimation method in sugarcane leaves using image processing techniques. In Proc. of Int. Conf. on Agric., Environ. and Biological Sci.(ICAEBS) (pp. 39-42).

[10]. Barbedo, J. G. A. (2014). An automatic method to detect and measure leaf disease symptoms using digital image processing. Plant Disease, 98(12), 1709-1716.

[11]. Baquero, D., Molina, J., Gil, R., Bojacá, C., Franco, H., & Gómez, F. (2014, September). An image retrieval system for tomato disease assessment. In 2014 XIX Symposium on Image, Signal Processing and Artificial Vision (pp. 1-5). IEEE.

[12]. Bhimte, N. R., & Thool, V. R. (2018, June). Diseases detection of cotton leaf spot using image processing and SVM classifier. In 2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS) (pp. 340-344). IEEE.

[13]. Biswas, S., Jagyasi, B., Singh, B. P., & Lal, M. (2014, June). Severity identification of potato late blight disease from crop images captured under uncontrolled environment. In 2014 IEEE Canada international humanitarian technology conference-(IHTC) (pp. 1-5). IEEE.

[14]. Bock, C. H., Poole, G. H., Parker, P. E., & Gottwald, T. R. (2010). Plant disease severity estimated visually, by digital photography and image analysis, and by hyperspectral imaging. Critical reviews in plant sciences, 29(2), 59-107.

[15]. Chowdhury, M. E., Rahman, T., Khandakar, A., Ayari, M. A., Khan, A. U., Khan, M. S., ... & Ali, S. H. M. (2021). Automatic and reliable leaf disease detection using deep learning techniques. AgriEngineering, 3(2), 294-312..

[16]. Chowdhury, M. E., Rahman, T., Khandakar, A., Ibtehaz, N., Khan, A. U., Khan, M. S., ... & Ali, S. H. M. (2021). Tomato Leaf Diseases Detection Using Deep Learning Technique. Technology in Agriculture, 453.

[17]. Chaudhary, P., Chaudhari, A. K., Cheeran, A. N., & Godara, S. (2012). Color transform based approach for disease spot detection on plant leaf. International journal of computer science and telecommunications, 3(6), 65-70.

[18]. Devaraj, A., Rathan, K., Jaahnavi, S., & Indira, K. (2019, April). Identification of plant disease using image processing technique. In 2019 International Conference on Communication and Signal Processing (ICCSP) (pp. 0749-0753). IEEE.

[19]. Dhaware, C. G., & Wanjale, K. H. (2017, January). A modern approach for plant leaf disease classification which depends on leaf image processing. In 2017 International Conference on Computer Communication and Informatics (ICCCI) (pp. 1-4). IEEE.

[20]. Diao, Z., Diao, C., & Wu, Y. (2017, August). Algorithms of wheat disease identification in spraying robot system. In 2017 9th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC) (Vol. 2, pp. 316-319). IEEE.

[21]. Francis, J., & Anoop, B. K. (2016, March). Identification of leaf diseases in pepper plants using soft computing techniques. In 2016 conference on emerging devices and smart systems (ICEDSS) (pp. 168-173). IEEE.

[22]. Gandhi, R., Nimbalkar, S., Yelamanchili, N., & Ponkshe, S. (2018, May). Plant disease detection using CNNs and GANs as an augmentative approach. In 2018 IEEE International Conference on Innovative Research and Development (ICIRD) (pp. 1-5). IEEE.

[23]. Ganatra, N., & Patel, A. (2020). A multiclass plant leaf disease detection using image processing and machine learning techniques. Int. J. Emerg. Technol, 11(2), 1082-1086.

[24]. Ganesan, P., Sajiv, G., & Leo, L. M. (2017, March). CIELuv color space for identification and segmentation of disease affected plant leaves using fuzzy based approach. In 2017 Third International Conference on Science Technology Engineering & Management (ICONSTEM) (pp. 889-894). IEEE.

