Leaf Classification Using Deep Learning and Transfer Learning Techniques

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1. Dataset Used

All models were trained and evaluated using the Flavia Leaf Dataset.

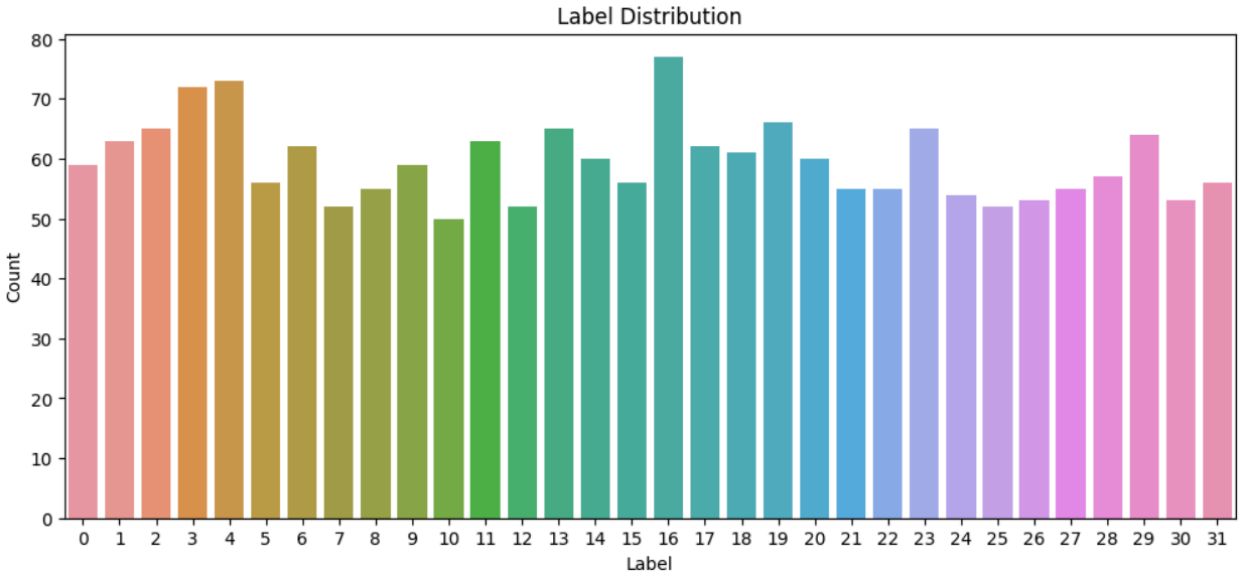
Dataset Description

- The Flavia dataset contains leaf images from 32 different plant species.
- Each class represents a unique leaf type.
- Images are RGB images with varying resolutions.
- The dataset is widely used for plant leaf classification and benchmarking deep learning models.

Preprocessing

- Images were resized according to model requirements:
    - 224 × 224 for VGG-19, ResNet50, MobileNetV2
    - 299 × 299 for InceptionV3
- Labels were encoded numerically using one-hot encoding.
- The dataset was split into:
    - 80% Training
    - 20% Testing

- Data was shuffled before training to ensure randomness and avoid bias.



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2. Model 1: VGG-19 (From Scratch)

Model Description

- A VGG-style Convolutional Neural Network built entirely from scratch.
- No pretrained weights were used.
- The architecture consists of:
    - Multiple convolutional layers
    - Max pooling layers
    - Fully connected layers at the end

