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DISEASE INTENSITY AND INCIDENCE OF PEST AND DISEASES ON EGGPLANT (*Solanum melongena* L.) IN WEDOMARTANI, SLEMAN REGENCY, SPECIAL REGION OF YOGYAKARTA

INTENSITAS DAN INSIDENSI PENYAKIT PADA HAMA DAN PENYAKIT TANAMAN TERONG (Solanum melongena L.) DI WEDOMARTANI, KECAMATAN SLEMAN, YOGYAKARTA

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Abstract

Eggplant (*Solanum melongena* L.) is a horticultural commodity whose production continues to increase in Indonesia, but pests and diseases remain a limiting factor affecting productivity. This study aims to identify the main types of pests and diseases in eggplant plants and assess appropriate control strategies to support sustainable productivity increases. The study was conducted at Rd. Blotan Sono, Wedomartani, Sleman, Special Region of Yogyakarta using a direct observation in the field with a random sampling technique. The results showed that the ladybug was the most dominant pest, with an attack intensity of 37 - 55% and an incidence of 57 - 86%. Yellow virus disease had a stable incidence of 14% with a low intensity ranging from 11 - 14%. Powdery mildew disease was found with an incidence of 28 - 43% and an intensity that increased from 4% to 12% during the observation period. Meanwhile, the *Halyomorpha halys* pest showed a relatively low attack rate with an intensity of 1 - 10%. These variations in intensity and incidence indicate differences in the level of threat each plant pest poses to eggplant growth. Based on these findings, consistent implementation of Integrated Pest Management (IPM) is necessary to minimize damage and maintain eggplant productivity. Recommended IPM strategies include field sanitation, pruning infected plant parts, crop rotation with non-hosts, the use of resistant varieties, and the use of biological agents and mechanical application of pesticides. Integrating these approaches is crucial to maintaining production levels while minimizing the environmental impact of chemical-based control.

Keywords: eggplant, koksi beetle, powdery mildew

Introduction

Indonesia is a country rich in natural resources, one of which is agriculture. Agriculture itself is the activity of cultivating plants carried out by humans to meet their living needs. One of the most widely cultivated vegetable commodities by the community is purple eggplant (*Solanum melongena* L.). Purple eggplant is well known among various groups because it has a delicious taste, affordable price, and can be processed into various dishes in a relatively easy and simple way. According to Poto *et al*. (2024), every 100 grams of fresh eggplant contains 24 calories, 1.1 g protein, 0.2 g fat, 5.5 g carbohydrates, 15 mg calcium, 37 mg phosphorus, 0.4 mg iron, 4 mg vitamin A, 5 mg vitamin C, 0.04 mg vitamin B1, and 92.7 g water. In addition, eggplant also contains alkaloids, solanine, and solasodine that are useful as medicines. These compounds are known to have beneficial pharmacological activities, including as antioxidants, anti-inflammatory, and antimicrobial agents.

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Based on data from the Central Bureau of Statistics (BPS) in 2024, eggplant production in Indonesia has continuously increased over the last three years. In 2021, eggplant production was recorded at 676,339 tons. Then, in 2022, production increased to 691,738 tons, showing a significant increase of 15,399 tons from the previous year. Eggplant production in 2023 again experienced an increase reaching 699,096 tons. This production rise reflects the efforts made by eggplant farmers to improve their harvest yields through various cultivation techniques, selection of superior varieties, and better management. Although production continues to rise each year, market demand for eggplant has not been fully met. This is caused by the high interest of the public in consuming eggplant as a vegetable with high nutritional value and competitive prices in the market. Increasing demand from consumers makes the existing eggplant supply unable to fully meet market needs. This condition presents both challenges and opportunities for farmers to continue increasing their productivity (Quttub *et al*., 2025).

However, purple eggplant cultivation faces various obstacles, especially pest and disease attacks. The pests that often attack eggplant plants are the koksi beetles. Koksi beetles (Epilachna sparsa) attack eggplant plants by biting the underside of the leaves. In severe attacks, they can damage all leaf tissue, leaving only the veins (Nabila *et al.*, 2022). In addition, there is the brown marmorated stink bug (*Halyomorpha halys*). The Brown Marmorated Stink Bug is a pest that attacks the leaves, stems, and especially the fruits of eggplant plants by piercing and sucking their sap, causing damage such as necrotic spots and defects on the eggplant fruits, which can reduce the quality of the harvest (Weber *et al*., 2017).

In addition to pests, diseases also pose serious problems in eggplant cultivation. One common disease is yellow leaf. This disease is caused by the gemini virus transmitted by the whitefly insect vector (*Bemisia tabaci*). B. tabaci is a leaf-sucking insect pest that plays a role in the spread and transmission of gemini virus in the field. The mechanism of yellow virus infection in eggplant plants manifests with symptoms of yellow leaves, stunted growth, and curling upward (Rahmani *et al*., 2023). Powdery mildew disease is characterized by the appearance of white powder on the leaves and stems (Hardianto *et al*., 2023).

Considering the high production potential of purple eggplant in Indonesia, pests and diseases remain unavoidable limiting factors. Pest and disease attacks can cause significant yield reductions and even total crop failure if not properly managed. This situation requires precise identification of pest and disease types through field sampling activities. Data obtained from identification results will be important in determining appropriate control strategies. The Integrated Pest Management (IPM) approach is one strategy that can be applied as it combines various effective, efficient, and environmentally friendly control methods. Implementing IPM based on field information enables farmers to reduce losses while maintaining agroecosystem sustainability. Therefore, this study was conducted to identify pests and diseases, and to review appropriate control strategies to support sustainable increases in purple eggplant productivity.

