Fuzzy Systems and Soft Computing
ISSN : 1819-4362

# A COMPREHENSIVE REVIEW ON DEEP LEARNING TECHNIQUES FOR MANGO LEAF DISEASE DETECTION

**Vivek Kumar**, Research Scholar, Department of CSE, Quantum University, Roorkee.
vksingh087@gmail.com
**Dr. Satender Kumar**, Dean Academics, Quantum University, Roorkee
satenderkumar.cse@quantumeducation.in

***Abstract:*** ***Mango leaf diseases pose significant challenges to the agricultural sector, particularly in regions like West Uttar Pradesh, India, where mango cultivation is prevalent. Traditional methods of disease detection through manual inspection are labor-intensive and prone to human error. Recent advancements in deep learning offer promising solutions for automating the detection and classification of mango leaf diseases. This review paper explores the various deep learning techniques applied to identify and manage mango leaf diseases, highlighting the efficacy of models like DenseNet-121, VGG-19, DenseNet169, InceptionV3, MobileNetV2, Hybrid model SVM, Fuzzy C Means, D-UDOX, RestNet, Conv-5 DCNN, ConvNext and YoloV8 etc, in achieving high accuracy rates and provides opinion to improve accuracy with small datasets, The review also discusses the impact of these technologies on improving yield and quality in mango production. Future research directions include optimizing models for small datasets, integrating advanced pre-trained models, and developing real-time detection systems for practical agricultural applications.***
***Keyword:*** ***Machine Learning, Deep Learning, CNN, RestNet, DenseNet.***

## INTRODUCTION

Tropical Fruit Mango (Mangifera indica) cultivated in many states of India particularly in Uttar Pradesh. In 2023-2024, the mango production in Uttar Pradesh, particularly in West UP, showed significant growth. The state's overall production of mangoes reached approximately 4.5 million metric tons, maintaining its position as the top mango-producing state in India. The favourable climatic conditions and improved agricultural practices contributed to this increase. Specific data for West UP indicates that districts like Saharanpur and Muzaffarnagar played a crucial role in this production boost (Data DESAGRI). In West Uttar Pradesh, mango leaf diseases are a significant concern for farmers and agricultural experts. There are following mango leaf diseases:

TABLE 1: POPULAR MANGO LEAF DISEASE

| **Name of Diseases** | **Infected Mango Leaf Images** |
|---|---|
| **1) Anthracnose**<br>A case of Anthracnose by pathogenic fungi Colletotrichum. Brown to dark Brown symptoms on leaves. |  |
| **2) Bacterial Canker**<br>A case of Bacterial Canker by the bacteria Xanthomonas campestris. |  |
| **3) Cutting Weevil**<br>The infestation of cutting Weevil in influenced by environmental condition such as rainfall and humidity. |  |

| | |
|---|---|
| **4) Die Back**<br>Die Back can be caused by Fungal infections like Botryosphaeria rhodina. |  |
| **5) Gall Midge**<br>Gall midges, common in mango-growing areas, lay eggs in plant tissue. Larvae develop within, causing abnormal growths called galls. |  |
| **6) Powdery Mildew**<br>Oidium Mangiferae Berthet fungus is responsible for Powery Mildew. |  |
| **7) Sooty Mould**<br>Honeydew fungi caused of sooty mould. |  |
| **8) White Scale**<br>Aulacapis tubercularis pest caused of White Scale. |  |

Effective management of these diseases often involves a combination of cultural practices, chemical treatments, and, increasingly, the application of machine learning techniques for early detection and classification .Mango leaf diseases significantly impact mango production in West Uttar Pradesh (UP). Common diseases such as anthracnose, powdery mildew, and bacterial leaf spot lead to considerable yield losses. For example, anthracnose alone can cause up to 90% loss in fruit production under favourable conditions. These diseases result in reduced fruit quality and quantity, affecting both local consumption and export potential. In terms of statistics, the overall production reduction due to mango leaf diseases can be quite substantial. In some regions, the decrease in yield has been reported to be as high as 30-50%, depending on the severity of the disease and the effectiveness of the management practices employed [1]. This reduction is due to the diseases causing defoliation, fruit drop, and direct damage to the fruit, leading to both pre-harvest and post-harvest losses.