Training Configuration

- Optimizer: Adam

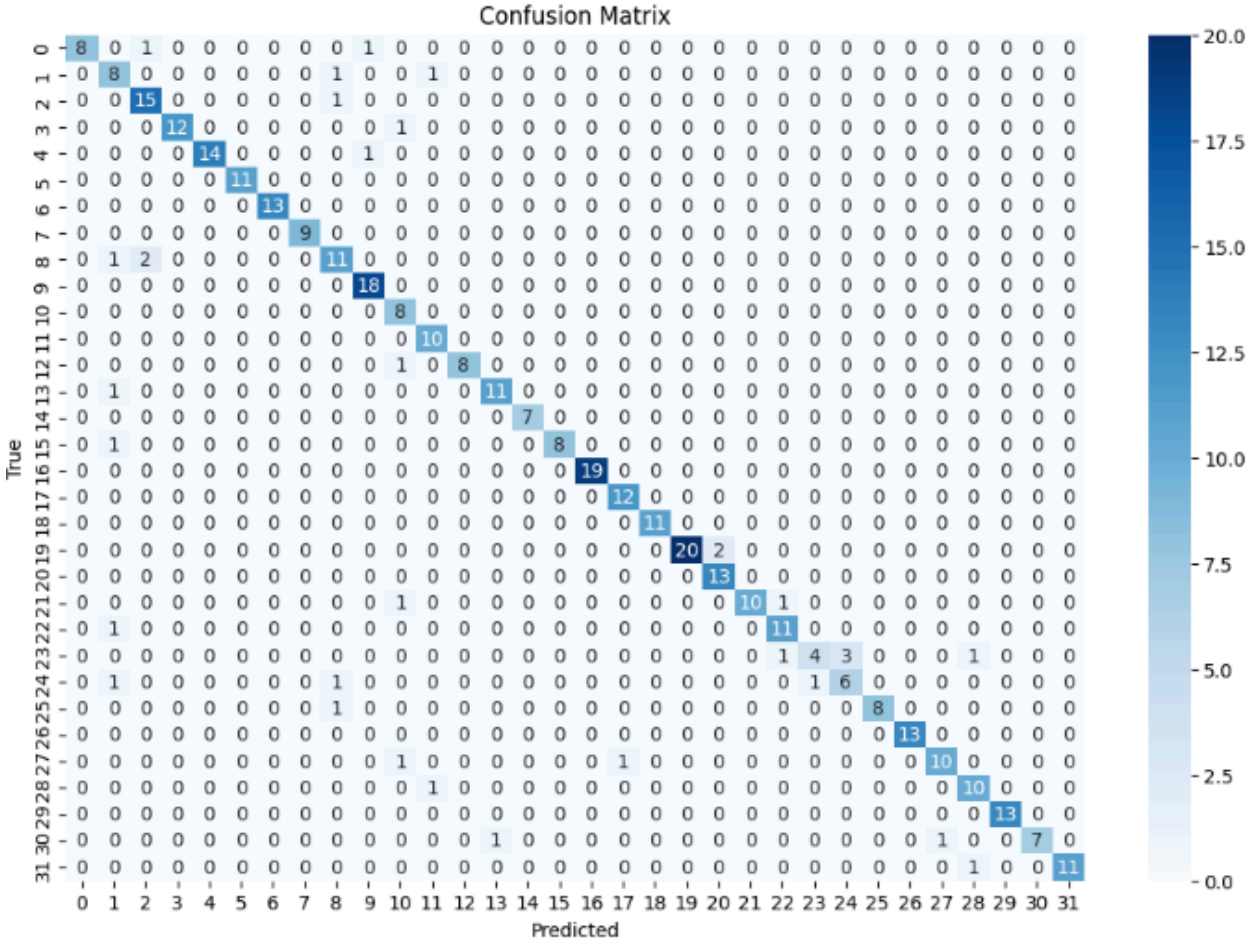
- Learning Rate: 0.0001
- Loss Function: Categorical Cross-Entropy
- Train/Test Split: 80/20
- Batch Size: 32
- Epochs: 35

