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ANALYSIS OF THE EFFECT OF AIR HUMIDITY AND CONIDIUM DENSITY ON EDAMAME LEAF RUST DISEASE (PHAKOPSORA PACHYRHIZI) IN IMMATURE OIL PALM AREAS

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Abstract

Leaf rust disease caused by *Phakopsora pachyrhizi* is an important disease of soybean and edamame that can reduce leaf function and yield potential. This study analyzed the effect of air humidity and conidium density on the severity of edamame leaf rust disease in immature oil palm areas. The research was conducted from March to May 2026 at the Practice Garden of the Indonesian Oil Palm Institute of Technology, Percut Sei Tuan, Deli Serdang, North Sumatra. Air humidity was observed in the morning, afternoon, and evening, while trapped conidia were observed using modified spore traps. Disease severity and disease incidence were recorded every five days and analyzed using multiple linear regression with SPSS. The observations showed that disease severity increased from 6% to 93%, while disease incidence reached 100%. Classical assumption testing showed that the regression model met the assumptions of normality, multicollinearity, and heteroscedasticity. The regression model was simultaneously significant (F = 437.006; Sig. = 0.000), with an R Square value of 0.954. Partially, air humidity did not significantly affect disease severity (t = -0.333; Sig. = 0.739), whereas conidium density had a positive and significant effect (t = 26.924; Sig. = 0.000). These results indicate that conidium density was the dominant factor associated with the development of edamame leaf rust disease in the observed immature oil palm area.

Keywords: Air Humidity, Conidium Density, Edamame, Leaf Rust, *Phakopsora pachyrhizi*

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is one of Indonesia's leading national commodities because of its substantial contribution to the national economy (Rahmawati, 2023). During the immature phase, oil palm plantations do not yet provide direct economic returns, although they still require intensive maintenance. Empty areas between young oil palm stands are often left unmanaged, even though these spaces have great potential to support farmers' income through productive use (Nasution et al., 2022). Intercropping in young oil palm areas can utilize the empty spaces between immature oil palm stands by planting other economically valuable crops. This practice can provide additional income, improve soil fertility, reduce erosion, and optimize land use in plantations (Agriani et al., 2025).

Soybean (*Glycine max* L.) is one of the crops that can be used as an intercrop in young oil palm plantations because it can still receive sufficient light and grow well (Yuliani et al., 2021). Edamame has high commercial value in Indonesia due to its popularity as a healthy snack (Iswiyanto et al., 2023). Soybean is also an important agricultural commodity globally because of its nutritional value, industrial potential, and strategic importance as a food and feed protein source (Uskutoglu, 2025). As an intercrop, edamame contributes to food security and supports the productive use of young oil palm land (Nurhayati et al., 2022).

Low domestic production may be caused by pest and disease problems. One of the major soybean diseases is leaf rust caused by *Phakopsora pachyrhizi* (Poromarto et al., 2025). Leaf rust can drastically reduce yield because infected leaves fall prematurely and photosynthesis is disrupted. If not properly controlled, this disease can cause substantial yield losses due to defoliation (Hossain et al., 2024). *P. pachyrhizi* is known as one of the most destructive soybean foliar pathogens, with the potential to cause severe yield losses under favorable conditions (Husein et al., 2025). Air humidity is one of the main environmental factors influencing the development of *P. pachyrhizi*. High humidity supports the formation and dispersal of urediniospores or conidia as the main infectious propagules. Conidial germination is favored at relative humidity levels above 70% (Uge et al., 2023;

Hossain et al., 2024). Conidia formed in uredinial pustules can be dispersed by wind, and adequate environmental humidity supports subsequent germination and infection (Ferreira et al., 2025). Therefore, the number of conidia dispersed in the field is expected to be closely related to disease development.

LITERATURE REVIEW

Leaf Rust Disease and Environmental Factors

P. pachyrhizi is a fungal pathogen that causes soybean leaf rust and can lead to serious production losses under severe conditions. This pathogen attacks soybean and edamame leaves, causing brown lesions that can develop into defoliation and reduced plant quality (Twizeyimana et al., 2023). According to Guntoro et al., (2025) this deficiency can be caused by various factors, starting from nutrient deficiencies and extreme weather which weakens the main plant so that pathogens easily attack plant tissue that is already weak or has wounds. Disease management requires attention to planting time and fungicide application according to humidity and temperature conditions that trigger infection. Epidemic prediction based on relative humidity data can improve the effectiveness of disease control (Henck et al., 2024).

In this study, leaf rust disease development was analyzed through the relationship among air humidity, conidium density, and disease severity. The statistical approach was designed to evaluate whether air humidity and conidium density simultaneously and partially explain variability in disease severity in edamame planted in immature oil palm areas.