Traditionally mango leaf disease detection, manual inspection by experts was time consuming, required more laborious and lead to human error. In today’s world AI play an important role in detection of plant leaf disease using deep learning technique. Deep learning, new opportunities have emerged for automating the detection process, thereby improving the efficiency and accuracy. The use of deep learning methods for the detection of diseases in mango leaves. This paper explore different deep learning models, datasets and strategies used in recent studies and evaluate their performance.

Deep learning has revolutionized the detection and diagnosis of mango leaf diseases, offering automated, precise, and cost-effective solutions that surpass traditional methods. Convolutional neural networks (CNNs), trained on extensive datasets, can accurately identify and classify various diseases, enabling early detection often before symptoms are visible to the naked eye [2]. This early intervention is crucial for effective disease management. Integrating these models with drones and mobile applications allows for real-time monitoring of orchards, providing continuous oversight and enabling prompt action. The high precision and accuracy of deep learning models minimize false positives and negatives, ensuring reliable and actionable diagnoses. Furthermore, deep learning systems are scalable and cost-effective, eliminating the need for extensive manual inspections and capable of covering large agricultural areas efficiently [3]. When integrated into decision support systems, they provide farmers with actionable insights and recommendations, enhancing overall crop management. Advanced models even predict disease outbreaks by incorporating temporal data and environmental conditions, allowing for proactive disease management. Thus, deep learning significantly improves the yield and quality of mango production by ensuring the health of orchards through efficient, accurate, and scalable disease detection and management systems.

## LITERATURE REVIEW

Recent advancements in mango leaf disease detection have continued to leverage emerging technologies such as machine learning, image processing, and remote sensing. Here are some examples of recent work in this field:

C.P Vijay et al.(2024), in this study a novel deep learning model is design by using a combination of VGG-19 and DenseNet-12, for optimal values hyperparameter optimization technique is used. The proposed framework get the nice accuracy of 94.72% in detecting eight distinct disease. The model was trained and tested on 4873 mango leaves images.[4] Md. Naimur Rahaman, Musthafezur Rahaman Chowdhury et al. (2023): by researcher aproposed a new machine learning model for mango leaf disease classification, insects and their solution. In the research, researcher used MobileNetV2, InceptionV3, and DenseNet169 model. For inceptionV3 training accuracy was 97.60% and validation accuracy 97.98%. With DenseNet169 have the training accuracy of 97.81% and validating accuracy 99.37% [5].

Abdullah Ali Salamai et al (2023). This study also proposed a novel DL based model that use Ecological information management with deep learning for detection of disease in mango leafs automatically. The invented visual modulation network can finds all classes of disease of mango leaves with high accuracy 98% to 100%. In this research, MangoLeafDB (Ahmed et al., 2023). Dataset was used which contains 4000 images of better visualization of resolution 240*320 in png format. This data set contains eight different classes of mango leaves namly Cutting Weeviel, Anthracnose, Bacterial Canker, Powdery Mildew, Gall Midge and Sooty Mold. Every class contains 500 images.[6] For Testing the model, researcher used Harumanis Mango Leaves Dataset (Gining et al., 2021) which contains three classes of leaf images namely, healthy leafs, Anthracnose, and sooty mold [7].

Redwan Ahmed Rizvee et al., (2023), In this study, researcher develops LeafNet based on deep learning to detect seven common disease of mango leaves with accuracy 98.55%. By using this LeafNet model, early symptoms of mango leaf can detect. In this research MangoleafDB dataset is used, contains Sooty Mould, Cutting Weevil, Anthracnose, Die Back, Bacterial Canker, Powdery Mildew and Gall Midge.[8] Sachin Jain at al., (2023), in this research, researcher develops a hybrid model SVM and SGD based on image segmentation with accuracy of 97.7%. SVM (Support vector machine) is used for mango leaf diseases classification.[9]

A. Selvakumar at al., (2023), in this research for feature enhanced and segmentation, use optimized Fuzzy C Means (FCM), Derivation-based Updated Dingo Optimizer (D-UDOx) is used for Parameter optimization and WO-RNN provides weighted features. D-UDOX for RNN and ResNet-150 is used to parameter modification. By using weighted and Features model achieves 93% F1-score and 96% accuracy[10]. Pragya Hari e. al., 2023. The researcher proposed a light weighted deep learning based model for detection of diseased of banana, mango and guava fruits. The model was trained by using eight distinct categories of diseased available in open database. In this researcher found the accuracy 99.41%[11].