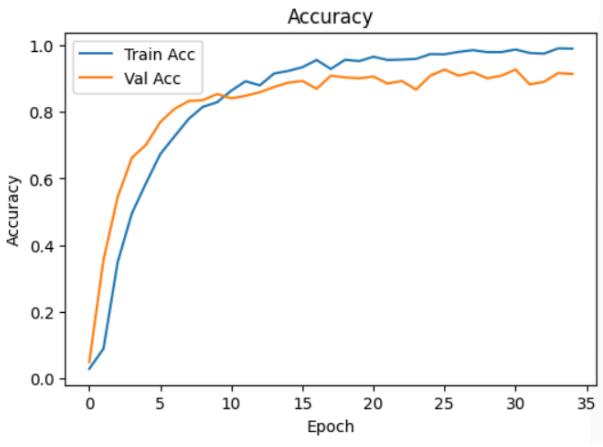
Performance

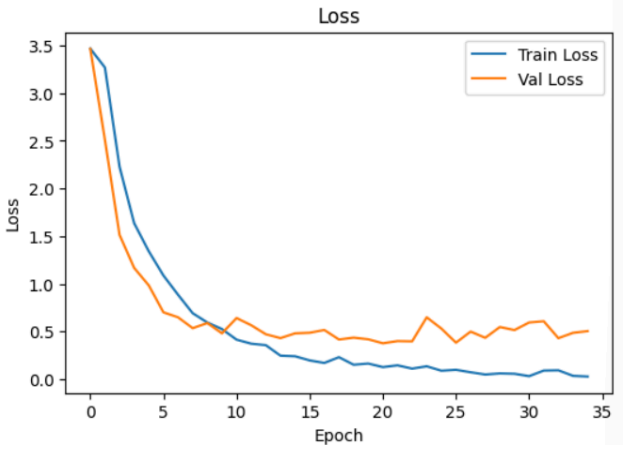
- Test Accuracy: 91%
- Macro Average F1-Score: 0.91
- Weighted Average F1-Score: 0.91

