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Survey on Mango Leaf Disease Detection Using Convolutional Neural Networks

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ABSTRACT: This study investigates the application of Convolutional Neural Networks (CNNs) for identifying mango leaf diseases such as Anthracnose, Powdery Mildew, Bacterial Canker, Die Back, and Leaf Spot, all of which severely impact mango yield and fruit quality. It reviews existing literature and approaches to understand how CNN-based models automatically learn and capture discriminative features from leaf images, including color variations, texture details, leaf morphology, and lesion patterns caused by diseases. Different CNN architectures, including AlexNet, VGG, ResNet, and EfficientNetV2, are analyzed and compared based on their classification accuracy, training efficiency, and scalability for large-scale agricultural applications. Reported results show that AlexNet achieves approximately 85–90% accuracy, VGG networks reach 88–93%, ResNet models perform between 92–96%, while EfficientNetV2 delivers the highest performance with about 95–98% accuracy. The study emphasizes the benefits of CNN-based approaches for mango leaf disease detection, such as higher accuracy compared to traditional manual inspection, early-stage disease detection capability, and suitability for deployment in large orchards. By reviewing recent advancements, this study provides insights into how deep learning techniques can enhance disease monitoring, guide future research, and support the development of automated systems for sustainable mango cultivation.

KEYWORDS: Mango Leaf Diseases, Convolutional Neural Networks, EfficientNetV2, Deep Learning, Feature Extraction, Agriculture

I. INTRODUCTION

Mango, widely regarded as the “king of fruits,” holds immense agricultural, economic, and nutritional significance, particularly in tropical and subtropical regions. It is one of the most extensively cultivated fruit crops, contributing substantially to farmers’ livelihoods and the agricultural economy. Despite its importance, mango production is highly vulnerable to a variety of leaf diseases such as Anthracnose, Powdery Mildew, Bacterial Canker, Die Back, and Leaf Spot. These diseases not only deteriorate the visual quality of leaves but also interfere with essential physiological processes like photosynthesis, ultimately leading to reduced yield and inferior fruit quality. The symptoms often appear in the form of discoloration, necrotic spots, lesions, or abnormal deformations on the leaf surface. If not detected at an early stage, these infections can spread rapidly across orchards, causing significant economic losses.

Conventional disease detection methods primarily depend on manual inspection carried out by agricultural experts or farmers. While effective to some extent, these approaches suffer from several limitations, including dependency on expert knowledge, time consumption, high labor costs, and susceptibility to human error. In many rural or large-scale farming scenarios, timely expert intervention may not always be feasible, leading to delayed diagnosis and improper treatment decisions. These limitations emphasize the need for an automated, dependable, and scalable system that can identify diseases at an early stage

In recent years, advancements in artificial intelligence, particularly in deep learning, have opened new avenues for automated plant disease detection. Convolutional Neural Networks (CNNs), a specialized class of deep learning models designed for image processing tasks, have demonstrated remarkable performance in identifying and classifying plant diseases. Unlike traditional machine learning techniques that depend on handcrafted features, CNNs automatically learn hierarchical feature representations directly from raw images, capturing intricate details such as color variations, texture



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patterns, and shape irregularities associated with different diseases. By training CNN models on large datasets of healthy and infected mango leaf images, it becomes possible to achieve highly accurate and consistent classification results. This makes CNN-based systems a promising and efficient solution for real-time disease monitoring and management in modern, large-scale mango orchards.



Fig 1: Some Common Mango Leaf Diseases

II. LITURATURE REVIEW

Mango leaf disease detection and classification have been widely explored using deep learning techniques to improve agricultural productivity and automate diagnosis. Recent studies have focused on improving accuracy, computational efficiency, and model interpretability.

Rayed et al. (2025) [1] proposed MangoLeafXNet, an explainable CNN-based deep learning model for accurate mango leaf disease classification. The study developed a lightweight custom CNN architecture capable of detecting multiple mango leaf diseases using image-based analysis. To improve model robustness, preprocessing and data augmentation techniques such as resizing, normalization, rotation, and flipping were applied. The authors also integrated Explainable AI techniques including Grad-CAM and LIME to visualize infected regions and improve interpretability of predictions. Experimental results showed that the proposed model achieved very high classification accuracy and outperformed several existing CNN models on multiple mango leaf datasets. The study demonstrated the effectiveness of combining CNN and Explainable AI for intelligent and reliable mango leaf disease detection systems.

