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Disease Intensity and Incidence of Black Sigatoka on Banana (*Musa paradisiaca*) in Karang Bendo, Banguntapan District, Bantul Regency, Special Region of Yogyakarta

Intensitas dan Insidensi Penyakit Black Sigatoka pada Tanaman Pisang (Musa paradisiaca) di Karang Bendo, Kecamatan Banguntapan, Bantul, Daerah Istimewa Yogyakarta

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Abstract

Banana (*Musa paradisiaca*) is one of the most important commodities for food security and local economy, particularly in Indonesia. However, banana productivity is threatened by several major biotic stress factors, including insect pests and fungal diseases. The present study was conducted in Karang Bendo, Banguntapan District, Bantul Regency, aiming to identify the presence and impact of major banana pests and diseases, namely Black Sigatoka disease. Field surveys were carried out using the Simple Random Sampling method, with observations on symptoms of infestation and infection on leaves, pseudostems, and corms. Data analysis was performed using descriptive statistics and ANOVA to determine infestation intensity. The results showed that Black Sigatoka (*Pseudocercospora fijiensis*) resulted in leaf spotting, reduced fruit shelf life, and increased control costs. Overall, these pests and diseases significantly affect banana growth, yield, and plantation longevity. Integrated pest and disease management strategies based on accurate field identification are required to reduce production losses and support sustainable banana cultivation.

Keywords: Banana, Black Sigatoga, Field surveys, Phatogen

Introductions

Agriculture serves as a primary source of food for humanity and significantly impacts the economic stability of many countries. Agriculture remains the primary livelihood for many developing countries. Banana cultivation plays a crucial role in the global agro-industry due to its rich content of essential minerals such as calcium, manganese, potassium, magnesium, and iron. These nutrients make bananas a popular choice worldwide, often considered a quick energy booster. According to recent data from Wikipedia, approximately 15% of global banana production is exported to Western countries, highlighting the importance of bananas in international trade. India leads global production, contributing approximately 25.7%, followed by countries such as the Philippines, Ecuador, Indonesia, and Brazil, which together account for 20% of global banana production. The United States is the top importer, accounting for approximately 18% of global banana imports (Narayanan *et al*., 2022).

Indonesia is home to a diverse variety of bananas, including those suitable for immediate consumption, those requiring processing before consumption, seeded bananas, fiber-producing bananas, and ornamental banana plants commonly found in home gardens. Banana plants thrive throughout Indonesia, thriving in almost every region, whether cultivated in gardens or growing wild on roadsides. The Musa paradisiaca banana species is widely favored by all levels of society in Indonesia due to its accessibility, affordability, and nutritional benefits. Bananas are rich in essential nutrients such as vitamins A, B, and C, fiber, carbohydrates, and minerals, making them an important source of energy and health support. Some nutritionists even recommend bananas as a carbohydrate substitute for staple foods like rice. The fiber and vitamin content in this fruit contributes to improved metabolic function, antioxidants that help fight free radicals, and promotes a feeling of fullness for longer, thus supporting overall health (Budiyanto *et al*., 2018)

However, banana production faces significant threats from diseases and climate-related changes that can cause significant losses, sometimes wiping out entire harvests. Major diseases affecting bananas include black Sigatoka. These diseases cause severe damage to banana plants, with symptoms such as leaf spotting, wilting, and stunted growth, ultimately reducing yield and fruit quality. Furthermore, banana plant susceptibility to these pathogens is exacerbated by environmental stressors such as temperature fluctuations and increased rainfall, which are becoming more common due to climate change. Disease control efforts, development of resistant cultivars, and sustainable agricultural practices are critical to maintaining banana production, supporting the economies that depend on this crop, and maintaining global food security (Narayanan *et al*., 2022).

Despite these advantages, banana cultivation in Indonesia faces significant challenges from various pests that hinder plant growth and productivity. Farmers often struggle to effectively manage this pest, necessitating the development of an expert system to assist farmers and communities in accurately diagnosing pest problems and implementing appropriate control measures. This control is essential for improving pest management, increasing banana production, and supporting livelihoods that depend on this important crop. The continuous increase in Black Sigatoka intensity indicates that the pathogen *Mycosphaerella fijiensis* actively developed within banana leaf tissues during the observation period. The rise in disease severity from 31% at the first observation to 64% at the last observation suggests that the environmental conditions and plant growth stage were likely favorable for pathogen development. Plant disease progression is determined by the interaction among host, pathogen, and environment (disease triangle), and disease severity increases when these three components are optimal for pathogen growth. (Budiyanto *et al*., 2018).

In the case of Black Sigatoka, high humidity and moist environments accelerate fungal spore germination and conidia dispersion on leaf surfaces, and Smith and Johnson (2019) reported that *M. fijiensis* spreads more aggressively under wet conditions and on banana plants with dense canopies that retain leaf moisture for longer periods; additionally, increasing necrotic tissue over time provides a greater source of spores, thereby increasing infection intensity in subsequent observations, which demonstrates that without control measures, Black Sigatoka can severely reduce photosynthetic activity due to leaf tissue damage, ultimately decreasing banana yield, thus highlighting the urgency of implementing appropriate management practices such as pruning infected leaves, using resistant cultivars, applying eco-friendly fungicides, and integrating biological control strategies to suppress disease progression in banana plantations (Esguera *et al*., 2024).

Based on the background described above, the following problem formulations can be identified. what is the impact caused by *Black Sigatoka* disease on banana plants. This study is limited to discussing biotic stress factors that affect banana plants, specifically diseases Black Sigatoka. It does not include other abiotic stress factors such as drought, nutrient deficiency, or soil conditions. The discussion focuses on the impacts of these pests and diseases on the growth, yield, and quality of banana plants, without providing an in-depth analysis of control or management strategies. Furthermore, the analysis is based solely on information obtained from literature studies and does not involve direct field experimentation. The objectives of this study are as follows. First, to analyze the impact of *Black Sigatoka* disease on leaf condition and the overall productivity of banana plants.

Materials And Method

The study population consisted of 30 banana plants located at the study site. Given the small population size, all 30 plants were included as a sample to ensure comprehensive data collection. Sampling was conducted using the simple random sampling method. This method involves assigning a unique number to each plant, then writing the numbers on small pieces of paper, folding them, and placing them in a container. These pieces of paper were thoroughly mixed, and numbers were randomly drawn to determine the order in which the plants were observed. This randomization technique ensured that each plant had an equal opportunity to be assessed, minimized observer bias, and adhered to modern research standards for fairness and accuracy.

This study focused on biotic stress factors, specifically Black Sigatoka. Field observations were conducted through direct inspection of each plant to record visible symptoms of pest and disease attacks, including leaf damage, leaf holes, yellowing, or wilting. Absolute damage is permanent damage to the

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plant to be harvested, such as the death of all plant tissue and wilting. Furthermore, damage considered absolute includes rotting or partial destruction of plant tissue, rendering the plant or part of the plant unproductive (Lahati and Saifuddin, 2022). To calculate absolute damage, use the following formula:

$$I = \frac{n}{N} \times 100\%$$

Description:
I = Incidence of attack (%)
n = Number of affected offspring
N = Number of offspring observed

$$IP = \frac{\sum(n \times v}{Z \times N} \times 100\%$$

Description:
I = Intensit of attack (%)
n = Number of affected offspring
Z = Highest scoring total
N = Number of offspring observed

Pest attack intensity was measured using a scoring system adapted from Nurfadhilah et al. (2024):

• Score 0 = No infection
• Score 1 = Very light infection (1–20% of plant organs affected)
• Score 2 = Light infection (21–40%)
• Score 3 = Moderate infection (41–60%)
• Score 4 = Severe infection (61–80%)
• Score 5 = Very heavy infection (81–100%)

This scoring system replaces the use a straightforward quantitative assessment of damage intensity across samples. Observations were conducted for one month, in October 2025, from the early vegetative stage to fruit ripening. Plants were monitored every 7 days, resulting in four observation periods to consistently capture changes in pest populations and disease symptoms. This methodology ensures a systematic, unbiased, and measurable approach to studying pest and disease dynamics in banana plants, consistent with contemporary research. The variables observed in this study include several key aspects. First, the types of pests and diseases that affect banana plants. Second, the frequency of attacks occurring during the observation period. Third, the specific plant parts that are affected by these pests and disease.

Results And Discussion

Table 1.1 Results of Black Sigatoga Disease Intensity on Banana Plants (*Musa paradisiaca*)

Disease Intensity	Results Scoring
Observation 1	31%
Observation 2	37%
Observation 3	52%
Observation 4	64%

Description : Black Sigatoga intensity on banana plants increased consistently over time, beginning at 31% in Observation 1 and reaching 64% in Observation 4. This trend reflects the progressive spread of *Pseudocercospora fijiensis* under favorable conditions.

The results showed that the intensity of Black Sigatoka disease on banana plants increased progressively at each observation period. At the first observation, the disease intensity was recorded at 31%, then increased to 37% at the second observation. A more noticeable increase was observed at the third observation, reaching 52%, and the highest intensity was recorded at the fourth observation with 64%. Overall, these findings indicate that the severity of Black Sigatoka continued to increase over time, demonstrating the active development of the pathogen on banana leaves.

The results demonstrated a progressive increase in Black Sigatoka severity in banana plants across the four observation periods, with disease intensity rising from 31% in Observation 1, to 37% in Observation 2, 52% in Observation 3, and reaching 64% in Observation 4. This increasing trend indicates continuous development of the pathogen *Pseudocercospora fijiensis* within banana leaf tissues over time. During the early stages (Observation 1 and 2), disease intensity remained comparatively low

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because infection was still in the initial lesion development phase and sporulation had not yet reached its peak. This corresponds to the pathogen's infection biology, which involves stomatal penetration followed by a latent period before visible streak-like lesions appear (Bebber, 2019).

The sharp increase in disease intensity at Observation 3 (52%) suggests a transition into an active necrotic phase, where lesions darken, leaf tissue begins to die, and sporulation becomes more abundant. The expansion of necrosis provides more inoculum sources, accelerating the spread of infection across the leaf surface. This escalation is consistent with the known pathogenic mechanism of *P. fijiensis*, in which fungal toxins induce cell death once exposed to light, resulting in the expansion of necrotic areas. The maximum intensity recorded in Observation 4 (64%) reflects advanced disease development, where widespread necrosis severely disrupts the photosynthetic capacity of the leaves and promotes a faster infection cycle due to increased spore availability (Kimunye *et al*., 2021).

The consistent increase in severity across observations reinforces the aggressive nature of Black Sigatoka, a disease capable of reducing banana yields by up to 80% if left unmanaged. Furthermore, the progressive disease development observed in this study suggests that environmental conditions were likely favorable for pathogen growth. High humidity, rainfall, and moist canopy conditions are known to enhance spore germination and dispersal of *P. fijiensis*. Therefore, the increasing intensity from Observation 1 to 4 not only reflects biological disease progression but also indicates that abiotic conditions supported pathogen establishment and infection. (Strobl and Mohan, 2020).

These findings highlight the importance of early and integrated disease management strategies, including removal of infected leaves, use of resistant cultivars, canopy management to reduce leaf wetness, and application of eco-friendly fungicides or biological control agents. Control measures should be implemented at early infection stages (similar to Observations 1 and 2) to prevent the rapid escalation observed in later phases (Observations 3 and 4), which pose greater risks of severe damage and yield loss (Agounet *et al*., 2024).

Table 1.2 Results of Black Sigatoga Disease Incidence on Banana Plants (*Musa paradisiaca*)

Disease Incidence	Results Scoring
Observation 1	80%
Observation 2	80%
Observation 3	86%
Observation 4	93%

Description : Black Sigatoga Incidence on banana plants increased consistently over time, beginning at 80% in Observation 1 and reaching 93% in Observation 4. This trend reflects the progressive spread of Pseudocercospora fijiensis under favorable conditions

Black Sigatoga disease incidence on banana plants showed a consistently high level of infection throughout the observation period. In Observations 1 and 2, disease incidence was already at 80%, indicating that most plants had been infected early. By Observation 3, incidence increased to 86%, and it reached 93% in Observation 4. This pattern illustrates the rapid spread and high infection pressure of Pseudocercospora fijiensis, especially under conditions that favor disease development.

The research results indicate that the incidence of Black Sigatoka disease in banana plants was high from the beginning of the observation period and continued to increase until the end of the observation period. In Observation 1, the disease incidence was recorded at 80%, and the same value was still found in Observation 2. An increase began to appear in Observation 3, with the incidence reaching 86%, and reached its highest value in Observation 4 at 93%. This pattern illustrates the active spread of the pathogen Pseudocercospora fijiensis in the study area.

