Mango Leaf Disease Classification using Deep Learning: A Comprehensive Survey

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Abstract. Mango cultivation plays a pivotal role in the development and growth of a country, contributing significantly to its economy and agricultural sector. The cultivation of mangoes not only provides a valuable source of income for farmers but also boosts export opportunities, fostering economic stability. However, the impact of mango leaf diseases poses a serious threat to global mango production. Diseases like anthracnose, powdery mildew, sooty mould, and gall midge can lead to reduced yields, diminished fruit quality, and economic losses for farmers. The timely detection and management of these diseases are crucial for mitigating their adverse effects. Fortunately, advanced technology, especially deep learning, has shown up as an effective ally in the early detection of these diseases. Therefore, the aim of this study is to present an updated survey report on this topic.

Keywords: Deep Learning, Mango, CNN, Agriculture, Plant Disease, Leaf Disease, Review

1 Introduction

India is the leading mango-producing nation globally, contributing to an estimated 40% of the total mango production. Mango is widely favoured by people around the world due to its remarkable versatility, substantial nutritional content, diverse assortment, delectable flavour, and exceptional aroma. Mango cultivation plays a vital role in global agriculture, serving as a major source of not just the nutrition but income as

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well as employment. However, Mango plants are susceptible to various diseases [1] that can impact their health and yield. Leaves being the food basis for plants, disease in leaf thereby affects the process of photosynthesis in so doing leading to plant death. The type of disease is identified by the symptoms and leaf area affected, so the rapid and accurate identification of mango leaf diseases is an imperative aspect [2] of agricultural management as it allows for early intervention and deterrence of prevalent infections.

Some of the common diseases affecting mango plants include Anthracnose, Red Rust, Downy Mildew, Sooty Mold, Powdery Mildew, Bacterial Canker, Die Back, Phoma Blight, Alternaria leaf spots or Alternaria leaf Blight, Alternaria leaf spots, Leaf Gall, and many more. The description of the same is depicted in Table 1.

Most of these diseases show up on the leaves of mango trees. They cause problems like spots, weird growth, or changes in color on the leaves. This can affect how the tree grows and produces fruit. Keeping an eye on the leaves is significant to identify these problems early and take care of the trees. As per the research conducted, Anthracnose affects around 39% of mango trees [3], 23% of trees are harmed by Powdery Mildew whereas Bacterial Canker [3] is a really bad disease that can completely ruin mango harvests, from 10% to even 100%. Therefore, it is rather crucial to understand that, these leaf issues at early stage else it can seriously impact on yield of mangoes. The application area of mango leaf disease identification stretches across innumerable areas of research, agriculture and technology encouraging efficient management of mango orchards for improving the yield as well as for employment. The integration of technology in agriculture continues to evolve, offering innovative solutions for disease management and improved crop yield. In recent years, advancements in computer vision and machine learning (ML), particularly the application of Convolutional Neural Networks (CNNs) [4, 5], Agricultural management [6], IoT and sensor technologies [7], and many more have demonstrated significant promise in automating the classification and identification of plant diseases. The main objective of the survey paper titled "Mango Leaf Disease classification using Convolutional Neural Networks: A survey and comparative study" is to explore and summarize the existing research, on how Convolutional Neural Networks (CNNs) are employed for classifying diseases in mango leaves. Convolutional Neural Networks (CNNs) are the class of ML model specifically designed for analyzing and processing visual data, such as images and videos.

Table 1. Some of the common mango leaf disease.