Salazar-Campos et al. (2025) [2] proposed a deep learning-based approach for automated grading of 'Kent' mango maturity according to Peruvian agricultural standards. The study developed a Convolutional Neural Network (CNN) model to classify mangoes based on their maturity level using image analysis techniques. A dataset containing 603 labeled mango images was used to optimize the CNN architecture by evaluating convolutional layers, pooling layers, image resolution, and training cycles. The optimized model achieved 96.04% classification accuracy, 90.91% recall, and 93.57% F1-score. Additionally, 5-fold cross-validation demonstrated strong robustness and consistent performance. The study found that lightweight CNN architectures can enable efficient, low-cost, and real-time automated fruit grading systems for smart agricultural applications and post-harvest quality control.

Rizvee et al. (2023) [3] proposed LeafNet, a customized Convolutional Neural Network (CNN) model for detecting seven prominent mango leaf diseases using image-based analysis. The study developed a lightweight deep learning architecture capable of classifying multiple mango leaf diseases and healthy leaves efficiently. The authors collected a mango leaf dataset from orchards and applied preprocessing and data augmentation techniques to improve model robustness and generalization. The proposed model focused on extracting important disease features while reducing computational complexity compared to traditional CNN architectures. The study indicates that CNN-based automated disease detection systems can support early disease identification of mango leaf and improve smart agriculture applications.



International Journal of Innovative Research in Computer and Communication Engineering (IJRCCE)

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Rastogi et al. (2024) [6] proposed a Convolutional Neural Network (CNN)-based approach for early plant disease detection using image analysis techniques. The study focused on identifying plant diseases at an early stage to minimize crop damage and improve agricultural productivity. The authors applied image preprocessing and feature extraction methods to enhance disease-related patterns in plant leaf images. The CNN model was trained to classify healthy and diseased plant leaves efficiently under varying environmental conditions. The study highlighted the importance of deep learning techniques in developing automated, fast, and reliable plant disease diagnosis systems for smart agriculture applications.

Richter et al. (2025) [7] presented a systematic review of transfer learning accelerated CNN-based plant leaf disease classification methods. The study analyzed recent deep learning approaches that utilize pretrained CNN architectures for plant disease detection and classification. The review discussed various transfer learning models, datasets, preprocessing methods, and evaluation techniques used in agricultural applications. The authors highlighted the advantages of transfer learning in improving classification performance, reducing training time, and overcoming limited dataset challenges. The study also identified research gaps and future directions for developing efficient and scalable plant disease diagnosis systems.

Bezabh et al. (2024) [8] proposed an ensemble Convolutional Neural Network (CNN) approach for mango disease classification using image-based analysis. The study combined multiple CNN models to improve disease recognition capability and enhance classification robustness. Image preprocessing and augmentation techniques were applied to improve model generalization and reduce overfitting. The ensemble framework focused on extracting diverse disease-related features from mango leaf images for better detection performance. The study demonstrated that ensemble deep learning models can provide reliable and efficient solutions for automated mango disease diagnosis in smart agriculture systems.

Khandelwal et al. (2024) [9] proposed an advanced machine learning framework for mango plant leaf disease classification using deep learning and feature fusion techniques. The study utilized image preprocessing and feature extraction methods to identify common mango leaf diseases from diseased and healthy leaf images. The framework extracted deep features using MobileNetV2 and EfficientNetV2 architectures, followed by feature fusion through dense layers to improve disease representation. Principal Component Analysis (PCA) was applied to reduce feature dimensionality, and a Support Vector Classifier (SVC) was used for final disease classification. The proposed system focused on improving classification efficiency, robustness, and early disease detection capability for smart agricultural applications.

Singh et al. (2019) [11] proposed a multilayer Convolutional Neural Network (CNN) model for classifying mango leaves infected by anthracnose disease. The study focused on automated disease identification using image-based deep learning techniques to reduce dependency on manual inspection. The proposed CNN architecture extracted hierarchical disease features from mango leaf images for effective classification. Preprocessing methods were applied to enhance image quality and improve feature learning capability. The study demonstrated that CNN-based approaches can support early detection of anthracnose disease and improve disease management in mango cultivation.