The consistently high disease incidence in the first two observations (80% in Observations 1 and 2) indicates that the majority of plants were infected from the outset. At this stage, the infection is likely still in the early symptom development phase, when the spots haven't fully developed but the pathogen has successfully colonized most of the plant. This condition is consistent with the nature of P. fijiensis, which can survive on the leaf surface and infect thru the stomata before symptoms are clearly visible. The increase in incidence from 80% to 86% at Observation 3 indicates the onset of the pathogen's active dissemination phase. At this stage, the old spots begin to produce large quantities of conidia, which are then dispersed to healthy plants by wind, rain splash, or contact between leaves. The pathogen causing Sigatoka has a high sporulation capacity and spreads efficiently, especially in wet leaf conditions and high humidity. Therefore, the increase in infected plants observed in the third observation reflects an increase in the inoculum source and an acceleration of the infection cycle (Aguenot *et al*., 2024).

The highest incidence observed in Observation 4 (93%) indicates that the disease has progressed to an epidemic stage, where almost all plants in the observation area have been infected. At this phase, pathogen sporulation peaks, and the potential for secondary infection increases significantly. This aligns with Cobrado and Fernandez (2025) report stating that Black Sigatoka can spread very quickly in humid canopy conditions, causing almost the entire crop to become infected in a short time if not controlled. This condition has the potential to cause significant production losses due to a decrease in photosynthetic leaf area.

The increasing incidence in each observation also indicates that environmental conditions support disease development. Abiotic factors such as high humidity, rainfall frequency, and low air ventilation are ideal conditions for the germination of P. fijiensis spores. Bebber *et al*. (2019) emphasize that diseases caused by tropical fungi such as Sigatoka are highly dependent on the humid canopy microclimate, as wet leaves are a primary condition for infection. Thus, field conditions during the study likely accelerated the spread and development of the disease.

Overall, the high incidence values from the beginning to the end of the observation period confirm the aggressive nature of Black Sigatoka, which can cause yield losses of up to 50–80% if not controlled. Therefore, implementing integrated pest management strategies becomes crucial, including pruning infected leaves, improving canopy aeration, using tolerant varieties, applying orchard sanitation, and using environmentally friendly fungicides or biological agents. According to Aguonet *et al*. (2024), early control should be implemented in the initial phase of the epidemic before rapid spread, as seen in the later stages (Observations 3 and 4), because delayed management often results in extensive leaf damage and reduced crop productivity.

Conclusion

The study demonstrates that Black Sigatoga disease poses a serious threat to banana plants in Karang Bendo, with both disease intensity and incidence increasing throughout the four observation periods. Disease intensity rose from 31% to 64%, while incidence increased from 80% to 93%, indicating the rapid and aggressive spread of the pathogen under favorable environmental conditions such as high humidity and a moist canopy. This progressive development leads to leaf tissue damage, reduced photosynthetic capacity, and potential yield losses of up to 50–80% if left unmanaged. These findings highlight the urgent need for integrated disease management strategies, including field sanitation, pruning of infected leaves, use of resistant cultivars, improved canopy aeration, and application of eco-friendly fungicides or biological control agents. Such measures must be implemented early in the infection process to prevent the disease from escalating and to maintain sustainable banana production.

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PEST AND DISEASE MONITORING WITH CONTROL MEASURES ON CHILI (*Capsicum frutescens* L.) PLANTATION IN TURI, SLEMAN, YOGYAKARTA

(*PEMANTAUAN HAMA DAN PENYAKIT SERTA TINDAKAN PENGENDALIANNYA PADA LAHAN CABAI (Capsicum frustescens L.) DI TURI, SLEMAN, YOGYAKARTA*)

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Abstract

Red bird's eye chili (*Capsicum frutescens* L.) is an important horticultural crop in Indonesia, whose productivity is often affected by pest and disease infestations. This study aimed to identify the types of pests and diseases present in chili plantations in Turi, Sleman, Yogyakarta, and to assess their incidence and intensity. The research was conducted from October to November 2025 using a diagonal sampling method at five observation points, with ten plants randomly selected at each point. The observations indicated that the main pests found were armyworms (*Spodoptera litura*) and thrips (*Thrips* sp.). The incidence of *S. litura* increased from 70% to 100%, while thrips ranged from 85% to 95% during the observation period. The intensity of pest attacks also showed an increasing trend, with *S. litura* ranging from 19.50% to 48% and thrips from 29% to 45%. The diseases identified included Geminivirus and anthracnose. Geminivirus incidence remained high (90–97.5%), with intensity increasing from 47.50% to 81.75%. Anthracnose incidence increased from 17.50% to 62.50%, while its intensity reached a peak of 32.5% before slightly declining. Overall, the results suggest that pest and disease occurrence tended to increase during the generative stage of the plants. These findings may serve as preliminary information to support the implementation of appropriate pest and disease management strategies in chili cultivation.

Keywords: *Chili cultivation, Disease incidence, Integrated pest management*, *Pest intensity*.

Introduction

Red Bird's eye chili (*Capsicum frustescens* L.) are a horticultural commodity with high economic value and market demand. This horticultural commodity plays an important role in Indonesia, both in terms of consumption and trade. In Indonesian culture, Bird's eye chili have become an integral part of the cuisine, as almost every dish uses Bird's eye chili, even if only in small amounts. In addition to providing a spicy flavor, Bird's eye chili contains vitamin C, beta-carotene (provitamin A). In addition, it also contains minerals such as phosphorus and calcium. The spicy taste of bird's eye chili comes from a compound called capsaicin (Mitra Agro Sejati, 2017). Bird's eye chili productivity often fluctuates due to plant pests and diseases. Pest attacks can result in a decrease in the quantity and quality of the harvest, causing economic losses for farmers.

The Turi region in Sleman, Yogyakarta, is known as one of the chili production centers that supplies local and regional markets. However, the humid environmental conditions in this region are conducive to the development of various types of pests and plant disease pathogens. The main pests found on chili plants include *Spodoptera* spp. (armyworm) and *Thrips parvispinus*. Yield loss in bird's eye chili due to thrips can reach 22.8% (Sarrani, 2023), armyworm can cause yield loss 40%-50% (Vijayalakshmi *et al.*, 2016). While the diseases commonly found are anthracnose (*Colletotrichum*

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capsici) and *Geminivirus*. Anthracnose can cause yield losses ranging from 10% to 100%, depending on environmental conditions (Widodo and Hidayat, 2017), *Geminivirus* can cause yield losses of up to 98.6% (Suhita *et al*., 2025). These pests and diseases cause tissue damage to plants and can reduce chili production if not properly controlled. This is further exacerbated by suboptimal cultivation practices, leading to increased attack intensity each growing season, excessive use of pesticides can lead to pest and disease resistance. (Jamin *et al*., 2024). Therefore, monitoring and control activities must be carried out routinely to prevent more detrimental impacts.

Monitoring aims to identify pest and disease attacks early, determine attack patterns, and understand the factors that influence the distribution and intensity of attacks. In addition, pest and disease monitoring is carried out to determine whether control measures are necessary to secure yields. The objective of pest and disease control is to prevent losses through effective, economical, and safe control methods. This is done to maintain high production (profitability), preserve the health and quality of the environment (safety), and ensure the durability of control measures (Muliasari and Trilaksono, 2020).

The limited availability of information regarding the intensity of pest and disease infestations in chili crops in Turi, Sleman, has encouraged the author to conduct and publish this study. This study aims to monitor pests and diseases in chili plants in Turi, Sleman, to identify the types, intensity, and patterns of infestation. The results are expected to provide recommendations for effective and environmentally friendly control measures as a reference for farmers and local governments in improving chili productivity in a sustainable manner.

Materials and Methods

This study was conducted on chili farms owned by Maharani with an area of 264 m^2 and a total population of 400 plants in Turi, Sleman, Yogyakarta, at an altitude of 418 m above sea level in October 2025. The tools used during the study were paper, pen, and camera. The materials used were chili plants showing symptoms of pest attack (armyworm and thrips) and disease (*Geminivirus* and anthracnose). This study was conducted on chili farms in Turi, Sleman, Yogyakarta. Samples were collected diagonally (Figure 1) at five observation points. Samples were collected from each point. The population per unit was 40 samples.

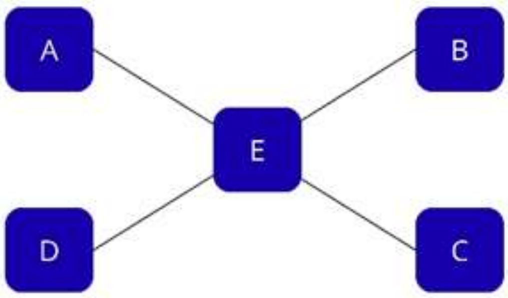

Figure 1. Pattern Sampling

1. Interval of Monitoring

   Monitoring was conducted once a week on 21 October 2025 (90 DAP), 28 October 2025 (97 DAP), 4 November 2025 (104 DAP), and 11 November 2025 (111 DAP). The selected interval represents the generative phase of chili plants, during which flowering and fruiting occur. This stage is considered critical because pest populations (armyworms and thrips) and disease incidence (*Geminivirus* and anthracnose) tend to increase and significantly affect yield quantity and quality. Weekly observations were chosen to capture the dynamics of pest and disease development over time.

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2. Observing Symptoms of Pest and Disease Attacks

Observations were conducted through direct visual inspection in the field by examining morphological symptoms on plant organs, including leaves, stems, and fruits. The observations were grouped based on pest and disease symptoms. Armyworm attacks were indicated by irregular holes and defoliation on leaves, while thrips attacks were characterized by silvery streaks, leaf curling, and distortion. *Geminivirus* infection showed symptoms of chlorosis, mosaic patterns, leaf curling, and stunted growth, whereas anthracnose was identified by dark, sunken lesions on fruits.

3. Incidence and Intensity Observation

The formula for calculating damage intensity is divided into two, which is absolute and non-absolute damage.

a. Absolute Damage

Absolute damage is permanent damage to the plant to be harvested, such as the death of all plant tissue and wilting. Furthermore, damage considered absolute includes rotting or partial destruction of plant tissue, rendering the plant or part of the plant unproductive (Lahati and Saifuddin, 2022). To calculate absolute damage, use the following formula:

$I = \frac{n}{N} \times 100\%$ Description:

I = Incidence of attack (%)
n = Number of affected offspring
N = Number of offspring observed

b. Non-Absolute Damage

Non-absolute damage is damage to parts of the plant, such as leaves, flowers, fruit, twigs, branches, and stems (Lahati and Saifuddin, 2022). To calculate non-absolute damage, use the following formula:

$IP = \frac{\Sigma (n \times v)}{Z \times N} \times 100\%$ Description:

IP = Attack Intensity (%)
n = Number of leaves attacked
N = Number of leaves observed
Z = Highest damage score scale value

The score for plant attacks by pests used is:
Score 0 = No attack
Score 1 = Very light attack (percentage of affected organs 1–20%);
Score 2 = Light attack (percentage of affected plant organs 21–40%);
Score 3 = Moderate attack (percentage of affected plant organs 41–60%);
Score 4 = Severe attack (percentage of affected plant organs 61–80%);
Score 5 = Very heavy attack (percentage of affected plant organs 81–100%) (Nurfadhilah *et al*., 2024).

Scale of disease intensity damage on chili plants:
Score 0 = Not infected
Score 1 = if the damage to the plant reaches 0 - < 25%;
Score 2 = if the damage to the plant reaches > 25%;
Score 3 = if the damage to the plant reaches > 50- <75%;
Score 4 = if the damage to the plant reaches 76 - < 100% (Nurfadhilah *et al*., 2024).

According to the Directorate General of Horticulture (2023), the disease severity assessment categories (y) are as follows:

Pest Damage Intensity Assessment Categories (x):
Light : x < 25% (less than or equal to 25%)
Moderate : 25% < x < 50% (greater than 25% up to 50%)
Severe : 50% < x < 85% (greater than 50% up to 85%)
Crop Failure : x > 85% (greater than 85%)

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Disease Severity Assessment Categories (y):
Light : y < 11% (less than or equal to 11%)
Moderate : 11% < y < 25% (greater than 11% up to 25%)
Severe : 25% < y < 85% (greater than 25% up to 85%)
Crop Failure : y > 85% (greater than 85%)

Results and Discussion

Table 1. Incidence of Pest Attacks on Chili Plants

Pest	Observation Week			
	1	2	3	4
Spodoptera litura	70%	95%	100%	100%
Thrips Sp.	85%	92.50%	92.50%	95%

Based on Table 1, the incidence of armyworms (*Spodoptera litura*) increased sharply from week 1 to week 4 of observation. It rose from 70% in week 1 to 95% in week 2 and reached 100% in weeks 3 and 4. Meanwhile, thrips (*Thrips* sp.) also showed consistently high incidence throughout the observation period. Their incidence started at 85% in week 1, increased to 92.5% in weeks 2–3, and reached 95% in week 4.