[25]. Gavhale, K. R., Gawande, U., & Hajari, K. O. (2014, April). Unhealthy region of citrus leaf detection using image processing techniques. In International Conference for Convergence for Technology-2014 (pp. 1-6). IEEE.

[26]. Goel, N., Jain, D., & Sinha, A. (2018, December). Prediction model for automated leaf disease detection & analysis. In 2018 IEEE 8th International Advance Computing Conference (IACC) (pp. 360-365). IEEE.

[27]. Gupta, D., & Belwal, M. (2018, August). Pest Identification and Control of Diseases in Crop Fields through Image Processing and Tracking of Atmospheric Parameters. In 2018 2nd International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC) I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC), 2018 2nd International Conference on (pp. 289-294). IEEE.

[28]. Gupta, K., Naik, K., & Bisen, R. (2018). Status of sesame diseases and their integrated management using indigenous practices. International Journal of Chemical Studies, 6(2), 1945-1952.

[29]. Golhani, K., Balasundram, S. K., Vadamalai, G., & Pradhan, B. (2018). A review of neural networks in plant disease detection using hyperspectral data. Information Processing in Agriculture, 5(3), 354-371.

[30]. Hampannavar, K., Bhajantri, V., & Totad, S. G. (2018, August). Prediction of crop fertilizer consumption. In 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA) (pp. 1-5). IEEE.

[31]. Harini, D. N. D., & Bhaskari, D. L. (2011). Identification of leaf diseases in tomato plant based on wavelets and PCA. In World Congress on Information and Communication Technologies (pp. 978-1).

[32]. Hetzroni, A., Miles, G. E., Engel, B. A., Hammer, P. A., & Latin, R. X. (1994). Machine vision monitoring of plant health. Advances in Space Research, 14(11), 203-212.

[33]. Hidayatuloh, A., Nursalman, M., & Nugraha, E. (2018, October). Identification of tomato plant diseases by Leaf image using squeezenet model. In 2018 International Conference on Information Technology Systems and Innovation (ICITSI) (pp. 199-204). IEEE.

[34]. Huang, K. Y. (2007). Application of artificial neural network for detecting Phalaenopsis seedling diseases using color and texture features. Computers and Electronics in agriculture, 57(1), 3-11.

[35]. Hussein, M. A., & Abbas, A. H. (2019). Plant leaf disease detection using support vector machine. Al-Mustansiriyah Journal of Science, 30(1), 105-110.

[36]. Jagtap, S. B., & Hambarde, M. S. M. (2014). Agricultural plant leaf disease detection and diagnosis using image processing based on morphological feature extraction. IOSR J. VLSI Signal Process, 4(5), 24-30.

[37]. Jian, Z., & Wei, Z. (2010, March). Support vector machine for recognition of cucumber leaf diseases. In 2010 2nd international conference on advanced computer control (Vol. 5, pp. 264-266). IEEE.

[38]. Joshi, K., Awale, R., Ahmad, S., Patil, S., & Pisal, V. (2022). Plant Leaf Disease Detection Using Computer Vision Techniques and Machine Learning. In ITM Web of Conferences (Vol. 44, p. 03002). EDP Sciences.

[39]. Kamble, J. K. (2018, February). Plant disease detector. In 2018 International Conference On Advances in Communication and Computing Technology (ICACCT) (pp. 97-101). IEEE.

[40]. Katyal, V. (2012). Leaf vein segmentation using Odd Gabor filters and morphological operations. arXiv preprint arXiv:1206.5157.

[41]. Kulkarni, A. H., & Patil, A. (2012). Applying image processing technique to detect plant diseases. International Journal of Modern Engineering Research, 2(5), 3661-3664.

[42]. Kulkarni, O. (2018, August). Crop disease detection using deep learning. In 2018 Fourth international conference on computing communication control and automation (ICCUBEA) (pp. 1-4). IEEE.

