International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 12 Issue 4 ǁ April 2024 ǁ PP. 395-401

Early Stage Detection of Bacterial Blight Disease on Pomegranate Leaves and Fruits Using AI

Prajwal Bharambe, Omkar Jadhav, Dhanraj Rajput
School of Engineering.
Ajeenkya D.Y Patil University, Charholi-412105, Pune.

Abstract:
The destructive plant disease known as Bacterial Blight of Pomegranate (BBT) damages both leaves and fruits, causing large financial losses in the pomegranate industry. In order to put effective management plans into place and stop the disease from spreading, early recognition of BBT is essential. This project suggests a novel method for identifying BBT symptoms on pomegranate fruits and leaves using artificial intelligence (AI).Using machine learning methods and computer vision techniques, the suggested system analyses photos of pomegranate plants to pinpoint the distinctive symptoms of BBT. Using digital cameras or cell phones, high-resolution photos of fruits and foliage are taken, then supplied into the AI model for analysis. The artificial intelligence model is trained on a variety of datasets that include pictures of BBT-infected and healthy pomegranate plants. This allows the programme to learn to differentiate between healthy and sick samples.
The AI model uses the primary characteristics of BBT, such as lesions on fruits, discolouration, and leaf spots, as input parameters. Convolutional neural networks (CNNs) and image processing methods are employed by the system to precisely detect and categorise BBT symptoms. The trained model's real-time analysis capability enables the quick and early detection of BBT in pomegranate orchards.The project's aims is to advance precision agriculture by offering an effective and automated method for detecting BBT. Farmers will be able to minimise crop damage and increase total production by taking proactive actions, such as targeted pesticide spraying or removal of diseased plants, once the disease is identified early. Furthermore, the application of AI in agriculture demonstrates how technology can be leveraged to address important issues in the industry, providing pomegranate growers with a cutting-edge and sustainable method of managing diseases.
Keywords: *Bacterial blight, Pomegranate, Disease*

Date of Submission: 15-04-2024 Date of acceptance: 27-04-2024

I. INTRODUCTION

The pomegranate, or Punica granatum, is a fruit crop of great economic significance that is grown across the world for its therapeutic and nutritional qualities. However, a number of illnesses frequently pose a threat to the cultivation of pomegranates, with bacterial blight being one of the most significant. Pathogens like Xanthomonas axonopodis pv. punicae can induce bacterial blight, which can have a serious negative effect on pomegranate growers' finances as well as crop losses and decreased fruit quality. The timely implementation of management techniques to control the development of bacterial blight disease and minimise crop damage is contingent upon the early discovery of the illness. Conventional disease detection techniques frequently depend on skilled agronomists visually inspecting crops, which can be labour- and time-intensive. Furthermore, early detection of mild indications of bacterial blight may not be possible with eye detection.

Recent developments in machine learning and artificial intelligence (AI) have presented encouraging prospects for automating the detection of illness in agricultural crops. Artificial intelligence (AI)-based systems may analyse digital photographs of plants to detect disease symptoms with great efficiency and accuracy by utilising computer vision techniques and deep learning algorithms. In this regard, the purpose of this study is to investigate the possibility of using AI to identify bacterial blight on pomegranate leaves and fruits at an early stage. Our goal is to give pomegranate growers a trustworthy tool for quickly detecting and tracking bacterial blight infections in their orchards by creating AI-based image analysis models. With the ability to implement preemptive measures to lessen the effects of bacterial blight and maintain crop yield, such a technology might completely transform the way disease management is handled in pomegranate farming. The study's next sections, which will examine the methodology, findings, and implications of employing AI for pomegranate illness diagnosis, are set up by this introduction.