The high incidence of armyworm infestation related to the biological characteristics of *S. litura*, which is a polyphagous pest capable of attacking plants at various growth stages. Young larvae feed on leaves by scraping the epidermis and leaving transparent patches and leaf veins, while older instars consume larger leaf portions, often causing near-total defoliation (Khamid and Siriyah, 2018). In the generative stage, larvae also damage chili fruits (Gustianingtyas *et al*., 2020).

The high incidence of thrips infestation observed in this study indicates that environmental conditions and host plant suitability strongly supported their population development. Thrips damage plant tissues by piercing and sucking leaves and shoots, causing silvering, brownish patches, upward leaf curling, and stunted growth, and they also act as vectors of Tobacco Streak Virus (Saranani, 2023). Thrips attack chili plants during both vegetative and generative stages, with higher infestations occurring during flowering (Sari and Sulfiani, 2022). Environmental conditions further support these pest developments, the average temperature in Turi during October–November was around 26°C, which falls within the optimal thermal range that accelerates the development and activity of *S. litura* and *Thrips* sp. (Uge *et al*., 2021; Ngilamele and Pinaria, 2020).

Table 2. Intensity of Pest Attack on Chili Plants

Pest	Observation Week			
	1	2	3	4
Spodoptera litura	19.50% (light)	29.50% (Moderate)	49% (Moderate)	48% (Moderate)
Thrips Sp.	29% (Moderate)	32.50% (Moderate)	42% (Moderate)	45% (Moderate)

Based on Table 2, the intensity of pest attacks on chili plants showed a progressive increase during the four week observation period. Two pest species were recorded, namely armyworm (*Spodoptera litura*) and thrips (*Thrips* sp.). The intensity of *S. litura* infestation began at 19.50% in the first week, then increased to 29.50% in the second week, followed by a sharp rise to 49% in the third week, before experiencing a slight decline to 48% in the final week. Similarly, thrips attack intensity consistently increased over time, with values of 29% in week one, 32.50% in week two, 42% in week three, and reaching 45% in week four.

This trend indicates the feeding behavior of *S. litura* larvae, which damage leaves and developing fruits as the plant transitions to the generative phase. *S. litura* is a polyphagous pest capable of causing severe leaf damage due to the feeding capacity of advanced larval instars, leading to suppressed plant growth and reduced yield potential (Cahyamurti and Purwanto, 2021). Thrips predominantly attack young tissues by puncturing cell surfaces and extracting cell sap, resulting in silvery discoloration, leaf deformation, and growth reduction. Thrips populations tend to increase as chili plants enter the flowering stage due to their preference for nutrient-rich and tender plant tissues (Sugiyono *et al*., 2017). Environmental conditions during the monitoring period including an average temperature of approximately 26°C and relatively high humidity likely supported the development of both pest species. *S. litura* intensity increases under warm and humid environments that favor egg hatchability and larval growth. Similarly, the development of thrips populations is accelerated under warm conditions, allowing rapid reproduction cycles (Sugiyono *et al*., 2017).

Control of armyworms can be achieved through crop rotation and intercropping as technical control measures, the use of natural enemies such as *Telenomus remus* and *Trichogramma* sp. as biological control measures, the use of light traps as physical control measures, and mechanical control by collecting and destroying Spodoptera eggs in the field (Prabaningrum and Moekasan, 2022). Meanwhile, thrips control is carried out using trap plants like yellow kenikir, installing silver mulch, sanitizing and cutting off affected parts of the plant, and installing yellow traps from 2 weeks of age. Biological control can be supported by natural enemies such as Coccinellidae, predatory mites, Chrysopidae, Anthocoridae, and the pathogen *Entomophthora* sp. (Meilin, 2014).

Table 3. Incidence of Disease Attacks on Chili Plants

Disease	Observation Week			
	1	2	3	4
Gemini	90% (Crop Failure)	97,50% (Crop Failure)	97,50% (Crop Failure)	97,50% (Crop Failure)
Anthracnose	17,50% (Moderate)	55% (Severe)	57,50% (Severe)	62,50% (Severe)

Based on Table 3, the incidence of Gemini virus disease showed an increase in the second week of observation (97 DAP), but thereafter the incidence remained stagnant. The incidence of anthracnose disease showed an increase in each observation week. Gemini viruses are transmitted by the whitefly vector *Bemisia tabaci*. he high incidence of Gemini virus is caused by the high population of whiteflies. The symptoms include vein clearing, leaf curling, leaf cupping, and yellow mosaic patterns. As the disease progresses, all young leaves turn bright yellow. Indonesia is a tropical country where chili is cultivated continuously throughout the year, allowing whiteflies to persist and continuously transmit the virus (Ali and Aprilia, 2018). Anthracnose is caused by the fungus *Colletotrichum capsici*, which induces brown lesions on the fruit surface, eventually leading to fruit rot (Sondakh *et al*., 2021). The increase in anthracnose incidence is associated with the rainy season, which creates a humid environment. Humid conditions favor fungal development, thereby increasing the incidence of anthracnose disease (Sarianti and Subandar, 2022).

Table 4. Intensity of Disease Attacks on Chili Plants

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Disease	Observation Week			
	1	2	3	4
Gemini	47,50%	67,50%	78,75%	81,75%
Anthracnose	6,25%	16,88%	32,5%	30,63%

Based on Table 4, the intensity of Gemini virus infection on chili plants increased steadily from 47.50% in the first week to 81.75% in the fourth week, indicating a continuous spread of the disease. This increase is likely associated with the high population of whiteflies, which act as vectors and facilitate rapid transmission among plants. In contrast, anthracnose disease intensity rose from 6.25% in the first week to a peak of 32.5% in the third week, showing a more gradual development pattern. However, in the fourth week, the intensity slightly decreased to 30.63%

The increasing intensity of the Gemini virus can be a serious threat that causes loss of chili crop yields because it is the main cause of leaf curling in chili plants, which can affect chili production (Malado *et al*., 2024). Gemini disease is transmitted by the whitefly vector (*Bemisia tabaci*). Environmental factors greatly influence the intensity and spread of this disease. Warm temperatures and high humidity increase whitefly activity and population, accelerating the spread of the gemini virus. In addition, the whitefly population is influenced by the abundance of available food sources. Whiteflies obtain food from chili plants that are entering the vegetative phase, where the plants experience rapid growth, characterized by an increase in height and number of leaves (Agustini *et al*., 2023).

The increase in anthracnose intensity is likely influenced by favorable environmental conditions, particularly temperature and humidity, which support the development and spread of the pathogen. Anthracnose is caused by the fungus *Colletotrichum capsici*, which induces brown lesions on the fruit surface that subsequently develop into fruit rot. This disease has a significant impact on red chili production, as higher infection levels are directly associated with reduced yield and, in severe cases, can result in losses of up to 100%. Moreover, anthracnose can infect almost all parts of the plant, including twigs, branches, leaves, and fruits, thereby intensifying its overall impact on crop performance. Environmental factors, especially high humidity and optimal temperature, play a crucial role in promoting spore germination and fungal growth (Agustini *et al*., 2023). However, the slight decrease in anthracnose intensity observed at the later stage may be attributed to the implementation of sanitation practices, such as the removal of infected plant parts, which helps reduce the source of inoculum and limits further disease spread in the field.

Control of the gemini virus can be achieved through several main methods, such as using virus-free seeds or seedlings, controlling the whitefly vector population using insecticides and natural nanopesticides appropriately, using mulch, and early monitoring of symptoms (Fitriani *et al*., 2025). Anthracnose can be controlled by using resistant varieties, as well as by utilizing biological agents such as endophytic bacteria that can inhibit pathogen growth, using organic fertilizers such as bokashi and controlling microorganisms such as *Trichoderma* sp. and PGPR. Land sanitation and planting distance management also help suppress the spread of anthracnose (Syafira *et al*., 2024).

Conclusion

Pest and disease attack on Red Bird's eye chili plants (*Capsicum frutescens* L.) exhibited distinct patterns of increase. The incidence and intensity of attacks by the armyworm (*Spodoptera litura*) and thrips (*Thrips* sp.) tended to increase as the plants progressed toward the generative phase, although the intensity of *S. litura* declined slightly toward the end of the observation period. Regarding

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diseases, *Geminivirus* infection showed a significant and sustained increase in intensity, indicating rapid spread associated with the activity of the vector *Bemisia tabaci*. Meanwhile, anthracnose increased until the third week, then decreased slightly in the fourth week. Overall, the dynamics of pest and pathogen attacks are influenced by the plant's growth stage and environmental conditions that support the development of pests and pathogens. These results underscore the importance of implementing integrated pest management through routine monitoring, vector control, and sanitation to reduce pest infestations and yield losses.

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RESPON TANAMAN EDAMAME TERHADAP PEMBERIAN KOMPOS HIJAU DAN PGPR BAMBU DI TANAH ALUVIAL

RESPONSE OF EDAMAME PLANTS TO THE APPLICATION OF GREEN COMPOST AND BAMBOO PGPR IN ALLUVIAL SOIL

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Abstract

Edamame, is a soybean originating from China, is widely cultivated as a vegetable plant and used as a snack. Edamame cultivation in West Kalimantan in alluvial soil has obstacles, namely the physical properties of hard and solid alluvial soil, soil biological properties that have poor microorganism activity. Efforts have been made to overcome these obstacles by using green compost and bamboo PGPR. The purpose of this study was to deteminethe interaction and effectiveness of green compost and bamboo PGPR in alluvial soil. The study was conducted in the city of Pontianak for ± 5 months. The study used a plot design divided into main factors consisting of 2 levels of bamboo PGPR, subplots consisting of 3 levels of green compost doses, namely k1 = 10 tons/ha, k2 = 20 tons/ha, k3 = 30 tons/ha so that 6 treatment combinations were produced that were repeated 4 times. The variables observed were the number of branches, dry weight, root volume, number of pods per plant, pod weight per plant. The results showed that there was no interaction between green compost and bamboo PGPR, the use of bamboo PGPR had an effect on the variables of root volume and pod weight, the percentage of seeded pods 2, the use of green compost had an effect on the percentage of edamame hollow pods in alluvial soil.

Keywords: Alluvial Soil, Bamboo PGPR, Edamame, Green Compost.

Abstrak

Edamame merupakan kedelai yang berasal dari cina, banyak dibudidayakan sebagai tanaman sayur dan dijadikan camilan. Budidaya edamame di Kalimantan Barat di tanah aluvial memiliki kendala yaitu sifat fisik tanah aluvial yang keras dan pejal, sifat biologi tanah yang memiliki aktivitas mikroorganisme yang kurang baik. Upaya yang dilakukan untuk mengatasi kendala tersebut dengan melakukan pemberian kompos hijau dan PGPR bambu. Tujuan penelitian ini untuk mendapatkan interaksi dan efektifitas pemberian kompos hijau dan PGPR bambu di tanah aluvial. Penelitian dilaksanakan di kota Pontianak selama ± 5 bulan. Penelitian menggunakan rancangan petak terbagi dengan faktor utama yang terdiri dari 2 taraf PGPR bambu, anak petak yang terdiri dari 3 taraf dosis kompos hijau yaitu k1= 10 ton/ha, k2= 20 ton/ha, k3= 30 ton/ha sehingga dihasilkan 6 kombinasi perlakuan yang diulang 4 kali. Variabel yang diamati yaitu jumlah cabang, berat kering, volume akar, jumlah polong per tanaman, berat polong per tanamam. Hasil penelitian menunjukan bahwa tidak terjadi interaksi pemberian kompos hijau dan PGPR bambu, penggunaan PGPR bambu berpengaruh pada variabel volume akar dan berat polong, persentase polong berbiji 2, penggunaan kompos hijau berpengaruh terhadap persentase polong hampa edamame di tanah aluvial.

Kata Kunci: Edamame, Kompos Hijau, PGPR Bambu, Tanah Aluvial

Pendahuluan

Edamame (*Glycine max (L). Merrill*) merupakan tanaman kedelai yang khas dari jepang akan tetapi tanaman edamame merupakan tanaman yang berasal dari China. Tanaman Edamame termasuk golongan polong-polongan yang banyak dibudidayakan sebagai tanaman sayur (*Vegetable soybean*) dan dijadikan camilan, memiliki biji polong yang lebih besar dibandingkan dengan kedelai biasa, memiliki rasa yang cenderung manis, berwarna hijau cerah dan merupakan sumber lemak dan protein nabati. Edamame sangat cocok untuk dikembangkan di Indonesia karena kondisi alam indonesia sangat mendukung, kedelai edamame dapat hidup tumbuh dengan baik pada kondisi iklim yang panas dengan curah hujan yang relative tinggi 100-400 mm/bulan (Dicky, 2020). Kedelai edamame dapat dibudidayakan pada dataran rendah sampai dataran tinggi dan dapat tumbuh sampai dataran tinggi dan dapat tumbuh disemua jenis tanah yang mempunyai drainase dan aerasi yang baik (Ramadhani et al., 2016).