METHODS

This research was conducted for three months, from March to May 2026, on edamame plants grown in a young oil palm area at the Practice Garden of the Indonesian Oil Palm Institute of Technology (ITSI) Medan, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra. This study used a quantitative descriptive method with direct visual observation to identify plants infected with leaf rust disease (*Phakopsora pachyrhizi*).

Two modified spore traps were installed in the experimental plot. Each trap was equipped with three glass slides positioned at different heights, namely the upper, middle, and lower positions. Before installation, the glass slides were coated with Vaseline as an adhesive so that spores attached to the surface would not be carried away by the wind. The spore traps were placed at two points in one plot measuring 9,5 m x 1.5 m, with each point located 25 cm from the end of the plot.

Air humidity was observed every morning, afternoon, and evening. The number of trapped conidia was observed every morning and evening. Disease severity and disease incidence were observed every five days. Data were processed using SPSS. Disease severity was calculated using the following formula:

$$\textbf{Disease severity (\%)} = [\Sigma(n \times V) / (Z \times N)] \times 100\%$$

where n is the severity score, V is the severity score of the observed leaf, Z is the highest score on the observation scale, and N is the total number of observed leaves.

Table 1. Disease Severity Assessment

Score	Criteria
0	No symptoms
1	Mild symptoms 0-25%
2	Moderate symptoms >25%
3	Moderate to severe symptoms >50%
4	Extensive symptoms >75%

Figure 1. Modified Spore Trap

RESULTS AND DISCUSSION

Based on field observations, plants infected by *P. pachyrhizi* showed brown spots on the upper (adaxial) and lower (abaxial) leaf surfaces. Laboratory observations using a binocular microscope showed that the pathogen had an oval morphology with a thin wall of approximately 1 μm. This is consistent with Wartono and Tasma (2021), who reported that uredospores are oval to elliptical. The uredospores were attached without stalks (sessile) (Reis, 2022). The observation results can be seen in Figure 2.

Figure 2. *(A)* Healthy plant *(B)* Infected plant: *Phakopsora pachyrhizi (C)* Uredospore *Phakopsora pachyrhizi* at 1000x magnification

Differences in the infection scale of *P. pachyrhizi* on leaves can be seen in Figure 3.

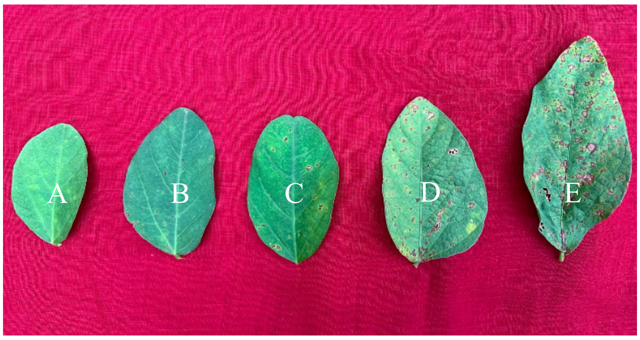


Figure 3. *(A)* Scale 0 *(B)* Scale 1 *(C)* Scale 2 *(D)* Scale 3 *(E)* Scale 4

Field Observation of Leaf Rust Disease Development

The relationship among air humidity, conidial density, and disease severity is presented in Table 2.

Table 2. Air Humidity, Conidium Density, and Disease Severity

Date	Air Humidity (%)	Number of Conidia	Disease Severity (%)
16/04/2026	71	4	0.06
17/04/2026	71	6	0.07
18/04/2026	75	4	0.08
19/04/2026	70	4	0.08
20/04/2026	78	7	0.09
21/04/2026	73	5	0.09
22/04/2026	78	4	0.10
23/04/2026	66	7	0.11
24/04/2026	69	7	0.11
25/04/2026	69	8	0.12
26/04/2026	71	6	0.13
27/04/2026	68	9	0.14
28/04/2026	66	11	0.15
29/04/2026	59	7	0.16
30/04/2026	65	11	0.16
01/04/2026	77	8	0.17
02/05/2026	74	10	0.18
03/05/2026	76	10	0.19
04/05/2026	76	13	0.20
05/05/2026	78	13	0.21
06/05/2026	67	12	0.22
07/05/2026	74	14	0.23
08/05/2026	72	15	0.25
09/05/2026	71	14	0.26
10/05/2026	72	17	0.27
11/05/2026	70	15	0.29
12/05/2026	73	18	0.31
13/05/2026	75	20	0.33
14/05/2026	72	22	0.35
15/05/2026	78	19	0.36
16/05/2026	79	20	0.39
17/05/2026	74	21	0.42
18/05/2026	75	21	0.45

Date	Air Humidity (%)	Number of Conidia	Disease Severity (%)
19/05/2026	73	23	0.48
20/05/2026	72	27	0.51
21/05/2026	72	25	0.55
22/05/2026	75	25	0.59
23/05/2026	72	29	0.63
24/05/2026	74	27	0.67
25/05/2026	73	30	0.72
26/05/2026	74	31	0.76
27/05/2026	75	35	0.80
28/05/2026	82	35	0.84
29/05/2026	80	34	0.89
30/05/2026	80	34	0.93

Classical Assumption Testing

Before interpreting the multiple linear regression model, classical assumption tests were performed. The dependent variable was disease severity in logarithmic form (Disease_Severity_log), while the independent variables were air humidity and conidium density.

