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Early Detection of the Fungal Pathogen *Pyricularia oryzae* Infrared Image-Based Rice Seed (*Oryza sativa* L.)

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Abstract

Blast disease *(P. oryzae)* is one of the main diseases in rice that can cause losses of up to 61% . This study aims to determine the effectiveness of infrared images in early detection of *Pyricularia oryzae symptoms* in rice seeds with a comparison of conventional methods and to determine the level of accuracy of infrared image analysis on the pathogenic fungus *Pyricularia oryzae*. This study was conducted from July to December 2025 at the Plant Health Laboratory I, Faculty of Agriculture, UPN "Veteran" East Java. This study used infrared images in detect the pathogen Pyricularia oryzae in rice plants; observations began with Image Acquisition, Image Preprocessing, Segmentation, Visualization, and Validation. The results showed that infection symptoms began to be detected on the 3rd day through pseudo-coloring images before the seeds showed visual symptoms conventionally, because the RGB image only showed color changes on the 4th to 5th day. Validation using regression analysis showed a strong relationship between the results of image estimation and direct observation in the laboratory. The regression model obtained is $y = 0.7468x + 0.0845$ with an R^2 value of 0.7033, which means that 70.33% of the variation in observation results can be explained by the image estimation results. The analysis in this study has the potential to be an early detection method because it can detect *Pyricularia oryzae fungus* on rice seeds with the percentage of symptoms obtained through image processing in the range of 30-52% and is more accurate than manual observation.

Keywords: Blast Disease, Preprocessing, Pseudo Coloring, Thresholding, Validation Test

1. Introduction

Rice *(Oryza sativa L.)* is one of the main commodity foods for Indonesian society. Paddy rice is widely cultivated because, compared with other food grains, it occupies the first level of production and consumption in Indonesian society (Mahmud & Purnomo, 2014). However, fluctuations in rice production in Indonesia still occur. In addition to low productivity, attacks by plant pests (OPT) are also a contributing factor, especially pathogens. Badan Pusat Statistik (2024 reported that rice production in Indonesia in 2024 is estimated at 52.66 million tons of dry milled grain (GKG), a decrease of 1.32 million tons of GKG, or 2.45 percent, compared to rice production in 2023, which was 53.98 million tons of GKG. It was concluded that farmers face major challenges due to pest attacks that can significantly reduce crop yields. Traditionally, pest identification is done manually, which requires a lot of time and effort. Along with technological developments, digital image processing offers an efficient and accurate solution in detecting and identifying pests in plants automatically.

Digital image processing is a branch of information technology that enables the analysis of images to obtain useful information. In the agricultural context, this technology is used to analyze crop images to detect pest or disease infestations. Methods used include *Haar Cascade Classifier, K-Nearest Neighbor (K-NN), Convolutional Neural Network (CNN), and Fuzzy C-Means Clustering.*

Digital *Image* Processing isa field of science that studies how an image That formed, processed, and analyzed so that it produces information that can be understood by humans. One of the processing the image in progress developed is detection early based image infrared that is draft data and technology - based agriculture For

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manage plant in a way efficient and sustainable way. Infrared image technology has used widely in various fields for non-destructive monitoring, including agriculture (Fauziah et al., 2021). With controlling the right pests, agricultural results can be increased, and the data obtained can be integrated with management systems for making better decisions.

The current challenges faced by farmers are that they should be able to identify pest attacks early. Furthermore, farmers should know the initial steps to detect these pests. However, some farmers still lack knowledge of pest identification, resulting in suboptimal harvests. One undesirable and detrimental organism in daily activities is a fungal infection. For example, the Ciherang variety of rice seeds is highly susceptible to blast disease caused by the pathogen *Pyricularia oryzae.* Therefore, technology is needed to detect disease attacks on rice seeds to minimize the risk of infection.

On the other hand, it is important to note that blast disease can cause significant losses because it damages various parts of the rice plant, such as leaves, stems, flowers, panicles, and seeds. Suganda et al (2016) reported that blast disease is one of the main diseases in rice plants, resulting in cultivation losses of up to 61%. The blast pathogen is a *seed-borne fungal species*, meaning it can survive on seeds and plant debris in the form of conidia and mycelium. Conventional analysis suggests that the spread of blast disease occurs due to pathogen inoculum carried on seeds.