J. Arun Pandian at. el., 2022, In this research, proposed Conv-5 DCNN model applied on 26 different plant disease of dataset size from 55,448 to 234000 images but original images was 6000 by using argumentation techniques like NST (Neural Style Transfer), Deep convolutional Generative Adversial (DCGAN) enlarge the size of dataset. In training 224552 images was used from the argumented dataset. The proposed model achieves the accuracy of 98.41% sin classification, and F1-Score 0.97[12]. Vakalapudi Krishna Pratap at el., 2024. In this research, VGG-16, MobileNet, GoogleNet, Yolov8 models are applied to identifying and classifying diseases in mango leaf. Yolov8 is applied with ABO (African Buffalo Optimization) or without ABO and get the accuracy 98 and 92.7 respectively [13]. Asha Rani K P, at el., 2023 Proposed ConvNeXtLarge model classify mango pathogens and pests with high accuracy rate 98.17% and 100% respectively. The model performance is depends on dataset quality, Pre-processing techniques and hyper parameter sections[14].

TABLE I**:** Summary of various ML & DL Models, used Datasets and Accuracy on Mango leaf disease detection.

| **Author** | **Disease** | **Model** | **Dataset** | **Class** | **Size** | **Limitations** | **Accuracy (%)** |
|---|---|---|---|---|---|---|---|
| C.P Vijay et al.[4](2024) | • *Cutting Weeviel*<br>• *Anthracnose*<br>• *Bacterial Canker*<br>• *Powdery Mildew Gall Midge*<br>• *Sooty Mold* | DenseNet-121 and VGG-19 | MangoLeafDB | 8 | 4873 | The study primarily discusses the proposed DV-PSO-Net model without comparing it to a wider range of existing models or techniques | 94.72 % |
| Md. Naimur Rahaman, Musthafezur Rahaman Chowdhury et al.[5] [2023] | • *Anthracnose*<br>• *Bacterial Canker in Leaf*<br>• *Gall Midge Leaf*<br>• *Giant Mealybug in Leaf*<br>• *Coating Mite in Leaf*<br>• *Cutting Weevil in Leaf*<br>• *Mealybug Fruit*<br>• *Mealybug in Leaf*<br>• *Powdery Mildew in Leaf* | DenseNet169, InceptionV3, MobileNet V2 | Krishi Batayon, Flickr[19][20], Mendeley, Google | 20 | 31804 | The model's performance may be impacted when dealing with low-quality images. | 97.98 % |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Redwan Ahmed Rizvee et al., [8][2023]. | • *Cutting Weeviel*<br>• *Anthracnose*<br>• *Bacterial Canker*<br>• *Powdery Mildew Gall Midge*<br>• *Sooty Mold* | LeafNet | MangoLeafDB | 7 | 4373 | There is a lack of discussion on the computational resources required for training and deploying the deep learning models, which is crucial information for practical implementation and scalability of the proposed system | 98.55 % |
| Sachin Jain at al.,[9] 2023 | • *Anthracnose*<br>• *black Soothy mold* | Hybrid model SVM and SGD | Harumanis Mango Leaves 2021 Dataset(Kaggle) | 3 | 1206 | Not provide insights into the interpretability of the deep learning model. | 97.7 % |
| A. Selvakumar at al.,[10] 2023. | • *Powdery Mildew*<br>• *Sooty Mould*<br>• *Aspergillus Rot Blacktip*<br>• *Gray Leaf Blight,*<br>• *Insect Damage,*<br>• *Red Rust,*<br>• *Rhizoctonia solani,*<br>• *Stem end rot* | Fuzzy C Means (FCM), Derviation-based Updated Dingo Optimizer (D-UDOx) | Collects the data manually from the mango research centre | 11 | 10,000 | The paper mentions the use of Deviation-based Updated Dingo Optimizer (D-UDOX) for parameter optimization, but it does not elaborate on the limitations or constraints of this optimization technique | 96% |
| Pragya Hari e. al.,[11] 2023. | *N/A* | VGG, RestNet, InceptionV3, DenseNet201 etc. | Mendeley | 8 | 450 | Not provide detailed information on the specific challenges or limitations faced during the implementation of the proposed lightweight convolutional neural network model for disease detection in fruit leaves | 97.41 % |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| J. Arun Pandian at. el., 2022 [12] | • *Apple, Mango Disease* | Conv-5 DCNN | Open research data repository | 26 | 6000 | Focus on specific DCNN models, not broader machine learning methods. | 98.41 % |
| Vakalapudi Krishna Pratap at el., 2024 [13] | • *Cutting Weeviel Anthracnose*<br>• *Bacterial Canker Powdery Mildew*<br>• *Gall Midge*<br>• *Sooty Mold* | ConvNext | Pathogen Dataset | 8 | 4000 | the specific details of the validation procedures, such as cross-validation and testing on alternative datasets, are not extensively elaborated | 98.69 % |

