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REVIEW ARTICLE **Open Access**

Analysis of the Effect of Sunlight Intensity on Leaf Spot Disease (*Cercospora sp*) in Edamame Plants (*Glycine max (L.)* Merrill) in Oil Palm Intercropping Systems

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Abstract

Edamame (*Glycine max* (L.) Merr.) is an important agricultural commodity in Indonesia, with increasing market demand both domestically and for export. One of the major biotic constraints in edamame cultivation is leaf spot disease caused by Cercospora sp. Environmental factors, particularly sunlight intensity and temperature, significantly influence the development of this disease. High sunlight intensity can reduce uredospore viability and limit fungal infection, while shaded or low-light conditions promote pathogen development due to increased humidity. This research aims to analyze the effect of sunlight intensity on the development of leaf spot disease caused by *Cercospora sp*. in edamame plants. The study was conducted at the experimental field of the Indonesian Palm Oil Institute, Medan, from March to May 2026. Parameters observed include disease incidence, disease intensity using a scoring scale, sunlight intensity measured with a lux meter, and temperature. The data were analyzed using ANOVA in SPSS. Results showed that disease intensity increased progressively from 0.02 to 0.60, and disease incidence reached 100% by early May 2026. Conidium count correlated positively and significantly with disease intensity ($r = 0.747$, $p < 0.05$), while sunlight intensity showed a weak, non-significant negative correlation ($r = -0.143$, $p = 0.347$). Multiple regression analysis ($F = 30.083$, $p = 0.000$) confirmed the significant simultaneous effect of both variables, with conidia count being the dominant factor in disease development.

Keywords: *Cercospora sp*, Disease Incidence, Edamame, Leaf Spot Disease, Sunlight Intensity

1. Introduction

Oil palm is a plantation commodity that produces vegetable oil, widely used in the food, cosmetics, and various other industries (Ronauly, 2024). In oil palm intercropping systems, edamame (Glycine max (L.) Merr.) is an important commodity with strong market prospects. Indonesian soybean production declined from 344,998 tons in 2020 to 200,916 tons in 2021 (BPS, 2021 in Hilmi et al., 2022). Meanwhile, market demand for edamame soybeans continued to rise, from 441,612 tons in 2012 to 721,382 tons in 2014 (Setiawati et al., 2018 in Akbar & Syarief, 2020).

Edamame is a type of soybean that has larger seed pods than most soybeans. The word "edamame " comes from Japanese, where "eda " means branch and "*mame* " means bean. Edamame (*Glycine max. (L) Merr.*) is an annual plant belonging to the Leguminosae family. Edamame is a legume plant in the same family as ordinary soybeans, so they have almost the same shape; the difference between the two is that the size of the edamame pods is larger, has a softer texture, is sweeter than ordinary soybeans and can be more easily digested by humans.

This type of soybean differs from ordinary soybeans mainly in size. The pods are larger, the taste is sweeter, and the harvest period is shorter (Fikardi Tauk et al., 2020; Arnoldus Fikardi Tauk, M.Th. Darini & Faculty of Agriculture, 2020). In addition to its nutritional value, edamame soybeans also have opportunities and market prospects that are still wide open due to their high economic value, where, in addition to being consumed in-country, edamame soybeans are also exported to meet the needs of the Japanese market (Sulistiorini et al., 2023).

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One of the main biotic constraints in edamame cultivation is leaf spot disease (Cercospora sp.), which can significantly reduce plant productivity. This infection begins with chlorophyll damage that triggers premature defoliation of the plant canopy, ultimately reducing the physical quality of the edamame pods produced (Savitri et al., 2025). Temperature, humidity, and light significantly influence the development of leaf spot disease. High sunlight intensity can reduce the germination of uredospores, so that uredospores can only survive for 6 hours at a light intensity of 700 lux (Prakoso et al., 2020). Conversely, shaded conditions tend to increase microhumidity that supports the sporulation *of Cercospora sp* (Hadiwiyono et al., 2025).

This study aims to analyze the effect of sunlight intensity on conidial spread and the development of leaf spot disease (Cercospora sp.) on edamame plants (*Glycine max* (L.) Merr.) in the oil palm intercropping system of the Indonesian Palm Oil Technology Institute, Medan.