One effort that can be made to minimize these problems is using early detection methods for plant diseases. Implementation of an automatic detection system based on image processing can be done using hardware such as a digital camera or *IoT*- based sensors connected to a computer system or *mobile device.* For example, research by Julyani & Khairullah (2025) utilizes image processing for automatic detection and identification of pests in plants. Another study (Zhu et al., 2018) also used thermography methods targeting *Cucumber mosaic virus* (CMV) in tomato plants and *Puccinia triticina* in wheat. This thermography method can visualize symptoms earlier than observing symptoms with the naked eye, namely 5 and 7 days after inoculation (DAI) in tomato and wheat plants, respectively.

The research was conducted to develop infrared image-based technology as a method for early detection of viral infections, using the model of the fungal pathogen *Pyricularia oryzae* in rice seeds. This research is expected to provide information and considerations regarding the early detection of *Pyricularia oryzae symptoms* in rice seeds compared to conventional early detection and identify the accuracy level of early detection of the fungal pathogen *Pyricularia oryzae* based on infrared image analysis, so that it can be used as an alternative early detection method for fungal infections in rice seeds.

2. Material and Methods

This research was conducted at the Plant Health Laboratory I and Microbiology Laboratory, Faculty of Agriculture, National Development University "Veteran" East Java in July – December 2025. The research location was at the coordinates -7.32 ^{o} LS and 112.79 ^{o} BT, with an altitude of 3– 6 meters above sea level with an average temperature ranging from 27.40 ^{o}C - 30.70 ^{o}C. The tools used in the research were Laminar Air Flow (LAF), analytical balance, autoclave, vortex, erlenmeyer, ose needle, petri dish, pipette, test tube, tweezers, beaker glass, Neubauer hemocytometer, bunsen, Olympus CX33 electro microscope, digital microscope modified with infrared lens, infrared flashlight, Microsoft Excel 2019, MATLAB R2024a, and a laptop.

This study uses infrared imagery in detect the pathogen Pyricularia oryzae in rice plants; the observation begins with Image Acquisition, Image Preprocessing, Segmentation, Visualization, and Validation. The implementation of the study consists of several stages, including rice seed sampling, sterilization of tools and materials, making PDA media, exploration and isolation of pathogens, calculating spore density, seed health tests, Koch postulates tests, conventional observations, and observations using infrared images. The sampling of rice seeds using the Ciherang variety was carried out using a random method according to *the International Seed Testing Association* (ISTA) procedure. Sterilization of tools and materials is the process of killing or eliminating all forms of microorganisms, including bacteria, viruses and fungi, found in laboratory tools and materials. PDA *(Potato Dextrose Agar) media were prepared to grow fungi and microorganisms. Exploration and isolation were carried out by observing in detail the signs of P. oryzae* pathogen attacks on rice plants and identifying them both macroscopically and microscopically. Calculation of spore density was carried out using the dilution method and counting with a hemocytometer. Seed health testing is conducted to determine the presence of pathogens in rice seeds. Postulate testing is used to prove that the isolate obtained is truly the causative agent of the visible disease symptoms. Conventional observation is carried out using traditional methods to detect the presence of pathogens or disease symptoms without the use of sophisticated technology. Infrared image observation is a technology for detecting the presence of pathogens or disease symptoms using certain tools or sophisticated technology. The observation begins with image acquisition, image preprocessing, segmentation, visualization, and validation (Figure 1).

Figure 1. Image Processing Flowchart

These observation parameters include the incubation period and accuracy level. The incubation period, or observation period, is the time period between the entry of a pathogen into a host and the appearance of visible disease symptoms. The accuracy level, or parameter, is used to determine the accuracy and agreement between the estimated results obtained through image analysis and direct laboratory observations.

Data analysis used in this study was carried out using several software programs, namely MATLAB R2022a and Microsoft Excel 2019. The results of the image acquisition that had been obtained were continued to the image data processing process until the visualization stage using MATLAB R2022a. Validation tests with accuracy level calculations were carried out using Microsoft Excel 2019 software.

3. Results and Discussion

Based on the results of macroscopic observations, the fungal isolate shows the characteristics of *Pyricularia oryzae*. It has a grayish-white colony which, over time, will change to dark gray to blackish and has a colony surface texture like fine hair or velvet (Figure 2). The characteristics that appear are in accordance with the statement of Wicaksono et al. (2017) that the fungus *Pyricularia oryzae* has a grayish-black colony morphology, is thin, and forms a circle resembling a ring.