Disease	Another Name	Disease Symptoms
Anthracnose	Colletotrichum gloeosporioides	Leaves with asymmetrical shaped lesions with dark borders further spreading towards fruit.
Red Rust	Cepbaleuros Virescens	Leaves with rusty red spots on its upper surface causing leaf discoloration.
Downy Mildew	Pseudoperonospora	Leaves with yellow lesions on its

	Cubensis	upper surface whereas the lower surface has a downy (furry) growth.
Sooty mold	Meliola Mangiferae	Leaves with black dusty mould (fungus) on the leaf surface causing the plant to completely turn black.
Powdery Mildew	Oidium Mangiferae	Leaves with white superficial powdery fungal growth causing premature fruit drop.
Back	Botryodiplodia (Lasiodiplodia) Theobromae	Leaves turn brown and the edge roll up causing the branch dies and leaf fall.
Phoma Blight	Phoma Glomerata	Only on old leaves; Leaves with angular and minute lesion initially, color changes from brown to cinnamon as lesions enlarges causing complete withering.
Bacterial Canker	Xanthomonas Campestris	Leaves with numerous lesions combined to form irregular cankerous patches causing leaves to turn yellow and finally leaf drop.
Alternaria Leaf spots	Alternaria leaf Blight	Leaves with several circular spots causing leaves to turn yellow and finally leaf drop.
Leaf Gall	Eriophyes Leiosoma	Leaves with formation of swellings or galls caused by several factors including insects, bacteria or environmental stress causing abnormal swellings or outgrowths on leaves.

CNNs has emerged as the vital component in computer vision applications showcasing achievements in tasks such as image recognition, object detection and for classifying imagery. CNNs comprises of several layers namely: Convolutional layers, Pooling layers and fully connected layers. The key advantages of CNNs are: Feature Learning, Translation invariance, Parameter sharing, and Spatial Hierarchies among many others. The paper aims to give an overview of the methods and methodologies utilized this context providing valuable insights into diverse CNN based models. Through a study the authors intent to highpoint the efficacy of techniques enabling researchers and professionals in agriculture and computer vision fields to make well informed decisions when choosing a methodology, for classifying mango leaf diseases using CNNs. The review of the literature in this paper comprises of 41 research articles concerned with identification and classification of mango leaf disease using various CNN based models. These papers are enumerated in the reference section and are drawn from the last seven years i.e., for the period 2018-2024. In this paper, all work associated to the CNN based disease identification will be meticulously examined.

The remaining part of this study are structured in the following manner. The research methodology and survey taxonomy are depicted in Section 2. An in-depth literature survey of CNN based models for mango leaf disease classification is illustrated as well as summarized in Section 3. Finally, this paper concludes and recommends some of the probable future research directions, which is available in Section 4.

2 Research Methodology and Survey Taxonomy

This review work typically focuses on identifying various research work carried forwarded by numerous researchers using various CNN-based models to identify and further classify the various types of diseases in mango leaves. In order to do so, this work classically encompasses an organized approach to gather, scrutinize, and compare information related to the use of CNNs for the same and furthermore endorse the best CNN model for classifying the disease in mango leaf. The standard search mechanism is employed in order to assemble the research articles from different renowned online search engines namely Google Scholar, ScienceDirect, SpringerLink, IEEE Xplore, ACM Digital Library and many more, which provides access to full-text academic literature across innumerable publication fields. The search was typically performed using some (Not limited to) terminologies as depicted in Fig. 1. The pictorial representation of the entire procedure of paper collection is highlighted in Fig. 2.

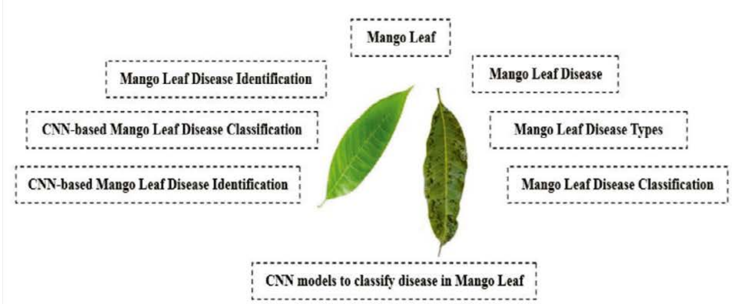

Fig. 1. Terminologies used to identify research articles related to CNN-based mango leaf disease classification.

