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LeafDNet: Transforming Leaf Disease Diagnosis Through Deep Transfer Learning

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ABSTRACT

The health and productivity of plants, particularly those in agricultural and horticultural industries, are significantly affected by timely and accurate disease detection. Traditional manual inspection methods are labor-intensive, subjective, and often inaccurate, failing to meet the precision required by modern agricultural practices. This research introduces an innovative deep transfer learning method utilizing an advanced version of the Xception architecture, specifically designed for identifying plant diseases in roses, mangoes, and tomatoes. The proposed model introduces additional convolutional layers following the base Xception architecture, combined with multiple trainable dense layers, incorporating advanced regularization and dropout techniques to optimize feature extraction and classification. This architectural enhancement enables the model to capture complex, subtle patterns within plant leaf images, contributing to more robust disease identification. A comprehensive dataset comprising 5491 images across four distinct disease categories was employed for the training, validation, and testing of the model. The experimental results showcased outstanding performance, achieving 98% accuracy, 99% precision, 98% recall, and a 98% F1-score. The model outperformed traditional techniques as well as other deep learning-based methods. These results emphasize the potential of this advanced deep learning framework as a scalable, efficient, and highly accurate solution for early plant disease detection, providing substantial benefits for plant health management and supporting sustainable agricultural practices.

1 | Introduction

Plants cultivated for ornamental, agricultural, or horticultural purposes are highly vulnerable to various diseases that adversely impact their health, productivity, and economic value. These diseases, which include bacterial, fungal, viral infections, and pest infestations, pose significant threats to global agriculture by diminishing crop yields, degrading quality, and escalating management costs. For instance, bacterial diseases such as *bacterial spots* in tomatoes and *bacterial canker* in mangoes result in considerable crop losses. Likewise, fungal diseases like *anthracnose* and *powdery mildew* affect mangoes and roses (Saleem, Potgieter, and Arif 2021, Albattah et al. 2022, Vishnoi, Kumar, and Brajesh 2021, Vallejo-Pérez et al. 2021, Sharma, Mittal, and Gupta 2024b). Viral infections, including the *tomato yellow leaf curl virus*, further complicate

Abbreviations: AI, Artificial Intelligence; AUC, area under curve; BN, batch normalization; CNN, convolutional neural network; DL, deep learning; GPU, graphics processing unit; Grad-CAM, gradient-weighted class activation mapping; ML, machine learning; R-CNN, region-based convolutional neural network; ReLU, rectified linear unit; ROC, receiver operating characteristic; SVM, support vector machine; XAI, explainable AI.

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