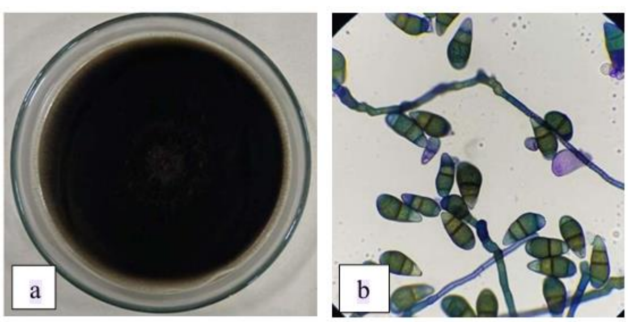


Figure 2. Microscopically observation *of Pyricularia oryzae* Fungal Isolate , (a) *Pyricularia oryzae Fungal Colony, (b) Pyricularia oryzae* Conidia

The Pyricularia oryzae isolate on rice plants produced the symptoms presented in Figure 3. The symptoms caused were the appearance of small, greenish-gray spots in the shape of a rhombus. This is in accordance with the statement of Sandy et al. (2024) that the initial symptoms on rice leaves attacked by *Pyricularia oryzae* are characterized by the appearance of oval or elliptical spots. Microscopically, the observation results showed that *the Pyricularia oryzae fungus* has clear to blue conidia and is pear-shaped, has septate hyphae with a darker color (Figure 2.b.). This is in accordance with the statement by Effendi et al. (2017), that, microscopically, *Pyricularia oryzae has pyriform* conidia that look like a pear with three cells and has a hyaline to pale gray color with smooth and thin conidial walls.

Figure 3. Rhombus-Shaped Symptoms of *Pyricularia oryzae Attacks, Results of Koch's Postulate Test*

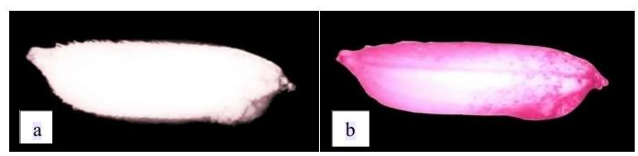


Figure 4. Infrared Image Acquisition, (a) Healthy Seeds Marked with White on the Entire Seed Area, (b) Diseased Seeds Marked with Red on the Symptomatic Parts of the Seeds.

Image acquisition results obtained under a microscope showed that there were differences between seeds without inoculating *P. oryzae isolates* (healthy seeds) and seeds inoculated with P. oryzae (symptomatic seeds). Seeds without inoculation with *P. oryzae* had a clean surface and did not show any morphological changes (Figure 4.a.). Seeds inoculated with *P. oryzae* showed signs and symptoms of the presence of P. *oryzae* fungus on rice seeds, which were indicated by the presence of brownish to blackish spots on the surface of the seeds, which were the result of the growth of mycelium and fungal spores (Figure 4.b.) (Sandy et al., 2024). Whereas in previous research, Zhu et al. (2018) stated that thermal image observation in diagnosing tomato disease only showed areas of healthy tomato leaves with a uniform low blue temperature, no temperature mutations, and an overall smooth leaf temperature transition. In virus-infected leaves, the color of the leaves was orange-yellow.

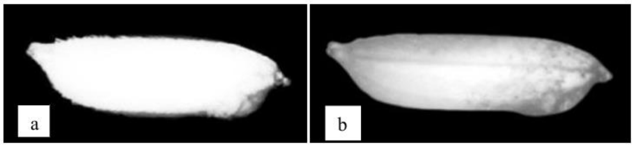


Figure 5. Grayscaling of Infrared Image , (a) Seed Healthy Marked with Color White on the entire seed area, (b) Seed Sick Marked with a Gray Scale on the Symptomatic Seed Parts.

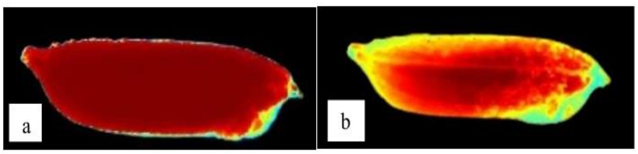


Figure 6. Pseudo-coloring, (a) Seeds Healthy Marked with Red Color on the Entire Seed Area , (b) Seed Sick Marked with Brighter Colors Colors on the Symptomatic Seed Parts.

