# Classification of Common Stem-based Dragon Fruit Diseases using Convolutional Neural Network

1st Carlos Andrei F. Magahis
*School of Electrical, Electronics, and Computer Engineering*
*Mapua University*
Manila, Philippines
cafmagahis@mymail.mapua.edu.ph

2nd Rionne Angelo Ugale
*School of Electrical, Electronics, and Computer Engineering*
*Mapua University*
Manila, Philippines
raugale@mymail.mapua.edu.ph

3rd Jocelyn F. Villaverde
*School of Electrical, Electronics, and Computer Engineering*
*Mapua University*
Manila, Philippines
jfvillaverde@mapua.edu.ph

***Abstract*—Dragon Fruit stem diseases significantly threaten crop yield and agricultural productivity. While multiple capable dragon fruit disease detection systems already exist, there is a scarcity of research investigating the application of ResNet-50 in classifying dragon fruit stem diseases. This study presents a portable device that can capture pictures of dragon fruit stems for early disease detection using a ResNet-50 convolutional neural network (CNN) model based on Raspberry Pi 3B+. Images of healthy and infected dragon fruit stems with visual symptoms of anthracnose, cactus virus x, and stem canker were collected using a standard webcam and preprocessed to train the model. The device was tested in a controlled environment and achieved a 91.67% accuracy in classifying between the three common stem diseases. The results demonstrate the potential of ResNet-50 for accurate and efficient dragon fruit stem disease identification.**

***Keywords—dragon fruit stem, ResNet-50, CNN, Raspberry Pi, anthracnose, cactus virus x, stem canker, classification***

## I. Introduction

The dragon fruit, commonly known as strawberry pear (*Hylocereus spp.*), medium sized, round fruit with a red and yellow peel and scale-like protrusions. It is cultivated on tropical climbing cacti and is commonly found in various regions of Asia, Central America, and South America [1]. Among its many benefits is the ability to reduce blood sugar and blood pressure levels especially on excessive nutritional status such as being overweight [2]. A study in 2023 created a model that can detect stem rot, black rot, scabies, and mosaic disease using CNN [3]. They achieved an accuracy of 85.06% using Multi-Layer Perceptron. Another study by Kulkarni V., et al. proposes the use of Deep Learning to detect and classify diseases and maturity levels of dragon fruit using region-based CNN and SVM [4]. There is also a study on August 2023 by Hakim L. et al that focuses on the detection of stem rot, smallpox, and insect stings by focusing on color and texture feature extraction and using SVM and k-NN approach to reach an accuracy of 87.5% [5].

Farmers in developing nations such as the Philippines struggle with plant diseases due to a lack of understanding and often leads to ineffective management practices, harming their crops [6]. Additionally, farmers were generally more equipped with knowledge to deal with common insects and other pests but are less proficient when it comes to handling diseases [7], especially uncommon crops marking the need to develop technologies to validate effective practices and form a comprehensive disease and pest management that focuses on environment-friendly approaches [8]. Crop yields are most affected by anthracnose, bacterial soft rot, stem canker, and soft rots. These have been on the rise globally since 2014 [9]. Researchers started investigating biocontrol, utilizing soil fungi to compete for nutrients against other fungal pathogens. A variant known as *Trichoderma asperellum K1-02* demonstrated a significant inhibition of up to 84.45% against stem canker inducing *N. dimidiatum* [10]. This is only one of the treatments against the pathogen though, as [11] also demonstrated inhibition of *N. dimidiatum* using organic materials. Dragon fruit is one the different *Cactaceae* species [12] found and cultivated in Southeast Asia. The most serious dragon fruit diseases include anthracnose, stem canker, and bacterial soft rot [8]. These have caused significant impacts on dragon fruit yields since 2016. It is still possible that more diseases and pathogens might require identification thus calling a need for improved monitoring [9]. In addition, the lack of publicly accessible dragon fruit datasets is preventing the development of comprehensive detection models to aid dragon fruit farming and disease prevention which would help in developing crop management techniques to ensure optimal growth [13]. Anthracnose is one of the most damaging diseases in dragon fruits. The disease's symptoms include brown spots and lesions with a watery texture on the fruit and stem. A study on anthracnose conducted at The University of Nottingham Malaysia Campus revealed that the effects of the disease, that can be caused by *Colletotrichum spp.*, results in a 50% loss in post harvests of different kinds of fresh produce in the market [14]. However, it is treatable with [14] stating that the traditional way of dealing with it in the post-harvest stage is with fungicides such as benomyl and prochloraz. Stem canker is a very dangerous disease commonly caused by *Neoscytalidium dimidiatum* that can render entire plantations unfruitful with reducing prices by up to 80% value [11] [15]. It is characterized by having round, brown lesions on the stem and developing pycnidia and orange spots on affected areas with matching rotting stem [16]. A paper conducted a study on culture of *N. dimidiatum* and observed that the fungal isolates could form lesions within three days of infection, and subsequently darken within seven days and occasionally form orange spots. Within ten days, black pycnidia forms on the canker surface and finally rots the stem away after 14 days [17]. Cacti viruses can be present in various cacti species and can be symptomatic and symptomatic along with a chance to be transmitted. Cactus Virus X is a plant virus that affects a wide variety of cacti, causing mottling in affected plants along with necrosis, deformed spines, and other alterations and is a global threat to the dragon fruit industry due to the damage it causes to the growth of the dragon fruit plant [18]. Additionally, *F.*

