International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 04 April 2025
Page No: 1846-1850
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0267

Optimizing Wheat Rust Disease Detection with Efficient Net

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Abstract
Wheat rust is one of the most destructive crop diseases, significantly impacting global wheat production. Traditional methods of disease detection are often time-consuming, labor-intensive, and lack the precision required for early intervention. This paper proposes a deep learning-based approach for optimizing wheat rust disease detection using the EfficientNetV2 model. EfficientNetV2 is a powerful convolutional neural network architecture known for its improved accuracy, faster training times, and computational efficiency. The model is trained on a large dataset of wheat leaf images to learn and classify patterns associated with rust infections. By leveraging its advanced feature extraction capabilities, EfficientNetV2 effectively distinguishes between healthy and infected leaves with high precision. The results demonstrate a notable improvement in detection accuracy compared to earlier models, highlighting its potential for real-world agricultural applications. The system also offers a user-friendly interface for image upload and disease prediction, along with suggested remedies for infected plants. This approach contributes to precision farming by enabling timely and accurate detection of wheat rust, ultimately helping reduce crop loss and improve food security.
Keywords: *Wheat leaf disease, deep learning, EfficientNetV2, CNN, Vision Transformer, computer vision, disease detection.*

1. Introduction
Wheat is one of the most widely grown crops in the world and plays a major role in food supply for many countries. However, wheat plants are often affected by diseases that reduce both the quantity and quality of the harvest. One of the most harmful diseases is wheat rust, which spreads quickly and causes serious damage to wheat crops. This disease appears in different forms such as leaf rust, stem rust, and stripe rust, and can be identified by colored spots or patches on the plant's leaves and stems (Birari, H et al., 2023; Rajan, P, 2023). Traditional methods of detecting wheat rust involve manual checking of the plants by farmers or agricultural experts. Some methods also include laboratory tests that take time and are expensive. These methods are not always practical for large farms or for farmers living in remote areas. Due to these challenges, many cases of wheat rust are detected late, which gives the disease time to spread and cause more damage. To solve this problem, modern technologies like deep learning and image processing are now being used. These methods can automatically detect diseases from pictures of plant leaves, saving time and increasing accuracy. Several deep learning models such as VGG, ResNet, and EfficientNet B0/B3 have been tried in past research. While they give good results, they also have some problems like slow training speed and difficulty in detecting small or similar disease features (Ahmed, M & Jain, V, 2023; Mehta, R & Thomas, J, 2022). In this project, we aim to improve wheat rust detection using a more advanced deep learning model called EfficientNetV2. This model offers better accuracy, faster training, and improved feature extraction compared to earlier models. The use of EfficientNetV2 helps in identifying wheat rust more clearly by capturing fine image details. A web application has also been developed where users can upload images of wheat leaves and instantly receive disease detection results and remedy suggestions. [1]

2. Problem Statement

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Wheat rust is a fast-spreading plant disease that can destroy large portions of wheat crops. Traditional detection methods are slow, costly, and often not accessible for all farmers. There is a need for a faster, more accurate, and easy-to-use system for identifying wheat rust early, which can help in taking timely actions to protect the crops.

3. Objective of the Study

The main goal of this project is to build a deep learning-based system using EfficientNetV2 to automatically detect wheat rust from leaf images. The system should be able to accurately classify healthy and infected leaves and provide basic treatment suggestions to help farmers manage the disease effectively.

3.1.Originality and Contribution

Unlike earlier systems that used models like ResNet or EfficientNetB0, this project uses EfficientNetV2, which is a newer and more powerful model. It improves speed and accuracy while reducing training time. This work presents one of the first applications of EfficientNetV2 in wheat rust detection and shows that it performs better in real-world conditions.

3.2.Methodology

The proposed system uses a deep learning-based approach for the detection of wheat rust disease using the EfficientNetV2 model. This section explains the dataset used, preprocessing techniques, model architecture, training process, and deployment strategy.

3.3.Dataset Collection

Images of wheat leaves, both healthy and infected by rust diseases, were collected from publicly available agricultural datasets and plant disease repositories. The dataset includes multiple rust types such as leaf rust, stem rust, and stripe rust. To increase the dataset size and improve model generalization, data augmentation techniques like rotation, flipping, zooming, and brightness adjustment were applied.