Tanah aluvial merupakan tanah yang terbentuk dari endapan lumpur sungai yang mengendap didataran rendah. Tingkat kesuburan aluvial dapat seragam dan dapat pula tidak seragam tergantung dari jenis bahan induknya (Bahrami & Ghahraman, 2019). Pengembangan tanaman edamame pada tanah aluvial memiliki kendala seperti sifat fisik yang cenderung keras dan pejal jika kering apabila basah tanah akan lekat, sedangkan pada sifat kimia tanah aluvial juga memiliki pH yang mendekati netral berkisar antara 5,3 hingga 5,8, serta memiliki aktivitas mikroorganisme yang kurang baik pada sifat biologinya.

Pemberian kompos dapat membantu memperbaiki sifat fisik pada tanah aluvial yang keras dan pejal karena kompos memiliki banyak sekali manfaat. Kompos adalah produk pelapukan dedaunan, alang-alang, jerami dan bahan organik lainnya oleh mikroorganisme. Pupuk kompos merupakan pupuk yang ramah lingkungan yang memiliki ragam manfaat seperti meningkatkan kesuburan tanah, sebagai pemantap agregat tanah, sumber hara untuk tanah dan tanaman (Damayanti, 2021). Kompos juga dapat meningkatkan struktur tanah, meningkatkan drainase dan pori pori tanah, meningkatkan daya tahan dan kapasitas tanah berpasir untuk menyerap air dan mengaktifkan unusr hara tanah, kompos juga dapat meningkatkan efisiensi pupuk kimia karena lebih murah, lebih baik dan lebih ramah lingkungan, ini dianggap sebagai pengganti pupuk kimia. Wicaksana et al. (2021), seperti pada penggunaan kompos hijau sangat cocok untuk budidaya tanaman edamame dikarenakan kompos hijau terbuat dari bahan organik hijau yang kaya akan kandungan nutrisi dan mikroorganisme yang baik untuk meningkatkan kesuburan tanah dan juga kompos hijau tidak mengandung bahan kimia yang apabila digunakan secara berlebihan dapat memberikan dampak negatif bagi pertumbuhan tanaman. Tanaman kedelai dapat tumbuh dengan baik pada tanah yang kaya kandungan bahan organik. Pemberian bahan organik seperti pupuk hijau dari famili leguminosa, dapat memperbaiki sifat fisik tanah, menyuplai bahan organik, menambah nitrogen, dan memperbaiki kehidupan jasad renik (Magdalena & Sudiarso, 2013).

Pemberian PGPR juga merupakan cara yang digunakan untuk memperbaiki sifat biologi tanah karena bakteri tersebut dapat memacu pertumbuhan (*Biostimulan*), penyedia unsur hara (*Biofertilizer*), pengendali patogen (*Bioprotectants*), dengan melakukan pemberian larutan PGPR dimaksud untuk mendapatkan bakteri baik yang ada didalam larutan tersebut, seperti contohnya bakteri pelarut fosfat yang dapat membantu penyerapan unsur hara P agar dapat larut dan diserap oleh tanaman. Bakteri pada PGPR akar bambu dapat mengeluarkan cairan yang dapat melarutkan mineral sehingga menjadi unsur hara yang tersedia, merombak dan mengurai bahan organik (dekomposisi bahan organik) menjadi nutrisi tanaman. Zat yang diproduksi bakteri PGPR yang bermanfaat bagi tanaman adalah produksi Asam Indol Asetat (IAA), Produksi enzim Aminocylopropane Carboxylic Acid (ACC) deaminase, produksi siderophore dan produksi kitinase, produksi glukanase dan produksi biotin, sementara aktivitas yang menguntungkan tanaman adalah aktifitas pelarut phospor dan aktifitas nitrogenase (Noor & Nurhadi, 2022) dengan demikian perlu dilakukan penelitian untuk mengetahui pengaruh dan interaksi pemberian kompos hijau dan PGPR bambu terhadap pertumbuhan dan hasil tanaman edamame ditanah aluvial. Sejalan dengan hal tersebut, penelitian ini bbertujuan untuk mengetahui respon tanaman edamame terhadap pemberian kompos hijau dan PGPR bambu pada tanah aluvial.

Metode Penelitian

Penelitian ini dilaksanakan di Jalan Letkol Sugiono, Pontianak, Kalimantan Barat. Waktu pelaksanaan penelitian ini berlangsung ± 5 bulan. Rancangan yang digunakan dalam penelitian ini adalah rancangan petak terbagi (split plot design), faktor utama (mainplot) adalah pemberian PGPR dengan 2 taraf perlakuan dan faktor anak petak (subplot) adalah dosis kompos hijau dengan 3 taraf

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perlakuan sehingga dihasilkan 6 kombinasi perlakuan yang diulang sebanyak 4 kali sehingga terdapat 24 unit percobaan. Masing-masing unit percobaan terdapat 3 tanaman sampel sehingga jumlah keseluruhan 72 tanaman.

1. Pemberian PGPR Bambu (a), yang terdiri dari 2 taraf yaitu:
   a_0 = Tanpa Pemberian Larutan PGPR Bambu
   a_1 = Dengan diberi Larutan PGPR Bambu (200ml/L)
2. Pemberian Kompos Hijau (k), yang terdiri dari 3 taraf dosis yaitu:
   k_1 = 10 ton/ha
   k_2 = 20 ton/ha
   k_3 = 30 ton/ha

Pelaksanaan penelitian yang dilakukan adalah melakukan pembuatan PGPR yang berasal dari perakaran tanaman bambu, kemudian melakukan pembuatan kompos hijau yang menggunakan daun segar tanaman gamal. Kemudian dilakukan persiapan media tanaman dengan melakukan pengambilan tanah aluvial lalu dilakukan pengayakan sehingga didapatkan tanah gembur dan terhindar dari sisa perakaran tanaman. Media tanam kemudian dicampurkan dengan kompos hijau daun gamal yang sudah matang, juga diberikan pupuk NPK 9:25:25 sebanyak 1 gram lalu diaduk hingga merata, kemudian dimasukan kedalam polybag berukuran 40□40 cm sesuai dengan perlakuan, juga diberikan tanah bekas penanaman tanaman kacang sebagai inokulum bakteri bintil akar. Benih edamame ditanam dengan cara dimasukan langsung kedalam lubang tanam. Pemupukan susulan dilakukan sebanyak 2 kali yaitu pada saat tanaman memasuki fase vegetatif maksimum dan pada saat pembentukan buah. Pemeliharaan tanaman yaitu penyiraman sebanyak 2 kali pada pagi dan sore hari, Penyulaman dilakukan apabila ada tanaman yang mati dan mengalami pertumbuhan yang kurang baik atau abnormal, Penyiangan dilakukan apabila ada gulma yang tumbuh didalam polybag tanaman edamame, Pengendalian hama dan penyakit dilakukan apabila tanaman menunjukan adanya gejala terserang hama dan penyakit dengan menggunakan pestisida alami, Panen dilakukan sebanyak 2 kali yaitu pada panen pertama untuk polong yang berbiji 3, sedangkan untuk panen yang kedua yaitu panen keseluruhan polong tanaman edamame.

Variabel yang diamati meliputi jumlah cabang, berat kering, volume akar, jumlah polong per tanaman, berat polong per tanaman edamame. Variabel lain yang diamati adalah jumlah polong tanaman edamame yaitu untuk %polong bernas, %polong hampa, %polong berbiji 2, %polong berbiji 3.

Hasil dan Pembahasan

Hasil analisis keragaman menunjukan bahwa pemberian kompos hijau dan PGPR bambu di tanah aluvial tidak terjadi interaksi, namun pemberian PGPR bambu berpengaruh nyata pada variabel volume akar dan berat polong, namun berpengaruh tidak nyata pada variabel jumlah cabang dan berat kering, jumlah polong per tanaman. Variabel hasil yang berpengaruh nyata pada pemberian PGPR bambu adalah persentase polong berbiji 2 dan pada pemberian kompos hijau persentase polong hampa, pada persentase polong berbiji 3 dan polong bernas berpengaruh tidak nyata. Rekapitulasi dari masing-masing variabel pertumbuhan dan hasil serta pada kualitas polong tanaman edamame disajikan pada tabel berikut ini.

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Table 1. Rekapitulasi Respon Pertumbuhan dan Hasil Tanaman Edamame terhadap Pemberian Kompos Hijau dan PGPR Bambu pada Tanah Aluvial Terhadap Semua Variabel Pengamatan.

Keterangan : P = Perlakuan

P	J (Cabang)	BK (g)	VA (cm³)	BP (g)	JP (Polong)	B (%)	H (%)	BB3 (%)	BB2 (%)
					PGPR				
Non PGPR	7,06	8,62	5,33 b	195,44 a	78,13	49,46	5,90	8,58	39,62 a
PGPR	7,33	12,81	9,67 a	234,14 a	91,71	49,25	7,00	10,29	41,42 a
BNJ 5%			3,39	43,46					4,22
					Dosis Kompos				
10 ton/ha	7,25	10,35	8,5	212,10	84,37	49,12	7,21 a	9,06	40,18
20 ton/ha	7,00	9,13	5,25	220,87	83,62	49,25	7,52 a	10,38	39,62
30 ton/ha	7,34	12,68	7,25	211,39	83	49,68	4,63 b	8,87	42,06
BNJ 5%							1,72		
					Kombinasi PGPR dan Kompos				
Non PGPR + 10 ton/ha	7,17	6,23	5	195,67	77,13	49,38	6,68	8,5	41,25
Non PGPR + 20 ton/ha	6,83	10,25	5,5	194,28	80,50	49,25	7,74	9	41
Non PGPR + 30 ton/ha	7,17	9,40	5,5	196,36	76,75	49,75	3,30	8,25	41,87
PGPR + 10 ton/ha	7,33	14,48	12	228,53	91,63	48,86	7,74	9,62	40,38
PGPR + 20 ton/ha	7,17	8,01	5	247,46	94,25	49,25	7,30	11,75	38,25
PGPR + 30 ton/ha	7,50	15,96	12	226,43	89,25	49,62	5,87	9,5	40,25

JC = Jumlah Cabang
BK = Berat Kering
VA = Volume Akar
BP = Berat Polong
JP = Jumlah Polong
% B = Persentase Polong Bernas
% H = Persentase Polong Hampa
% BB3 = Persentase Polong Berbiji 3
% BB2 = Persentase Polong Berbiji 2

Hasil rekapitulasi data menunjukan pemberian kompos hijau dan PGPR bambu terhadap variabel pengamatan yang berpengaruh nyata dan berpengaruh tidak nyata, Hasil pengamatan dapat dilihat dengan cara uji beda nyata jujur (BNJ), yang dapat dilihat dari tabel berikut ini.

Tabel 2. Uji Beda Volume Akar, Berat Polong, Polong Berbiji 2 Pengaruh Pemberian PGPR Bambu.

Pemberian PGPR	Volume Akar (cm³)	Berat Polong (g)	Polong Berbiji 2 (%)
Diberi	9,67 a	234,14 a	41,42 a
Tidak diberi	5,33 b	195,44 a	39,62 a
BNJ 5%	3,39	43,46	4,22

Keterangan: Nilai rerata yang diikuti huruf yang sama tidak berbeda nyata pada uji beda nyata Jujur (BNJ) taraf kepercayaan 5%

Hasil analisis keragaman menunjukan bahwa tidak terjadi interaksi pemberian kompos hijau dan PGPR bambu pada seluruh variabel pengamatan yaitu pada variabel jumlah cabang, berat kering tanaman, volume akar, jumlah polong per tanaman dan berat polong per tanaman. Berdasarkan hasil analisis keragaman menunjukan pemberian PGPR bambu berpengaruh nyata pada variabel pertumbuhan yaitu volume akar akan tetapi berpengaruh tidak nyata pada variabel jumlah cabang dan berat kering tanaman, hal ini diduga pemberian PGPR mampu memicu pembentukan fitohormon yaitu hormon auksin pada tanaman edamame yang membantu merangsang pembentukan akar pada tanaman edamame. Menurut (Noor, 2022) aktifitas dan zat produksi bakteri PGPR yang bermanfaat bagi tanaman diantaranya adalah produksi asam indol asetat (IAA). Secara umum aplikasi PGPR berdampak baik pada tanaman baik parameter vegetatif dan generatif dan akan lebih memberikan dampak positif jika dilakukan pencampuran dengan aplikasi bahan organik lain seperti fermentasi urin, fermentasi pupuk kandang dan kompos. Berdasarkan hasil analisis keragaman menunjukan pemberian PGPR bambu berpengaruh nyata pada variabel hasil, yaitu berat polong per tanaman. Perlakuan PGPR berpengaruh tidak nyata pada variabel jumlah polong per tanaman. Hal ini diduga bakteri yang terkandung didalam PGPR dapat membantu penyerapan unsur hara sehingga mendorong pembentukan dan perkembangan polong pada tanaman edamame. Menurut (Ningrum et al., 2017)didalam biostimulan PGPR terdapat bakteri yang dapat membantu penyerapan unsur hara kalium dan fosfor yang berfungsi dalam mendorong pembentukan dan perkembangan buah dan berat buah. Selain itu menurut Jannah (2022) kelompok bakteri yang terdapat dalam PGPR yang akan bersimbiosis secara langsung dan tidak langsung dengan tanaman mampu membantu penyediaan hara tanaman, dan adanya kolonisasi akar oleh bakteri akan meningkatkan pertumbuhan tanaman.