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*incarnatum* and *A. minisclerotigenes* are newly identified pathogens to infect dragon fruits [22]. This study uses Raspberry Pi which is a powerful microprocessor used by many in image processing. Reliable and effective image processing techniques can be utilized to identify different herbal plant species' leaves [20]. CNN has also been used to study and identify Bacterial leaf blight in rice leaves which is a very important crop in the Philippines [21], the Durian plant leaves [22], the Lanzones tree [23] and their respective diseases. It is also used in one study to classify mushrooms to determine what is edible [24]. CNN is also used to identify nutrient deficiencies [25] to enhance agricultural yields of different crops such as onions. [26]. Image processing can be applied to precision agriculture to provide much needed utility in fruit grading which is conducted in a study to determine ripeness and size of a tomato fruit [27] with 93.33% accuracy ranking second against VGG19's 95% and InceptionV3's 91.67% in terms of accuracy [28]. It was also used to detect potential health issues like a study on healthy and diseases abaca samples using CNN [29], and identification of damaged shelled corn [30] which contributes to a more efficient cultivation of plants and crops and minimize loss using image processing.

While deep learning techniques have shown promise in fruit disease detection, there is a scarcity of research investigating the application of ResNet-50 architecture in classifying dragon fruit diseases. This lack of study hinders our understanding of how effective ResNet-50 is in identifying critical diseases like stem canker, anthracnose, and cactus virus X.

This paper intends to bridge these gaps by implementing a classification system of common stem-based dragon fruit diseases using convolutional neural network. In particular, the study aims to: (1) develop a portable device using Raspberry Pi 3B+ that can capture pictures of dragon fruit stems and classify common diseases based on visual symptoms, particularly stem canker, anthracnose, and cactus virus x using image processing, (2) use ResNet-50 architecture of Convolutional Neural Network (CNN) to classify diseases, and (3) determine the accuracy of the prototype using the confusion matrix as a statistical tool.

This study aims to develop methods for early detection of common stem diseases, empowering farmers with knowledge to identify and respond to outbreaks quickly. This rapid intervention can minimize crop loss, boost farm productivity, and ultimately increase profitability. The study has the potential to contribute to a more profitable agricultural industry for dragon fruit farmers.

This study only focuses on the classification of stem canker, cactus virus x, and anthracnose found on dragon fruit stems and on its implementation on the Raspberry Pi 3B+ using ResNet-50 Architecture.

## II. Methodology

This paper aims to use computer vision with the help of machine learning to identify common stem-based diseases caught by dragon fruit crops using the ResNet-50 convolutional neural network (CNN) algorithm.

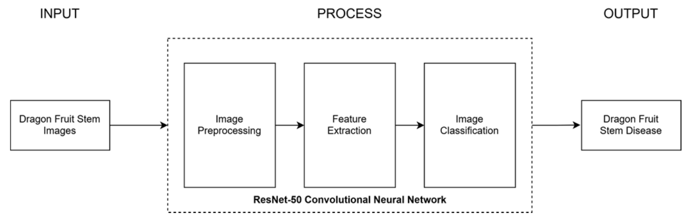


Fig. 1. Conceptual Framework of the Study

Figure 1 shows the conceptual framework of the study. The inputs used by the system are dragon fruit stem images only, which should be captured using the external camera connected to the Raspberry Pi board. Afterward, the captured image goes through the classification algorithm, specifically the ResNet-50 CNN, to classify and identify the disease present in the stem of the dragon fruit. Then, the identified disease is displayed as output using the external LCD panel connected to the board as well.