[43]. Kumar, A., Sarkar, S., & Pradhan, C. (2019, April). Recommendation system for crop identification and pest control technique in agriculture. In 2019 International Conference on Communication and Signal Processing (ICCSP) (pp. 0185-0189). IEEE.

[44]. Kumari, T., Kannan, M. J., & Vinutha, N. A Survey on Plant Leaf Disease Detection. International Journal of Computer Applications, 975, 8887.

[45]. Li, J., Jia, J., & Xu, D. (2018, July). Unsupervised representation learning of image-based plant disease with deep convolutional generative adversarial networks. In 2018 37th Chinese control conference (CCC) (pp. 9159-9163). IEEE.

[46]. Majid, K., Herdiyeni, Y., & Rauf, A. (2013, September). I-PEDIA: Mobile application for paddy disease identification using fuzzy entropy and probabilistic neural network. In 2013 International Conference on Advanced Computer Science and Information Systems (ICACSIS) (pp. 403-406). IEEE.

[47]. Majumdar, D., Kumar, D., Chakraborty, A., & Dutta, D. (2014). detection & diagnosis of plant leaf disease using integrated image processing approach. International Journal of Computer Engineering and Applications, VI–III.

[48]. Malathi, M., Aruli, K., Nizar, S. M., & Selvaraj, A. S. (2015). A survey on plant leaf disease detection using image processing techniques. International Research Journal of Engineering and Technology (IRJET), 2(09).

[49]. Meunkaewjinda, A., Kumsawat, P., Attakitmongcol, K., & Srikaew, A. (2008, May). Grape leaf disease detection from color imagery using hybrid intelligent system. In 2008 5th international conference on electrical engineering/electronics, computer, telecommunications and information technology (Vol. 1, pp. 513-516). IEEE.

[50]. Mukherjee, M., Pal, T., & Samanta, D. (2012). Damaged paddy leaf detection using image processing. Journal of Global Research in Computer Science, 3(10), 07-10.

[51]. Muthukannan, K., Latha, P., Selvi, R. P., & Nisha, P. (2015). Classification of diseased plant leaves using neural network algorithms. ARPN Journal of Engineering and Applied Sciences, 10(4), 1913-1919.

[52]. Naikwadi, S., & Amoda, N. (2013). Advances in image processing for detection of plant diseases. International Journal of Application or Innovation in Engineering & Management, 2(11).

[53]. Nardari, G. V., Romero, R. A., Guizilini, V. C., Mareco, W. E., Milori, D. M., Villas-Boas, P. R., & Santos, I. A. D. (2018, November). Crop anomaly identification with color filters and convolutional neural networks. In 2018 Latin American Robotic Symposium, 2018 Brazilian Symposium on Robotics (SBR) and 2018 Workshop on Robotics in Education (WRE) (pp. 363-369). IEEE.

[54]. Narmadha, R. P., & Arulvadivu, G. (2017, January). Detection and measurement of paddy leaf disease symptoms using image processing. In 2017 International Conference on Computer Communication and Informatics (ICCCI) (pp. 1-4). IEEE.

[55]. Nisale, S. S., Bharambe, C. J., & More, V. N. (2011). Detection and analysis of deficiencies in groundnut plant using geometric moments. International Journal of Agricultural and Biosystems Engineering, 5(10), 608-612.

[56]. Pandian, J. A., Kumar, V. D., Geman, O., Hnatiuc, M., Arif, M., & Kanchanadevi, K. (2022). Plant Disease Detection Using Deep Convolutional Neural Network. Applied Sciences, 12(14), 6982.

[57]. Pantazi, X. E., Moshou, D., & Tamouridou, A. A. (2019). Automated leaf disease detection in different crop species through image features analysis and One Class Classifiers. Computers and electronics in agriculture, 156, 96-104.

[58]. Patil, S., & Chandavale, A. (2015). A survey on methods of plant disease detection. Int J Sci Res, 4(2), 1392-1396.