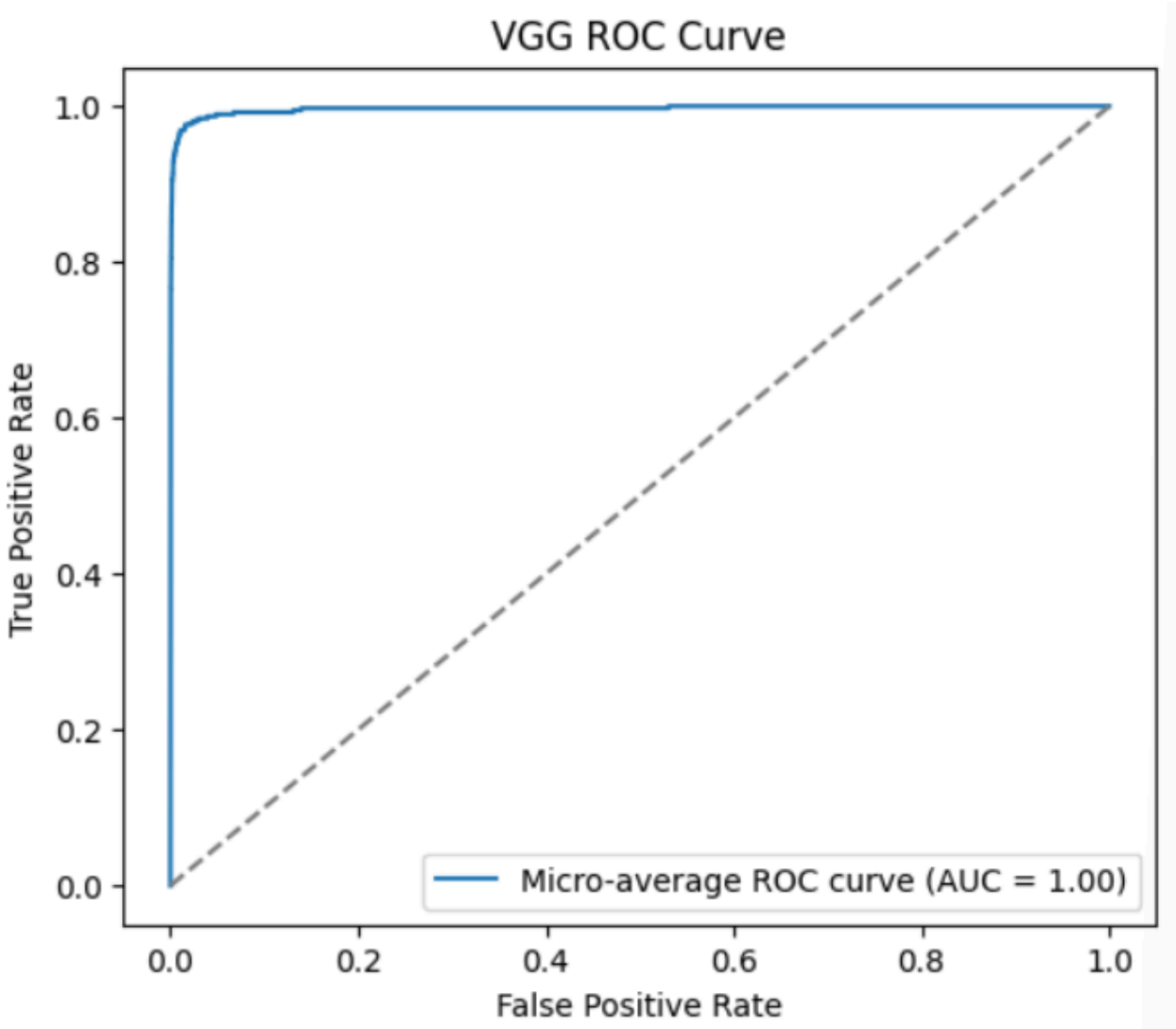
Remarks

- Serves as a strong baseline model.
- Performance is limited due to:
    - Training from scratch
    - Relatively small dataset size
- Some classes show lower recall, indicating difficulty distinguishing visually similar leaves.


Confusion Matrix
True
Predicted


Accuracy
Train Acc
Val Acc
Accuracy
Epoch


Loss
Train Loss
Val Loss
Loss
Epoch



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3. Model 2: ResNet50 (Transfer Learning)

Model Description

- ResNet50 is a deep residual network that uses skip connections.
- Pretrained on the ImageNet dataset.
- Transfer learning was applied by:
    - Freezing base layers

    - Training custom classification layers for leaf classification

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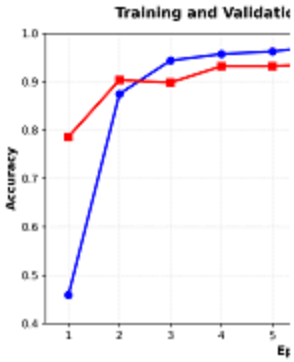
Evaluation Metrics

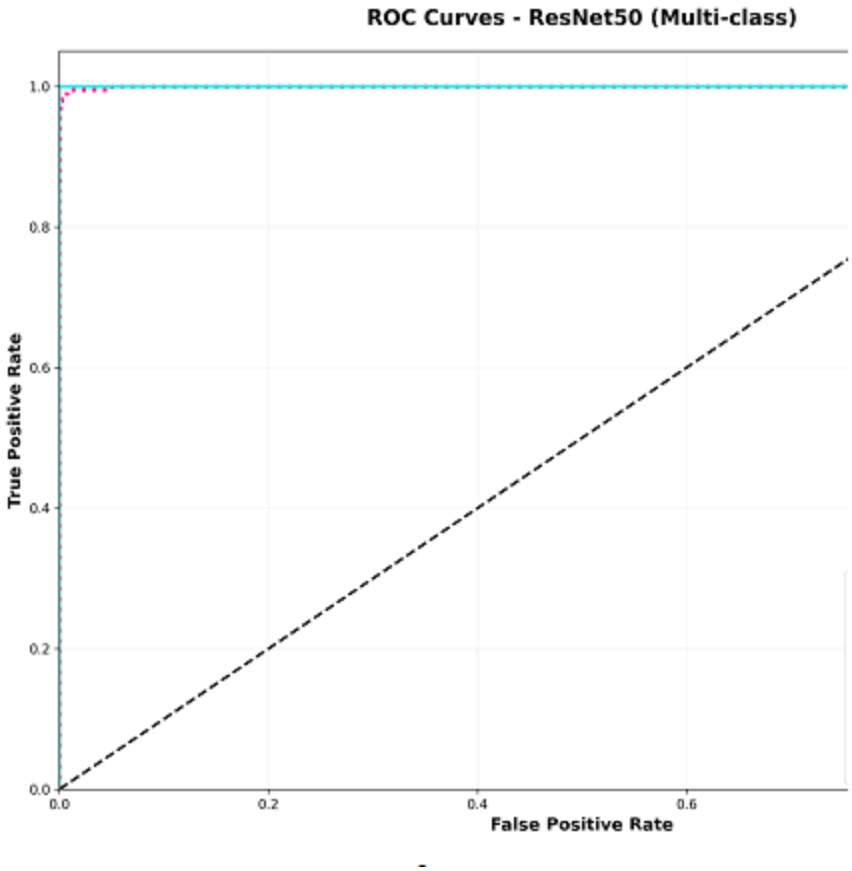
- Accuracy: 97.89%
- Precision: 98.28%
- Recall: 97.89%
- F1-Score: 97.89%
- AUC: 1.00