METHODOLOGIES

Detecting mango leaf diseases using deep learning involves leveraging Convolutional Neural Networks (CNNs) for image classification, allowing automatic feature learning to classify leaf images by disease type. Transfer learning optimizes model training by fine-tuning pre-trained networks like ImageNet on smaller mango leaf datasets, enhancing performance with reduced data needs. Image pre-processing, including augmentation and normalization, boosts model robustness. Object detection techniques such as Faster R-CNN and YOLO localize disease spots, providing detailed insights into affected areas. Semantic segmentation further refines analysis by pixel-wise categorization of healthy versus diseased regions. Ensemble methods combine model outputs for improved accuracy, while deployment strategies like model quantization and lightweight architectures optimize real-world applicability on embedded systems or edge devices, tailored to specific dataset sizes and computational constraints.

The diagram illustrates a comprehensive workflow for detecting mango leaf diseases using a Convolutional Neural Network (CNN) model. The process begins with dataset preparation, where a large number of images of mango leaves are collected and annotated to indicate whether they are healthy or affected by specific diseases. These images then undergo pre-processing steps that include resizing to a standard size for uniformity and computational efficiency, as well as augmentation through various transformations like rotations and flips to artificially expand the dataset and improve the model's robustness. Additionally, normalization of pixel values to a standard range is performed to enhance the model's performance during training. The next phase involves training the CNN model. A suitable CNN architecture, comprising convolutional layers, pooling layers, and fully connected layers, is designed and initialized. The annotated and pre-processed dataset is fed into this model, which learns to identify distinctive features and patterns associated with healthy and diseased leaves. Optimization techniques and loss functions are employed to minimize prediction errors and enhance accuracy. Following the training, the model is evaluated using a separate set of images that were not part of the training dataset to assess its generalization capability and overall performance, with metrics such as accuracy, precision, recall, and F1-score being calculated.

Finally, the trained CNN model is used to predict the health status of new, unseen mango leaf images. The model classifies each image as either healthy or affected by a specific disease, providing actionable insights that can inform farmers and agricultural workers. This enables timely intervention and effective disease management, thus illustrating how deep learning, through a systematic and rigorous approach, can significantly enhance the detection and diagnosis of mango leaf diseases.