Tabel 3. Uji Beda Jumlah Polong Hampa Pengaruh Pemberian Kompos Hijau.

Dosis Kompos (ton/ha)	Polong Hampa (%)
20	7,52 a
10	7,21 a
30	4,63 b
BNJ 5%	1,72

Keterangan: Nilai rerata yang diikuti huruf yang sama tidak berbeda nyata pada uji beda nyata Jujur (BNJ) taraf kepercayaan 5%

Pemberian kompos hijau daun gamal berdasarkan hasil analisis keragaman menunjukan hasil berpengaruh tidak nyata pada volume akar, jumlah cabang, berat kering, berat polong dan jumlah polong per tanaman. Hal ini diduga karena penyerapan unsur hara pada kompos hijau daun gamal masih rendah pada masing-masing taraf perlakuan yang diberikan. Tanah yang digunakan sebagai media tanam sudah memiliki sifat fisik yang remah sehingga penggunaan kompos hijau daun gamal yang rendah masih dapat diminimalisir oleh tanaman edamame. Menurut (Mushin, 2017) mengemukakan bahwa jika penyediaan unsur hara dalam pupuk organik terbilang lambat untuk produksi tanaman dan selain itu ada juga faktor genetik dan faktor lingkungan yang menyebabkan tidak memberikan hasil yang nyata. Tanah yang sudah gembur inilah yang dalam pengolahan nya sudah baik sehingga tanah tersebut sudah kaya akan kandungan unsur hara yang mana membuat unsur hara lebih mudah untuk diserap oleh tanaman edamam. Ada beberapa fungsi N,P,dan K antara lain N untuk pertumbuhan vegetative. P berfungsi dalam pembentukan bunga,buah dan biji juga merangsang pertumbuhan akar agar lebih memanjang dan kuat sehingga tanaman akan lebih tahan terhadap kekeringan, sementara K berfungsi dalam proses metabolisme seperti fotosintesi dan respirasi (Alpani & Taher, 2017).

Kualitas polong tanaman edamame yang diberikan kompos hijau dan PGPR bambu menunjukan bahwa kompos hijau berpengaruh nyata pada variabel kualitas polong hampa. Pemberian PGPR akar bambu berpengaruh nyata pada variabel jumlah polong berbiji 2. Hal ini diduga pemberian PGPR bambu yang berlebihan akan mempengaruhi jumlah polong berbiji 2 pada tanaman edamame, sedangkan pada pemberian dosis PGPR akar bambu yang berlebih juga sangat dipengaruhi oleh lingkungan, apabila pada saat pemberian dosis PGPR baru diberikan namun kondisi cuaca kemudian menjadi hujan sehingga PGPR yang baru diberikan tidak diserap sepenuhnya oleh tanaman tetapi tercuci oleh air hujan. Menurut, (Fashoka, 2017) penyerapan cahaya matahari yang lebih banyak dapat mempengaruhi proses fotosintesis pada tanaman, dan fotosintat hasil foto sintesis dapat digunakan untuk pembentukan biji yang akan mempengaruhi berat biji pada tanaman kacang. Semakin banyak unsur hara P yang tersedia bagi tanaman, maka semakin banyak pula yang dapat diserap tanaman, sehingga fotosintesis akan meningkat dan pada akhirnya akan meningkatkan berat biji per tanaman (Margenda et al., 2020). Unsur hara,air dan cahaya matahari sangat diperlukan untuk pertumbuhan tanaman kedelai yang ditranslokasi dalam bentuk bahan kering selama fase pertumbuhan kemudian pada akhir fase vegetative akan terjadi penimbunan hasil fotosintesis pada organ-organ tanaman seperti batang,buah dan biji. (Rahmadani, 2020).

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Kesimpulan

Berdasarkan hasil penelitian penggunaan kompos hijau dan PGPR bambu tidak terjadi interaksi pada pertumbuhan dan hasil tanaman edamame di tanah aluvial oleh karena tanah aluvial yang digunakan merupakan tanah aluvial yang sudah gembur dan remah serta sudah kaya akan unsur hara karena juga dibantu oleh pemberian pupuk anorganik. Penggunaan PGPR bambu dapat menyebabkan peningkatan variabel volume akar, berat polong, serta dapat meningkatkan kualitas polong berbiji 2, penggunaan kompos hijau dapat mengurangi kualitas polong hampa tanaman edamame di tanah aluvial. Dalam percobaan yang telah dilakukan dapat disarankan perlu penelitian lebih lanjut menggunakan dosis PGPR yang lebih tinggi pada media tanam aluvial yang lebih padat serta mengurangi penggunaan pupuk anorganik sehingga penggunaan pupuk organik bisa lebih maksimal.

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PENGARUH *RED MUD* DAN *RHIZOBIUM* TERHADAP PERTUMBUHAN DAN HASIL EDAMAME PADA TANAH GAMBUT

THE EFFECT OF RED MUD *AND* RHIZOBIUM *ON THE GROWTH AND YIELD OF EDAMAME IN PEAT SOIL*

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Abstract

Edamame (Glycine max (L.) Merill) is a plant that is widely cultivated as a vegetable. *The use of peat soil as a planting medium has various obstacles such as low nutrient availability, high cation exchange capacity, low alkaline saturation, and low soil pH. Efforts that can be made are the provision of ameliorant in the form of red mud as an alternative to dolomite and the addition of rhizobium bacteria. This study aims to obtain the proper dose of red mud and rhizobium interaction for the growth and yield of edamame plants in peat soils. This study uses an experimental method with a Complete Random Design (CRD) pattern consisting of the first factor is red mud (R) consists of 4 levels, namely r_0 = dolomite lime (control) 32.2 g/plant, r_1 = 10 tons/ha equivalent to 78.1 g/plant, r_2 = 15 tons/ha equivalent to 117.1 g/plant, and r_3 = 20 tons/ha equivalent to 156.2 g/plant. The second factor is rhizobium (B) consists of 2 levels, namely b0= without rhizobium and b1= with rhizobium. Thus 8 treatment combinations were obtained and repeated 3 times. Each experimental unit has 4 plant samples, making a total of 96 plants. Based on the results of the study, there was no interaction between the granting of red mud and rhizobium on all observed variables. A dose of red mud of 15 tons/ha is an effective dose to produce the amount of pod and the amount of root nodules, while treatment with rhizobium can increase the amount of root nodules by 30.46%.*

Keywords: *Edamame, peat soil, red mud, rhizobium*

Abstrak

Edamame (Glycine max (L.) Merrill) merupakan tanaman yang banyak dibudidayakan sebagai sayuran. Penggunaan tanah gambut sebagai media tanam memiliki berbagai kendala, seperti rendahnya ketersediaan unsur hara, kapasitas tukar kation yang tinggi, kejenuhan basa yang rendah, dan pH tanah yang rendah. Upaya yang dapat dilakukan untuk mengatasi kendala tersebut adalah pemberian amelioran berupa *red mud* sebagai alternatif pengganti kapur dolomit serta penambahan bakteri *Rhizobium*. Penelitian ini bertujuan untuk memperoleh dosis *red mud* yang tepat serta mengetahui interaksi antara *red mud* dan *Rhizobium* terhadap pertumbuhan dan hasil tanaman edamame pada tanah gambut. Penelitian ini menggunakan metode eksperimen dengan Rancangan Acak Lengkap (RAL) pola faktorial. Faktor pertama adalah *red mud* (R) yang terdiri atas 4 taraf, yaitu r0 = kapur dolomit (kontrol) 32,2 g/tanaman, r1 = 10 ton/ha setara dengan 78,1 g/tanaman, r2 = 15 ton/ha setara dengan 117,1 g/tanaman, dan r3 = 20 ton/ha setara dengan 156,2 g/tanaman. Faktor kedua adalah *Rhizobium* (B) yang terdiri atas 2 taraf, yaitu b0 = tanpa *Rhizobium* dan b1 = dengan *Rhizobium*. Dengan demikian, diperoleh 8 kombinasi perlakuan dan masing-masing diulang sebanyak 3 kali. Setiap satuan percobaan terdiri atas 4 tanaman sampel, sehingga total terdapat 96 tanaman. Hasil penelitian menunjukkan bahwa tidak terdapat interaksi antara pemberian *red mud* dan *Rhizobium* terhadap seluruh variabel yang diamati. Pemberian *red mud* dengan dosis 15 ton/ha merupakan dosis efektif dalam menghasilkan jumlah polong dan jumlah bintil akar, sedangkan pemberian *Rhizobium* dapat meningkatkan jumlah bintil akar sebesar 30,46%.

Kata kunci: Edamame, tanah gambut, *red mud*, *Rhizobium*

PENDAHULUAN

Edamame (*Glycine max* (L.) Merill) merupakan tanaman yang berasal dari Jepang, termasuk golongan polong-polongan yang banyak dibudidayakan sebagai tanaman sayur *(Vegetable soybean)* yang memiliki biji polong yang lebih besar dibandingkan dengan kedelai biasa, memiliki rasa yang cenderung manis, berwarna hijau cerah dan merupakan sumber lemak dan protein nabati. Penggunaan tanah gambut sebagai media tanam memiliki berbagai kendala seperti ketersediaan unsur hara yang rendah, tingginya kapasitas tukar kation (KTK), kejenuhan basa (KB) yang rendah, dan pH tanah yang rendah.

Upaya yang dapat dilakukan untuk meningkatkan pH tanah gambut, salah satunya yaitu pemberian amelioran berupa *red mud* sebagai pengganti kapur. *Red mud* adalah residu atau bahan buangan yang berasal dari pengolahan bauksit untuk produksi alumina. *Red mud* memiliki pH yang sangat basa yaitu sekitar 13-14 sehingga dapat meningkatkan pH pada tanah yang bersifat masam (Muchtar, 2009). Tanaman edamame merupakan salah satu tanaman kacang-kacangan yang bisa bersimbosis dengan bakteri *rhizobium*. *Rhizobium* adalah salah satu kelompok bakteri yang berkemampuan sebagai penyedia hara bagi tanaman. *Rhizobium* mampu mengikat nitrogen bebas di udara menjadi ammonia (NH_3) yang akan diubah menjadi asam amino yang selanjutnya menjadi senyawa nitrogen yang diperlukan tanaman untuk tumbuh dan berkembang (Sari dan Retno 2015). Aktivitas bakteri rhizobium didalam tanah termasuk dalam pembentukan bintil akar dipengaruhi oleh pH tanah. Rhizobium berkembang secara aerob di dalam tanah dan tumbuh optimal pada suhu 25-30ºC dengan pH 6-7. Beberapa strain rhizobium masih dapat bertahan pada pH ≥ 4,5 (Rosales et al., 2013). Secara alami rhizobium ada di dalam tanah, namun jumlahnya terbatas sehingga perlu adanya penambahan melalui inokulasi dengan biakan murni rhizobium agar pembentukan bintil akar dapat lebih efektif. Penambahan red mud dengan berbagai dosis akan meningkatkan pH tanah pada rentang yang berbeda, perbedaan pH ini akan mempengaruhi pembentukan bintil akar dan aktivitas bakteri sehingga fiksasi nitrogen akan bervariasi.

Berdasarkan uraian diatas, maka rumusan masalah pada penelitian ini adalah apakah terdapat dosis *interaksi red mud* dan *rhizobium* yang terbaik untuk pertumbuhan dan hasil edamame pada tanah gambut dengan tujuan untuk mendapatkan dosis interaksi *red mud* dan *rhizobium* yang terbaik untuk pertumbuhan dan hasil tanaman edamame pada tanah gambut.