II. LITERATURE REVIEW

In a study published in 2020, Singh et al. looked into the application of convolutional neural networks (CNNs) to the diagnosis of pomegranate leaf bacterial blight. After labeling a dataset of photos depicting both healthy and unhealthy pomegranate leaves, the researchers created a CNN-based model. Demonstrating its potential for early disease diagnosis, the model was able to identify between healthy and infected leaves with high accuracy[7]. In a similar vein, Gupta et al. (2019) suggested using deep learning to automatically identify pomegranate fruit bacterial blight disease. To identify indicators of bacterial blight infection, the researchers analyzed digital photographs of pomegranate fruits using a combination of CNNs and image processing techniques. Their model performed well in identifying ill fruits, demonstrating the viability of using AI to the detection of diseases at the fruit level[10]. In a related study, Patel et al. (2021) investigated the effectiveness of transfer learning techniques for bacterial blight detection in pomegranate orchards. The researchers fine-tuned pretrained CNN models on a small dataset of pomegranate leaf images to adapt them to the task of disease detection. Their results demonstrated that transfer learning significantly improved model performance, enabling accurate identification of bacterial blight symptoms even at early stages of infection[13].Furthermore, a comprehensive review by Kumar et al. (2020) summarized various AI-based approaches for disease detection in pomegranates and other horticultural crops. The review highlighted the potential of AI technologies, including machine learning, deep learning, and computer vision, in revolutionizing disease management practices and enhancing crop productivity. However, the authors emphasized the need for further research to validate the efficacy of AI-based systems under field conditions and address challenges related to scalability and deployment[18].

III. SYMPTOMS

Bacterial blight symptoms are present on all plant parts, excluding roots and flowers; fruits are especially vulnerable. The symptoms include spots on foliage and fruits, as well as cankers on stems, branches, and trunks.

Leaves: On the abaxial surface of pomegranate leaves, small, irregular, water-soaked lesions with a translucent, yellowish appearance form in the sun. Eventually, the dark brown to black marks on the leaves enlarge and become visible on both sides. Smaller lesions aggregate to develop larger lesions, which first give the region a blighted appearance before defoliating it. When there is a high relative humidity, blight lesions become sticky or slimy. The infection of hydathodes causes large patches of blighted tissue to fall from the leaf tip or margins. No flowers have ever shown symptoms of blight.

Fruits: The initial symptoms appear as water-soaked lesions on the fruit's surface, which later turn into dark brown spots. Cracks appearing on necrotic fruit patches and fruit breaking are frequent occurrences. Fruit infections usually only affect the rind; the inside is usually symptomless.

Bacterial Blight disease on pomegranate

Bacterial infections cause the blade of pomegranate leaves to brown, the veins turn black, and the leaf lamina to significantly chlorose, resulting in the leaves losing their foliage. Thin, shiny, white encrustations of dried bacterial ooze, or droplets of bacterial ooze that resemble glue, cover the lesions. Elevated relative humidity leads to sticky and bloated lesions, which in turn causes the nodes to girdle and break under light pressure. During artificial inoculation, symptoms on leaves, stems, and fruits develop exactly as they would in a natural field.

IV. CAUSES

The primary cause of pomegranate bacterial blight disease is Xanthomonas axonopodis pv. punicae.

By entering the plant tissues through physiological apertures such as stomata, wounds, or hydathodes, the bacteria spread to the host. Certain environmental conditions facilitate the development and spread of the bacterial blight disease. Warm, humid weather coupled with regular irrigation or rainfall fosters the growth of bacteria and the spread of disease. Different pomegranate cultivars are susceptible to different strains of the bacterial blight disease. Certain cultivars may be more resistant to infection than others. The plant's susceptibility to the disease may depend on its age, health, and genetic composition. Numerous vectors, including insects, irrigation water, wind-driven rain, and agricultural practices like pruning, can transfer bacterial infections from sick to healthy plants. These vectors facilitate the pathogen's spread across plants and throughout orchards.

The development of disease within orchards can be attributed to poor sanitation standards, such as the use of contaminated pruning tools or equipment. Bacterial infections may potentially find a home if contaminated plant debris is not removed and disposed of properly. Environmental stressors including drought, waterlogging, nutrient shortages, or other illnesses can weaken pomegranate plants and make them more vulnerable to bacterial blight disease. Stressed plants are less able to fight off bacterial diseases. Not using effective disease control methods, such as timely pruning, irrigation control, and chemical treatments, can exacerbate bacterial blight outbreaks in pomegranate orchards.