From the above studies, it is evident that while many models achieve high accuracy, they suffer from limitations such as lack of explainability, high computational cost, limited dataset diversity, and absence of severity detection or treatment recommendations. Therefore, there is a need for a model that not only provides accurate disease detection but also includes explainable AI, severity analysis, and practical usability for farmers.

III. DATASETS

Most studies utilized custom mango leaf image datasets collected from orchards under real environmental conditions. Public datasets such as MangoLeafBD, MangoPest, MLDID, and PlantVillage are widely used for training and evaluation of CNN models. Dataset diversity, image quality, and class balance play a crucial role in improving disease classification performance. Many researchers also apply pre-processing and augmentation techniques such as resizing, normalization, rotation, and flipping to improve model generalization and reduce overfitting.



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1. MangoLeafBD Dataset

The MangoLeafBD dataset contains more than 4,000 images of healthy and diseased mango leaves used for mango leaf disease classification research. The dataset includes the disease classes like Anthracnose, Bacterial Canker, Cutting Weevil, Die Back, Gall Midge, Powdery Mildew, and Sooty Mold along with healthy leaf images.

2. MLDID Dataset

The MLDID dataset contains around 3,000 healthy and diseased mango leaf images captured under real environmental conditions. The dataset includes mango leaf diseases such as Anthracnose, Powdery Mildew, Sooty Mold, Bacterial Canker, and Red Rust along with healthy leaves.

3. MangoPest Dataset

The MangoPest dataset contains over 2,400 images of mango pests and infected mango leaves. The dataset includes pest categories such as Fruit Fly, Hopper, Mealy Bug, Stem Borer, Shoot Borer, and Leaf Webber used for pest identification and disease analysis.

IV. CNN-BASED MANGO LEAF DISEASE DETECTION METHODOLOGY

1. Input Image:

The process starts when the system receives an image of a mango leaf. This image may show visible signs of infection such as dark spots, yellow patches, fungal growth, or discoloration. The input image may also vary in background, lighting, and angle because it is usually captured in natural farm conditions. Since the accuracy of the detection depends heavily on the quality of the input image, a clear and focused leaf image helps the system identify disease features more effectively.

2. Preprocessing:

Preprocessing plays a crucial role in preparing the mango leaf images before feeding them into the CNN model for analysis. All images are first resized to a fixed resolution (such as 224×224 pixels) to maintain uniformity across the dataset. This is followed by normalization, where pixel values are scaled to a smaller numerical range to improve training efficiency and accelerate convergence. Additionally, noise removal techniques are applied to minimize unwanted background elements and enhance the clarity of important leaf features. To further strengthen the model's generalization ability, data augmentation methods such as rotation, flipping, zooming, and brightness adjustments are used to artificially expand the dataset and simulate real-world variations. Overall, preprocessing ensures that the CNN receives clean, standardized, and diverse input data, leading to more accurate and robust disease classification results.

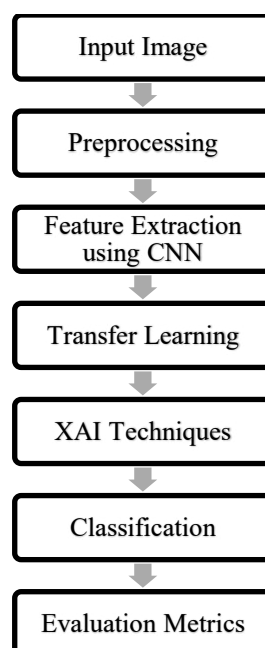


Fig 2: Methodology



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3. Feature Extraction using CNN:

Convolutional Neural Networks (CNNs) are widely used for automatic feature extraction and disease classification from mango leaf images. Popular CNN architectures include AlexNet, VGG16, ResNet50, DenseNet, MobileNet, EfficientNet, and EfficientNetV2. These models automatically learn disease-related features such as texture, color patterns, lesions, and infected regions. The feature extraction stage is the core part of the system where the Convolutional Neural Network learns disease-specific characteristics directly from the input images. The process begins with convolution layers, where small learnable filters slide across the image to detect important visual patterns such as texture irregularities, lesion shapes, infected regions, and color changes. Next, the ReLU activation function is applied to introduce non-linearity, enabling the model to learn complex relationships within the data that simple linear transformations cannot capture. As the image moves deeper through multiple convolution layers, the network progressively learns high-level abstract features, allowing clear differentiation between various mango leaf diseases. This automated feature extraction eliminates the need for manual feature engineering and significantly improves accuracy, making CNNs highly effective for plant leaf disease detection.