One-Sample Kolmogorov-Smirnov Test

Table 3. One-Sample Kolmogorov-Smirnov Test

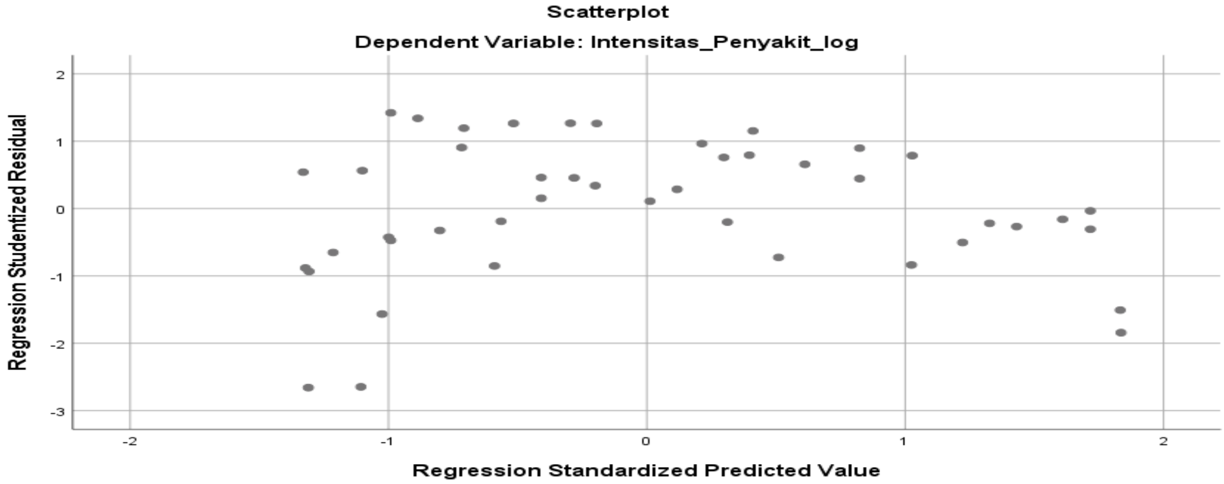
Data	Kolmogrov-Smirnov A	Asymp.Sig
Air Humidity (X1)		0,200
Number of Conidia (X2)	0,05	0,200
Disease Intensity		0,200
Requirements	If Asymp.Sig > 0.05 then the data are normally distributed. The results of the normality test for the research variables show a normal distribution.	
Conclusion	If Asymp.Sig > 0.05 then the data are normally distributed. The results of the normality test for the research variables show a normal distribution.	

The Asymp. Sig. (2-tailed) value obtained for the air humidity variable (X1) is 0.200, for the conidia density variable (X2) is 0.200, and for the disease intensity variable is also 0.200. With a significance level of $\alpha = 0.05$, this data is considered to be normally distributed, meaning the normality assumption is met.

Table 4. Multicollinearity Test

Data	Tolerance	VIF
Air Humidity (X1)	0,821	1.218
Number of Conidia (X2)	0,821	1.218
Disease Intensity	Jika nilai tolerance > 0,10 dan VIF < 10, maka bebas dari gejala multikolinearitas	
Requirements	Hasil uji adalah tidak terjadi gejala multikolinearitas	

If the tolerance value > 0.10 and VIF < 10, then it's free from multicollinearity symptoms. The test results show that there are no symptoms of multicollinearity. Regression Studentized Residuals and Regression Standardized Predicted Values. The residual points were randomly distributed around zero and did not form a specific pattern; therefore, the model did not indicate heteroscedasticity.