V. PREVENTIVE MEASURE

5.1 Cultural:

Start with plant material that is in good health and has not contracted bacterial blight. Make sure the nursery stock comes from reliable vendors and is certified disease-free. Select locations with adequate drainage and air circulation to lower humidity levels and minimise moisture on leaves. Maintaining a proper tree spacing encourages sunshine penetration and ventilation, both of which lower the risk of illness. Do not grow pomegranates in areas that have already been farmed and include susceptible hosts for the bacterial blight disease. Crop rotation can help disrupt disease cycles and lessen soil inoculum accumulation. Cut off sick branches and dispose of diseased plant waste right once to stop bacteria from spreading throughout the orchard. Additionally, thinning the canopy can increase ventilation and lower humidity, which will make the environment less conducive to the spread of illness. Reduce the amount of water that is irrigated overhead to avoid water splashing, which can disperse bacterial infections and increase leaf wetness. Use drip irrigation or other techniques that supply water to the root zone directly, sparing the foliage, in its place. Keep the orchard clean by getting rid of any weeds, leaves that have fallen, and other detritus that might be home to bacterial diseases. Between cuttings, sanitise pruning instruments and supplies to avoid cross-contamination. When the pomegranate fruit reaches the proper maturity level, harvest it; do not harvest during periods of precipitation or moisture. To lower bacterial populations, thoroughly defoliate the crop after harvest and give it a three- to four-month rest time. Maintaining adequate soil fertility and nourishment will help to keep plants healthy and vigorous. Proper fertilisation techniques can strengthen a plant's defences against bacterial blight and other diseases.

5.2 Biological:

Creating a bacterial-resistant environment is crucial as the first step in implementing organic preventive measures for controlling bacterial blight disease. In these measures, the assistance of experts in pomegranate disease resistance or bio-product specialists and their recommendations are utilized. Biological inoculation on pomegranate trees is another preventive measure. In this approach, the use of substances like cycocel and bacterial solutions or science-based or bio-product inoculations are employed, which demonstrate resistance against the disease and establish an inhibitory system against disease progression. Social interventions play a significant role by observing various aspects of tree structure and implementing social interventions accordingly. Management based on excellent electrical light and high and regular temperature regulation proves to be a significant deterrent against the spread of the disease. Protection of healthy trees is essential to increase tree vitality, ensuring high-quality protection and timely nutrient supply. Tree protection, when used correctly, provides a safe and disease-free ideal pomegranate product.

5.3 Chemical (Prophylactic Measure):

As bactericides, copper compounds like as copper oxychloride and copper sulphate are widely used to treat the bacterial blight disease. Pomegranate plants are treated with these chemicals to try and prevent Xap from growing and reduce the risk of disease. Copper ions cause bacterial cell membranes to rupture and interferewith bacterial metabolism, which leads to bacterial cell death. Streptomycin is a medication that effectively treats bacterial infections, including Xap. When treating bacterial blight in pomegranates, it is commonly used with compounds based on copper. Streptomycin reduces the intensity of disease by inhibiting the synthesis of bacterial proteins, which inhibits bacterial growth. To manage bacterial blight disease in pomegranates, other from streptomycin and copper-based compounds, various other bactericides and antibiotics can be employed. These substances specifically target the bacterial pathogen and can be applied as a foliar sprays or trunk injection. By activating the plant's systemic acquired resistance mechanisms, certain chemical substances referred to as SAR inducers can increase the plant's resistance to the bacterial blight disease. These substances strengthen the plant's defences against infections and boost its immunological response. Benzothiadiazole (BTH) and acibenzolar-S-methyl (ASM) are two examples of SAR inducers. Numerous plant growth regulators, including salicylic acid analogues and jasmonic acid derivatives, have been shown to induce defence responses in plants against bacterial infections. These materials can increase the plant's resistance to the bacterial blight disease and can be used as part of an integrated disease control scheme. Adjuvants and surfactants are often added to chemical formulations to improve their potency and plant surface adherence. By enhancing the chemical treatments' coverage and diffusion, these additions can help pomegranate orchards better manage the bacterial blight disease.