Hasil penelitian (Puspa et al., 2023), menunjukkan bahwa, pengaruh pemberian pupuk kandang bebek 20 ton/ha dan *red mud* 4 ton/ha bepengaruh nyata terhadap jumlah cabang, jumlah polong per tanaman, dan berat polong per tanaman pada tanaman edamame di tanah gambut. Hasil Penelitian (Lestari, 2023), menunjukkan bahwa, pemberian *red mud* 18 ton/ha dan bokashi limbah sayuran 15 ton/ha merupakan dosis efektif terhadap pertumbuhan dan hasil lobak putih pada tanah gambut. Hasil penelitian (Evita et al., 2022), menunjukkan bahwa, pemberian *rhizobium* 10 g/kg benih memberikan pengaruh terbaik terhadap pertumbuhan dan hasil tanaman kedelai di tanah ultisol.

METODE PENELITIAN

Penelitian ini dilaksanakan di Lahan Percobaan Fakultas Pertanian, Universitas Tanjungpura. Penelitian ini dilaksanakan dari bulan Maret sampai dengan bulan Oktober 2024. Alat yang digunakan pada penelitian yaitu ayakkan, cangkul, corong, ember, gelas ukur, kertas label, meteran, oven, parang, terpal, timbangan digital, *thermohygrometer*, alat tulis dan alat dokumentasi (kamera) sedangkan untuk bahan yaitu benih edamame, tanah gambut, red mud, kapur dolomit, *rhizobium*, polybag, pukan ayam, pupuk NPK *generative fertilizer* 9:25:25+TE, polinet, dan pestisida.

Penelitian ini menggunakan metode eksperimen dengan pola Rancangan Acak Lengkap (RAL) yang terdiri dari dua faktor, faktor pertama yaitu *red mud* (R) yang terdiri dari 4 taraf yaitu r_0= kapur dolomit (kontrol) 32,2 g/tanaman, r_1= 10 ton/ha setara dengan 78,1 g/tanaman, r_2= 15 ton/ha setara dengan 117,1 g/tanaman, dan r_3= 20 ton/ha setara dengan 156,2 g/tanaman. Faktor kedua yaitu *rhizobium* (B) yang terdiri dari 2 taraf yaitu b_0= tanpa *rhizobium* dan b_1= dengan *rhizobium*. Sehingga diperoleh 8 kombinasi perlakuan diulang sebanyak 3 kali. Masing-masing unit percobaan terdapat 4 sampel tanaman sehingga total keseluruhan 96 tanaman.

Pelaksanaan penelitian meliputi persiapan tempat penelitian dengan cara membersikan rumput, kayu, maupun sampah lainnya, persiapan *Red mud* dengan cara dikeringkan terlebih dahulu, kemudian dihaluskan dan diayak menggunakan ayakan sehingga *red mud* yang diperoleh bertekstur halus. Persiapan media tanam berupa tanah gambut yang diambil pada kedalaman 0-20 cm. Tanah gambut dibersihkan terlebih dahulu dari sampah yang berukuran besar seperti akar, daun maupun serasah lainnya. Tanah ditimbang sebanyak 8 kg, kemudian ditambah dengan *red mud* sesuai dengan taraf perlakuan, setelah itu dicampur dengan merata dan dimasukkan kedalam polybag kemudian di inkubasi selama 2 minggu. Untuk perlakuan kontrol, tanah diberi kapur dolomit dengan dosis 32,2 g/polybag untuk meningkatkan pH tanah menjadi 5,5. Selama masa inkubasi, tanah dijaga kelembapannya agar tidak kering, jika terlihat kering maka dilakukan penyiraman. Setelah 2 minggu masa inkubasi maka dilakukan analisis tanah pada semua perlakuan khususnya analisis Ph tanah.

Inokulasi bakteri dilakukan sebelum penanaman menggunakan bakteri *rhizobium* (Legin Rhizoka). Perbandingan untuk pencampurannya yaitu 5 g untuk 1 kg benih kedelai edamame dengan cara basahi benih terlebih dahulu menggunakan air bersih setelah itu *rhizobium* dicampurkan secara merata dengan benih edamame. Penanaman dilakukan dengan cara membuat lubang tanam dengan kedalaman 1,5-2 cm terlebih dahulu kemudian masukkan 2 benih kelubang tanam dan tutup kembali menggunakan tanah. Setelah berumur 1 minggu maka dilakukan penjarangan dengan memilih salah satu tanaman yang tumbuh dengan baik untuk dibiarkan hidup. Pemupukan dasar menggunakan pupuk kandang kotoran ayam dengan dosis 78,1 g/tanaman. Pemupukan dasar dilakukan setelah inkubasi dan 3 hari sebelum penanaman dengan cara mencampurkan tanah yang ada di dalam polybag dengan pupuk kandang kotoran ayam tanpa mengeluarkan tanah yang ada didalam polybag.

Pemeliharaan meliputi penyiraman dilakukan 2 kali sehari yaitu pada pagi dan sore hari sesuai dengan kapasitas lapang yaitu 400 ml/polybag, kecuali jika hari hujan maka tidak dilakukan penyiraman, penyulaman dilakukan apabila terdapat benih yang tidak tumbuh, tanaman kurang sehat (cacat), dan mati ketika tanaman berumur kurang lebih 7 hari. Penyulaman menggunakan bibit tanaman yang disediakan khusus untuk penyulaman dengan usia yang sama dengan tanaman edamame lainnya, penyiangan gulma dimulai pada 9 hari setelah tanam (HST) saat ada gulma yang tumbuh disekitar lahan maupun didalam polybag. Penyiangan dilakukan secara manual dengan cara mencabut gulma menggunakan tangan maupun menggunakan parang dengan cara menebas gulma yang tumbuh, pemupukan susulan dilakukan sebanyak dua kali dengan menggunakan pupuk NPK *generative fertilizer* 9:25:25+TE dengan dosis 2,34 g/tanaman untuk pemupukan pertama pada usia 20 HST sedangkan untuk pemupukan yang ke dua dengan dosis 1,17 g/tanaman pada usis 40 HST, pengendalian hama dan penyakit dilakukan secara preventif dengan melalui penyemprotan pestisida hayati berbahan tembakau satu kali dalam seminggu dan penggunaan pestisida kimia yaitu Furadan pada usia 7 hari setelah tanam dan Dupont Prevathon pada saat terdapat gejala serangan ulat pada daun dan polong. Panen polong edamame dilakukan ketika sudah sesuai dengan kriteria panen. Kriteria panen segar untuk tanaman edamame memiliki ciri-ciri polong berisi penuh, mulus, dan berwarna hijau tua. Pemanenan pada penelitian dilakukan dua kali pada usia 62 HST dan 68 HST dengan cara memetik polong pada setiap tanaman. Variabel pengamatan yang dilakukan meliputi tinggi tanaman 2 MST, tinggi tanaman 3 MST, volume akar, berat kering tanaman, jumlah polong per tanaman, berat polong per tanaman, dan jumlah bintil akar.

HASIL DAN PEMBAHASAN

Berdasarkan hasil analisis keragaman menunjukkan bahwa tidak terdapat interaksi antara pemberian *red mud* dan *rhizobium* terhadap semua variabel pengamatan, namun perlakuan *red mud* secara tunggal berpengaruh nyata terhadap variabel pengamatan jumlah polong, berat polong dan jumlah bintil akar sedangkan untuk perlakuan *rhizobium* secara tunggal berpengaruh nyata terhadap variabel pengamatan jumlah bintil akar. Selanjutnya untuk variabel yang berpengaruh nyata dilakukan uji beda nyata jujur (BNJ).

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Tabel 1. Hasil uji BNJ pengaruh *red mud* terhadap jumlah polong, berat polong, dan jumlah bintil akar.

Perlakuan	Jumlah polong (polong)	Berat polong (g)	Jumlah bintil akar	
			Data asli (buah)	Trans Log X
Kontrol	41,44 a	114,01 a	113,25	4,58 ab
Red mud 10 ton/ha	34,83 b	97,80 ab	46,03	3,77 b
Red mud 15 ton/ha	35,55 ab	95,91 b	155,42	4,73 a
Red mud 20 ton/ha	39,66 ab	110,30 ab	132,20	4,84 a
BNJ 5%	3,42	10,30		0,64

Keterangan: Nilai rerata yang diikuti huruf yang sama berbeda tidak nyata pada uji BNJ 5 %.

Hasil uji BNJ pada Tabel 1 menunjukkan bahwa variabel pengamatan jumlah polong pada perlakuan kontrol berbeda nyata terhadap perlakuan *red mud* dosis 10 ton/ha, namun berbeda tidak nyata terhadap dosis *red mud* 15 ton/ha dan *red mud* 20 ton/ha. Variabel pengamatan berat polong pada perlakuan kontrol berbeda nyata terhadap *red mud* dosis 15 ton/ha, namun berbeda tidak nyata terhadap dosis *red mud* 10 ton/ha dan *red mud* 20 ton/ha. Variabel pengamatan jumlah bintil akar pada perlakuan *red mud* dosis 10 ton/ha berbeda nyata terhadap *red mud* dosis 15 ton/ha dan *red mud* 20 ton/ha, namun berbeda tidak nyata terhadap perlakuan kontrol.

Tabel 2. Hasil uji BNJ pengaruh *rhizobium* terhadap jumlah bintil akar.

Perlakuan	Jumlah bintil akar	
	Data asli (buah)	Trans Log X
Tanpa *rhizobium*	77,68	4,24 b
Dengan *rhizobium*	145,76	4,72 a
BNJ 5%		0,46

Keterangan: Nilai rerata yang diikuti huruf yang sama berbeda tidak nyata pada uji BNJ 5%.

Hasil uji BNJ pada Tabel 2 menunjukan bahwa variabel pengamatan jumlah bintil akar perlakuan dengan *rhizobium* berbeda nyata terhadap perlakuan tanpa *rhizobium*.

Pemberian *red mud* berfungsi sebagai amelioran atau pembenah tanah yang dapat memperbaiki sifat kimia pada tanah gambut. Perlakuan kontrol (dolomit) pada penelitian ini memberikan pengaruh yang nyata terhadap variabel pengamatan jumlah polong, berat polong, dan jumlah bintil akar, hal ini dapat disebabkan karena dolomit mengandung unsur kalsium dan magnesium yang berguna untuk meningkatkan pH. Hal ini sesuai dengan pernyataan (Ilham et al., 2019), bahwa dolomit mengandung Kalsium Oksida (CaO) dan Magnesium Oksida (MgO). Kalium yang terkandung dalam dolomit mampu meningkatkan pH, yang mana unsur hara yang ada semakin tersedia, kegiatan jasad renik dalam tanah semakin meningkat, dan sifat fisik tanah dapat diperbaiki. Menurut (Chen et al., 2018), magnesium merupakan komponen organik kritis dari protein, asam nukleat, enzim, klorofil, dan hormon yang terlibat dalam metabolisme fisiologis, yang memainkan peran penting dalam pertumbuhan dan perkembangan tanaman.

Hasil analisis uji BNJ pada Tabel 1, menunjukan bahwa dosis *red mud* 10 ton/ha memberikan pengaruh yang sama seperti kontrol (dolomit) pada variabel berat polong. *Red mud* 15 ton/ha memberikan pengaruh yang sama pada variabel jumlah polong dan jumlah bintil akar, sedangkan *red mud* 20 ton/ha memberikan pengaruh yang sama pada variabel jumlah polong, berat polong, dan jumlah bintil akar. *Red mud* dapat menggantikan fungsi dolomit untuk meningkatkan pH pada tanah gambut, hal ini dikarena *red mud* memiliki pH yang bersifat basa yaitu 10,85 dan juga mengandung beberapa unsur hara seperti, kalsium, magnesium, kalium, dan natrium yang tinggi. Pengunaan *red mud* pada tanah gambut dalam penelitian ini dapat menaikan pH awal 4,33 menjadi 4,80-5,74. Menurut penelitian (Bimasri & Murniati, 2017), peningkatan pH menyebabkan peningkatan ketersediaan hara yang dibutuhkan oleh tanaman kedelai untuk pertumbuhannya. Semakin meningkat pH media mendekati pH yang dibutuhkan oleh tanaman, maka laju pertumbuhan dan jumlah produksi yang dihasilkan tanaman akan semakin baik.