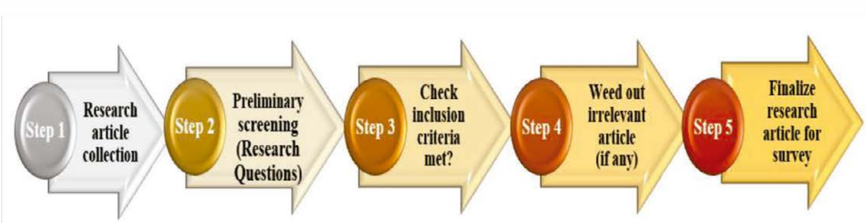

Fig. 2. Pictorial representation of the research article collection process.

In doing so, all the duplicate and irrelevant research papers were weeded out. Total 57 research articles were finalized that were published by prominent publishers including IEEE, Elsevier, Springer, MDPI, and Taylor & Francis.

Fig. 3(a) shows that year-wise publication count of mango leaf disease detection using CNN models. It can be noticed that publication count is increasing from 2018 to 2025 which reflects the good research interest of this topic. Publication percentage by different publishers like IEEE, Springer, Elsevier, Taylor & Francis, IOP, Inderscience, etc. is presented in Fig. 3(b). Fig. 4(a) highlighting the top three publishers with year wise publication. It can be seen that IEEE has the highest publication count especially in the year of 2023 and 2024. On the other hand, Fig. 4(b) is the demonstration of the top three publishers with publication type. It can be noticed that most of the conference paper (nearly 25) is published by IEEE in the year 2024. Whereas the journal articles are mostly published by Springer and Elsevier.

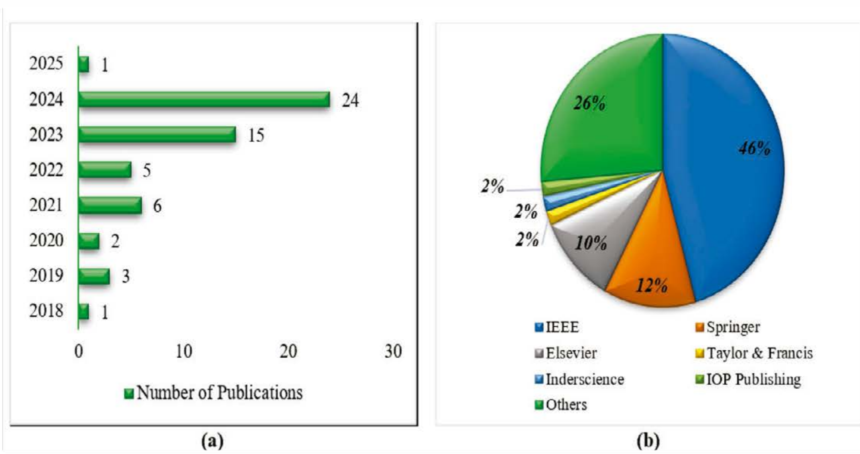

Fig. 3. (a) Year-wise publication count; (b) Publishers with publication percentages.

Table 2 presents the three popular datasets of the mango leaf disease and these are MangoLeafBD, MLDID, and MLDD. The image count of each dataset with class details are presented in that table. Total eight classes are considered here and total 4000, 3000, and 2336 images present in the MangoLeafBD, MLDID, and MLDD dataset, respectively. Most popular is MangoLeafBD dataset with 53 citations according to Google Scholar till 30.01.2025. A significant constraint of this study is that the utilized MangoLeafBD dataset images were not taken in a real-world environment.