4. Transfer Learning:

Transfer learning techniques utilize pretrained CNN models trained on large datasets such as ImageNet to improve disease classification performance. Researchers commonly fine-tune pretrained models like ResNet50, MobileNet, and EfficientNetV2 for mango leaf disease detection tasks. Transfer learning reduces training time and improves performance when limited datasets are available.

5. Explainable AI Techniques:

Explainable Artificial Intelligence (XAI) techniques are integrated with CNN models to improve interpretability and transparency of predictions. Common XAI methods include Grad-CAM, LIME, SHAP, and saliency maps. These techniques help visualize infected leaf regions and explain how the model identifies specific diseases.

6. Classification:

The extracted features are passed to a fully connected layer with a Softmax classifier, which classifies the input image into categories such as healthy or specific mango leaf diseases.

7. Evaluation Metrics

Evaluation metrics are used to measure the performance of CNN-based disease detection models. Common metrics include accuracy, precision, recall, F1-score, confusion matrix, and loss values. These metrics help compare different deep learning models and evaluate their effectiveness in disease classification tasks.

V. COMPARATIVE ANALYSIS

Several Convolutional Neural Network (CNN) architectures have been commonly used for mango leaf disease classification, each offering different strengths in terms of accuracy, computational cost, and real-time suitability. AlexNet delivers moderate accuracy (around 85%–90%) with fewer parameters and faster training, making it suitable for quick experimentation, though real-time performance is limited. VGG16 and VGG19 provide higher accuracy (88%–93%) but contain a very large number of parameters, resulting in slow training and poor suitability for real-time applications. ResNet50 and ResNet101 achieve high accuracy (92%–96%) using residual skip connections, balancing performance and computational efficiency better than VGG models. InceptionV3 also offers strong accuracy (91%–95%) with moderate parameter size and training speed, making it suitable for deployment but not specifically optimized for lightweight systems. EfficientNetV2 stands out with exceptional accuracy (95%–98%), fewer parameters, and fast training, making it ideal for real-time and resource-constrained environments due to its efficient scaling strategy. MobileNetV2 provides impressive performance (90%–94%) with extremely low computational requirements and very fast training, making it highly suitable for mobile and field-based use, although its accuracy is slightly behind EfficientNetV2.



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Table 1: Comparative Analysis of different CNN Models

Model	Accuracy	Params	Speed	Real Time
AlexNet	85–90%	60M	Fast	Moderate
VGG16/19	88–93%	138M	Slow	Low
ResNet50	92–96%	25M	Moderate	Moderate
InceptionV3	91–95%	23M	Moderate	Moderate
MobileNetV2	90–94%	3.4M	Very Fast	Very High
EfficientNetV2	95–98%	7–20M	Fast	High

VI. APPLICATIONS

A. Lightweight CNN models like MobileNet and EfficientNetV2 can run efficiently on smartphones and low power devices, enabling real-time disease detection directly in the field. Farmers can capture a leaf photo and instantly get disease results, allowing early intervention and preventing spread.

B. CNN-based systems automate diagnosis, removing the need for expert inspection and reducing cost and time. Even non-specialists can easily identify diseases using mobile apps, minimizing human error and supporting independent decision-making.

C. The same CNN architecture can be adapted for different crops by changing the dataset. This flexibility enables multi-crop disease detection systems, supporting smart agriculture and large-scale digital farming solutions.

VII. CONCLUSION AND FUTURE WORK

CNN-based models enable fast and accurate mango leaf disease detection, reducing the need for manual inspection and expert support. Advanced architectures such as EfficientNetV2 and ResNet provide reliable classification performance under real-field conditions. In the future, the system can be enhanced with real-time detection, severity analysis, treatment recommendation, mobile deployment, and integration with drones, smart cameras, soil, and weather data. These improvements can transform the system into an intelligent agricultural tool for better crop monitoring, disease management, and improved crop yield.

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