### *A. Hardware Development*

Shown in figure 2 is the prototype hardware block diagram. The system was implemented using Raspberry Pi 3B+ as the main component, which is used for processing images, along with an external standard web camera attached through its universal serial bus (USB) port. Input images will be captured through the camera and the output message will be displayed on the TFT liquid crystal display (LCD) panel. The system also used an LED light to help with the illumination of the subject during the image capture process.

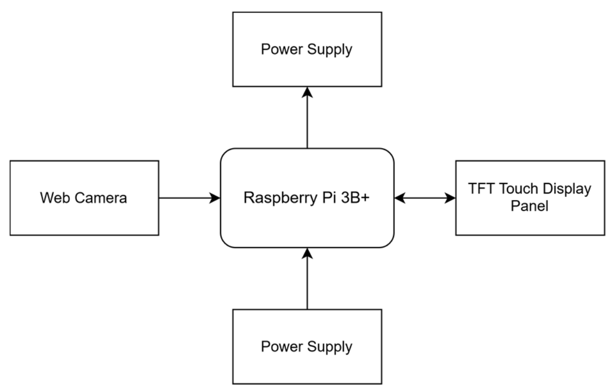


Fig. 2. Hardware block diagram.

### *B. Software Development*

As seen from Figure 3, the system starts by acquiring images of dragon fruit stems using an external web camera, followed by preprocessing the images.

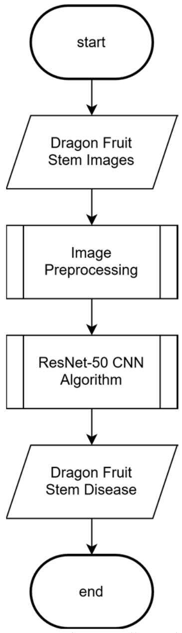


Fig. 3. Software flowchart

Afterward, the images undergo various processes to prepare them before feeding them to the model. It includes (1) resizing, to match the input size to the ResNet-50 Model, which is 224x224 pixels, (2) normalization of images so that the pixel values would have consistent brightness and contract to make them more suitable for analysis independent of lighting condition, and finally, (3) application of gaussian blur filter which reduces detail and noise in the images and helps smooth edges and details. These are shown in figure 4.

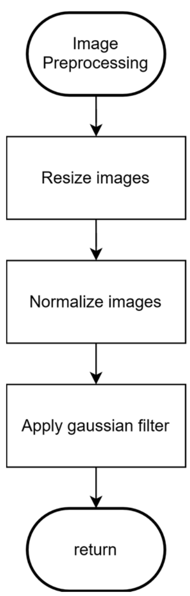


Fig. 4. Image preprocessing functions.

The pre-processed images go to the ResNet-50 CNN model afterward for further processing and disease classification. The algorithm starts by extracting significant features, such as lines and edges, to highlight the dragon fruit. Then, the disease will be identified using the neural network algorithm.

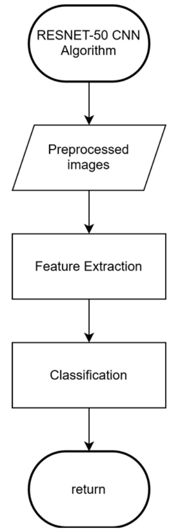


Fig. 5. ResNet-50 model operations.

Once classified, the name of the disease that the dragon fruit stem has is displayed as output on the TFT LCD panel connected to the Raspberry Pi board.

## C. Data Gathering

Multiple images of dragon fruit stems with various diseases were captured and acquired using a standard web camera to create the dataset that was used for training and testing the model. The dataset consists of 8080 images, which were manually augmented using an external computer vision tool and platform. The dataset was randomly divided into a training set and a validation set with each set containing 80% and 20% of the dataset, respectively. The testing set was gathered directly from the device using the web camera. The class labels for each image in the dataset are verified by a professional in plant pathology to ensure factual validity and accuracy.