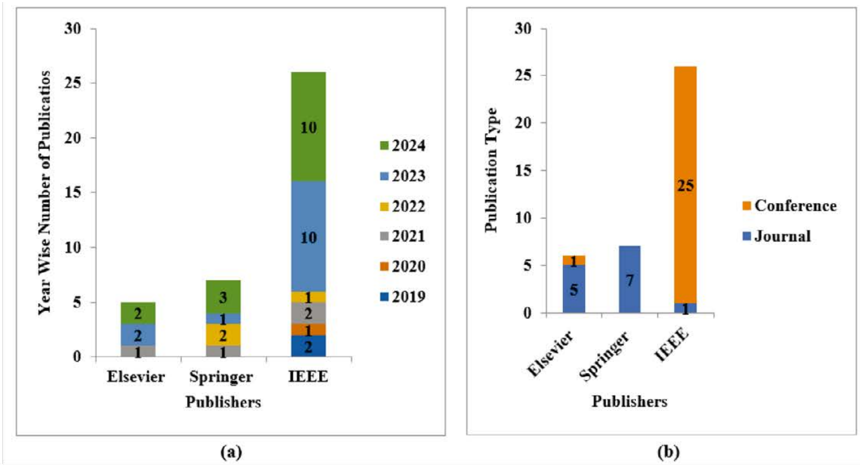

Fig. 4. (a) Top three publishers with year wise publications; (b) Top three publishers with publication type.

Table 2. Three Popular Datasets for Mango Leaf Disease.

SL.	Disease Name	Image Count of MangoLeafBD Dataset [8] YEAR: 2023	Image Count of MLDID Dataset [9] YEAR: 2024	Image Count of MLDD Dataset [10] YEAR: 2024
1	Anthracnose	500	600	326
2	Bacterial Canker	500	600	343
3	Cutting Weevil	500	…	307
4	Die Back	500	600	320
5	Gall Midge	500	600	319
6	Healthy	500	600	250
7	Powdery Mildew	500	…	206
8	Sooty Mould	500	…	265
Total		4000	3000	2336