Materials and Methods

1. Research Implementation

The research was conducted from 28th October to 20th November 2025. The research was conducted at the Rd. Blotan Sono, Wedomartani, Sleman Regency, Special Region of Yogyakarta. The materials used in this research were eggplant plants. The tools used in this research were stationery and cameras. Observation is a technique used to observe symptoms of pest and disease attacks on eggplant plants, so it is necessary to conduct observations as a reference for conducting further research. Observations are carried out by observing and recording the level of disease damage to plants.

2. Research Methods

The research was conducted using a survey method or direct observation in the field. Sampling was carried out using diagonal random sampling. Simple random sampling is a method of selecting a sample from a population in which each member of the population has an equal chance of being selected. This sampling process ensures that the sample quality remains

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unaffected, as each member of the population has an equal probability of being chosen for inclusion in the sample (Nabila *et al.*, 2022). Sampling was carried out by selecting 10% eggplant plant samples from the total plant population per bedding. Each bedding has 16-20 plants, the first beeding has 20 plants, second bedding has 16 plants, and third bedding had 16 plants. 3 plant samples were taken from the first bedding, 2 plants from the second bedding, and 2 plants from the third bedding. Pest observations were carried out visually and documented with cameras. Documentation was carried out to strengthen the data obtained in the field using a cellphone camera. The results of the documentation in the form of field photographs will be attached as research data. Research was conducted from 28th October 2025 to 20th November 2025, with observations carried out once every 7 days.

3. Data Analysis

The parameters observed were pest attack symptoms and the intensity of pest and disease attacks. Pest and disease attack intensity was determined using a scale of 0–5.

Scoring	Damage Level on Plants
0	No Damage
1	1-20% Damage on Plant (Very Light)
2	20-40% Damage on Plant (Light)
3	40-60% Damage on Plant (Average)
4	60-80% Damage on Plant (Severe)
5	80-100% Damage on Plant (Very Severe)

The percentage of attack intensity can be calculated based on symptoms using the following formula (Wagiyanti *et al.*, 2024):

$$IS = \frac{(ni \times vi)}{Z \times N} \times 100\%$$

Description:
IS = Attack Intensity (%)
ni = Number of plant parts showing the i score
vi = Score of the i plant part
N = Number of plant parts observed
Z = Highest damage scale value.

The incidence and severity of the disease were obtained using the Townsend and Heuberger disease incidence calculation formula (Masnilah *et al.*, 2020):

$$I = \frac{a}{b} \times 100\%$$

Description:
I: Disease Incidence
a: Number of affected plants
b: Number of observed plants

Results and Discussion

Observation results of eggplant plant diseases and pests in Wedomartani, Sleman Regency can be seen in following images:

1. Yellow Leaf Virus Disease

The incidence of yellow leaf virus disease in eggplants found in Table 1 is scored at 14%. During the observation, 1 out of 7 samples were reported to have been infected with yellow leaf virus disease caused by Begomovirus, total population during the observation is 52. Disease incidence was calculated using the amount of infected sample plants and total sample plants. Due to the constant amount of infected during the observation, every observation had the same incidence of yellow leaf disease caused by Begomovirus, that is 14%. The disease intensity can also be found on Table 2 ranging from 11% on the first observation, 12.8% on the second

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observation, 13% on the third observation, and 14% on the fourth observation. 1 out of 7 samples were found to have been infected with this virus and showing this disease. This disease can be caused by the eggplant plants being planted beside chili plants that can indirectly infect this virus through insect vectors such as *Bemisia tabaci* (Sidik *et al.*, 2023).

Table 1. Disease Incidence of Yellow Leaf Virus Disease on Eggplant Plants

	Disease Incidence
1	14%
2	14%
3	14%
4	14%

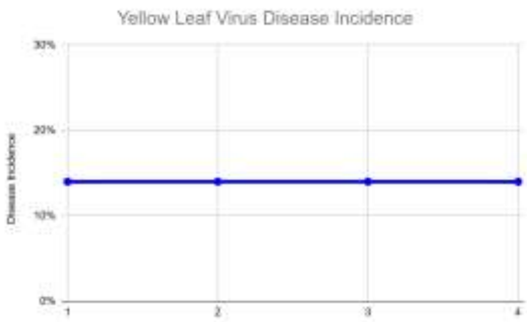
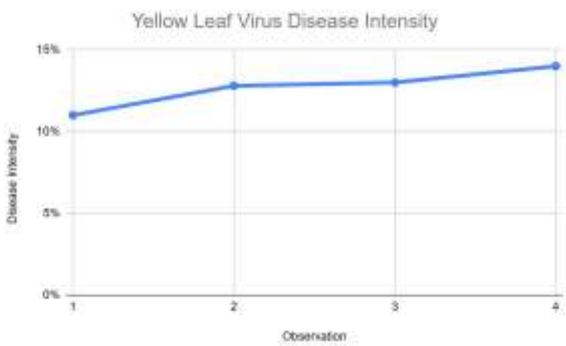


Table 2. Disease Intensity of Yellow Leaf Virus Disease on Eggplant Plants

Observation	Disease Intensity	Category
1	11%	
2	12.8%	Light Attack Intensity
3	13%	
4	14%	



Plants infected with Begomovirus exhibit characteristic symptoms such as yellow mosaic, mottled, curled, green mosaic, upward and/or downward curling of leaves, and stunted growth (Aulia *et al.*, 2022). During the observation, some symptomps of Begomovirus such as yellow, green mosaic leaves and stunted growth were identified. Even though not many plants are affected by this disease, the incidence of yellow virus disease in eggplants is because of the vector insects for this disease, that is expected to be *Bemisia tabaci*. It is suspected that the whitefly vectors might have come from the chili plants that are planted beside the eggplant plants. During this observation however, no whiteflies were spotted or identified on or near any sample plants. This could be caused by predators that are weaver ants. Research by Salsabilla and Riyanto (2021) reported that weaver ants can become potential predators for whiteflies. Weaver ants will create

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small colonies to attack whiteflies that live in groups, so they will attack in one place together and close together. Due to the severe virus attack from the first observation, it is suspected the whitefly population was eliminated beforehand by weaver ants.