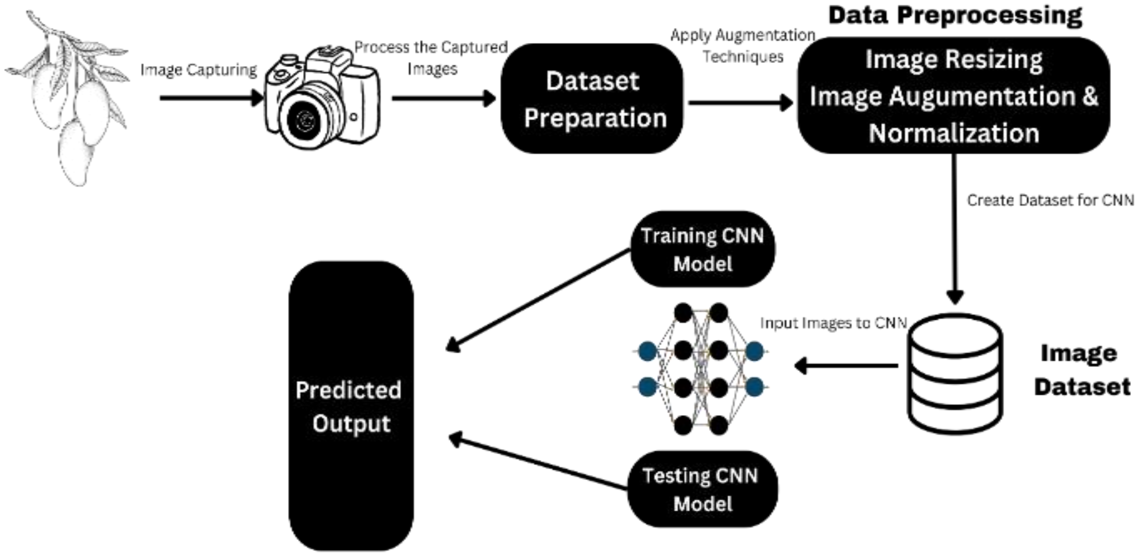
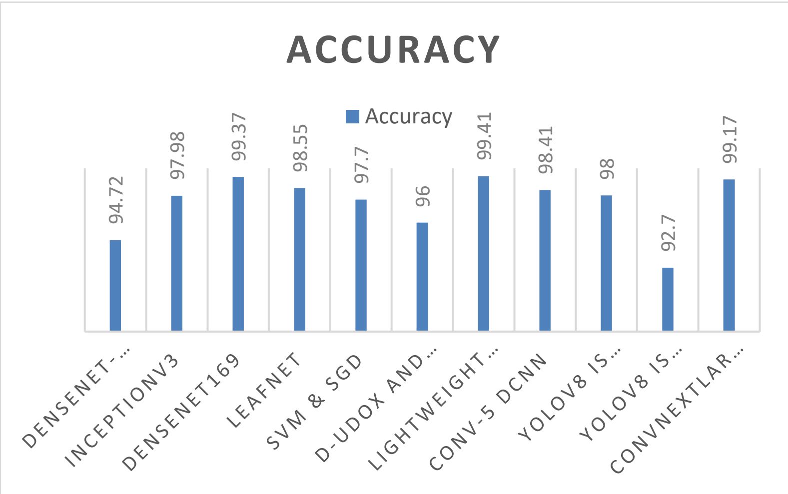



Fig: 1 Process of CNN for Mango Leaf Disease Detection

RESULT

The performance of deep learning models is typically evaluated by using metrics such as accuracy, recall, F1-score and precision. This Studies have presents high accuracy rates for mango leaf disease detection using deep learning models. This study conclude that high accuracy 99.41% is achieved by using lightweight CNN model and also noticed least accuracy 92.7% by using YOLOv8 object detection model.




SUGGESTION

To optimize models for small datasets in mango leaf disease detection, several strategies are recommended. Utilizing transfer learning allows leveraging pre-trained models on large datasets, adapting them to the specific small dataset. Data augmentation techniques, such as rotation, flipping, and scaling, artificially expand the dataset, enhancing model generalization. Regularization methods like dropout and weight decay prevent overfitting, while synthetic data generation using Generative Adversarial Networks (GANs) increases training data. Few-shot learning approaches, model ensembling, and active learning strategies help maximize the use of limited labeled data. Lastly, thorough hyperparameter optimization ensures the model performs optimally with the available small dataset. These strategies collectively enhance the performance and practical applicability of deep learning models in mango leaf disease detection.

FUTURE WORK

The future work encompasses a comprehensive exploration and enhancement of deep learning models for plant disease detection and classification in agriculture. It includes investigating the impact of transfer learning on small datasets, optimizing models using Particle Swarm Optimization (PSO), and exploring multi-class classification with pesticide recommendations. Additionally, research focuses on integrating DenseNet169 for improved accuracy, balancing model complexity with performance in agricultural settings, and enhancing real-time disease detection using advanced pre-trained models and novel data augmentation techniques. The aim is to develop robust, accurate, and explainable AI tools accessible to farmers, potentially integrated with resource-constrained devices or drone surveillance systems for field acquisition settings, enabling effective disease management across various crops.