3 Literature Survey

This section presents the up-to-date literature survey of CNN based mango leaf disease detection and classification field. However, only journal articles are discussed here. A Multilayer CNN was developed by Singh et al. [11] in the year 2019 for the purpose of classifying mango leaves affected with Anthracnose disease. The dataset used for training and testing the MCNN consisted of 1070 real-time images collected at Shri Mata Vaishno Devi University, located in Katra, Jammu and Kashmir, India. The experimental outcome showed that the proposed method attained higher accuracy of 97.93% when compared with other state-of-art approaches namely PSO, SVM, and RBFNN. Saleem et al. in the year 2021 [12] presented a CNN model for segmenting the diseased part of mango leaves and the same was evaluated on the real dataset collected by the mango research institute, Multan, Pakistan. Resizing, contrast enhancement, followed by image augmentation, and ground-truth synthesis of the input image were performed as part of the pre-processing. The suggested approach was used for segmentation. Prior to feature fusion, feature extraction and fusion, and PCA-based feature reduction were completed. Several classifiers were then used to complete the classification process. The experimental conclusion evidently highlighted that the presented model produced a good performance in terms of accuracy of 98.9% when compared with other models namely CNN, MCNN and Mangonet. Rajbongshi et al. in 2021 [13] proposed a work that focused on mango leaf disease (Anthracnose, Gall Machi, Powdery Mildew, Redrust) identification using numerous CNN models namely DenseNet201, ResNet50, ResNet152V2, InceptionResNetV2, InceptionV3, and Xception with transfer learning techniques. The presented method was evaluated on real dataset comprising of 1500 images and the result obtained revealed that the different CNN models employed generated high performance with DenseNet201 model outperformed by attaining the high accuracy of 98.00% than other models. Chowdary and Puviarasi in 2022 [14] compared the CNN with Fuzzy means algorithm for the purpose of disease namely Bacteria blight identification in mango leaves making use of 10 images from the seed buzz website. The feature extraction technique involved applying the transform algorithm to the pre-processed data. Subsequently, the diseased leaf images of mango were classified using CNN. The CNN-based system achieved an accuracy of 95.2%, surpassing the 93.5% accuracy achieved by the Fuzz Mean approach. Prabu and Chelliah al. in the year 2022 [15] proposed a CNN framework optimized by crossover-based levy flight distribution (CROLFD) algorithm for the purpose of mango leaf disease identification and classification considering 380 images taken from the farms of Andhra Pradesh, India. Data augmentation technique to prevent overfitting, for feature selection CNN with CROLFD, MobileNetV2 model was considered for learning phase and SVM for disease classification. The experimental result demonstrated that the proposed model generates high accuracy of 94.5% in comparison with other models namely NN with SVM-72.63%, BBDC-92.67%, ML-78.32%, MCNN-92.30%, ANN-80.4% and CNN-84.13%. Sharma et al. in the year 2022 [16] proposed a Deep Learning techniques, CNN for the identification of mango leaf diseases namely Anthracnose, Red rust and Powdery mildew, considering 980 images from Sher-e-Kashmir University of Agriculture Sciences and Technology, Jammu (SKUAST-J). Different image augmentation methodology was used on the dataset, CNN was further employed on the augmented data for the classification of mango diseased leaves. The experimental results indicated that the presented model successfully detected and identified mango leaf disease with an accuracy of 90.36%. A novel CNN model named as LeafNet was introduced by Rizvee et al. in the year 2023 [17] for sensing 7 different mango leaf diseases by considering 1800 images from MangoLeafBD dataset. The proposed model produced the accuracy of 99.55% compared to other tested models namely AlexNet-99.25%, VGG 16-78.4%. Salamai et al. in the year 2023 [18] elaborated a deep learning approach, visual modulation network that was basically proposed to enhance the diagnosis process of mango diseases considering images from MangoLeafBD dataset (1800 images) and Harumanis Mango Leaves Dataset (1395 images). The proposed work basically focusses on introducing a visual modulation network that would have the ability to identify and learn the visual representation of the diseased leaves through active linear layers. In order to handle the discontinuity of non-overlapped patching, overlapped patching embedding mechanism was employed, visual modulators were used to help the model learn the feature of diseased leaf in the process, and finally features identified were summarized with a global average pooling layer to classify the diseases of mango leaf. The proposed model attained an accuracy of 99.23%. Rani and Gowrishankar [19] deployed five versions of the ConvNeXt model: ConvNeXtBase, ConvNeXt-Large, ConvNeXtXLarge, ConvNeXtTiny, and ConvNeXtSmall, on the Mango-LeafBD Dataset for leaf disease diagnosis. Experimental findings demonstrated that larger models often surpassed smaller models, signifying their capacity to learn intricate properties. The