Image 1. Weaver Ants on Eggplant Plant; **Image 2.** Yellow Leaf Virus Disease in Eggplant Plant

Based on the disease intensity percentage in Table 2, Begomovirus in eggplants intensity is marked into the light category (< 25%) of disease attacks. From these results, we can take efforts to help control and eliminate any risk of further spreading diseases through IPM (Integrated Pest Management). An approach that could be taken with a light category is replacing the infected or abnormal plant with a new and healthy plant. Other efforts such as planting resistant variants of eggplant plants, doing planting rotation with non-host plants, and field sanitation could also be done (Vinisafitri *et al.*, 2022). Although, replacing infected plants could be the most helpful strategy in this observation because only 1 out of 7 sample plants were infected, and results were constant over 4 observations. Therefore, replacing plants could benefit more than other strategies.

2. Powdery Mildew Disease

The incidence rate of powdery mildew disease in Table 3 shows that in the first observation, the incidence rate was 28.57%, then increased in the second to fourth observations to 43%. There were 7 eggplant samples observed, with 2 plants infected with powdery mildew in the first observation. In the second to fourth observations, there were 3 plants infected with powdery mildew out of the seven samples. The powdery mildew disease intensity data in Table 4 shows an increase over time. In the first observation, the disease intensity was recorded at 4.28%, then increased to 7.14% in the second observation, 9% in the third observation, and reached 12.85% in the fourth observation.

Table 3. Disease Incidence of Powdery Mildew Disease on Eggplant Plants

Observations	Disease Incidence
1	28.57%
2	42.85%
3	42.85%
4	42.85%

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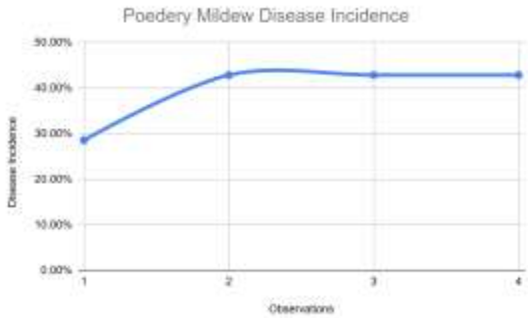
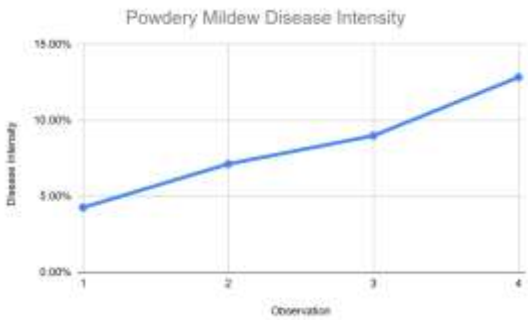


Graphic 3. Powdery Mildew Disease Incidence

Table 4. Disease Intensity of Powdery Mildew s Disease on Eggplant Plants

Observation	Disease Intensity	Category
1	4.28%	Light Attack Intensity
2	7.14%	
3	9%	
4	12.85%	



Graphics 4. Powdery Mildew Disease Intensity

This powdery mildew disease is characterised by the appearance of white spots resembling flour on the surface of the leaves, as shown in Image 2. Powdery mildew is caused by fungi of the order Erysiphales (phylum Ascomycota). These symptoms are consistent with the research by Siadari *et al*. (2023). Powdery mildew usually attacks young leaves, characterized by the presence of white powdery particles which are a collection of mycelium, conidiophores, and conidia of the fungus that causes powdery mildew. The symptoms of the disease are a mass of conidia formed on the conidiophores, which are white in colour and are a characteristic feature of this disease. Mature spores will detach and cover the surface of the tissue and be spread by the wind, causing infection (Sastrahidayat, 2016). If left unchecked, the fungus will continue to absorb nutrients from the plant tissue, while the dust-like white layer covering the leaves can inhibit the photosynthesis process. As a result, the growth of eggplant plants is inhibited (Siadari *et al.,* 2023)**.**

The control of powdery mildew disease includes mechanical control, which involves picking all leaves infected by the fungus that causes powdery mildew, planting resistant varieties, implementing cultural techniques such as environmental sanitation, crop rotation with non-host plants, and fertilization with sulfur and zinc nutrients. In addition, powdery mildew can also be controlled biologically, using botanical fungicides (neem seed extract and compost tea) and biological fungicides (the fungus *Ampelomyces quisqualis*). The last alternative is spraying with chemical fungicides if the previous methods are unable to control powdery mildew (Sumatini and Rahayu, 2017).

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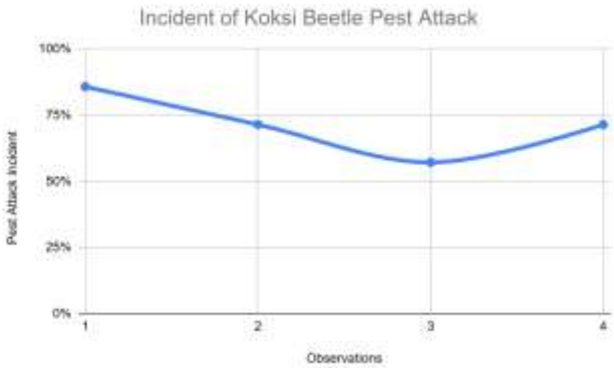
Image 2. Powdery Mildew Disease in Eggplant Plant

3. Koksi Beetle

The incidence rate of koksi beetle pest attacks in Table 5 shows that in the first observation, the incidence rate was 85.71%, then decreased in the second and third observations to 57.14% and the fourth observation increased to 71.42%. There were 7 eggplant samples observed, 6 plants were attacked by ladybug pests in the first observation. In the second observation, 5 beetles were infested, in the third observation, 4 beetles, and in the fourth observation, 5 beetles were infested from seven samples. The powdery mildew disease intensity data in Table 6 shows an increase over time. In the first observation, the disease intensity was recorded at 13.14%, then increased to 45.71% in the second observation, 52% in the third observation, and reached 55.14% in the fourth observation.