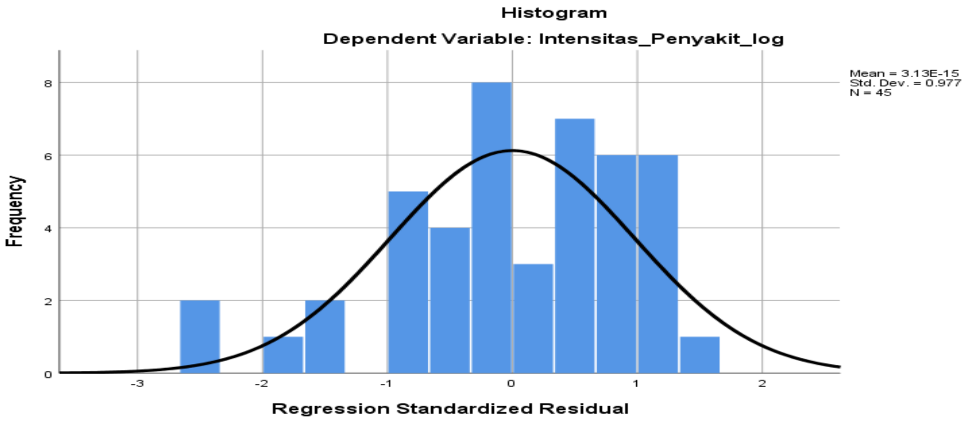


Figure 4. Histogram Regression Standarized Residual

Multiple Linear Regression Analysis
Variables Entered/Removed

Table 5. Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Conidium_Density, Air_Humidity	.	Enter

Model Summary

Table 6. Coefficients / t-Test

Variabel Y	Parameter	Unstandarized Coefficients		Standarized Coefficients			VIF
		B	Std.Error	Beta	t	Sig.	
Severity	(Constan)	0,901	0,196		4,606	0,000	1,218
	Air Humidity (X1)	-0,001	0,003	-0,012	-3,33	0,739	1,218
	Number of Conidia (X2)	0,034	0,001	0,982	26.924	0,000	

Based on the coefficient table, the regression equation is:
Y = 0.901 - 0.001X1 + 0.034X2
where Y is log_disease_severity, X1 is air_humidity, and X2 is conidium_density.
The air humidity variable had a t value of -0.335 with a significance value of 0.739. Because 0.739 is greater than 0.05, air humidity did not have a significant partial effect on log disease severity. The regression coefficient of -0.001 indicates a very small negative relationship when the other variable was held constant. The conidium density variable had a t value of 26.924 with a significance value of 0.000. Because 0.000 is lower than 0.05, conidium density had a positive and significant partial effect on log disease severity. The regression coefficient of 0.034 indicates that every one-unit increase in conidium density increased log disease severity by 0.034 units, assuming the other variable remained constant. These statistical results strengthen the field observation pattern that increasing conidium density was followed by increasing disease severity. Conversely, air humidity did not show a significant partial effect in the regression model because humidity values during the observation period were generally already within a range favorable for pathogen development. Therefore, variation in conidium density was more directly related to disease development than variation in humidity.

ANOVA

Table 7. ANOVA / F-Test

Parameter	Analisis
	X → Y
Sig.	0,000
A	0,05
F Count	437.006
F Table	3,22
Requirement	Sig. < α maka H_0 ditolak H_a diterima F. hitung > F Tabel maka H_0 ditolak H_a diterima
Conclusion	Kelembapan udara dan kepadatan konidium berpengaruh signifikan terhadap intensitas penyakit

The ANOVA table shows an F value of 437.006 with a significance value of 0.000. Because the significance value was lower than 0.05, air humidity and conidium density simultaneously had a significant effect on log disease severity.

Table 8. Coefficient of Determination

Model	R	R Square	Adjusted R Suare	Std. Error of the Estimate
1	.977a	0,954	0,952	0,07424

a. Predictors: (Constant), Conidium_Density, Air_Humidity.

The R Square value of 0.954 indicates that air humidity and conidium density can explain 95.4% of the variation in the logarithm of disease severity. The remaining 4.6% is explained by factors outside the regression model. Furthermore, leaf rust also reduced edamame productivity in this study. The difference in edamame productivity between the experimental beds treated with insecticide and fungicide (2.615 g) and the control beds treated with insecticide and fungicide (4.798 g) is illustrated in the image below.

A B

Figure 6. *(A)* Experimental Beds (B) Control Beds

CONCLUSION

This study shows that the development of edamame leaf rust disease caused by *Phakopsora pachyrhizi* in immature oil palm areas is strongly related to conidium density. Field observations showed that disease severity increased during the observation period. The regression model met the classical assumptions of normality, multicollinearity, and heteroscedasticity. Simultaneously, air humidity and conidium density had a significant effect on log disease severity, as indicated by the F value of 437.006 and the significance value of 0.000. The coefficient of determination showed an R Square value of 0.954, meaning that 95.4% of the variation in log disease severity was explained by the two independent variables. Partially, air humidity did not significantly affect log disease severity, whereas conidium density had a positive and significant effect. These results indicate that conidium density is the dominant explanatory factor in the observed disease development and should be considered in monitoring and managing edamame leaf rust disease in immature oil palm areas.

SUGGESTION

Edamame farmers should monitor air humidity regularly and carry out integrated disease control. Further research is recommended to use a longer observation period and include both the rainy and dry seasons to allow for a more comprehensive analysis of disease development. Furthermore, research can be conducted on the effectiveness of various control methods to develop effective control strategies.

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