ConvNeXtXLarge model had the highest accuracy: 98.79% for mango pests, 100% for mango diseases, and 99.17% for the aggregated dataset. Hari and Singh [20] proposed a lightweight CNN model for detecting defective leaves in banana, guava, and mango was developed. The model introduced the principle of feature reutilization at three distinct stages. The investigation revealed that the approach employs 101,000 parameters and attains a 99.14% accuracy in identifying disease-affected leaves. Furthermore, it surpasses 15 distinct cutting-edge pre-trained CNN models regarding its precision and degree of complexity. Vijay and Pushpalatha [21] developed a hybrid CNN model based on EfficientNetB4 and a Customized CNN model to detect the 8 classes of mango leaf diseases accurately. The proposed hybrid model achieved 93.01% accuracy by outperforming VGG-16 and Efficient-NetB4. Hossain et al. [22] employed Vision Transformers (ViTs) for the detection of mango leaf diseases and conducted a comparison with CNN models. They suggested an optimised model utilising a pretrained Data-efficient Image Transformer (DeiT) architecture that attains 99.75% accuracy, surpassing numerous prevalent CNNs. They proved that ViTs can obtain optimal outcomes in fewer epochs than CNNs, resulting in less training duration. They also presented a smartphone application, utilizing the proposed model as a backbone. Bezabh et al. [23] enhanced the efficiency of classification by using preprocessing techniques (noise elimination, segmentation, and data augmentation) and feature extraction utilizing GoogLeNet and VGGNet. The classification model was subsequently developed with fully connected layer classifiers on the extracted features of mango leaf imagery. The ensemble model exhibited excellent results with a testing accuracy of 99.21%. A comparative analysis of the effectiveness of CNN frameworks, specifically AlexNet, VGG-16, and ResNet-50, for the identification of mango leaf diseases was conducted in [24]. Comparisons were made between these models with and without the application of transfer learning methods. AlexNet achieved a testing accuracy of 94.54% while requiring less training time. ResNet-50 and VGG-16 achieved testing accuracies of 98.56% and 98.26%, respectively. Varma et al. [25] employed many pre-trained deep learning models, including VGG19, InceptionV3, ResNet152V2, DenseNet121, InceptionResNetV2, MobileNetV2, and Xception Models. The InceptionV3 model achieved the highest accuracy of 99.87%, surpassing other models. Singh et al. [26] devised a deep learning model, employing many intricate algorithms, datasets, and validation techniques, utilising the softmax activation function for training. The results indicated that the suggested model achieved an accuracy of 99.76% on the MangoLeafBD dataset. Gautam et al. [27] used an ensemble stacked deep learning model to automatically identify mango leaf diseases. The suggested technique involved initially segmenting the images for the area of greatest interest and subsequently inputting them into a series of diverse deep neural networks. The results of the proposed deep model were combined with a machine learning model to detect leaf disease. Selvakumar and Balasundaram [28] presented an automated method wherein input pictures were enhanced through a contrast enhancement method and subsequently segmented using optimized Fuzzy C Means (FCM). Parameter optimization was conducted using the Deviation-based Updated Dingo Optimizer (D-UDOX). The D-UDOX selected weighted features. The classifier of the Optimized Recurrent Neural Network (WO-RNN) received the weighted features. Deep features were extracted from a segmented image utilizing ResNet-150. The classification utilizing the extracted deep features was executed by WO-RNN. The parameter adjustment was executed utilizing D-UDOX for RNN and ResNet-150. The proposed model attained 96% accuracy and a 93% F1 score, demonstrating superior performance compared to current studies. Veling and Patil [29] created a multi-strategy model for the detection of mango leaf disease. The initial image contrast enhancement was executed using Contrast-Limited Adaptive Histogram Equalization (CLAHE). CNN were utilized for the profound feature extraction, with the features from both inputs concatenated for subsequent processing. The Adaptive Squirrel-Grey Wolf Search Optimization (AS-GWSO) was employed for weighted feature selection to identify the most significant features. Enhanced Long Short-Term Memory (LSTM) is utilized in the classification phase, with parameter optimization achieved through the same AS-GWSO to improve classification accuracy. Mahmud et al. [30] introduced a lightweight DenseNet model for the identification of mango leaf diseases. The findings indicated that the optimized DenseNet architecture (DenseNet78), combined with an appropriate growth rate, adjusted block size, and layer count, achieves maximum accuracy, yielding 99.47% in recognizing healthy and 99.44% in diagnosing different diseases. Vijay and Pushpalatha [31] came up with DVNet, a new kind of deep mutual learning model that combines the best parts of Densenet 121 and VGG19 neural networks. Particle Swarm Optimization (PSO) was used for hyperparameter optimization, a technique for determining optimal values. The suggested framework attains a remarkable accuracy of