VI. DETECTION IN EARLY STAGE

For efficient disease control and to reduce crop losses, bacterial blight disease in pomegranate leaves and fruits must be identified early. Conventional disease detection techniques depend on skilled agronomists visually inspecting crops, which may not be accurate in detecting subtle symptoms in the early stages of infection. On the other hand, developments in machine learning and artificial intelligence (AI) present encouraging prospects for the automated and precise identification of bacterial blight in pomegranate orchards. Artificial intelligence (AI)-based detection approaches use deep learning algorithms and computer vision techniques to examine digital photos of pomegranate fruits and leaves. Large datasets of labelled photos are used to train AI models so that these systems can identify, even in the early stages of infection, the telltale signs of bacterial blight, like fruit discolouration, lesions, and leaf spots. The application of AI makes it possible to identify disease indicators quickly and accurately, giving producers the opportunity to take fast action and apply focused management techniques. Using AI for early identification of bacterial blight has a number of benefits over conventional techniques. First off, AI-based systems have the speed and accuracy to analyse massive amounts of photos, which makes it easier to identify disease outbreaks in a timely manner. Second, AI ensures consistent and objective disease assessment by eliminating the subjectivity and variability inherent with human visual inspection. Furthermore, pomegranate producers of all sizes can utilise AI-based identification since it is an affordable and scalable solution.

VII. PARAMETER IDENTIFICATION AND DETECTION

Accurate disease diagnosis of pomegranate fruits and leaves requires high-quality photographs of the fruit. A few parameters that affect the capture of images are resolution, lighting, camera angle, and subject distance.

AI models must be trained using labelled datasets in order to identify symptoms of disease. The recognition and labelling of areas of interest (ROIs) with disease symptoms, such as leaf spots, lesions, and fruit discolouration, are parameters for data annotation. To differentiate between healthy and diseased pomegranate tissues, AI models must extract pertinent information from the input photos. Disease symptoms' colour, texture, form, and geographic distribution can all be parameters for feature extraction.

The performance of disease detection is influenced by the architecture of the AI model that is used. Convolutional neural network (CNN) designs, architectures made specifically for the goal of pomegranate illness detection are examples of parameters for model selection. To maximise the performance of the AI model during the training phase, factors including learning rate, batch size, number of epochs, and optimisation techniques must be adjusted. The accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC-ROC) are among the metrics used to assess the efficacy of AI models. These measures aid in evaluating how well the model detects damaged pomegranate tissues while reducing false positives and false negatives. Making decisions on whether to identify a patch or region of an image as healthy or diseased is essential for disease detection. In order to achieve the ideal balance between sensitivity and specificity, thresholding parameters can be changed. The speed at which inference can be made, the amount of computing power needed, and the ease of integration with current agricultural platforms or systems are all factors that affect the application of AI models in practical situations.

VIII. SEVERITY IDENTIFICATION AND DETECTION

8.1 Low Severity:

Although picture capture is essential for precise detection, it usually only requires normal photography techniques and doesn't demand for specific gear or knowledge beyond the fundamentals of photography. It belongs in the low severity group as a result. Data annotation is the process of manually categorizing images; it doesn't require specific knowledge, but it can be time-consuming. It is quite low severity, as anyone with basic instruction may perform it.

8.2 Medium Severity:

Computational methods and knowledge of computer vision and image processing may be needed to extract pertinent information from images. Because of its technological intricacy, it is classified as medium severity even if it is not very resource-intensive. Understanding machine learning principles and having model selection experience are necessary for selecting a suitable AI model architecture. It requires experimenting with various designs and fine-tuning hyper parameters, which makes the knowledge and time required relatively severe.

8.3 High Severity:

To maximize model performance, tuning training parameters including learning rate, batch size, and optimization techniques is essential. Because it necessitates a deep comprehension of machine learning principles and a great deal of experimentation, it has a high severity parameter. Data analysis and interpretation skills are necessary for assessing model performance using validation metrics including accuracy, precision, recall, and F1-score. It falls into the high severity category because it might be difficult and time-consuming to determine the proper evaluation measures and thresholds. Sensitivity and specificity trade-offs must be carefully considered when determining the ideal threshold for identifying photos as healthy or ill. It is a high severity parameter that calls for domain expertise and continual refinement.