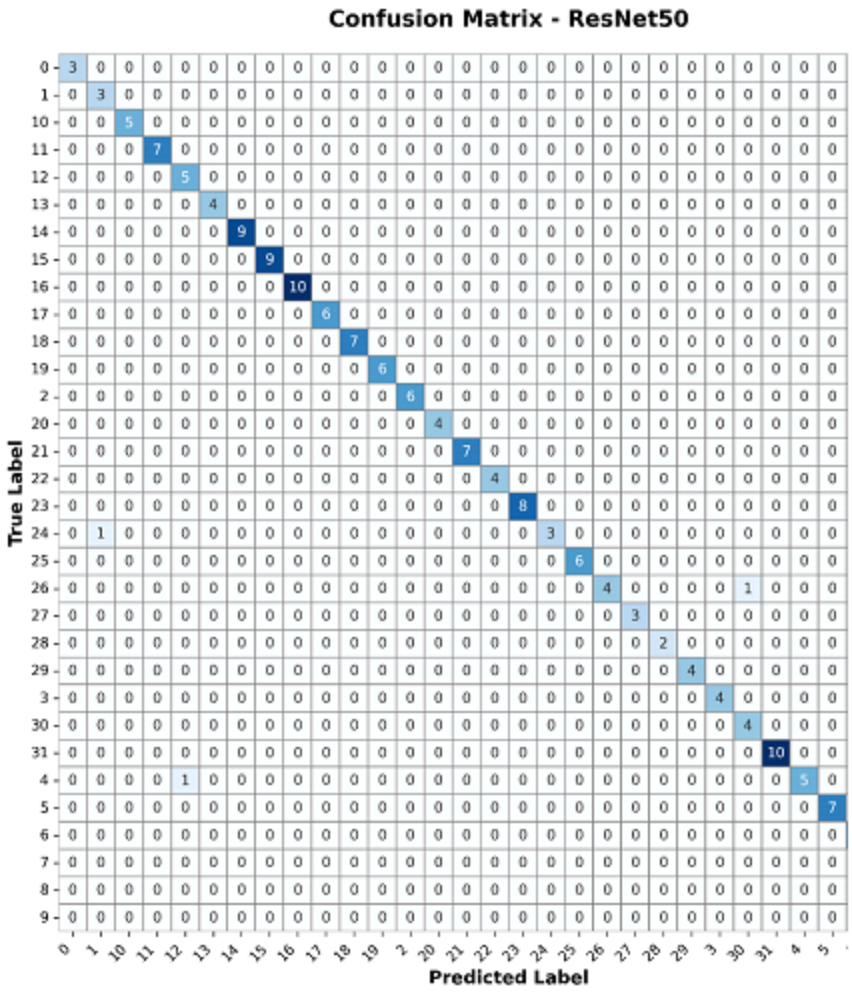
Remarks

- Residual connections help prevent vanishing gradients.
- Demonstrates excellent generalization.
- Significantly outperforms the VGG model trained from scratch.


Training and Validation Loss - ResNet50
Training Loss
Validation Loss
Loss
Epoch


Training and Validatic
Accuracy


ROC Curves - ResNet50 (Multi-class)
True Positive Rate
False Positive Rate



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4. Model 3: MobileNetV2 (Transfer Learning)

Model Description

- MobileNetV2 is a lightweight and computationally efficient CNN.
- Pretrained on ImageNet.
- Used as a fixed feature extractor with frozen base layers.