94.72% in identifying diseased and healthy leaves. Zhang et al. [32] created a lightweight double branch inverted residual attention network (CBAM-DBIRNet) model that combines the inverted residual network with the attention mechanism to find out what stage of illness anthracnose is in mango leaves. The results showed that the CBAM-DBIRNet model was 98.42% accurate at identifying the stages of anthrax, 97.80% recall, and 97.89% proficient in its F1 score. The model's size and parameters were 0.64 MB and 0.15 million, respectively.

3.1 Discussion and Analysis

The literature review indicates that various primary CNN models, including AlexNet, Inception, ResNet, VGG, MobileNet, DenseNet, Xception, EfficientNet, Yolo, and their enhanced variants, have been employed for the classification of mango leaf diseases. Fig. 5 illustrates the proportion of the specified CNN models and their variants utilized in the domain of disease categorization. AlexNet, Inception, and ResNet are unequivocally the three foremost CNN models utilized for the identification and categorization of mango leaf diseases. Fig. 6(a) illustrates the mango leaf diseases predominantly examined by researchers. Anthracnose is clearly the predominant leaf disease in this domain. Transfer learning is a methodology that enables models to utilize previously learned information for new, related tasks, particularly beneficial when data is scarce for a novel challenge. In the realm of mango leaf disease detection and classification, the acquisition of a substantial dataset is a significant challenge. Consequently, researchers employed transfer learning-based CNN models in this domain. Fig. 6(b) illustrates the proportion of CNN models utilizing scratch training and transfer learning. Transfer learning is evidently underutilized in the domain of mango leaf disease detection. Therefore, researchers must concentrate on that. Fig. 7(a) depicts the proportion of traditional and lightweight CNN models employed for mango leaf disease detection. The advancement of lightweight CNN models is inadequate. Merely 15% of the total employed models are lightweight, necessitating researchers to concentrate on this area, since lightweight CNN models have yielded promising outcomes [30, 32]. Fig. 7(b), on the other hand, shows the percentage of classic CNN models and metaheuristics-optimized CNN models that were found in the literature review. It is evident that, although metaheuristic approaches are highly effective for optimizing weighting parameters, their application in CNN for mango leaf disease detection and classification is not frequent. Merely 18% of total CNN models are optimized with the application of metaheuristic techniques. Consequently, the advancement of metaheuristics optimized CNN models represents a promising future direction.

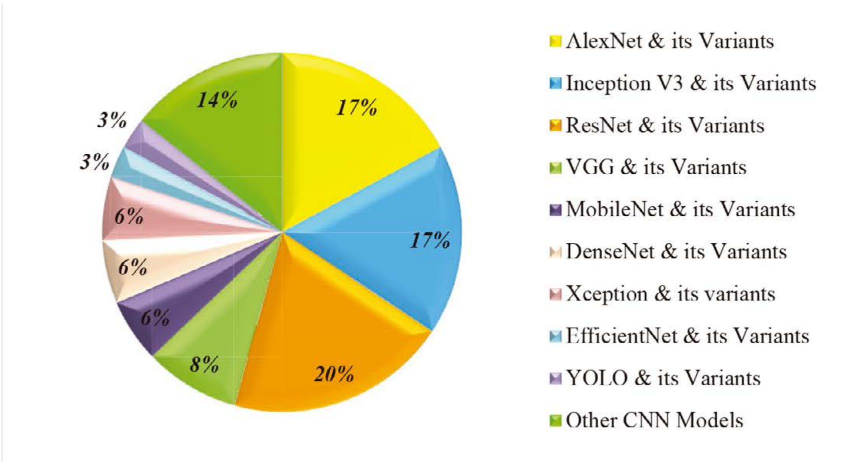

Fig. 5. Distribution of CNN models and its variants addressed in selected research articles.

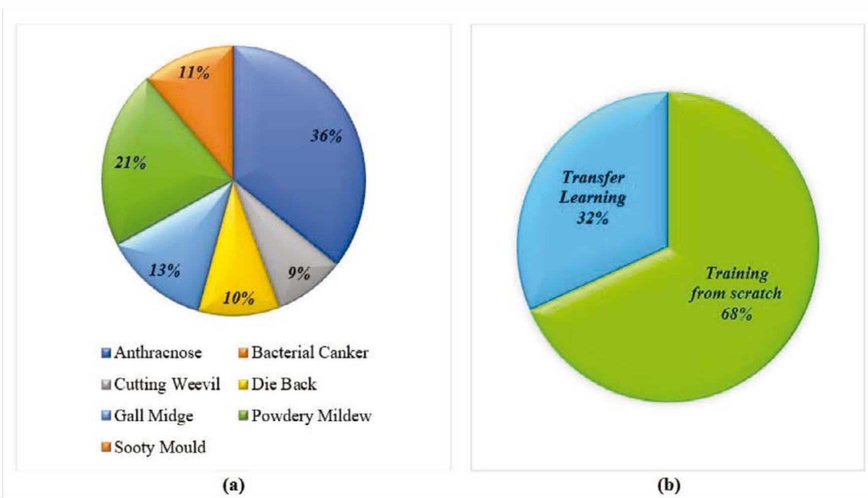

Fig. 6. (a) Disease considered by the researchers as per the survey; (b) Percentage of CNN models with Scratch training and Transfer learning.