Hasil analisis uji BNJ pada Tabel 2, menunjukan bahwa pada variabel pengamatan jumlah bintil akar perlakuan dengan *rhizobium* berbeda nyata dengan tanpa *rhizobium*, hal ini dikarenakan perlakuan tanpa *rhizobium* hanya memperoleh *rhizobium* yang ada secara alamiah di tanah sedangkan perlakuan dengan *rhizobium* memperoleh *rhizobium* dari penambahan legin (Rhizoka) sehingga jumlah bakteri *rhizobium* yang ada lebih tersedia dari perlakuan tanpa *rhizobium*. Jumlah bintil akar ditentukan dari banyaknya jumlah bakteri *rhizobium* yang tersedia, sehingga semakin banyak jumlah bakteri *rhizobium* yang tersedia maka jumlah bintil akar juga akan semakin banyak yang terbentuk. Menurut hasil penelitian (Ni'am & Bintari, 2017), menyatakan bahwa pemberian inokulan legin mampu membantu menambah jumlah bakteri bintil akar. Bakteri *rhizobium* merupakan kelompok bakteri yang dapat bersimbiosis mutualisme dengan tanaman legum, kelompok bakteri ini mampu menginfeksi akar tanaman dan membentuk bintil akar. Bintil akar merupakan jaringan abnormal dari bagian akar tanaman yang terbentuk akibat adanya interaksi antara akar tanaman dengan bakteri *rhizobium* yang berfungsi untuk mendukung penambatan nitrogen dari atmosfer dan akhirnya dapat dimanfaatkan tanaman untuk pertumbuhannya. Hal ini sesuai dengan pernyataan (Novriani, 2011), bahwa bintil akar berfungsi untuk memfiksasi nitrogen di atmosfer dan menyalurkannya sebagai unsur hara yang diperlukan tanaman inang dalam bentuk asam amino pada tanaman kedelai. Menurut (Muyassir, 2013), nitrogen adalah salah satu dari unsur esensial yang penting untuk pertumbuhan tanaman khususnya pada masa vegetatif. Unsur nitrogen ini tidak hanya berfungsi untuk meningkatkan pertumbuhan tanaman tetapi juga sebagai unsur pembentuk protein dan klorofil.

Pengamatan jumlah bintil akar pada usia 26 hari setelah tanam (destruktif) bakteri *rhizobium* masih belum membentuk bintil akar pada tanaman edamame namun pada pengamatan bintil akar usia 68 hari setelah tanam (setelah panen), tanaman edamame sudah membentuk bintil akar. Menurut (Adisarwanto, 2014), bintil akar dibentuk oleh *rhizobium* pada saat tanaman kedelai edamame masih muda yaitu setelah terbentuknya rambut akar pada akar utama atau cabang akar. Bintil akar terbentuk akibat adanya rangsangan pada permukaan akar yang menyebabkan bakteri dapat masuk kedalam akar dan berkembang dengan pesat di dalamnya. Terlambatnya pembentukan bintil akar pada penelitian ini kemungkinan disebabkan oleh unsur hara bagi tanaman edamame pada masa pertumbuhan sudah mencukupi terutama kandungan unsur nitrogennya. Unsur hara pada masa pertumbuhan tanaman didapat dari adanya kandungan hara dari tanah gambut, *red mud*, pupuk kandang kotoran ayam dan NPK *generative fertilizer* 9:25:25+TE. Menurut penelitian (Wicaksono et al., 2015), jumlah nitrogen sangat mempengaruhi gagal tidaknya pembentukan bintil akar. Nitrogen di dalam tanah berbentuk nitrat yang mempunyai kemampuan menghilangkan bulu-bulu akar yang dibutuhkan bakteri untuk menginfeksi akar sehingga mengurangi kemampuan akar untuk memproduksi bintil akar. Selain itu pH tanah juga merupakan salah satu faktor yang dapat mempengaruhi aktifitas bakteri *rhizobium* dan pembentukan bintil akar. Menurut (Rosales et al., 2013), *Rhizobium* dapat berkembang dengan optimal di dalam tanah dengan pH 6-7 akan tetapi beberapa strain *rhizobium* masih dapat bertahan pada pH ≥ 4,5.

Tanaman memperoleh unsur hara dari tanah gambut, *red mud*, *rhizobium*, pupuk kandang kotoran ayam, NPK *generative fertilizer* 9:25:25+TE. Ketersediaan unsur hara yang cukup bagi tanaman dapat membantu tanaman untuk memperoleh hasil produksi yang maksimal. Hasil penelitian (Bolly & Jeksen, 2021), menunjukan bahwa, ketersediaan unsur hara yang seimbang akan mempengaruhi laju pertumbuhan dan perkembangan tanaman. Hasil penelitian (Rustiana et al., 2021), ketersediaan unsur hara merupakan salah satu faktor penting yang dapat mempengaruhi hasil produksi tanaman. Penelitian ini memperoleh rerata berat polong sebesar 104,51 g/tanaman atau setara dengan 13,37 ton/ha. Deskripsi tanaman edamame varietas Ryoko 75 menunjukan hasil panen sebesar 8-9 ton/ha.

Faktor lingkungan juga mempengaruhi proses pertumbuhan dan hasil tanaman edamame meliputi suhu, kelembaban dan curah hujan yang terjadi pada saat penelitian berlangsung. Berdasarkan hasil pengamatan di lapangan rerata suhu berkisar antar 29-30°C, rerata kelembaban berkisar antara 71-

80%, dan data curah hujan berkisar 123-180 mm/ bulan. Sedangkan rerata suhu, kelembaban dan curah hujan yang sesuai dengan syarat tumbuh edamame yaitu rerata suhu berkisar 25-27°C, rerata kelembaban 75-90% dan curah hujan yang ideal berkisar 100-200 mm/bulan. Hasil data rerata menunjukan bahwa kelembapan dan curah hujan sudah mendukung untuk pertumbuhan tanaman edamame sedangkan suhu lebih tinggi dari yang diingikan tanaman edamame. Menurut penelitian (Sulaminingsih et al., 2024), bahwa suhu yang tinggi dapat menyebabkan proses fisiologis tanaman berjalan tidak baik seperti mempercepat laju respirasi tanaman, mengurangi efisiensi fotosintesis, dan mengganggu proses reproduksi tanaman.

Hama dan penyakit yang menyerang tanaman edamame selama penilitian yaitu siput, belalang dan ulat sedangkan untuk penyakitnya yaitu bercak daun. Adanya serangan hama dan penyakit pada tanaman edamame menyebabkan kerusakan dan jika dibiarkan maka serangan hama dan penyakit tersebut akan semakin banyak, sehingga perlu dilakukan pengendalian menggunakan pestisida. Menurut (Herlina, 2021), hama dan penyakit tanaman dianggap sebagai permasalahan utama dalam sistem produksi pertanian karena dapat menyebabkan kehilangan hasil panen. Oleh sebab itu, diperlukan upaya untuk mengendalikan hama dan penyakit agar tidak memberikan dampak yang merugikan terhadap hasil panen baik secara kualitas maupun kuantitas. Pengendalian hama dan penyakit dilakukan secara preventif dengan melalui penyemprotan pestisida hayati berbahan tembakau satu kali dalam seminggu dan penggunaan pestisida kimia yaitu Furadan dengan bahan aktif karbofuran pada usia 7 hari setelah tanam dan Dupont Prevathon dengan bahan aktif klorantraniliprol pada saat terdapat gejala serangan ulat pada daun dan polong.

KESIMPULAN

Berdasarkan hasil penelitian tidak terdapat interaksi antara pemberian *red mud* dan rhizobium terhadap semua variabel pengamatan. Dosis *red mud* 15 ton/ha merupakan dosis yang efektif untuk menghasilkan jumlah polong dan jumlah bintil akar sedangkan perlakuan dengan *rhizobium* dapat meningkatkan jumlah bintil akar sebanyak 30,46%.

SARAN

Disarankan untuk melakukan penelitian lanjutan mengenai residu media tanam yang telah digunakan sebelumnya untuk mengetahui residu dari penggunaan *red mud* sebagai bahan amelioran.

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MONITORING OF PLANT PEST AND DISEASE ORGANISM ATTACKS ON PEANUT *(Arachis hypogaea* L.) PLANTS IN SINDUREJO VILLAGE

(*PEMANTAUAN SERANGAN HAMA DAN ORGANISME PENYAKIT PADA TANAMAN KACANG TANAH (Arachis hypogaea L.) DI DESA SINDUHARJO*)

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Abstract

Peanuts are one of the food commodities. The decline in peanut crop productivity is caused by the Plant Pests Organism (PPO). The dominant pests affecting peanut crops are cutworms (Agrotis spp.), Armyworm (Spodoptera litura), leaf beetle (Phaedonia inclusa) and mealybugs (Pseudococcus spp.). This study was conducted in October-November 2025 in Jalan Bima, Nglaban, Sinduharjo, Ngaglik, Sleman, Yogyakarta. This study used random sampling analyzed using analysis of variance (ANOVA). Data collection was carried out through direct observation of PPO attack symptoms and calculation of the intensity and frequency of PPO attacks on peanut plants.
Keywords: Peanut crops, plant pest organism, monitoring

Abstrak

Kacang tanah merupakan salah satu komoditas pangan. Penurunan produktivitas tanaman kacang tanah disebabkan oleh Organisme Pengganggu Tanaman (OPT). Hama dominan yang menyerang tanaman kacang tanah adalah ulat potong *(Agrotis* spp.*),* ulat grayak *(Spodoptera litura),* kumbang daun (*Phaedonia inclusa*) dan kutu putih *(Pseudococcus* spp.*).* Penelitian ini dilakukan pada bulan Oktober-November 2025 di Jalan Bima, Nglaban, Sinduharjo, Ngaglik, Sleman, Yogyakarta. Penelitian ini menggunakan metode sampling acak yang dianalisis menggunakan analisis variansi (ANOVA). Pengumpulan data dilakukan melalui pengamatan langsung pada gejala serangan OPT dan perhitungan intensitas serta frekuensi serangan OPT pada tanaman kacang tanah.
Kata Kunci: tanaman kacang tanah, hama tanaman, pemantauan

INTRODUCTION

Peanuts (*Arachis hypogaea* L.) are an important agricultural commodity in Indonesia, both as a food source and a source of income for farmers. Unfortunately, peanut productivity is often disrupted by pests and diseases. These attacks can significantly reduce crop yields, in some cases by as much as 50–80%. The main problem is the lack of accurate data on when attacks occur, how severe they are, and the types of Pests that attack. As a result, control measures are often untimely and ineffective, causing farmers to suffer losses and a decline in crop quality (Rahayu, 2016).

Some types of pests that commonly attack peanuts include cutworms (*Agrotis* spp.), armyworm (*Spodoptera litura*), leaf beetle (*Phaedonia inclusa*), mealybugs (*Pseudococcus* spp.), and stem borers. Meanwhile, diseases that cause considerable damage include leaf rust caused by the fungus *Puccinia arachidis*, as well as leaf spots caused by *Cercospora personata* and *Cercospora arachidicola*. Leaf rust spreads through uredospores that develop on plant debris, while leaf spot is characterized by the appearance of brown spots with yellow rings on the leaf surface. If not properly controlled, this disease can cause a drastic decline in crop yields (Kasim *et al.*, 2024).

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Based on these issues, regular monitoring or observation of pest attacks on peanut fields is necessary. This monitoring aims to identify the types of pests and diseases that attack, the patterns of attack, and the severity of the attack. Through accurate data, farmers and extension workers can make more appropriate control decisions in accordance with the principles of Integrated Pest Management (IPM). IPM is a paradigm shift in agricultural practices that emphasizes a holistic approach to pest control that aligns economic, environmental, and social objectives. IPM uses a combination of biological, mechanical, and chemical control methods (Arsi *et al*., 2024).

Monitoring is carried out through direct observation in the field and the use of simple technologies such as pest traps. Identifying pest and disease attacks early can reduce the need for widespread pesticide application (Arsi *et al*. 2024). To obtain representative data, sampling is carried out using a random sampling method, so that each part of the land has an equal chance of being observed. This technique is expected to provide a more objective picture of the distribution and intensity of pest attacks, as well as the factors that influence them, such as climatic conditions, crop varieties, and planting patterns.

This study is based on the basic concept of pests, namely organisms that interfere with plant growth and production. A literature review shows that routine monitoring can reduce pest attacks by 30-50% and reduce the inappropriate use of pesticides. Several monitoring methods that have been applied in various previous studies include visual observation, the use of pheromone traps, and recording of attack symptoms. The principles of IPM are an important foundation in developing control strategies that not only kill pests but also maintain ecosystem balance and environmental health (Indiati and Marwoto, 2017).

In addition, understanding the morphology of peanut plants is also important in the process of identifying attack symptoms. This plant has taproots, round stems that are red, purple, or green in color and up to 55 cm long, as well as double-pinnate compound leaves consisting of four oval-shaped leaflets that are slightly hairy. These characteristics help in recognizing the early symptoms of attack, so that early detection can be carried out more accurately.

It is hoped that the results of this study will produce a monitoring system that is easy for farmers to implement, provides accurate information, and supports more effective control decision-making. In addition, this study is also expected to serve as a reference in the development of agricultural extension programs and sustainable pest management policies. With systematic monitoring, farmers can be more productive, crop yields can increase, and the negative impacts of pesticide use can be minimized (Cahyaningrum dan Suhartini, 2023).