[59]. Pawar, S., Ugale, V., Patil, H., Sujgure, K., & Dhepale, N. Review on: Plant Leaf Disease Detection Using Image Processing.

[60]. Pilli, S. K., Nallathambi, B., George, S. J., & Diwanji, V. (2015, February). eAGROBOT—A robot for early crop disease detection using image processing.

In 2015 2nd International Conference on Electronics and Communication Systems (ICECS) (pp. 1684-1689). IEEE.

[61]. Prasad, S., Kumar, P., & Jain, A. (2011, December). Detection of disease using block-based unsupervised natural plant leaf color image segmentation. In International conference on swarm, evolutionary, and memetic computing (pp. 399-406). Springer, Berlin, Heidelberg.

[62]. Pujari, J. D., Yakkundimath, R., & Byadgi, A. S. (2013). Automatic fungal disease detection based on wavelet feature extraction and PCA analysis in commercial crops. International Journal of Image, Graphics and Signal Processing, 6(1), 24-31.

[63]. Pujari, J. D., Yakkundimath, R., & Byadgi, A. S. (2014, December). Identification and classification of fungal disease affected on agriculture/horticulture crops using image processing techniques. In 2014 IEEE International Conference on Computational Intelligence and Computing Research (pp. 1-4). IEEE.

[64]. Pydipati, R., Burks, T. F., & Lee, W. S. (2005). Statistical and neural network classifiers for citrus disease detection using machine vision. Transactions of the ASAE, 48(5), 2007-2014.

[65]. Rajiv, K., Rajasekhar, N., Prasanna Lakshmi, K., Srinivasa Rao, D., & Sabitha Reddy, P. (2020, September). Accuracy Evaluation of Plant Leaf Disease Detection and Classification Using GLCM and Multiclass SVM Classifier. In Congress on Intelligent Systems (pp. 41-54). Springer, Singapore.

[66]. Rangarajan, A. K., Purushothaman, R., & Ramesh, A. (2018). Tomato crop disease classification using pre-trained deep learning algorithm. Procedia computer science, 133, 1040-1047.

[67]. Ranjan, M., Weginwar, M. R., Joshi, N., & Ingole, A. B. (2015). Detection and classification of leaf disease using artificial neural network. International Journal of Technical Research and Applications, 3(3), 331-333.

[68]. Rathod, A. N., Tanawal, B., & Shah, V. (2013). Image processing techniques for detection of leaf disease. International Journal of Advanced Research in Computer Science and Software Engineering, 3(11).

[69]. Sandika, B., Avil, S., Sanat, S., & Srinivasu, P. (2016, November). Random forest based classification of diseases in grapes from images captured in uncontrolled

environments. In 2016 IEEE 13th international conference on signal processing (ICSP) (pp. 1775-1780). IEEE.

[70]. Sannakki, S. S., Rajpurohit, V. S., & Birje, S. J. (2012). Comparison of different leaf edge detection algorithms using fuzzy mathematical morphology. International Journal of Innovations in Engineering and Technology, 1(2), 15-21.

[71]. Sannakki, S. S., Rajpurohit, V. S., Nargund, V. B., Kumar, A., & Yallur, P. S. (2011). Leaf disease grading by machine vision and fuzzy logic. Int J, 2(5), 1709-1716.

[72]. Saradhambal, G., Dhivya, R., Latha, S., & Rajesh, R. (2018). Plant disease detection and its solution using image classification. International Journal of Pure and Applied Mathematics, 119(14), 879-884.

[73]. Shanmugam, L., Adline, A. A., Aishwarya, N., & Krithika, G. (2017, April). Disease detection in crops using remote sensing images. In 2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR) (pp. 112-115). IEEE.

[74]. Sharma, R., Singh, A., Dutta, M. K., Riha, K., & Kriz, P. (2017, July). Image processing based automated identification of late blight disease from leaf images of potato crops. In 2017 40th international conference on telecommunications and signal processing (TSP) (pp. 758-762). IEEE.