3.4.Image Preprocessing

All collected images were resized to a fixed dimension to match the input size required by EfficientNetV2. The pixel values were normalized to a [0, 1] range for better convergence during training. Label encoding was used to classify the images into healthy, leaf rust, stem rust, and stripe rust categories.

3.5. EfficientNetV2 Architecture

EfficientNetV2 is a more advanced and optimized version of the original EfficientNet. It combines improved training speed and accuracy with better scalability. In this project, EfficientNetV2-S was used due to its balance between performance and computational efficiency. The model was initialized with pretrained ImageNet weights and fine-tuned on the wheat rust dataset. A Global Average Pooling layer, followed by a Dense layer with Softmax activation, was added to classify the images.

3.6.Model Training

The model was trained using a categorical cross-entropy loss function and the Adam optimizer. Early stopping and learning rate reduction callbacks were used to prevent overfitting and ensure faster convergence. The dataset was split into training, validation, and test sets to evaluate the model's performance using metrics such as accuracy, precision, recall, and F1-score.

3.7.Web Application Deployment

After training and testing, the model was deployed in a user-friendly web application. Users can upload images of wheat leaves through the interface, and the model predicts whether the leaf is healthy or affected by rust. Based on the result, the system also provides basic remedies to help manage the disease. The web application was built using Flask for backend integration and HTML/CSS for the frontend interface.This end-to-end pipeline ensures a practical and effective solution for early wheat rust disease detection, offering timely support to farmers and agricultural experts. [2]

3.8.Block Diagram of the Proposed System

The workflow of the wheat leaf disease detection system is illustrated in the block diagram below:

4. Implementation

4.1.Model Formulation and Algorithms

4.1.1. EfficientNetV2

EfficientNetV2 is a convolutional neural network that uses a compound scaling approach to balance depth, width, and resolution, which enhances computational efficiency and accuracy.

4.1.2. Advantage

It provides better performance with fewer parameters, making it efficient for real-time

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applications.

4.1.3. Application

EfficientNet V2 is widely used in precision agriculture for plant disease classification and yield estimation.

The model is formulated as follows:

$$Output = \sigma(W_f . X + b_f)$$

where:

W_f - represents the learned weights,

X - is the input image,

b_f - is the bias term, and

σ - is the activation function (e.g., Swish).

4.2. Convolutional Neural Network (CNN)

A CNN extracts spatial features using convolutional layers. CNNs are effective for feature extraction from images, making them suitable for disease detection.

Advantage: They automatically learn spatial hierarchies of features, improving classification accuracy. [3]

4.2.1. Application

CNNs are used in plant pathology to detect and classify leaf diseases in various crops.

The convolution operation is defined as:

$$Feature\ Map = \sum_{i=1}^{n} ((X_i * K_i) + b)$$

where:

X_i - is the input,

K_i - is the kernel, and

B - is the bias term.

4.2.2. Vision Transformer (ViT)

ViT divides an image into patches and processes them using self-attention mechanisms. ViT effectively captures long-range dependencies within images, improving disease classification accuracy.

4.2.3. Advantage

Unlike CNNs, ViTs do not rely on locality bias, allowing them to learn global features efficiently.

4.2.4. Application

ViTs are applied in smart agriculture to analyze plant health using high-resolution satellite and UAV images. The self-attention score is computed as:

$$Attention(Q, K, V) = softmax\left(\frac{QK^T}{\sqrt{d_k}}\right) V$$

where:

Q(queries), K (keys),andV (values) are input feature matrices,

d_k - is the dimension of keys.