The main objectives of this study are to identify the types of pests that attack peanut plants, observe the patterns and severity of attacks, analyze the factors that influence the intensity of attacks, and provide recommendations for efficient, practical, and environmentally friendly control strategies. Through the achievement of these objectives, it is hoped that farmers can carry out more targeted control and harvest yields can increase sustainably. Overall, this research is an important scientific step to support more environmentally friendly, efficient, and sustainable peanut cultivation. With this approach, we are not only helping farmers, but also maintaining food security and the sustainability of the agricultural system in Indonesia (Mawarda *et al*., 2023).

MATERIALS AND METHODS

This research method was designed to measure plant pests attacks on peanut fields with a total population of 500 plants. This study used a quantitative approach with a field survey method conducted on peanut plantations on land on Bima Street, Nglaban, Sinduharjo, Ngaglik, Sleman, Yogyakarta, during October 2025-November 2025. Samples were collected using random sampling techniques by observing 50 random samples with diagonal X and identifying Plant Pests Organism (PPO) attacks on peanut plants. Data collection was carried out by directly observing PPO attack symptoms, with the frequency and intensity of attacks observed at 4-day intervals. The final observation was conducted 3 weeks before harvest time. The data obtained was then analyzed descriptively to determine the frequency and intensity of attacks, as well as analysis of variance (ANOVA) to compare the intensity of attacks. This method is expected to describe the intensity of PPO attacks on peanut fields and can be used to determine the appropriate control method.

To calculate absolute damage, use the following formula:

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Incidence of attack

$$I = \frac{n}{N} \times 100\%$$

Description:
I = Incidence of attack (%)
n = Number of affected offspring
N = Number of offspring observed

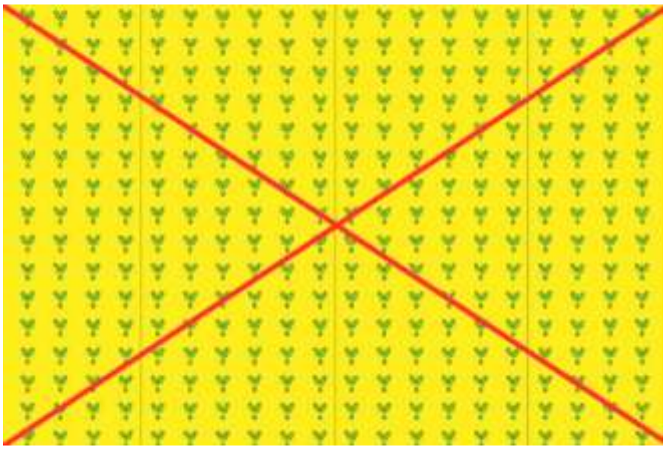

Figure 1. Pattern Sampling

Pest Attack Intensity Score:
0: No attack
1: Very light attack < 25%
2: Light attack 25-50%
3: Moderate attack 50-75%
4: Severe attack 75%-99%
5: Dead 100% (Susanto, 2009)

Disease damage level score:
0: No attack
1: Leaf surface damaged 1- ≤ 20%
2: Leaf surface damaged up to 20 - ≤ 40%
3: Leaf surface damaged up to 40 - ≤ 60%
4: Leaf surface damaged up to 60 - ≤ 80%
5: Leaf surface damaged up to >80% (Korwa *et al*., 2009)

RESULTS AND DISCUSSION

Pest and disease attacks are one of the main factors affecting the quality and quantity of peanut crops. The results of identifying pest and disease attacks on peanut crops in the fields of Sindurejo Village provide an important overview of the conditions that can affect crop growth and yield. Plant pests and diseases are major factors that need to be addressed because they can reduce productivity if not dealt with quickly and appropriately. The main pests found in this observation were armyworms (*Spodoptera litura*) and leaf beetles (*Phaedonia inclusa*), while the diseases found were chlorotic, which is one of the typical symptoms of infection by viruses from the Potyvirus group, especially Peanut Mottle Virus (PeMoV) and Peanut Stripe Virus (PStV), and leaf spots caused by *Alternaria* sp. fungi.

The armyworm (*Spodoptera litura*) is a polyphagous pest that attacks many types of food and horticultural crops, including peanuts. Its life cycle involves complete metamorphosis from egg, larva, pupa, to moth, with a total duration of approximately 30–60 days. Moths lay eggs in clusters of about 350 on the surface of leaves, and after 3–5 days the eggs hatch into larvae that initially feed on the leaf epidermis before spreading and eating away at the entire leaf surface until only the leaf veins remain. The larvae are pale green with black heads and two black spots on their abdominal segments. They undergo five instars over 12–15 days before entering the pupal stage in the soil for 7–8 days and then becoming adult moths that are active at night. Symptoms of attack are characterized by irregular bite marks on the leaves, leaves that appear hollowed out or with only the leaf veins remaining, jagged leaf edges due to bites, the presence of larval excrement (frass) on the leaf surface or soil under the plant, and in severe attacks, the plant appears stunted, dwarfed, and its growth is inhibited due to a decrease in photosynthetic capacity. Caterpillar infestation can cause severe damage to leaves, thereby disrupting the photosynthesis process and overall plant growth. (Fattah and Ilyas, 2016).

According to Sundari (2023), the *Phaedonia inclusa* leaf beetle has a life cycle in which adult females lay eggs in clusters (± 10 eggs) on the underside of leaves; the eggs are slightly elongated and pale yellow in color, hatching in about 4 days into larvae that feed on flowers and young pods in their early instars. then after molting (± 3 times) the larvae walk into the soil to become pale yellow pupae 3–5 mm long that last for about 8 days, before emerging as adult beetles 4–5 mm in size with shiny black domed bodies and brown heads and wing edges. Imagoes are active mainly in the morning and evening, attacking leaves, plant shoots, flowers, and pods; when disturbed, these beetles drop to the ground as if dead. The symptoms of leaf beetle pest attacks on peanut plants are marked by the appearance of irregular holes on leaves, shoots, and flowers due to the feeding activity of adult beetles, which can progress from minor damage in the form of thin streaks to partial or total defoliation. This damage causes inhibited shoot growth, reduced pod formation, and decreased photosynthetic capacity, ultimately lowering the plant's vigor.

Alternaria sp. fungus on peanut plants (*Arachis hypogaea*) is a pathogen that causes leaf spot disease, characterized by the appearance of dark brown to black spots on the leaves, often forming concentric circles, with darker edges and a grayish center; the spots can spread and merge, causing the leaves to turn yellow, dry out, and fall prematurely. The morphology of the pathogen is characterized by dark brown hyphae, erect conidiophores, and elongated oval conidia with transverse and longitudinal septa, having a distinctive pointed tip (beak). Infection develops rapidly under high humidity and warm temperatures, especially in stressed plants, and results in reduced photosynthetic area and lower peanut yields (Afini *et al.*, 2023).

Chlorotic fan spot disease in peanut plants is one of the characteristic symptoms of infection by viruses from the Potyvirus group, especially Peanut Mottle Virus (PeMoV) and Peanut Stripe Virus (PStV), which attack young leaf tissue, causing early chlorosis in the form of pale yellow spots that then spread and form a fan-like pattern on the leaf blades. This symptom is often accompanied by mosaic, green-yellow mottling, mild necrosis on the leaf margins, and distortion or curling that interferes with photosynthesis. Morphologically, potyviruses have flexible filamentous particles without a coat, measuring approximately 700–900 nm, carrying a positive single-stranded RNA genome that replicates in the cytoplasm of host cells and moves between cells through plasmodesmata and phloem tissue. Further infection causes stunted plant growth, a reduction in the number of productive branches, decreased pod filling, smaller seed size, and a significant decrease in yield. the spread of this disease is largely transmitted by aphids (*Aphididae*) in a non-persistent manner, especially in fields planted with peanuts repeatedly without crop rotation, resulting in high vector populations and inoculum sources (Sutarman and Supriadi, 2019).

Table 1. Incidence of Pest Attacks on Peanut Plants

Pest	Week			
	1	2	3	4
Spodoptera litura	78%	86%	100%	100%
Phaedonia inclusa	34%	68%	98%	100%

Observations of pest attacks on peanut plants revealed two types of pests, namely armyworms and leaf beetles. Based on table 1. Incidence of pest attacks on peanut plants shows that the incidence of armyworms was 78% in the first week, 86% in the second week, and increased to 100% in the third and fourth weeks. Leaf beetles were recorded with an incidence of 34% in the first week, rising to 68% in the second week, 98% in the third week, and 100% in the fourth week.

Observations show that the older the plant, the higher the incidence of pest attacks. Symptoms of attacks caused by S. litura include young larvae eating the upper epidermis of leaves, while older larvae eat the entire leaf except for the leaf veins, causing the affected leaves to appear white (Mirsam, 2016). Symptoms of leaf beetle infestation on peanut plants are characterized by the appearance of irregular holes on leaves, shoots, and flowers due to the feeding activity of imagoes, which can develop from minor damage in the form of thin scratches to partial or total defoliation. This damage causes stunted shoot growth, reduced pod formation, and decreased photosynthetic capacity, which ultimately reduces plant vigor (Sundari, 2023).

Tabel 2. Intensity of Pest Attacks on Peanut Plants

Pest	Week			
	1	2	3	4
Spodoptera litura	21,2%	28%	44,8%	50,8%
Phaedonia inclusa	7,6%	16,8%	29,6%	38,8%

Based on Table 2, the intensity of pest attacks on peanut plants showed the following results: 21.2% in the first week, 28% in the second week, continuing to increase to 44.8% in the third week, and 50.8% in the fourth week. Leaf beetles were recorded with an incidence of 7.6% in the first week, then rose to 16.8% in the second week, then 29.6% in the third week, and 38.8% in the fourth week.

The increase in pest attack intensity is caused by nutritional differences at each stage of plant growth and vegetation in peanut fields. It can also be caused by the influence of climate on high pest reproduction when the average air humidity is 70% and the air temperature is 18-23%. The larger the population of a particular pest species, the greater the food requirements of that pest, in this case the host plant, so that the damage caused by the pest is proportional to the increase in the pest population (Palit et al., 2016).

Tabel 3. Incidence of Diseases Attacks on Peanut Plants

Disease	Week			
	1	2	3	4
Chlorotic	88%	88%	100%	100%
Leaf Spot	56%	72%	96%	100%

Based on Table 3, the incidence of chlorotic disease attacks on peanut plants showed results of 88% in the first and second weeks, then increased to 100% in the third and fourth weeks. Leaf spot disease was recorded with an incidence of 56% in the first week, then rose to 72% in the second week, then increased again to 96% in the third week, reaching 100% in the fourth week.

Symptoms of leaf spot disease are characterized by the appearance of blackish-brown spots spreading across the leaf surface. In mild cases, the spots appear small and scattered, but over time they enlarge and become surrounded by a yellow halo. In severe cases, the spots merge and cover most of the leaf surface (Mahendra *et al*., 2025). Chlorotic symptoms caused by PstV that appear on infected peanut leaves include mottling, chlorosis between dark green leaf veins, and wrinkling. The initial symptoms of PstV infection are seen on the youngest peanut leaves, which appear slightly wrinkled and have irregular dark green spots. On older leaves, these symptoms develop into mottling or mosaic patterns (Mirsam, 2016).

Tabel 4. Intensity of Disease on Peanut Plants

Disease	Week			
	1	2	3	4

Chlorotic	29,6%	30,4%	51,2%	62,4%
Leaf Spot	17,2%	23,2%	45,2%	57,2%

Based on Table 4, the intensity of chlorotic disease attacks on peanut plants showed results of 29.6% in the first week, 30.4% in the second week, continuing to increase to 51.2% in the third week and 62.4% in the fourth week. Leaf spot disease was recorded with an intensity of 17.2% in the first week, then rose to 23.2% in the second week, then 45.2% in the third week, and 57.2% in the fourth week.This increase occurs in line with the growth phase of peanut plants and is supported by environmental conditions that are suitable for growth. Factors such as plant variety, virus strain, plant age at infection, and environmental conditions determine the level of PStV infection (Kasim et al., 2023). Environmental conditions with high humidity and warm temperatures accelerate the pathogen's life cycle and increase the likelihood of infection. Rainfall can lower the ambient temperature and increase air humidity, creating conditions that support pathogen development (Nasution and Siregar, 2019).

CONCLUSION

This study shows that the dynamics of pest and disease attacks on peanut plants increase with the age of the plants and the progression of the growth phase. Both groups of pests—caterpillars and leaf beetles—as well as chlorotic and leaf spot diseases show a progressive pattern of attack, indicating that plant susceptibility increases in line with morphological development and favorable environmental conditions. This emphasizes the importance of implementing pest and disease control strategies early, continuously, and in an integrated manner to minimize damage to plants. Further research is recommended to evaluate the effectiveness of integrated control and to examine the influence of environmental conditions and plant physiological responses so that pest and disease control strategies for peanuts can be developed in a more adaptive and efficient manner.

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