## D. Experimental Setup

The prototype was used in a fixed setup to capture images of dragon fruit stems, as seen from Figure 6. The setup will be invasive to dragon fruit crops, as it involves cutting samples of the dragon fruit stem with disease and placing it in the capturing area. An LED was installed above the capture area which can be turned on to achieve better prediction results. In taking the shot, ensure that the affected area of the dragon fruit stem is clearly captured in the image frame. After which, the image classification model will operate to give predictions on the captured disease.

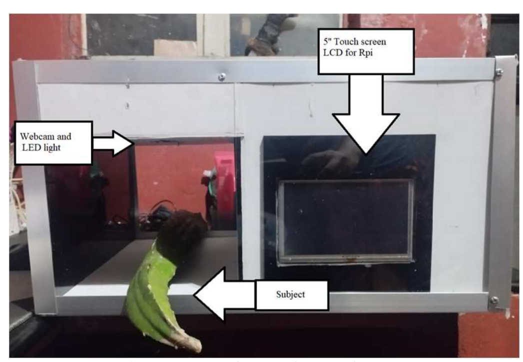


Fig. 6. Actual experimental setup.

Since the device revolves around image processing, performance may be dependent on proper lighting. Three different lighting setups are examined to test its performance and shown in figures 7, 8, and 9.

Fig. 7. Setup 1: Direct lighting over the sample in the capture area.

Figure 7 shows direct lighting from the LED above the capture area, beside the camera.

Fig. 8. Setup 2: No lighting over the sample in the capture area.

Figure 8 shows the absence of lighting over the sample when the LED above the capture area was turned off.

Fig. 9. Setup 3: Medium lighting from outside the capture area.

And finally, figure 9 shows a portion of light coming from outside the capture area. The results of the performance measurement of the model based on lighting setup is broken down on table I.

TABLE I. TESTING TABLE OF LIGHTING SETUP

| Trial | Lighting | Actual | Predicted | Remarks |
|---|---|---|---|---|
| 1 | Setup 1 | healthy | healthy | TRUE |
| | Setup 2 | healthy | cactus virus x | FALSE |
| | Setup 3 | healthy | healthy | TRUE |
| 2 | Setup 1 | anthracnose | anthracnose | TRUE |
| | Setup 2 | anthracnose | cactus virus x | FALSE |
| | Setup 3 | anthracnose | cactus virus x | FALSE |
| 3 | Setup 1 | cactus virus x | cactus virus x | TRUE |
| | Setup 2 | cactus virus x | cactus virus x | TRUE |
| | Setup 3 | cactus virus x | cactus virus x | TRUE |

From the given data, there is 66.67% better chance for the model to accurately predict the visual symptoms of the diseases on dragon fruit stems.

## III. RESULT AND DISCUSSION

To measure the performance of the prototype and the model, it was tested thoroughly against unseen data or actual field data, which are the data that are acquired outside of training. The model's performance was tested on dragon fruit stems that it has not seen, and the results were tabulated. The prototype is operated using Raspberry pi OS with a custom developed application that uses the trained model to predict the disease of the dragon fruit stem in the testing area using the webcam with led lights to provide lighting.

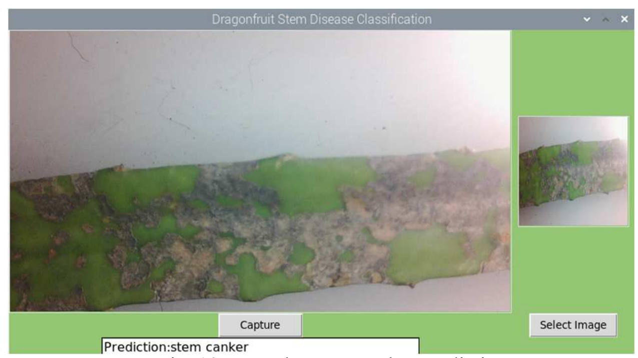

Fig. 10. Sample Stem Canker prediction.

Figure 10 shows the GUI (graphical user interface) in capturing the dragon fruit stem with their respective diseases. The image on the right is a preview of the latest image that was analyzed for prediction while the bigger portion of the application is the video feed showing underneath the webcam. To make a prediction, after positioning the dragon fruit stem, press capture and wait for the program to process the image. Once finished, the prediction will appear on the text box underneath the capture button. Afterwards, the application will show the latest capture on the right side. There is also a *Select Image* button on the lower right portion that allows the user to select an image from the system and make a prediction on that image instead which will follow the above procedures as well.