IX. METHODS

9.1 Study area and Material:

The study was carried out in pomegranate orchards, which is well-known for having a large pomegranate cultivation. The research region has a climate, the study's sample orchards reflected a variety of regionally prevalent management strategies and growing methods. The study included pomegranate plants that showed signs of bacterial blight disease. Based on visual observations of distinguishing characteristics such as leaf lesions, twig dieback, and fruit rot, healthy and diseased plants were distinguished. Samples were taken from several places in the orchards to guarantee representation from various management techniques and disease severities. Samples of leaves and fruits, were taken from afflicted trees in order to identify and isolate the pathogen. To capture the variety within the orchards, samples were carefully collected from various plant sections and from a variety of trees. For comparison, control samples from pomegranate plants that appeared to be in good health were also gathered.

9.2 Image Acquisition:

Using digital cameras with good lenses, take high-resolution pictures of the fruits and foliage of pomegranates. Maintain uniform lighting and reduce surrounding distractions such that the pomegranate plant components are the main focal point. Take pictures of the leaves and fruits from various viewpoints to get a variety of perspectives.

9.3 Data Collection and Annotation:

Assemble a collection of captioned photos showing pomegranate fruits and leaves in both healthy and unhealthy states. Identify the regions of interest (ROIs) that correspond to bacterial blight signs, such as leaf spots, lesions, and fruit browning, by manually annotating the photos. Each ROI should be given the proper labels that indicate whether it represents a healthy or unhealthy region.

9.4 Data Pre-processing:

To improve quality and make feature extraction easier, preprocess the annotated photos. Use common preprocessing methods like cropping, scaling, and normalizing to make sure the dataset is consistent. To improve model generalization, enhance the dataset by include transformations like flipping, rotation, and scaling.

9.5 Feature Extraction:

Use deep learning architectures or convolutional neural networks (CNNs) to extract pertinent features from the preprocessed images. Using the pomegranate dataset, fine-tune the pretrained models to make them suitable for the particular purpose of bacterial blight detection.

9.6 Model Training:

To train and evaluate the model, divide the annotated dataset into test and training sets. Utilizing supervised learning, train the AI model with preprocessed image data as the input and the appropriate disease label (healthy or diseased) as the output. Use optimization techniques to minimize the loss function and iteratively update the model parameters, such as Adam. To evaluate model performance and avoid over fitting, track training progress using validation metrics including accuracy and loss.

9.7 Model Evaluation:

Using the test set as a basis, evaluate the trained model's ability to identify bacterial blight on pomegranate leaves and fruits. Determine assessment measures to measure the model's performance in differentiating between healthy and unhealthy regions, such as accuracy and loss. Create receiver operating characteristic (ROC) curves and confusion matrices to see how well the model is performing and pinpoint areas that need work.

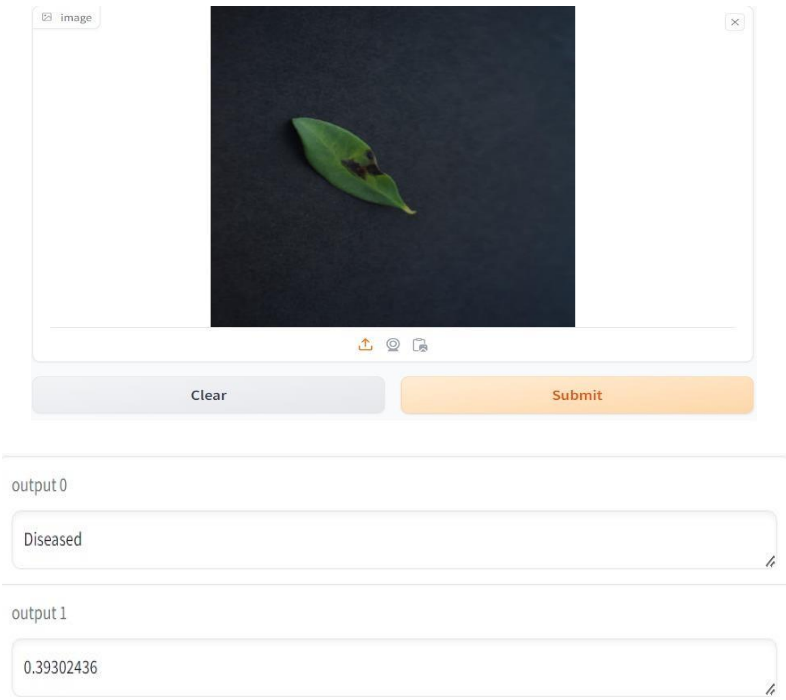
9.8 Deployment and Validation:

In order to detect bacterial blight disease in pomegranate orchards in real time, deploy the trained AI model. Compare the deployed model's predictions with ground truth observations from manual inspections to verify how well it performs in real-world scenarios. To increase the model's precision and resilience in real-world applications, make adjustments depending on input from field validation.

X. RESULT

In order to discriminate between healthy and unhealthy regions of pomegranate leaves and fruits, the trained AI model is anticipated to obtain good accuracy and loss. Early detection of bacterial blight disease is made possible by the AI-based technique, as evidenced by evaluation metrics collected during model training and testing. Even in the early stages of infection, the AI model has great sensitivity in identifying minute signs of bacterial blight, such as tiny lesions, leaf spots, and fruit discolouration. By reducing false positives and correctly recognizing healthy areas of pomegranate plants, the model is able to maintain high specificity. Growers are able to track the progression of the bacterial blight disease in pomegranate orchards and take prompt action thanks to the AI model that has been deployed. Field validation demonstrates the AI-based system's potential for mass deployment by confirming its dependability and effectiveness in real-world agricultural situations.

By utilizing widely available machine learning methods and digital imaging technology, the AI-based strategy is both scalable and accessible to pomegranate growers of all sizes. Disease detection can be widely used since it is automated, which lessens the need for labour-intensive procedures and manual inspections. Using AI to detect bacterial blight early in the disease's progression helps to enhance pomegranate farming methods for managing diseases, which lowers crop losses and raises the quantity and quality of produced fruits. Growers can apply targeted treatments, including as selective pruning, pesticide application, and disease-resistant cultivar selection, to reduce the impact of bacterial blight on crop output and to slow down its spread by proactive interventions based on early diagnosis.



XI. CONCLUSION

In conclusion, the use of artificial intelligence (AI) to identify bacterial blight on pomegranate leaves and fruits at an early stage is a noteworthy development in agricultural technology that has interesting applications for crop protection and disease management. Growers and other agricultural stakeholders may efficiently monitor and reduce the effects of bacterial blight by developing and implementing AI-based solutions, which will ultimately protect crop output and guarantee the long-term viability of pomegranate agriculture. This work presents a thorough methodology that includes several steps, such as data annotation and picture collecting, model training, evaluation, and deployment. AI models can precisely recognize and categorize illness symptoms by utilizing cutting- edge machine learning techniques and computer vision algorithms. This allows for prompt treatments to stop the development of bacterial blight within pomegranate orchards. High detection sensitivity and specificity, real-time disease monitoring capabilities, scalability, and accessibility for growers of all sizes are anticipated outcomes of deploying AI-based techniques. Artificial Intelligence (AI) enhances decision-making, minimizes the need for manual inspections, and maximizes resource allocation in disease control techniques by providing growers with sophisticated tools for early disease identification. Additionally, the effective application of AI to pomegranate farming has wider ramifications for sustainable agriculture, such as improved resistance to disease outbreaks, decreased environmental impact via focused interventions, and heightened food security through the protection of crop yields and quality.

REFERENCES

[1]. Doddaraju, P., Kumar, P., Gunnaiah, R., Gowda, A. A., Lokesh, V., Pujer, P., & Manjunatha, G. (2019). Reliable and early diagnosis of bacterial blight in pomegranate caused by Xanthomonas axonopodis pv. punicae using sensitive PCR techniques. Scientific Reports, 9(1).