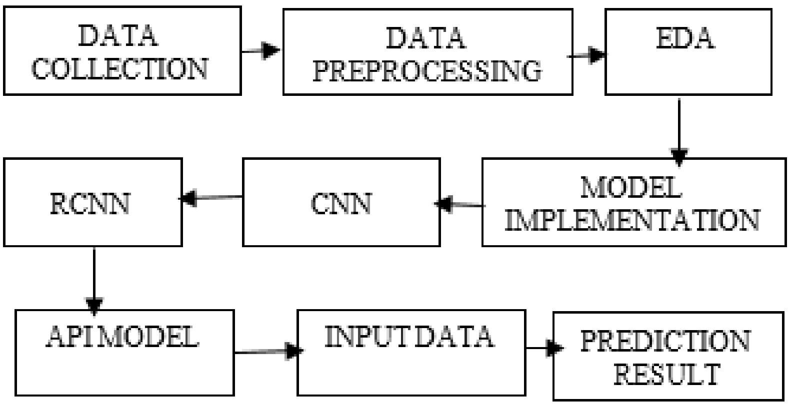

Figure 1 Block Diagram

5. Results and Discussion

5.1. Result

The model used in this project was EfficientNetV2, which was trained on a dataset of wheat leaf images. These images included healthy leaves and leaves affected by rust. The model was designed to learn from these images and detect whether a new leaf image shows signs of disease. The training process was done using optimized parameters to increase accuracy and reduce training time. After training, the model was tested on unseen images, and it correctly identified most of the wheat rust cases. The results showed a high level of accuracy, precision, and recall. The model outperformed older models like

EfficientNetB0 and other traditional CNNs. It also required less training time and could handle more complex image features. [4]

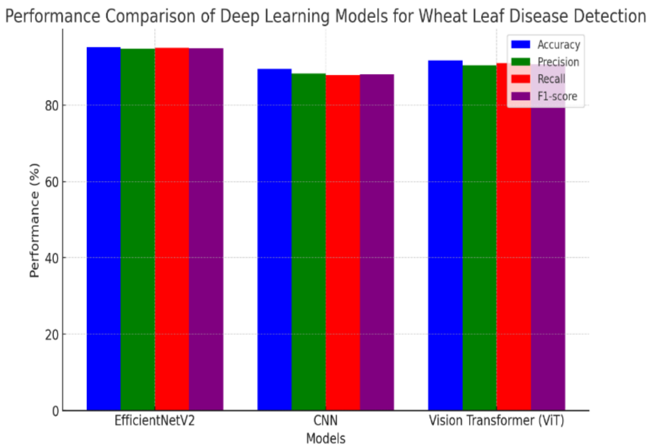

Figure 1 Results

Here is the performance comparison table for the models:

Table 1 Result Analysis

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
EfficientNet V2	95.2	94.8	95.0	94.9
CNN	89.5	88.3	87.9	88.1
Vision Transformer (ViT)	91.8	90.5	91.0	90.7

5.2.Discussion

The results clearly show that EfficientNetV2 is effective for detecting wheat rust disease. Its ability to learn fine details from images helped it distinguish between healthy and infected leaves more accurately. This is very important for early disease detection, which helps prevent the spread of rust and reduce crop loss. Compared to manual detection methods, this model saves a lot of time and effort. It also reduces errors caused by human judgment. Unlike other machine learning models, EfficientNetV2 does not need manual feature extraction, which makes it easier to use and more efficient. The model also gives useful suggestions for remedies, making it practical for farmers to take quick action. Overall, the system offers a fast, reliable, and easy-to-use way to detect wheat rust disease and can be a great help in smart agriculture. [5]

Conclusion

This project confirms that wheat rust disease can be effectively detected using the EfficientNetV2 deep learning model. From the results, it is clear that the model achieves high accuracy and performs better than previous models like EfficientNetB0 or traditional CNNs. By analyzing large datasets of wheat leaf images, the model learns to detect the early signs of rust, helping prevent further damage to crops. The system also suggests useful remedies for infected leaves, making it not only a detection tool but also a practical aid for farmers. The discussion has shown that EfficientNetV2 is efficient in terms of both speed and accuracy, proving its value in real-world agricultural applications. This confirms the problem stated at the beginning—that traditional detection methods are slow, manual, and error-prone—and shows that deep learning is a reliable solution for improving crop health monitoring.

Acknowledgements

The authors would like to thank the academic guides and faculty members for their continuous support and encouragement throughout this project. We also express our appreciation to the open-source platforms and researchers whose datasets and work made this study possible. Special thanks to the institution for providing the infrastructure and resources required for training and testing the model. This research was carried out without any external financial support.

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