2. Material and Methods

The study used a descriptive-correlational survey method *without* treatment manipulation (Permadi et al., 2024). Data were collected through periodic observations every 7 days (weekly), resulting in 45 observation data points. The research materials included edamame seeds, mulch, bamboo, slides, duct tape, glass slides, cover slips, alcohol, distilled water, and Cacto-Fuchsin dye. Tools included a lux meter, hygrometer, light microscope, micrometre, spore trap, and camera. Observation Parameters**:**

1. Disease intensity (IP) is calculated using the formula:
$$\mathbf{IP = \Sigma (n_i \times v_i) / (Z \times N) \times 100\%,}$$
with attack categories referring to a scale of 0–4 (Table 1).
2. Disease incidence is calculated based on the proportion of plants showing symptoms of infection.
3. The intensity of sunlight is measured using a lux meter in the morning, afternoon and evening, then averaged.
4. The number of conidia is counted using a spore trap installed in the planting area and observed microscopically.

Table 1. Scale of leaf spot disease attack categories

Scale (v)	Infected Leaf Surface Area	Severity Description
0	0%	No attacks
1	≤25%	Leaf area causing disease symptoms (mild criteria)
2	>25%–50%	Area of leaves affected/producing symptoms (moderate criteria)
3	>50%–75%	Leaf area causing symptoms (severity criteria)
4	>75%	Leaf area causing symptoms (very large criteria)

Source: https://doi.org/10.22146/agroteknologi.2022.16.2.95

Data were analyzed using the Kolmogorov-Smirnov normality test, Pearson correlation analysis, and multiple linear regression with SPSS version 26. Classical assumption tests include normality, multicollinearity, and heteroscedasticity tests.

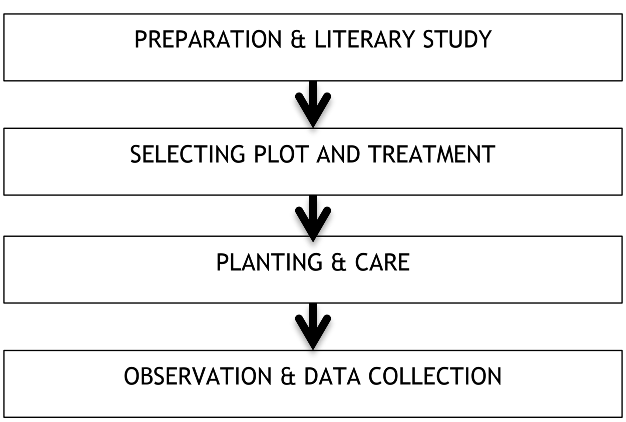

Figure 1. Research flow diagram

3. Results and Discussion

3.1. General Conditions of the Research Location

The research was conducted at the ITSI Plantation practice site in Deli Serdang Regency, North Sumatra. Measurements of sunlight intensity using a lux meter, the development of leaf spot disease (Cercospora sp.), disease incidence, and conidia counts were conducted. Leaf spot disease was first detected in the late vegetative phase and continued to develop until the generative phase. Initial symptoms are characterized by the appearance of small, yellow-brown spots on the leaf surface, which then develop into larger spots and cause a decline in the quality of the leaves as photosynthetic organs.

3.2. Disease Intensity and Incidence

Leaf spot disease intensity increased throughout the observation period, from 2% on April 15, 2026, to 60% on May 30, 2026. This increase was followed by an increase in disease incidence from 65.0% to 100% in early May and persisted until the end of the observation (Table 2). This indicates that the disease spread throughout the sample plants and continued to develop in the infected leaf tissue.

At the start of the observation, disease incidence had reached 65%, but disease intensity remained relatively low (2%). After the pathogen successfully infected the entire plant population, the disease progressed through the formation of pustules and conidia, causing further damage to leaf tissue. The results of this study align with those of Fitri Mei Arini & Arya Pamungkas (2025), who reported that increasing leaf rust attack intensity was related to the increasing development of pathogen infection in leaf tissue.