Table 5. Incident of Koksi Beetle Pest Attack on Eggplant Plants

Observation	Disease Incidence
1	85.71%
2	71.42%
3	57.14%
4	71.42%



Graphics 5. Incident of Koksi Beetle Pest Attack

Table 6. Intensity of Koksi Beetle Pest Attack on Eggplant Plants

Observation	Disease Intensity	Category
1	37.14%	
2	45.71%	Severe Attack Intensity
3	52%	
4	55.14%	

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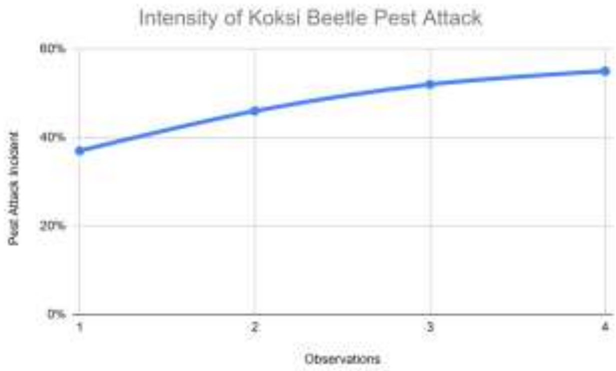

Graphics 6. Intensity of Koksi Beetle Pest Attack

Koksi beetle (*Coccinellidae*) are considered to have an impact on the cultivation of Solanaceae plants because many species act as biological control agents for plant pests and as phytophagous insects. There are 15 species of predatory ladybugs that prey on aphids found in Asia. Phytophagous ladybugs are plant eating insects. These beetles are herbivorous and have specific host plants, namely members of the Solanaceae family (Sutarma et al., 2023). Symptoms of ladybug infestation can be found on eggplant leaves. Eggplant leaves contain nitrogen and secondary metabolites such as alkaloids, making them highly palatable to these insect pests. Ladybugs feed on the leaf lamina, leaving the veins and midribs uneaten. This i s because the leaf lamina is softer and easier to ingest (Arsi et al., 2023).

Pest control in eggplant plants can be achieved through planting patterns, one of which is plant spacing. Planting too close together makes it easier for pests to move from one plant to another, resulting in more infested plants (Arsi et al., 2022). Delayed control during the generative phase of a plant can result in yield loss. Common control methods used by farmers include the use of synthetic pesticides, such as organophosphates, carbamates, and pyrethroids. The negative impacts of synthetic pesticide use on the environment include pollution, killing natural enemies, developing pest resistance, accumulating pesticide residues in produce, and poisoning of farmers who use them (Nabila et al., 2023).


Image 4. *Coccinellidae* Pest in Mature Stage; **Image 5.** *Coccinellidae* Pest in Larva Stage

4. Brown Marmorated Stink Bug

The brown marmorated stink bug pest attack rate in Table 7 shows that in the first observation, the incidence rate was 14%, then increased in the second to fourth observations to 29%. There were 7 eggplant samples observed, with 1 plant attacked by the brown marmorated stink bug in the first observation. In the second to fourth observations, there were 2 plants attacked by the brown marmorated stink bug out of seven samples. Data on the intensity of the brown marmorated stink bug pest attack in Table 8 shows an increase over time. In the first observation, the disease intensity was recorded at 1.42%, then increased to 5.14% in the second observation, 8% in the third observation, and reached 10% in the fourth observation.

Table 7. Incident of Brown Marmorated Stink Bug Pest Attack on Eggplant Plants

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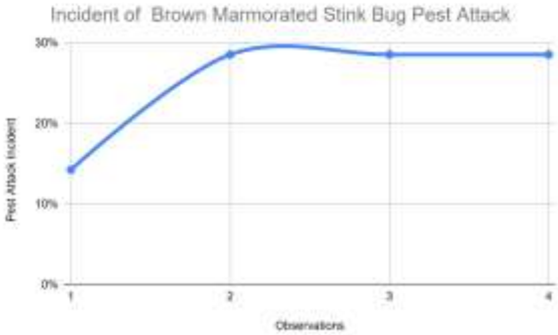
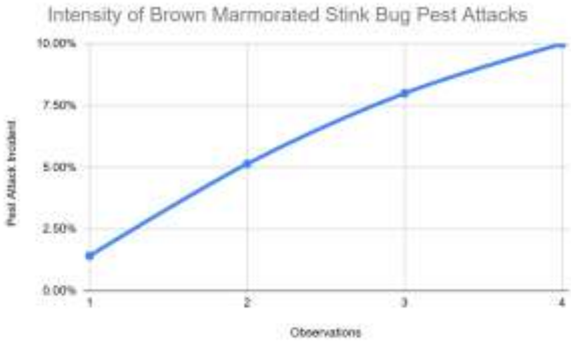
Observation	Disease Incidence
1	14%
2	29%
3	29%
4	29%



Graphics 7. Incident of Brown Marmorated Stink Bug Pest Attack

Table 8. Intensity of Brown Marmorated Stink Bug Pest Attacks on Eggplant Plants

Observation	Disease Intensity	Category
1	1.42%	Light Attack Intensity
2	5.14%	
3	8%	
4	10%	



Graphics 7. Intensity of Brown Marmorated Stink Bug Pest Attack

Brown Marmorated Stink Bug (*Halyomorpha halys)* is an invasive insect pest in the Pentatomidae family that attacks more than 100 cultivated plants, including vegetables such as eggplant. This insect measures 12–17 mm, is shield-shaped, and marmorated brown in color. Symptoms in eggplant plants caused by H. halys typically affect leaves, young stems, and especially the fruit. When the insect pierces the eggplant, it sucks out cellular fluids, causing brown spots, hardening, silvery discoloration, and scarring of the fruit's skin. Puncture marks can also serve as entry points for secondary pathogens, causing rot or reduced fruit quality at harvest (Leskey and Nielsen, 2018).