TABLE II. TESTING TABLE

| Trial | Actual | Predicted | Remarks |
|---|---|---|---|
| 1 | anthracnose | healthy | FALSE |
| 2 | anthracnose | anthracnose | TRUE |
| 3 | anthracnose | anthracnose | TRUE |
| 4 | anthracnose | anthracnose | TRUE |
| 5 | anthracnose | anthracnose | TRUE |
| 6 | anthracnose | anthracnose | TRUE |
| 7 | anthracnose | anthracnose | TRUE |
| 8 | anthracnose | anthracnose | TRUE |
| 9 | anthracnose | anthracnose | TRUE |
| 10 | anthracnose | stem canker | FALSE |
| 11 | anthracnose | anthracnose | TRUE |
| 12 | anthracnose | anthracnose | TRUE |
| 13 | anthracnose | anthracnose | TRUE |
| 14 | anthracnose | anthracnose | TRUE |
| 15 | anthracnose | anthracnose | TRUE |
| 16 | cactus virus x | healthy | FALSE |
| 17 | cactus virus x | cactus virus x | TRUE |
| 18 | cactus virus x | cactus virus x | TRUE |
| 19 | cactus virus x | cactus virus x | TRUE |
| 20 | cactus virus x | cactus virus x | TRUE |
| 21 | cactus virus x | cactus virus x | TRUE |
| 22 | cactus virus x | cactus virus x | TRUE |
| 23 | cactus virus x | cactus virus x | TRUE |
| 24 | cactus virus x | cactus virus x | TRUE |
| 25 | cactus virus x | cactus virus x | TRUE |
| 26 | cactus virus x | cactus virus x | TRUE |
| 27 | cactus virus x | cactus virus x | TRUE |
| 28 | cactus virus x | cactus virus x | TRUE |
| 29 | cactus virus x | cactus virus x | TRUE |
| 30 | cactus virus x | cactus virus x | TRUE |
| 31 | healthy | healthy | TRUE |
| 32 | healthy | healthy | TRUE |
| 33 | healthy | healthy | TRUE |
| 34 | healthy | healthy | TRUE |
| 35 | healthy | healthy | TRUE |
| 36 | healthy | healthy | TRUE |
| 37 | healthy | healthy | TRUE |
| 38 | healthy | healthy | TRUE |
| 39 | healthy | anthracnose | FALSE |
| 40 | healthy | healthy | TRUE |
| 41 | healthy | healthy | TRUE |
| 42 | healthy | healthy | TRUE |
| 43 | healthy | healthy | TRUE |
| 44 | healthy | healthy | TRUE |
| 45 | healthy | healthy | TRUE |
| 46 | stem canker | stem canker | TRUE |
| 47 | stem canker | stem canker | TRUE |
| 48 | stem canker | stem canker | TRUE |
| 49 | stem canker | anthracnose | FALSE |
| 50 | stem canker | stem canker | TRUE |
| 51 | stem canker | stem canker | TRUE |
| 52 | stem canker | stem canker | TRUE |
| 53 | stem canker | stem canker | TRUE |
| 54 | stem canker | stem canker | TRUE |
| 55 | stem canker | stem canker | TRUE |
| 56 | stem canker | stem canker | TRUE |
| 57 | stem canker | stem canker | TRUE |
| 58 | stem canker | stem canker | TRUE |
| 59 | stem canker | stem canker | TRUE |
| 60 | stem canker | stem canker | TRUE |

Table II shows the results of the testing that the researchers conducted. Out of fifty (50) trials, the system detected eleven (11) correctly as stem canker, ten (10) as correctly as anthracnose, eleven (11) correctly as cactus virus, and eleven (11) correctly as healthy. Among the incorrect predictions, there were two (2) stem canker samples incorrectly predicted as anthracnose, as well as two (2) samples of anthracnose which are also incorrectly identified as stem canker, signifying the overlapping features and similarities of the symptoms of these diseases. There was also one (1) sample of anthracnose misclassified as healthy, one (1) cactus virus x infected stem misclassified as healthy, and one (1) healthy stem mistaken as anthracnose.