Table 2. Relationship between disease intensity and disease incidence in edamame plants in 2026

Information	04/15	20/04	04/25	30/04	05/05	10/05	05/15	20/05	25/05	30/05
Disease Intensity (%)	2	4	7	10	15	20	27	36	47	60
Disease Incidence (%)	65.0%	73.3%	83.3%	96.7%	100%	100%	100%	100%	100%	100%

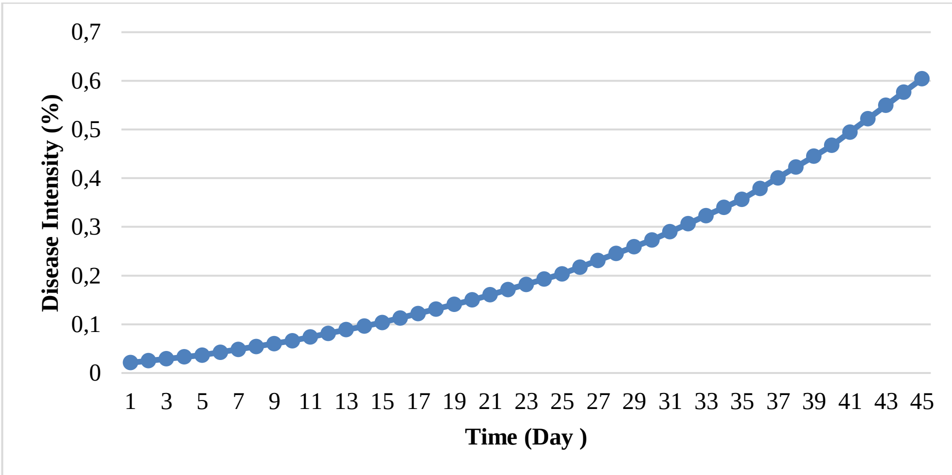

Figure 2. Development of Leaf Spot Disease Intensity (Cercospor sp) in Edamame Plants

3.3. Dispersal of Conidia Cercospora sp

The results of the observations showed that the number of conidia captured during the study ranged from 10 to 39 per observation, with an average of 12.69 conidia per day and 15.20 per night.

Figure 3. Photo of the spore trap tool from the research. Source: Personal Documentation (2026)

Spore traps capture microscopic particles carried by air currents, including conidia *of Cercospora sp.* The number of spores captured is then used as an indicator of the pathogen's spread in the field. More spores captured mean a greater chance of new infections in healthy plants.

After collecting the spores, observations continued under a microscope to identify and count the number of captured conidia. Microscopic observations were conducted to ensure that the observed spores were *Cercospora sp conidia* based on their morphological characteristics. Microscopic observations allowed us of count the captured conidia and obtain quantitative data on the level of spore dispersal. This data was used as one of the main variables in the analysis of the relationship between sunlight intensity and the development of leaf spot disease in *edamame plants.*

Based on observations, the number of conidia captured during the study ranged from 10 to 39 per observation. In general, the number of conidia increased with increasing disease intensity, although fluctuations occurred at some observation points, likely influenced by environmental conditions such as humidity, temperature, and sunlight intensity.

The number of conidia captured at night was higher than during the day, presumably due to the high humidity at night, which supports the process of formation and release of *Cercospora sp conidia,* as shown in **Table 3**.

Figure 4. Observation Using a Microscope. Source: Personal Documentation (2026)

Table 3. Data on sunlight intensity on the number of conidium catches and disease intensity

No.	Light Intensity (Lux)	Daytime Conidia (conidium)	Nocturnal Conidium (conidium)	Average Disease Intensity (%)
1	1141	4	6	0.02
2	1213	6	10	0.03
3	1311	5	13	0.03
4	3524	12	10	0.03
5	3862	12	15	0.04
6	5865	14	17	0.04
7	4845	10	11	0.05
8	5116	7	17	0.05
9	5864	8	14	0.06
10	5588	13	13	0.07
11	3063	9	18	0.07
12	4456	13	18	0.08
13	5023	13	14	0.09
14	3008	11	16	0.10
15	5412	10	17	0.10
16	5118	16	11	0.11
17	1000	14	17	0.12
18	1055	9	16	0.13
19	1309	13	14	0.14
20	2493	11	17	0.15
21	1955	13	8	0.16
22	2947	14	12	0.17
23	5893	9	10	0.18
24	6402	11	15	0.19
25	3948	11	16	0.20
26	3927	13	11	0.22
27	1535	14	15	0.23
28	3813	15	15	0.25
29	3570	11	13	0.26
30	5389	14	15	0.27
31	3625	15	15	0.29
32	6496	14	15	0.31
33	6055	16	12	0.32
34	2991	18	17	0.34
35	3548	14	21	0.36
36	3084	18	19	0.38
37	4779	16	19	0.40
38	1707	12	16	0.42
39	3173	12	14	0.45
40	4102	19	20	0.47
41	2631	14	21	0.49
42	2474	19	20	0.52
43	3204	17	20	0.55
44	1477	17	21	0.58
45	2249	15	20	0.60
Amount	**161,240**	**571**	**684**	**10.1**
Average	**3,583.11**	**12.69**	**15.20**	**0.22**