Control of *Halyomorpha halys* in eggplant is carried out in an integrated manner through monitoring, cultural, biological, and chemical approaches. Monitoring using yellow sticky traps or direct observation helps detect early pest emergence. Culturally, land sanitation, weed removal, and planting timing can suppress populations by reducing hiding places for adults. Biological control utilizes egg parasitoids such as *Trissolcus japonicus*, which effectively reduces hatching rates. At high populations, insecticides such as pyrethroids and neonicotinoids can be used selectively, but applications must be timely, especially during fruit formation, as this phase is

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most vulnerable to the pest. This integrated approach is essential to maintain control of *H. halys* populations without disrupting natural enemies and preventing resistance (Leskey and Nielsen, 2018).


Image 6. *Halyomorpha halys* Pests on eggplant plants; **Image 7.** *Halyomorpha halys* Pest Attack on Eggplant Fruit

Conclusion

Plant pest attacks on eggplants in Wedomartani consist of yellow leaf virus disease, powdery mildew, koksi beetle, and brown marmorated stink bugs, with koksi beetle being the most dominant pest with the severe intensity of attack, while yellow leaf virus disease, powdery mildew, and brown marmorated stink bugs show low intensity. In general, these conditions indicate the need for proper pest management through the implementation of Integrated Pest Management (IPM), including land sanitation, pruning of infected parts, crop rotation, use of resistant varieties, and selective biological and chemical control to maintain the productivity of eggplants.

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IDENTIFICATION OF PEST AND DISEASE ATTACKS ON CORN PLANTS IN MAGUWOHARJO VILLAGE FIELDS

IDENTIFIKASI SERANGAN HAMA DAN PENYAKIT PADA TANAMAN JAGUNG DI LAHAN DESA MAGUWOHARJO)

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Abstract

Corn (*Zea mays* L.) is one of the most important cereal crops in the world, after wheat and rice. Corn cultivation often faces serious challenges due to pest and disease attacks that cause significant losses for farmers. This study aimed to identify the incidence and damage intensity caused by major pests (fall armyworm and grasshopper) and diseases (leaf blight and downy mildew) in corn fields at Maguwoharjo Village. A quantitative survey using a simple random sampling method with diagonal clustering was applied to 500 corn plants, representing 10% of the population. Observations were made weekly from 6 to 10 weeks after planting (WAP), recording symptoms and calculating infestation levels to better inform targeted pest and disease management strategies. The results of the study show that grasshoppers and armyworms are the main pests, with an incidence rate of 70% and an attack intensity of 40% for grasshoppers, and an incidence rate of 50% with an attack intensity of 17% for armyworms. In addition, leaf blight and smut diseases also have significant incidence rates, reaching 100% and 84%, with attack intensities of 47% and 35%, respectively. This research provides important information for the development of integrated control strategies to reduce losses due to pest and disease attacks on corn crops.

Keywords: *Armyworm, Downy Mildew, Grasshopper, Leaf Blight*

Introduction

Corn (*Zea mays* L.) is one of the most important cereal crops in the world, after wheat and rice. This plant originates from the Americas, where it has been cultivated for thousands of years by Mesoamerican civilizations. Corn plays a crucial role in various aspects of life, serving as a staple food for humans, animal feed, and a raw material for industry. Corn has an annual life cycle. Its stem is upright and unbranched, with distinct nodes. The leaves are long and alternate, with parallel veins. The most distinctive part of corn is its fruit, which is in the form of an ear. An ear of corn consists of kernels attached to the central cob and covered by husks. Corn kernels are rich in carbohydrates, particularly starch, making them a vital source of energy.

Corn cultivation often faces serious challenges due to pest and disease attacks that cause significant losses for farmers. The decline in yield occurs not only in quantity but also in quality. Infected corn often shows poor physical quality, such as suboptimal kernel size or even rot, which directly affects the market value of the product. To overcome this problem, farmers generally rely on the use of chemical pesticides. However, the use of chemical pesticides has limitations, since their specificity is not always effective against all types of pests and diseases. In addition, repeated and improper application can trigger resistance in target organisms, requiring higher doses and greater costs (Susanti, 2022).

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Dependence on chemicals has broad negative impacts. From an ecological perspective, pesticide residues can contaminate ecosystems, including soil and water sources, and threaten beneficial non-target organisms, such as pollinators and natural predators of pests. From a health perspective, pesticide exposure can endanger farmers who are not equipped with adequate personal protective equipment. Moreover, chemical residues remaining on harvested crops can be harmful to consumers (Abror, 2023).

Corn plants are often affected by various pests and diseases that can reduce yields. One significant disease is leaf blight, which causes corn leaves to turn yellow and dry due to fungal infection, thereby disrupting the photosynthesis process. Downy mildew, caused by the fungus *Peronosclerospora maydis*, also frequently attacks corn, characterized by leaves turning yellowish-white with parallel stripes along the veins, which inhibits plant growth. In extreme cases, losses due to diseases such as leaf blight and downy mildew can reach 50% or more (Arsi *et al*., 2024).