TABLE III. CONFUSION MATRIX

| | | **ACTUAL VALUES** | | | |
|---|---|---|---|---|---|
| **PREDICTED VALUES** | | Stem Canker | Anthracnose | Cactus Virus X | Healthy |
| | Stem Canker | 14 | 1 | 0 | 0 |
| | Anthracnose | 1 | 13 | 0 | 1 |
| | Cactus Virus X | 0 | 0 | 14 | 1 |
| | Healthy | 0 | 1 | 0 | 14 |

Table III shows the confusion matrix after testing the device in a controlled environment, as stated in the experimental setup. This summarizes the total number of predictions of the device against actual values.

$$Accuracy = \frac{14+13+14+14}{60} \cdot 100 \qquad (1)$$

Applying the Accuracy formula, as seen from equation 1, gives a total of 91.67% accuracy for the model testing for its ability to classify Stem Canker, Anthracnose, and Cactus Virus x symptoms from healthy dragon fruit stems. The system's model capability fell a little lower than the results of [3], [4], and [5] but while all of these studies employ machine learning, all of these studies, including this study, use different machine learning algorithms with different techniques as this study focuses on the application of ResNet-50 to classify the symptoms of stem canker, anthracnose, and cactus virus x. The finished model's capability to reach an accuracy of 91.67% means that it acquired the features to reliably classify the symptoms of said diseases most of the time.

In line with that, the proponents made a comparison of its performance against another model — the VGG16 CNN model. This model was also trained with the same dataset used to train the ResNet-50. Out of 40 trials, it managed to achieve an 85% accuracy in classifying dragon fruit stem diseases.

## IV. Conclusion and Recommendation

The study created a system that uses ResNet-50's capabilities and classifies healthy dragon fruit stems apart from stems with stem canker, anthracnose, and cactus virus x symptoms. It accomplished this by using a prototype equipped with the Raspberry pi 3B+, and a 1080p USB webcam, accomplishing an accuracy of 91.67% during its testing which was calculated using a confusion matrix. Additionally, while the diseases in the dataset that are used to train are annotated by a plant pathology professional, the use of this prototype must be considered as only doing a visual assessment made by an expert as the training only involved the extraction of features that the camera can see. Nonetheless, as a prototype model, this performance is very satisfactory especially considering that stem canker and anthracnose have very similar features as cactus virus x symptoms such as mottling are mostly very subtle in nature and may not be recognized at first glance which further validates the model and ResNet-50's capabilities when detecting visual features of plant symptoms.

The researchers' training of the images was faced with difficult challenges and thus recommend using a higher quality camera, as they have learned that some symptoms of diseases affecting the dragon fruit plant can have very subtle details while some symptoms look very similar to the case of stem canker and anthracnose. The researchers also recommend using a later version of the Raspberry Pi for easier prototype development, as well as experimenting with other models, both simpler and more complex ones, and gathering larger and more diverse datasets to further the possibilities of machine learning in the field of agriculture and disease detection.

## References


[1] M. Farid Hossain, S. M. Numan, and S. Akhtar, "Cultivation, Nutritional Value and Health Benefits of Dragon Fruit (Hylocereus spp.): A Review," 2021. [Online]. Available: http://ijhst.ut.ac.ir

[2] S. Fadlilah, A. Sucipto, F. Khasanah, D. Setiawan, and N. Hamdani Rahil, "Dragon Fruit (Hylocereuspolyrhizus) Effectively Reduces Fasting Blood Sugar Levels and Blood Pressure on Excessive Nutritional Status."

[3] L. Hakim, A. R. Asyhari, S. P. Kristanto, D. Yusuf, J. A. Prasetyo, and H. M. Siregar, "Classification of Dragon Fruit Stem Diseases Using Convolutional Neural Network," INTENSIF: Jurnal Ilmiah Penelitian dan Penerapan Teknologi Sistem Informasi, vol. 7, no. 2, pp. 262–275, Aug. 2023, doi: 10.29407/intensif.v7i2.20093.

[4] V. Kulkarni, P. Kosamkar, C. Singh, P. Ingle, and V. Modi, "Detection and Classification of Diseases and Maturity of Dragon Fruits," in Lecture Notes in Networks and Systems, Springer Science and Business Media Deutschland GmbH, 2022, pp. 365–374. doi: 10.1007/978-981-16-5987-4_37.