Model Configuration

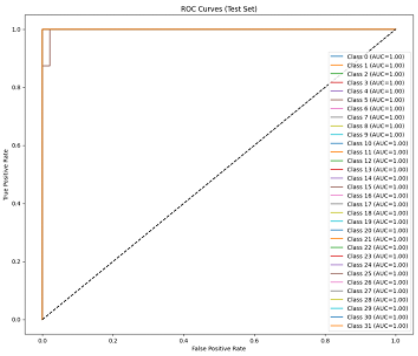
- Input Size: 224 × 224
- Batch Size: 32
- Global Average Pooling Layer
- Dense Layer: 128 neurons (ReLU)
- Output Layer: Softmax with 32 classes

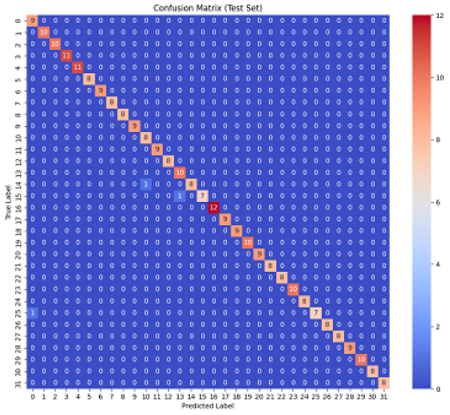
Performance

- Test Accuracy: 99%
- Macro Average Precision: 0.99
- Macro Average Recall: 0.99
- Macro Average F1-Score: 0.99

Remarks

- Achieves excellent accuracy with low computational cost.
- Highly suitable for:
    - Real-time applications
    - Mobile and edge devices





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5. Model 4: InceptionV3 (Transfer Learning)

Model Description

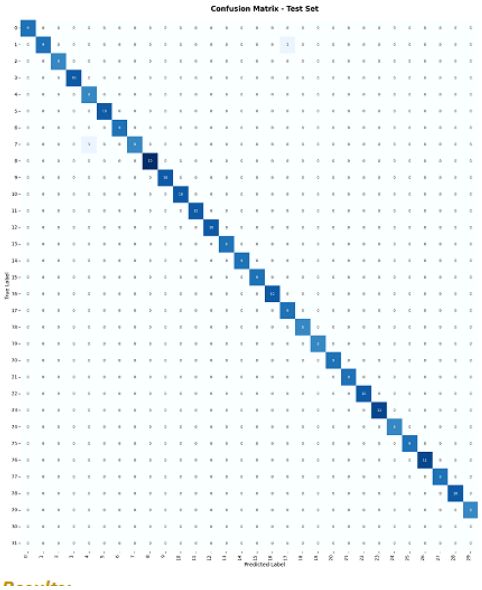
- InceptionV3 uses multi-scale convolutional filters within inception modules.
- Pretrained on ImageNet.
- Fine-tuned specifically for leaf classification.

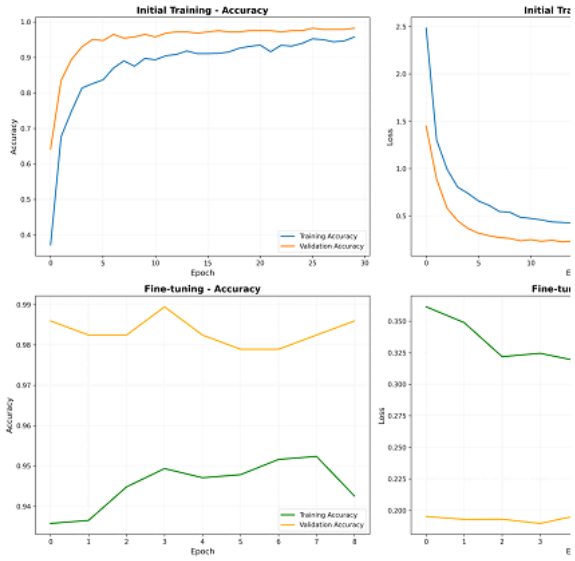
Performance Metrics

- Final Test Accuracy: 99.33%
- Precision: 0.9940
- Recall: 0.9933
- F1-Score: 0.9933
- Number of Classes: 32

Remarks

- Achieved the highest overall performance among all models.
- Strong class-wise precision and recall across most leaf categories.
- Best suited for complex visual patterns.





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6. Model Comparison Summary

Model Name	Training Type	Test Accuracy
VGG-19	From Scratch	91%
ResNet50	Transfer Learning	97.89%
MobileNetV2	Transfer Learning	99%
InceptionV3	Transfer Learning	99.33%

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7. Conclusion

- Transfer learning significantly improves performance compared to training from scratch.
- InceptionV3 achieved the best overall results.

- MobileNetV2 offers an excellent trade-off between accuracy and efficiency.
- Model selection should consider dataset size, task complexity, and deployment constraints.