The fall armyworm (*Spodoptera frugiperda*) is a major pest that damages corn leaves, stems, and cobs by feeding on plant tissues, particularly in young plants and seedlings, with the potential to cause plant death. Fall armyworm attacks corn from the vegetative phase to the generative phase. Symptoms of infestation include window panning, where leaves appear transparent due to the loss of the epidermal layer, leaf holes, and frass resembling sawdust found on both stems and cobs. This damage inhibits plant growth, and if the larvae reach the growing point, it can result in plant death (Ariska *et al*., 2021). Another frequently encountered pest is the grasshopper (*Valanga nigricornis*), which attacks the leaves. This grasshopper attacks the leaves, with symptoms including the corn leaves being eaten from the edge to the center. The grasshopper attacks the leaves, leaving only the veins and stems. Under certain conditions, this insect can even eat the veins and stems, damaging the plant and reducing yields (Patty, 2012).

The identification of pests and plant diseases is a fundamental step in Integrated Pest Management (IPM) for sustainable agriculture. Identifying pests and diseases in plants is a crucial aspect of effective and sustainable agricultural management. This process involves recognizing and understanding the organisms that can cause damage to crops. Accurate identification allows farmers and researchers to precisely determine the types of pests and diseases attacking plants, thereby clarifying the causes of damage. This serves as the main foundation for designing targeted control strategies, avoiding excessive pesticide use, and minimizing negative impacts on the environment and human health. With proper identification, crop damage can be minimized, productivity can be increased, and the sustainability of agricultural production can be better maintained (Lapinangga *et al*., 2024).

The research aims to gain a deeper understanding of the symptoms and extent of damage caused by pests and diseases to plants at the research site. By accurately identifying these conditions, the research helps to determine the most appropriate and effective control methods so that pesticide use can be optimized. This approach is expected to assist farmers in managing pest and disease attacks more efficiently, reducing excessive pesticide application, while simultaneously increasing crop productivity and preserving environmental sustainability.

Materials and Methods

This study uses a quantitative approach with a survey design to assess the population and level of infestation of Plant Pests and Diseases (Plant Pest Organisms/OPT) in corn plants in Maguwoharjo Village. Samples taken were 10% of the population, namely 50 samples with a total sample of 500 plants. Sampling was carried out using the Simple Random Sampling method with a diagonal observation pattern in clusters by observing plants randomly in the field and identifying symptoms of damage caused by corn pests and diseases. Observations began at the end of October when the plants were approximately 6 WAP and ended in mid-November or when the plants were approximately 10 WAP. Observations were carried out at weekly intervals. Data collection was carried out through direct field observation and calculation of infestation intensity.

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Figure 1. Diagonal cluster pattern

After making observations, the incidence and intensity of damage will be calculated using the formula:

Incident of attack

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

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

Intensity of damage

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

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

Table 1. Pest and Disease Attack Intensity Score in Corn:

Range	Category
0	Plants asymptomatic and infected (0%)
1	Plants with symptoms and infected with a percentage (≤ 25%)
2	Plants with symptoms and infected with a percentage (> 25-50%)
3	Plants with symptoms and infected with a percentage (> 50-75%)
4	Plants with symptoms and infected with a percentage (≥ 75%)

Source: Arsi *et al.,* 2024.

Table 2. Pest and Disease Attack Intensity Criteria.

Range	Category
I ≤ 25%	Low Attack Intensity
25% < I ≤ 50%	Moderate Attack Intensity
50% < I ≤ 85%	Severe Attack Intensity
I > 85%	Intensity of Puso Attacks

Source: Hawiyah *et al.,* 2022.

Results and Discussion

Pest attacks

The main pests identified during observation based on visible symptoms were grasshoppers and armyworms. Grasshoppers (*Valanga nigricornis*) are active insects during the day. In the morning, they fly and circle to find a location, and at dusk, they land on a location to mate, lay eggs, and eat the plants they land on. Adult grasshoppers initially attack the edges of corn leaves, then move towards the center of the leaf until they reach the leaf veins (Figure 2). Symptoms of a grasshopper attack include tears in the leaves and in severe attacks, only the leaf veins are visible. Bite marks from grasshopper attacks

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differ from those from caterpillar bites. The holes from grasshopper attacks have jagged and rough edges, while the bite marks from caterpillars are smoother (Rohman *et al.,* 2020).

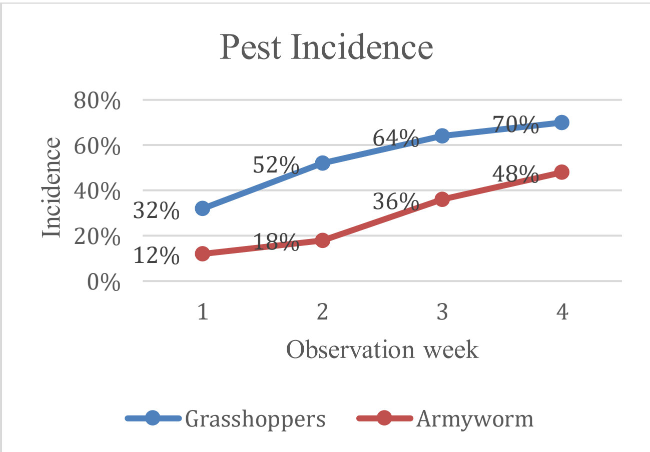
Symptoms of *S. frugiperda* attacks found on corn plants that are still in the vegetative phase include the presence of larval movement marks on the leaves, the presence of coarse powder resembling sawdust, and residual larval feces on the surface of the leaves (Figure 3). This is in accordance with the opinion of Id *et al* (2019), *S. frugiperda* infestation in corn can be seen from the presence of residual feces in the leaf funnel. *S. frugiperda* pests are able to attack the growing points of plants which can result in the failure of shoots/young leaves of the plant to develop (Maharani *et al*., 2019). *S. frugiperda* attacks the shoots of plants that have not fully opened (rolled up) causing the growing leaves to have a cut-like shape (Apriyandi *et al.,* 2021).