[5] L. Hakim, S. P. Kristanto, D. Yusuf, M. N. Shodiq, and W. A. Setiawan, "Disease Detection of Dragon Fruit Stem Based on The Combined Features of Color and Texture," INTENSIF: Jurnal Ilmiah Penelitian dan Penerapan Teknologi Sistem Informasi, vol. 5, no. 2, pp. 161–175, Aug. 2021, doi: 10.29407/intensif.v5i2.15287.

[6] R. Nelson et al., "Working with Resource-Poor Farmers to Manage Plant Diseases," 2001.

[7] L. A. Lutap and M. I. Atis, "Pest Management in Vegetable Production: The Case of the Rainfed Lowlands in Ilocos Norte".

[8] A. J. Rodeo, A. Castro, K. U. Leuven, and E. Esguerra, "Postharvest handling of dragon fruit (Hylocereus spp.) in the Philippines," 2018. [Online].Available: https://www.researchgate.net/publication/325191316

[9] M. A. Balendres and J. C. Bengoa, "Diseases of dragon fruit (Hylocereus species): Etiology and current management options," Crop Protection, vol. 126. Elsevier Ltd, Dec. 01, 2019. doi: 10.1016/j.cropro.2019.104920.

[10] W. Intana, J. Kumla, N. Suwannarach, and A. Sunpapao, "Biological control potential of a soil fungus Trichoderma asperellum K1-02 against Neoscytalidium dimidiatum causing stem canker of dragon fruit," Physiol Mol Plant Pathol, vol. 128, Nov. 2023, doi: 10.1016/j.pmpp.2023.102151.

[11] J. D. Taguiam, E. Evallo, J. Bengoa, R. Maghirang, and M. A. Balendres, "Susceptibility of the three dragon fruit species to stem canker and growth inhibition of Neoscytalidium dimidiatum by chemicals," Journal of Plant Pathology, vol. 102, no. 4, pp. 1077–1084, 2020, doi: 10.1007/s42161-020-00551-0.

[12] J. M. D. Bilang, P. A. A. L. Balbuena, and J. F. Villaverde, "Cactaceae Detection Using MobileNet Architecture," in 2021 IEEE 13th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management, HNICEM 2021, Institute of Electrical and Electronics Engineers Inc., 2021. doi: 10.1109/HNICEM54116.2021.9731868.

[13] T. Khatun, M. A. S. Nirob, P. Bishshash, M. Akter, and M. S. Uddin, "A comprehensive dragon fruit image dataset for detecting the maturity and quality grading of dragon fruit," Data Brief, vol. 52, Feb. 2024, doi: 10.1016/j.dib.2023.109936.

[14] P. K. Bordoh, A. Ali, M. Dickinson, Y. Siddiqui, and G. Romanazzi, "A review on the management of postharvest anthracnose in dragon fruits caused by Colletotrichum spp.," Crop Protection, vol. 130. Elsevier Ltd, Apr. 01, 2020. doi: 10.1016/j.cropro.2019.105067.

[15] I. Muas, E. Mansyah, and S. Yuliati, "Dragon Fruit Production and Marketing in Indonesia: Standard Quality in the Global and Regional Levels."

[16] M. H. Mohd, B. Salleh, and L. Zakaria, "Identification and Molecular Characterizations of Neoscytalidium dimidiatum Causing Stem Canker of Red-fleshed Dragon Fruit (Hylocereus polyrhizus) in Malaysia," Journal of Phytopathology, vol. 161, no. 11–12, pp. 841–849, Dec. 2013, doi: https://doi.org/10.1111/jph.12146.

[17] D. Thongkham and K. Soytong, "Isolation, Identification, and Pathogenicity Test from Neoscytalidium dimidiatum Causing Stem Canker of Dragon Fruit," International Journal of Agricultural Technology, vol. 12, no. 7, pp. 2187–2190, 2016.

[18] K. S. Dy, P. Wonglom, C. Pornsuriya, and A. Sunpapao, "Morphological, Molecular Identification and Pathogenicity of Neoscytalidium dimidiatum Causing Stem Canker of Hylocereus polyrhizus in Southern Thailand," Plants, vol. 11, no. 4, Feb. 2022, doi: 10.3390/plants11040504.