The processing image results from two tests, namely image grayscale and image pseudocolor. Based on the generated grayscale image, the seed parts colored white show healthy seeds (Figure 5. a). Color white signify intensity reflection high light Because surface seed clean, solid, and not experiencing structural changes due to infection. On the other hand , the part visible seeds gray describe symptomatic seeds or sick (Figure 5.b.). Gray color shows a decline in light-reflection intensity, resulting in changes in texture, spots, or damage to the seed surfaceseeds . While the results image *pseudocolor* above , visible that colored area red show seed in condition healthy (Figure 6.a.). Color red signify intensity light height that describes surface seed Still intact , clean , and not experience damage network . Meanwhile, that part of the edge colored yellow shows symptomatic seeds or infected disease. Color yellow indicates existence decline in intensity, leading to changes in the structure of the network, spots , or attack pathogens (Figure 6.b.). Meanwhile, in the study previously Zhu et al., (2018), stated in the observation image thermal in diagnostics disease tomato only showing leaf area healthy tomatoes show temperature low uniform blue, no happen mutation temperature, and a smooth transition in temperature across the leaves. On the leaves infected with the virus shown with color the leaves orange-yellow .

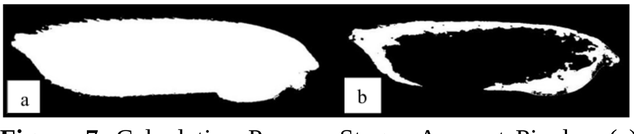


Figure 7. Calculation Process Stages Amount Pixels , (a) Total Pixels Marked with Color White on the Entire Seed Area , (b) Symptomatic Part Pixels Marked with Color White in Symptomatic Areas Just.

At the stage of validation, the image started with extracting the total pixels of image seeds that have been cleaned from the background behind so that all pixels represent the physical seed digitally (Figure 7.a.). Next, the number of symptomatic pixels that have been marked through the *thresholding* process in RGB space is calculated (Figure 7.b.).

Based on the validation results in Table 1, the percentage of symptoms obtained through image processing is in the range of 30–52%, while the results of manual observation show a range of 30–50%. This pattern indicates that both methods yielded consistent values, with samples with high estimated values in image processing also showing high values in manual observation. The average percentage of symptoms based on image estimation was 40%, while manual observation showed an average value of 38%. This 2% difference is still within acceptable limits for visual analysis, especially since manual observation methods are susceptible to differences in perception between observers in determining the boundaries of symptomatic areas. Research by Zhu et al. (2018) indicates that the time to observe symptoms appears earlier than manual observation in tomato mosaic and wheat leaf rust, at 5 days and 7 days, respectively.

The regression results on day 7 showed a positive relationship between the percentage of disease detected through image estimation and direct observation of rice seeds (Figure 8). The regression equation obtained was $y = 0.7468x + 0.0845$, which means that every 1% increase in image-based disease detection was followed by an increase of approximately 0.75% in direct observation results. The small constant value indicates that when image estimation is very low, direct observation results also tend to be low.

Observations of the incubation period (Table 2) showed that the first to second day showed a dominant red color evenly across the entire surface of the seeds. This red color is interpreted as the seeds being healthy and not showing any symptoms of *P. oryzae fungal infection*. This also corresponds to the results of visual observations (RGB images) on the same day, where the seed surface appeared clean and bright without any physical color changes. Starting on the third day after inoculation, the pseudo-coloring image began to show a color change on the edges of the seeds to greenish-yellow. This color change indicates an initial reaction of *P. oryzae infection* that is starting to develop on the outer layer of the seeds. However, visually, the seeds have not shown any symptoms. Visually, in the RGB images on the fourth to fifth day, a brownish color change began to appear on the surface of the seeds, indicating the initial appearance of pathogen symptoms. On the sixth and seventh days, the yellow area in the pseudo-coloring image expanded, indicating an increasing level of infection in the seeds. This is also supported by visual changes that show the seeds appear darker and the presence of blackish spots typical of *P. oryzae fungal infection*.

Based on the research Zhu et al. (2018), the infrared thermography image of the virus that has not been inoculated leaves shows a uniform pale blue color, and the average temperature of the light blue area after calculation is 23.2°C. A thermal image of the 3rd day after inoculation is presented. As the infestation process progresses, the leaves show a uniform increase in yellowish color with an average temperature of 24.1°C, which is an average of 0.6°C higher than the overall temperature before inoculation. Thus, pseudocoloring results in infrared images can detect changes in seed condition earlier and more accurately than visual observations.