[75]. Singh, K. K. (2018, November). An artificial intelligence and cloud based collaborative platform for plant disease identification, tracking and forecasting for farmers. In 2018 IEEE International Conference on Cloud Computing in Emerging Markets (CCEM) (pp. 49-56). IEEE.

[76]. Singh, A., & Singh, M. L. (2015, July). Automated color prediction of paddy crop leaf using image processing. In 2015 IEEE Technological Innovation in ICT for Agriculture and Rural Development (TIAR) (pp. 24-32). IEEE.

[77]. Singh, V., & Misra, A. K. (2017). Detection of plant leaf diseases using image segmentation and soft computing techniques. Information processing in Agriculture, 4(1), 41-49.

[78]. Soni, P., & Chahar, R. (2016, July). A segmentation improved robust PNN model for disease identification in different leaf images. In 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES) (pp. 1-5). IEEE.

[79]. Sridhathan, S., & Kumar, M. S. (2018). Plant infection detection using image processing. International Journal of Modern Engineering Research (IJMER), 8(7).

[80]. Sudha Rani, K., & Priya Madhuri, B. (2021). Plant Leaf Disease Detection Using Machine Learning Techniques. In Computer Networks and Inventive Communication Technologies (pp. 511-518). Springer, Singapore.

[81]. Sukmana, S. E., & Rahmanti, F. Z. (2017, October). Blight segmentation on corn crop leaf using connected component extraction and CIELAB color space transformation. In 2017 International Seminar on Application for Technology of Information and Communication (iSemantic) (pp. 205-208). IEEE.

[82]. Suresha, M., Shreekanth, K. N., & Thirumalesh, B. V. (2017, April). Recognition of diseases in paddy leaves using KNN classifier. In 2017 2nd International Conference for Convergence in Technology (I2CT) (pp. 663-666). IEEE.

[83]. Suryawati, E., Sustika, R., Yuwana, R. S., Subekti, A., & Pardede, H. F. (2018, October). Deep structured convolutional neural network for tomato diseases detection. In 2018 international conference on advanced computer science and information systems (ICACSIS) (pp. 385-390). IEEE.

[84]. Tiwari, D., Ashish, M., Gangwar, N., Sharma, A., Patel, S., & Bhardwaj, S. (2020, May). Potato leaf diseases detection using deep learning. In 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS) (pp. 461-466). IEEE.

[85]. Tucker, C. C., & Chakraborty, S. (1997). Quantitative assessment of lesion characteristics and disease severity using digital image processing. Journal of Phytopathology, 145(7), 273-278.

[86]. Verma, S., Chug, A., & Singh, A. P. (2018, September). Prediction models for identification and diagnosis of tomato plant diseases. In 2018 International Conference on advances in computing, communications and informatics (ICACCI) (pp. 1557-1563). IEEE.

[87]. Wang, H., Li, G., Ma, Z., & Li, X. (2012, May). Application of neural networks to image recognition of plant diseases. In 2012 International conference on systems and informatics (ICSAI2012) (pp. 2159-2164). IEEE.

[88]. Wang, J., He, J., Han, Y., Ouyang, C., & Li, D. (2013). An adaptive thresholding algorithm of field leaf image. Computers and electronics in agriculture, 96, 23-39.

[89]. Yao, Q., Guan, Z., Zhou, Y., Tang, J., Hu, Y., & Yang, B. (2009, May). Application of support vector machine for detecting rice diseases using shape and color texture features. In 2009 international conference on engineering computation (pp. 79-83). IEEE.

[90]. Youwen, T., Tianlai, L., & Yan, N. (2008, May). The recognition of cucumber disease based on image processing and support vector machine. In 2008 congress on image and signal processing (Vol. 2, pp. 262-267). IEEE.

[91]. Zheng, X., & Wang, X. (2010). Leaf vein extraction based on gray-scale morphology. International Journal of Image, Graphics and Signal Processing, 2(2), 25.