Figure 2. Symptoms of a Grasshoppers Attack

Figure 3. Symptoms of Armyworm Attack

Table 3. Incidence of Grasshoppers and Armyworm Attacks on Corn Crops (%)

Pest	Week of Observation			
	1	2	3	4
Grasshoppers	32.00	52.00	64.00	70.00
Armyworm	12.00	18.00	36.00	50.00



Graph 1. Incidence of Grasshoppers and Armyworm Attacks on Corn Crops

Based on Table 3, the incidence of grasshopper and armyworm attacks on corn plants showed an increase during the one-month observation period. This indicates that there was an increase in grasshopper and armyworm attacks on other sample plants. Grasshoppers began attacking plants at 10 days after planting and increased at 30-45 days after planting. The presence of grasshoppers can be caused by the availability of abundant other vegetation (grass) around the plants that can act as hosts for grasshoppers (Rahman *et al*., 2020). Meanwhile, armyworms also attack during the vegetative phase of plants, especially at 2 to 6 weeks of age when young leaves and shoots of plants are vulnerable to

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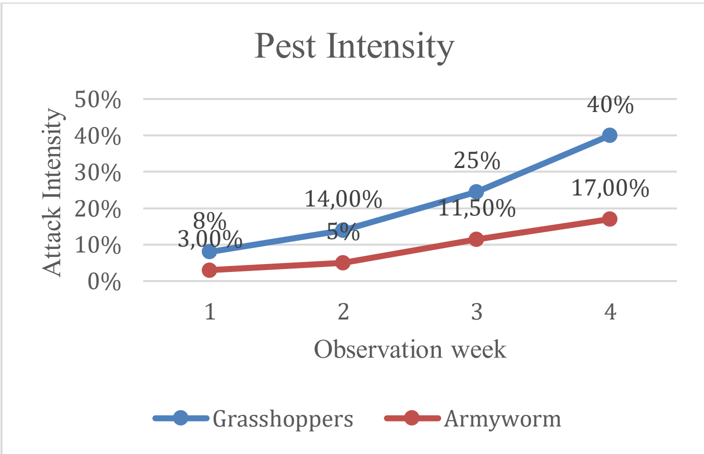
attack. The high incidence of armyworms is influenced by the availability of abundant host plants and irregular planting times. Uneven planting times in a field will result in the continued availability of hosts and food preferred by *S. frugiferda* (young corn plants) (Hartina and Toana, 2023). These two pests primarily attack leaves, resulting in reduced leaf area and negatively impacting photosynthesis and corn plant growth. This condition has the potential to reduce corn yields if pest control is not implemented promptly (Hawiah *et al*., 2022).

Table 4. Intensity of Grasshoppers and Armyworm Attacks on Corn Crops (%)

Pest	Week of Observation			
	1	2	3	4
Grasshoppers	8.00	14.00	24.50	40.00
Armyworm	3.00	5.00	11.50	17.00



Graph 2. Intensity of Grasshoppers and Armyworm Attacks on Corn Crops

Based on Table 4, the intensity of grasshopper attacks on corn crops during the four weeks of observation was consistently higher than that of armyworms. In the fourth week, the intensity of grasshopper attacks reached 40%, classified as moderate, while all observations of armyworms showed an intensity below 25%, classified as mild. The higher intensity of grasshopper attacks is thought to be related to the availability of primary hosts, namely wild grasses that thrive in corn fields (Rondo *et al*., 2016). This development is further supported by increased rainfall at the start of the rainy season, which increases grass populations and provides an ideal food source and habitat for grasshoppers to breed. Pest activity and reproduction are highly dependent on environmental suitability and adequate food sources, so land environments with dominant grass cover tend to trigger an increase in grasshopper populations (Ainun *et al*., 2023).

The low intensity of armyworm attacks in this study was primarily influenced by the incompatibility of weather conditions during the observation period with the climate preferences required by *S. frugiperda*. Ecologically, *S. frugiperda* thrives optimally in warm, humid environments with moderate rainfall, thus increasing larval feeding activity and survival (Arsi *et al*., 2023). In contrast, the study was conducted at the beginning of the rainy season, when rain fell almost daily, potentially causing some eggs and larvae to be washed away or killed by the high rainfall. This finding aligns with Widhayasa and Darma (2022), population fluctuations and armyworm attacks on corn are closely related to weather factors, with the dry season showing higher attack rates than the rainy season because high rainfall acts as a form of natural physical control in the field by reducing the population and activity of armyworms.

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Pest control for grasshoppers and armyworms on corn crops can be carried out using an Integrated Pest Management (IPM) approach, which includes land preparation and sanitation such as turning over and cleaning plant debris to break the pest life cycle, monitoring populations to determine the right time for action, and utilizing natural enemies such as birds, spiders, and parasitoids to control pest populations biologically. In addition, the use of pest-resistant corn varieties and crop rotation are also important to prevent repeated attacks. When pest attacks are severe, selective insecticide spraying at the appropriate dosage can be carried out while still paying attention to the preservation of natural enemies so that pest resistance does not occur. This approach aims to maintain the balance of the ecosystem and ensure that corn productivity remains optimal (Sembel, 2010).

Disease attacks

Leaf blight is one of the important diseases of corn plants that attacks the leaves, and severe infestations can significantly reduce production yields (Hamidson *et al*., 2023). The symptoms of leaf blight appear as brown spots on the leaves (Figure 4). The initial infection shows symptoms of small, oval-shaped spots that elongate into ellipses and then develop into necrotic lesions (called blight), which are grayish-green or brown in color. These spots first appear on the lower leaves and then spread to the upper leaves. Severe infection caused by leaf blight can result in rapid wilting or drying of corn plants (Riri *et al*., 2023).