## CONCLUSION

The paper highlights the significant advancements made in using deep learning techniques for the detection and diagnosis of mango leaf diseases. It emphasizes the high accuracy achieved by various models, notably the lightweight CNN model with an accuracy of 99.41% and the YOLOv8 object detection model with the least accuracy of 92.7%. The study concludes that deep learning has revolutionized the detection and management of mango leaf diseases, providing automated, precise, and cost-effective solutions that surpass traditional methods. Integrating these models with drones and mobile applications allows for real-time monitoring, providing continuous oversight and enabling prompt action. The high precision and accuracy of these models minimize false positives and negatives, ensuring reliable and actionable diagnoses. The paper also suggests future work in exploring and enhancing deep learning models for plant disease detection, including transfer learning, optimization techniques like Particle Swarm Optimization (PSO), and multi-class classification with pesticide recommendations.

## REFERENCES

[1] Thunderstorms Sour Mango Yield In Uttar Pradesh; Slash Nearly 20% of Produce | Weather.com

[2] S. P. Mohanty, D. P. Hughes, and M. Salathé, "Using deep learning for image-based plant disease detection," *Front. Plant Sci.*, vol. 7, no. September, pp. 1–10, 2016, doi: 10.3389/fpls.2016.01419.

[3] K. P. Ferentinos, "Deep learning models for plant disease detection and diagnosis," *Comput. Electron. Agric.*, vol. 145, no. Feb, pp. 311–318, 2018, doi: 10.1016/j.compag.2018.01.009.

[4] C. P. Vijay and K. Pushpalatha, "Pg 1 novel deep mutual learning model with Heuristic search using Particle Swarm optimization for Mango leaf disease detection," *J. Integr. Sci. Technol*, vol. 2024, no. 5, p. 804, 2024, [Online]. Available: http://pubs.thesciencein.org/jist

[5] N. Rahaman *et al.*, "A Deep Learning Based Smartphone Application for Detecting Mango Diseases and Pesticide Suggestions," *Int. J. Comput. Digit. Syst.*, vol. 13, no. 1, pp. 1273–1286, 2023, doi: 10.12785/ijcds/1301104.

[6] Abdullah Ali Salamai et al., "Enhancing mango disease diagnosis through eco-informatics: A deep learning approach," *Ecol. Inform.*, vol. 14, no. July, pp. 285–303, 2023, doi: 10.1109/PIECON56912.2023.10085869.

[7] R. A. J. M. Gining, S. S. M. Fauzi, N. M. Yusoff, T. R. Razak, M. H. Ismail, and N. A. Zaki, "Harumanis mango leaf disease recognition system using image processing technique," vol. 23, no. 1, pp. 378–386, 2021, doi: 10.11591/ijeecs.v23.i1.pp378-386.

[8] R. A. Rizvee *et al.*, "LeafNet: A proficient convolutional neural network for detecting seven prominent mango leaf diseases," *J. Agric. Food Res.*, vol. 14, no. July, 2023, doi: 10.1016/j.jafr.2023.100787.

[9] S. Jain and P. Jaidka, "Mango Leaf disease Classification using deep learning Hybrid Model," *2023 Int. Conf. Power, Instrumentation, Energy Control. PIECON 2023*, pp. 1–6, 2023, doi: 10.1109/PIECON56912.2023.10085869.

[10] A. Selvakumar and A. Balasundaram, "Automated Mango Leaf Infection Classification using Weighted and Deep Features with Optimized Recurrent Neural Network Concept," *Imaging Sci. J.*, vol. 72, no. 3, pp. 285–303, 2024, doi: 10.1080/13682199.2023.2204036.

[11] P. Hari and M. P. Singh, "A lightweight convolutional neural network for disease detection of fruit leaves," *Neural Comput. Appl.*, vol. 35, no. 20, pp. 14855–14866, 2023, doi: 10.1007/s00521-023-08496-y.

[12] J. A. Pandian *et al.*, "A Five Convolutional Layer Deep Convolutional Neural Network for Plant Leaf Disease Detection," *Electron.*, vol. 11, no. 8, 2022, doi: 10.3390/electronics11081266.

[13] V. K. Pratap and N. S. Kumar, "Deep Learning based Mango Leaf Disease Detection for Classifying and Evaluating Mango Leaf Diseases," no. April, 2024.

[14] K. P. Asha Rani and S. Gowrishankar, "ConvNeXt based Mango Leaf Disease Detection: Differentiating Pathogens and Pests for Improved Accuracy," *Int. J. Adv. Comput. Sci. Appl.*, vol. 14, no. 6, pp. 73–82, 2023, doi: 10.14569/IJACSA.2023.0140608.