Table 1. Calculation of the Number of Pixels in Image Estimation and Observation

Day 7	Total Pixel	Symptomatic Pixels	Presentation Estimate	Observation
U1P1	352784	135657	38%	35%
U1P2	371299	157303	42%	45%
U1P3	354098	143161	40%	40%
U1P4	346984	142873	41%	40%
U1P5	344535	100500	29%	30%
U2P1	377827	150109	40%	40%
U2P2	373112	119289	32%	35%
U2P3	352667	139806	40%	40%
U2P4	352434	117937	33%	30%
U2P5	387294	160185	41%	40%
U1P1	360779	111248	31%	30%
U3P2	370002	135907	37%	35%
U3P3	327613	168295	51%	45%
U3P4	360598	123379	34%	30%
U3P5	369661	139473	38%	40%
U4P1	354678	146850	41%	35%
U4P2	298014	118364	40%	35%
U4P3	339058	134256	40%	35%
U4P4	350485	126951	36%	35%
U4P5	389476	180295	46%	40%
U5P1	364209	167926	46%	40%
U5P2	330138	171711	52%	50%
U5P3	357184	183893	51%	50%
U5P4	353206	126049	36%	35%
U5P5	356581	114201	32%	40%
Average			40%	38%

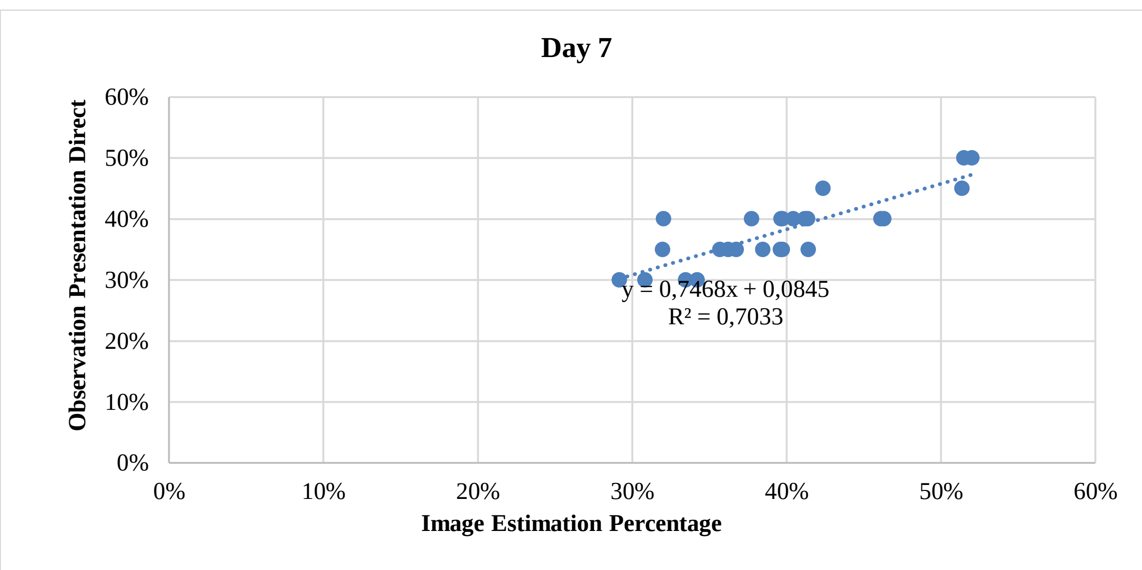
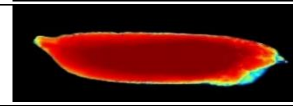
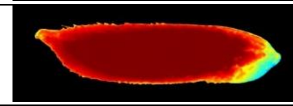
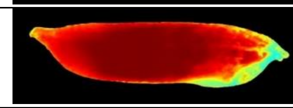
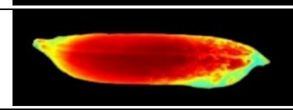
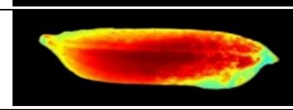
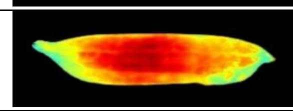


Figure 8. Graph of Regression Analysis of Image Estimation with Observation Results

Table 2. Results of Incubation Period Observations

Day 4 Observation	RGB image	*Pseudo-Coloring* Result Image
1.		
2.		
3.		
4.		
5.		
6.		
7.		

4. Conclusion

The conclusion obtained from this study is that infrared images are proven to be more effective in detecting early symptoms of *Pyricularia oryzae infection* compared to conventional methods. Symptoms of infection began to be detected from the 3rd day through pseudo-colored images, while visually only color changes were observed on the 4th to 5th day. Validation using regression analysis showed a strong relationship between the results of image estimation and direct observation in the laboratory. The regression model obtained was $R^2 = 0.7033$, which means that the results of image estimation can explain 70.33% of the variation in observation results. The analysis in this study has the potential to be an early detection method because it can detect the *Pyricularia oryzae fungus* in rice seeds with the percentage of symptoms obtained through image processing in the range of 30–52% and is more accurate than manual observation.

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