Source: Primary research data (2026)

In general, the relationship between sunlight intensity and the number of conidia captured during the day shows a regression equation of $y = 0.0002x + 11.948$ with a coefficient of determination (R^2) of 0.0092, while at night it is obtained as $y = -0.0001x + 15.588$ with $R^2 = 0.0024$. Both values indicate a very weak relationship between light intensity and the number of conidia. This result suggests that Cercospora sp sporulation is influenced not only by light intensity but also by other environmental factors such as humidity, temperature, rainfall, and wind speed (Prakoso et al., 2020).

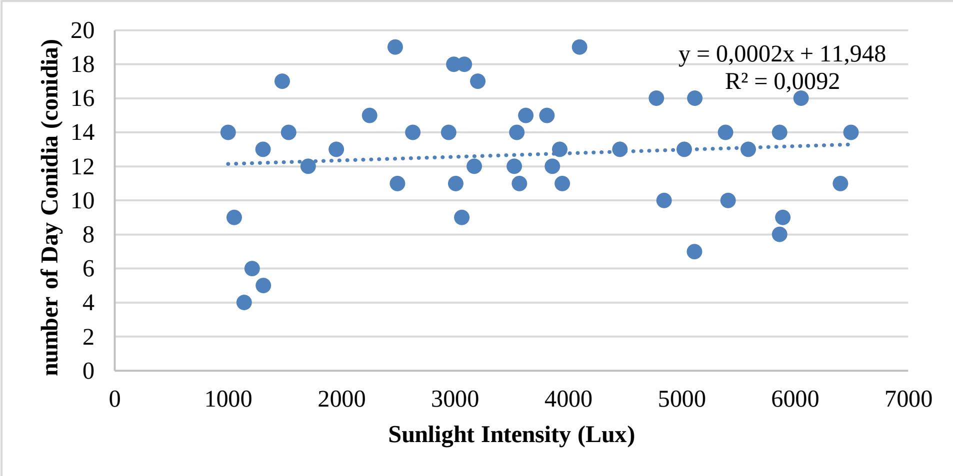

Figure 5. Relationship between Sunlight Intensity and the Number of Daytime Conidium Captures

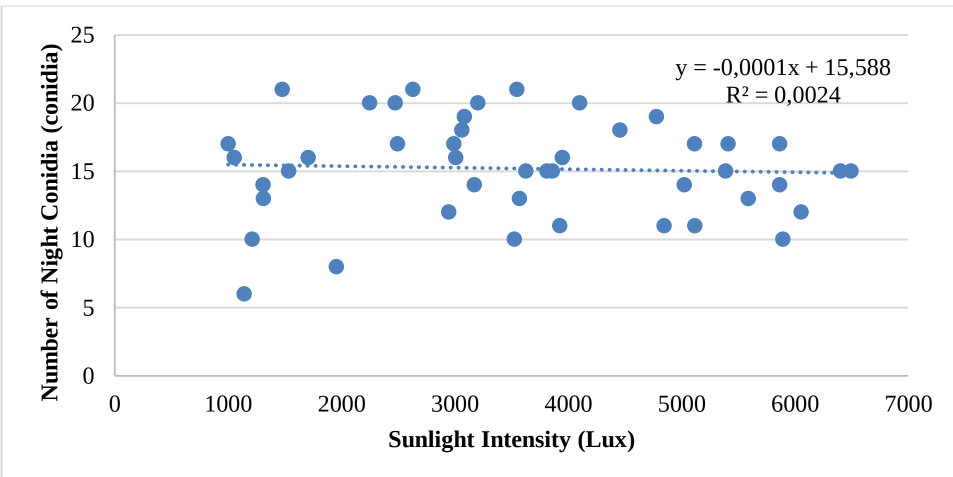

Figure 6. Relationship between Sunlight Intensity and the Number of Night Conidium Captures