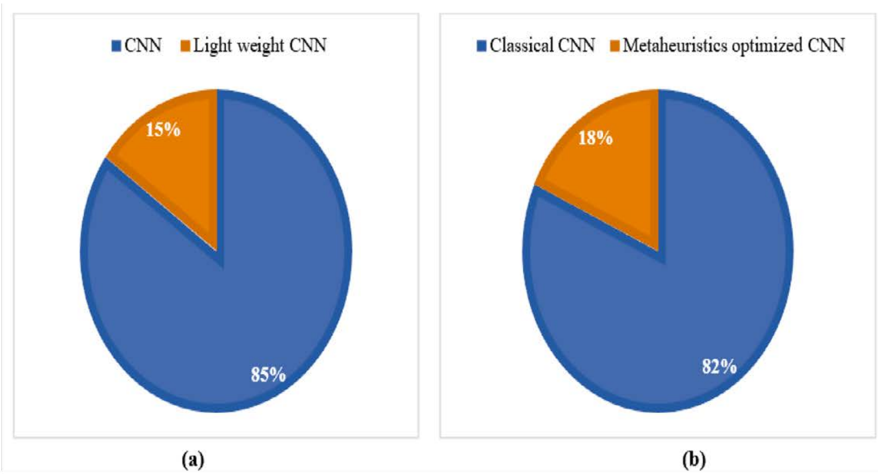

Fig. 7. (a) Percentage of classical CNN and light weight CNN models; (b) Percentage of classical CNN and Metaheuristics optimized CNN models.

4 Conclusion and Future Directions

Agriculture is a linchpin in the growth trajectory of developing countries, playing a vital role in fostering economic development and societal well-being. In these nations, a substantial portion of the population engages in agricultural activities, making it a cornerstone for livelihoods. The cultivation of crops not only contributes significantly to the country's Gross Domestic Product (GDP) but also generates employment opportunities across the agricultural value chain. The impact of mango cultivation, specifically, exemplifies the transformative potential of agriculture. Mangoes, with their high demand and popularity both domestically and internationally, become a key player in economic prosperity. The cultivation of mangoes not only adds value to the agricultural GDP but also diversifies the sector, mitigating risks associated with mono-cropping. Additionally, mango cultivation creates income avenues for farmers, fosters the growth of agro-processing industries, and opens up opportunities for export, enhancing the overall economic landscape of the developing country. In essence, agriculture, with a focus on crops like mangoes, serves as a catalyst for holistic growth, intertwining economic prosperity with sustainable development.

The production of mangoes faces significant challenges, among which leaf diseases pose a notable threat. Leaf diseases, such as anthracnose, powdery mildew, sooty mould, and gall midge can pose significant threats, causing defoliation, reduced photosynthesis, and lower yields. These diseases are often caused by fungal pathogens and are exacerbated by factors such as humidity, temperature fluctuations, and poor agricultural practices. However, advancements in technology, specifically the application of DL models, offer a promising solution for early prediction and management of these diseases.

Several future works can be made to improve the mango leaf disease classification task which are as follows: (1) Obtaining the dataset from a real-world environment. This could enhance the performance of trained models, ensuring a more accurate identification of diseases affecting mango leaves. (2) Develop a novel hybrid DL architecture by using an attention-based mechanism or combining current DL models to enhance accuracy. (3) Additionally, Nature Inspired Optimization Algorithm (NIOA) can be incorporate for selecting the best hyper parameters automatically for fine-tuning the CNN model. (4) Create a model that will run efficiently in mobile environments that will help farmers to promptly detect plant diseases and take appropriate precautions. (5) Segmentation of leaf disease area plays an important role in disease detection and classification [33, 34, 35]. Therefore supervised [33, 34] and unsupervised [35] segmentation techniques can be utilized in future.

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