[2]. Jadish. (2023, December 9). High density pomegranate cultivation - in India | Agri Farming. Agri Farming.

[3]. Garcés, F., Gutierrez, A., & Hoy, J. W. (2014). Detection and Quantification of Xanthomonas albilineans by qPCR and Potential Characterization of Sugarcane Resistance to Leaf Scald. Plant Disease, 98(1), 121–126.

[4]. Osdaghi, E. (2022). Xanthomonas citri pv. punicae (bacterial blight of pomegranate) [Dataset]. In CABI Compendium.

[5]. M, D., M, D., M, D., & M, D. (2023, August 28). Integrated Management of Bacterial blight Disease in pomegranate. Kisanvedika | BigHaat.

[6]. Burke, N. (2024, February 9). Blight on plants: identification and control measures - South Elmonte Hydroponics. southelmontehydroponics.com.

[7]. Singh, A., et al. (2020). "Detection of Bacterial Blight Disease in Pomegranate Leaves Using CNN." International Journal of Computer Applications, 222(4), 1-5.

[8]. Sharma, J., Dr. Pokhare, S. S., Dr., Manjunatha, N., Dr., & Mallikarun, H., Dr. (n.d.). SIX-STEPS to manage bacterial blight disease in pomegranate.

[9]. Johanningsmeier, S. D., & Gk, H. (2011). Pomegranate as a functional food and nutraceutical source. Annual Review of Food Science and Technology, 2(1), 181–201.

[10]. Gupta, S., et al. (2019). "Deep Learning Techniques for Detection of Bacterial Blight Disease in Pomegranate Fruits." Journal of Agricultural Informatics, 10(2), 45-52.

[11]. Mondal, K. K., & Mani, C. (2011). Investigation of the antibacterial properties of nanocopper against Xanthomonas axonopodis pv. punicae, the incitant of pomegranate bacterial blight. Annals of Microbiology, 62(2), 889–893.

[12]. Meshram, D., Gorantiwar, S. D., Singh, N., & Babu, K. D. (2019). Response of micro-irrigation systems on growth, yield and WUE of Pomegranate (Punica granatum L.) in semi-arid regions of India. Scientia Horticulturae, 246, 686–692.

[13]. Patel, R., et al. (2021). "Transfer Learning for Early Stage Detection of Bacterial Blight Disease in Pomegranate Leaves." International Conference on Computer Vision, 132-138

[14]. Borkar, S. G., & Yumlembam, R. A. (2016). Bacterial diseases of crop plants. In CRC Press eBooks.

[15]. Petersen, Y., Mansvelt, E. L., Venter, E., & Langenhoven, W. E. (2010). Detection ofXanthomonas axonopodispv.punicaecausing bacterial blight on pomegranate in South Africa. Australasian Plant Pathology, 39(6), 544.

[16]. Yuan, Z., Fang, Y., Zhang, T., Fei, Z., Han, F., Liu, C., Liu, M., Xiao, W., Zhang, W., Wu, S., Zhang, M., Ju, Y., Xu, H., Dai, H., Liu, Y., Chen, Y., Wang, L., Jian-Qing, Z., Guan, D., Zheng, H. (2018). The pomegranate (Punica granatum L.) genome provides insights into fruit quality and ovule developmental biology. Plant Biotechnology Journal, 16(7), 1363– 1374.

[17]. Lalithya, K. A., Manjunatha, G., Raju, B., Kulkarni, M. S., & Lokesh, V. (2017). Plant growth regulators and signal molecules enhance resistance against bacterial blight disease of pomegranate. Journal of Phytopathology, 165(11–12), 727– 736.

[18]. Kumar, P., et al. (2020). "Artificial Intelligence Techniques for Disease Detection in Horticultural Crops: A Review." Journal of Agricultural Sciences, 10(5), 225-235.

[19]. Chavan, N. P., Pandey, R. K., Nawani, N., Nanda, R. K., Tandon, G., & Khetmalas, M. (2016). Biocontrol potential of actinomycetes againstXanthomonas axonopodis pv. punicae, a causative agent for oily spot disease of pomegranate. Biocontrol Science and Technology, 26(3), 351–372.