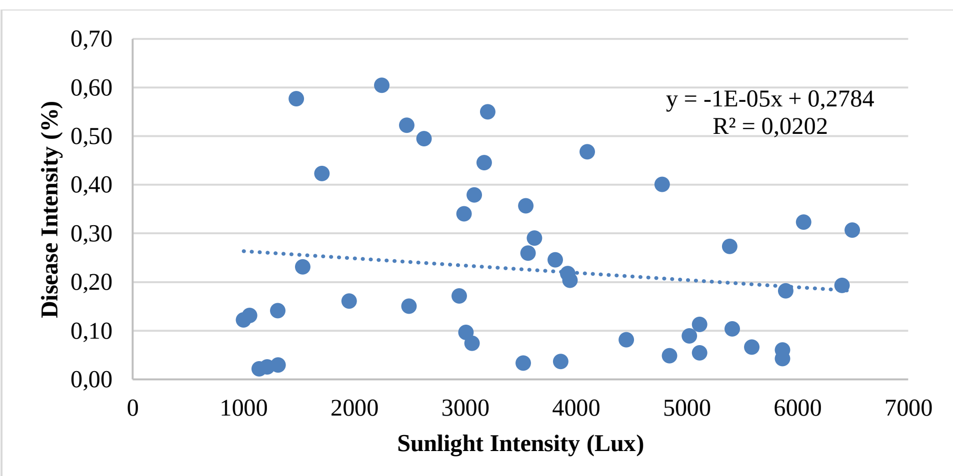

Figure 7. Relationship between Sunlight Intensity and Disease Intensity

3.4. Statistical Test

The Kolmogorov-Smirnov normality test (Table 4) shows that the three research variables have an Asymptotic Significance value (2-tailed) > α = 0.05, so that the data distribution of the three variables is not significantly different from a normal distribution and the normality assumption is met.

Table 4. Results of the One-Sample Kolmogorov-Smirnov normality test

Parameter	Light Intensity (X_1)	Disease Intensity (Y)	Number of Conidia (X_2)
N	45	45	45
Mean	3,583.11	0.2249	27.96
Standard Deviation	1,630,225	0.17040	6,109
Test Statistics (KS)	0.080	0.115	0.108
Asymp. Sig. (2-tailed)	0.200	0.162	0.200

Source: SPSS Output (2026)

3.5. Multiple Linear Regression Analysis and F Test

Multiple linear regression analysis produces the equation:

$$\mathbf{Y = -0.298 - 0.00001831X_1 + 0.021X_2}$$

where Y = disease intensity (%), X_1 = sunlight intensity (lux), and X_2 = number of conidia. The regression coefficient of sunlight intensity is negative (-0.00001831), indicating that increasing sunlight intensity tends to decrease disease intensity. The regression coefficient of conidia number is positive (0.021), indicating that every one-unit increase in the number of conidia will increase disease intensity by 0.021.

Table 5. Results of the F test of the relationship between sunlight intensity and the number of conidia and disease intensity.

Model	Sum of Squares	db	Middle Square	F Count	Sig.
Regression	0.752	2	0.376	30,083	0,000
Residual	0.525	42	0.013	–	–
Total	1,278	44	–	–	–

Source: SPSS Output (2026)

Based on **Table 5**, the calculated F value of 30.083 with a significance value of 0.000 ($<\alpha = 0.05$) shows that the intensity of sunlight and the number of conidia simultaneously have a significant effect on the intensity of leaf spot disease (*Cercospora sp.*) in edamame plants.

3.6. Correlation of Light Intensity and Number of Conidia with Disease Intensity

Pearson correlation analysis between light intensity (X_1) and disease intensity (Y) showed a correlation coefficient value of r = -0.143 with a significance value of p = 0.347 ($> \alpha = 0.05$) (**Table 6**). This result indicates that an increase in light intensity tends to be followed by a decrease in disease intensity, but the relationship is not statistically significant.