[19] M. Masyahit, K. Sijam, Y. Awang, M. Ghazali, and M. Satar, "First Report on Bacterial Soft Rot Disease on Dragon Fruit (Hylocereus spp.) Caused by Enterobacter cloacae in Peninsular Malaysia," INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY Int. J. Agric. Biol, vol. 11, pp. 659–666, [Online]. Available: http://www.fspublishers.org

[20] Z. Peng et al., "Analysis of Bacterial Community Composition and Ecological Function during Soft Rot Process in Pitaya (Hylocereus spp.) Stems," J Chem, vol. 2022, 2022, doi: 10.1155/2022/9169433.

[21] D. P. Emejas Jr., C. M. Jumao-As, and F. R. P. Salvaña, "Identification of common fungal pathogens of dragon fruit (Hylocereus undatus) in Sarangani Province, Philippines," Environmental and Experimental Biology, vol. 21, no. 3, pp. 93–99, Nov. 2023, doi: 10.22364/eeb.21.11.

[22] R. M. Laire Ang and N. B. Linsangan, "Herbal Medicinal Plant Identification Using Leaf Vein Through Image Processing and Convolutional Neural Network," in IEEE Region 10 Annual International Conference, Proceedings/TENCON, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 1046–1051. doi: 10.1109/TENCON58879.2023.10322529.

[23] A. N. Yumang, J. F. Villaverde, M. H. C. Tan, and J. K. D. Tulfo, "Bacterial Leaf Blight Identification of Rice Fields Using Tiny YOLOv3," in 4th IEEE International Conference on Artificial Intelligence in Engineering and Technology, IICAIET 2022, Institute of Electrical and Electronics Engineers Inc., 2022. doi: 10.1109/IICAIET55139.2022.9936825.

[24] J. Al Gallenero and J. Villaverde, "Identification of Durian Leaf Disease Using Convolutional Neural Network," in 2023 15th International

Conference on Computer and Automation Engineering, ICCAE 2023, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 172–177. doi: 10.1109/ICCAE56788.2023.10111159.

[25] A. S. Muhali and N. B. Linsangan, “Classification of Lanzones Tree Leaf Diseases Using Image Processing Technology and a Convolutional Neural Network (CNN),” in 4th IEEE International Conference on Artificial Intelligence in Engineering and Technology, IICAIET 2022, Institute of Electrical and Electronics Engineers Inc., 2022. doi: 10.1109/IICAIET55139.2022.9936833.

[26] K. P. L. Bongat, L. A. P. Garcia, and M. V. C. Caya, “Fine-Grained Classification of Edible Mushrooms Using Convolutional Neural Network,” in 2023 IEEE 5th Eurasia Conference on IOT, Communication and Engineering, ECICE 2023, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 537–542. doi: 10.1109/ECICE59523.2023.10382988.

[27] L. K. B. Navarro, K. C. H. Mateo, and C. O. Manlises, “CNN Models for Identification of Macro-Nutrient Deficiency in Onion Leaves (Allium cepa L.),” in 2023 IEEE 5th Eurasia Conference on IOT, Communication and Engineering, ECICE 2023, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 396–400. doi: 10.1109/ECICE59523.2023.10383126.

[28] K. Balavani, D. Sriram, M. B. Shankar, and D. S. Charan, “An Optimized Plant Disease Classification System Based on Resnet-50 Architecture and Transfer Learning,” in 2023 4th International Conference for Emerging Technology, INCET 2023, Institute of Electrical and Electronics Engineers Inc., 2023. doi: 10.1109/INCET57972.2023.10170368.

[29] J. Legaspi, J. R. Pangilinan, and N. Linsangan, “Tomato Ripeness and Size Classification Using Image Processing,” in 2022 5th International Seminar on Research of Information Technology and Intelligent Systems, ISRITI 2022, Institute of Electrical and Electronics Engineers Inc., 2022, pp. 613–618. doi: 10.1109/ISRITI56927.2022.10052810.

[30] J. R. Pangilinan, J. Legaspi, and N. Linsangan, “InceptionV3, ResNet50, and VGG19 Performance Comparison on Tomato Ripeness Classification,” in 2022 5th International Seminar on Research of Information Technology and Intelligent Systems, ISRITI 2022, Institute of Electrical and Electronics Engineers Inc., 2022, pp. 619–624. doi: 10.1109/ISRITI56927.2022.10052920.