Table 6. Pearson correlation of X_1 (light intensity) with Y (disease intensity)

	Light Intensity (X_1)	Disease Intensity (Y)
Pearson Correlation	1	-0.143
Sig. (2-tailed)	–	0.347
N	45	45

Source: SPSS Output (2026)

In contrast to light intensity, the correlation between the number of conidia (X_2) and disease intensity (Y) showed a value of r = 0.747 with p = 0.000 ($< \alpha = 0.05$) (**Table 7**). The value of r = 0.747 indicates a strong positive correlation, meaning that as the number of conidia increases, disease intensity tends to increase.

Table 7. Pearson correlation of X_2 (number of conidia) with Y (disease intensity)

	Number of Conidia (X_2)	Disease Intensity (Y)
Pearson Correlation	1	0.747**
Sig. (2-tailed)	–	0,000
N	45	45

Source: SPSS output (2026). Note: significant correlation at the 0.01 level (2-tailed)

Simultaneously (**Table 8),** the number of conidia (X_2) had a strong and significant positive correlation with disease intensity (r = 0.747; p = 0.000), while light intensity (X_1) had a very weak and insignificant negative correlation (r = -0.143; p = 0.347). The simultaneous R value of 0.767 indicates that the combination of the two variables has a fairly strong relationship with disease intensity.

3.7. Model Validation and Accuracy

The quality of the multiple linear regression model was evaluated based on the parameters R, R^2, Adjusted R^2, Std.

Error of the Estimate, and model significance simultaneously (Table 9). The R^2 value of 0.589 indicates that the model explains 58.9% of the variation in disease intensity. The Adjusted R^2 value of 0.569 indicates the model's explanatory power after correction for the number of independent variables.

Table 8. Simultaneous correlation matrix of X_1 , X_2 , and Y

Variables	Disease Intensity (Y)	Light Intensity (X_1)	Number of Conidia (X_2)	Sig.
Disease Intensity (Y)	1	-0.143	0.747**	–
Light Intensity (X_1)	-0.143	1	0.042	0.347 / 0.784
Number of Conidia (X_2)	0.747**	0.042	1	0.000 / 0.784

Source: SPSS output (2026). Note: significant correlation at the 0.01 level (2-tailed)

Table 9. Summary of regression model quality evaluation

Evaluation Parameters	Mark	Interpretation
R (Multiple Correlation)	0.767	Strong simultaneous relationship
R^2 (Coefficient of Determination)	0.589	The model explains 58.9% of the variation in Y
Adjusted R^2	0.569	Model corrected values
Standard Error of Estimate	0.11182	Average model prediction error
F count	30,083	Significant model
Sig. F	0,000	Significant simultaneous effect
Durbin-Watson	0.780	There are indications of positive autocorrelation

Source: SPSS Output (2026)

The Durbin-Watson value of 0.780 indicates positive autocorrelation in the model residuals, making this model more appropriate for descriptive and exploratory use. However, the significant F-test results (F = 30.083; p = 0.000) indicate that the model is suitable for describing the relationship patterns between variables. This finding aligns with Hadiwiyono et al. (2025), who reported that environmental conditions with lower light intensity and higher humidity are more conducive to the development of leaf rust disease.

4. Conclusion

The intensity of leaf spot disease (Cercospora sp) in edamame plants increased progressively from 0.02 to 0.60 during the observation period, with the disease incidence reaching 100% in early May 2026. The number of conidia captured ranged from 10–39 conidia per observation, where the average number of night conidia (15.20) was higher than the day (12.69), indicating that night conditions were more favorable for Cercospora sp sporulation. The results of multiple linear regression analysis produced the equation $Y = -0.298 - 0.00001831X_1 + 0.021X_2$, with the number of conidia as the dominant factor in influencing the disease intensity. Simultaneously, the intensity of sunlight and the number of conidia significantly influenced the intensity of leaf spot disease (F count = 30.083; p = 0.000 < 0.05). Partially, the number of conidia significantly affected disease intensity (r = 0.747; p = 0.000), while sunlight intensity had no significant effect (p = 0.347 > 0.05).

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