Downy mildew is characterized by small chlorotic spots on the leaves that develop into parallel bands aligned with the main leaf veins, appearing white to yellowish on the leaf surface (Figure 5). In addition, chlorotic lines follow this pattern. Downy mildew infection stunts plant growth and disrupts cob formation. In severe cases, plants may fail to form cobs altogether (Muis *et al*., 2018).

Figure 3. Symptoms of Leaf Blight Disease Attac

Figure 4. Symptoms of Downy Mildew Disease Attack

Table 5. Incidence of Leaf Blight and Downy Mildew Disease Attacks on Corn Plants (%)

Disease	Week of Observation			
	1	2	3	4
Leaf Blight	68.00	84.00	98.00	100.00
Downy Mildew	26.00	54.00	76.00	84.00

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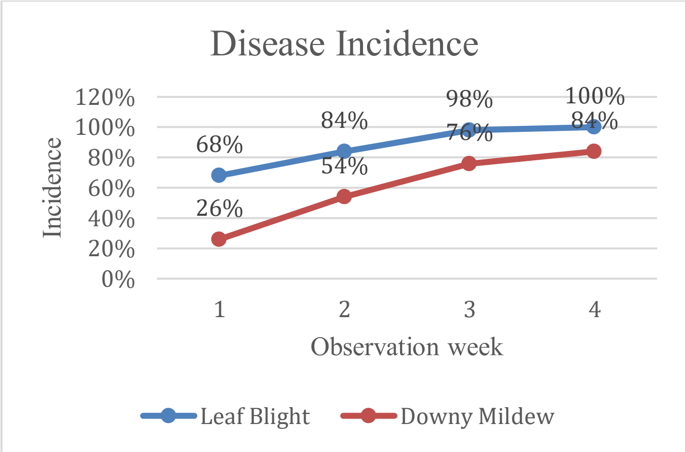
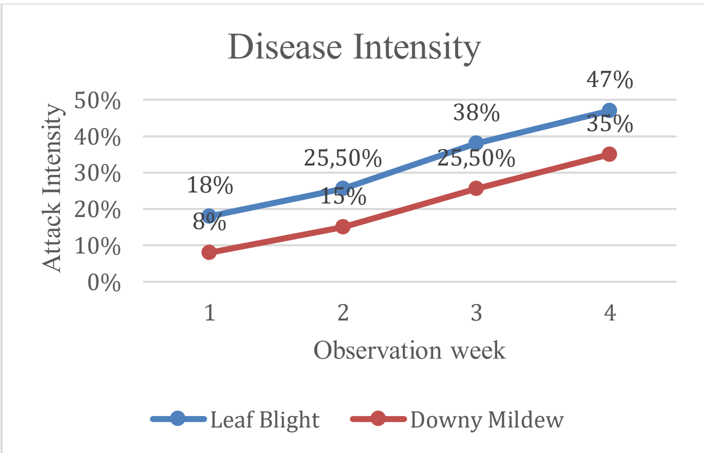


Graph 3. Incidence of Leaf Blight and Downy Mildew Disease Attacks on Corn Plants

Based on Table 5, the incidence of leaf spot disease and downy mildew disease increased up to 100% and 84%. This high value indicates that almost all samples suffered from leaf spot disease and downy mildew disease. Both diseases are caused by fungi, namely *Bipolaris maydis* for leaf spot disease and *Peronosclerospora maydis* for downy mildew disease. The transmission activity of these diseases occurs in the form of conidia and is generally disseminated by wind through the air (Hamidson *et al*., 2023). This supports the rapid transmission of leaf spot disease from one plant to another easily. The spread of pathogens through wind and air can transmit pathogens over long distances (Sukorini and Roeswitawati, 2023).

Table 6. Intensity of Leaf Blight and Downy Mildew Disease Attacks on Corn Plants (%)

Diseases	Week of Observation			
	1	2	3	4
Leaf Blight	18.00	25.50	38.00	47.00
Downy Mildew	8.00	15.00	25.50	35.00



Graph 4. Intensity of Leaf Blight and Downy Mildew Disease Attacks on Corn Plants

Based on Table 6, the intensity of leaf blight and downy mildew attacks has increased. In the latest observation, the level of leaf blight attacks reached 47% and downy mildew reached 35% with a moderate category. The severity of the disease can usually be influenced by environmental factors. Leaf blight disease easily develops at air temperatures between 18-27°C and in humid conditions (Ramadona

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et al., 2023). Similarly, downy mildew infection is supported by high humidity (Sulfitri *et al*., 2024). This is supported by the high rainfall during the observation period, which caused the land to be foggy and humid. Conditions that support the growth of these fungi often occur during the rainy season, where high humidity can increase the risk of infection and exacerbate attacks (Sumarlin *et al*., 2018). According to Amara *et al* (2020), abiotic environmental factors, such as humidity and temperature, have a significant influence on the development of downy mildew and leaf blight, which can trigger an increase in the intensity of attacks.

This disease is caused by fungi, so it spreads easily and quickly. To overcome this, environmentally friendly control measures that take into account the ecology of the environment are needed. Integrated Pest Management (IPM) is an effective solution because it integrates monitoring of environmental conditions, land sanitation, the use of disease-resistant varieties, and good humidity management. All of these are very important to reduce the impact of this disease and maintain corn productivity. In addition, creating an optimal agronomic environment, such as adjusting planting distances to improve air circulation and regulating fertilization, also plays a role in preventing fungal growth. With this integrated and sustainable approach, fungal disease attacks on corn can be minimized without damaging the ecological balance in agricultural land (Muis *et al*., 2018).

Conclusion

This study highlights the vulnerability of corn crops in Maguwoharjo Village to pest and disease pressures, emphasizing the need for timely and well-coordinated management practices. The observed patterns indicate that both insect pests and fungal diseases can develop rapidly under favorable environmental conditions, reinforcing the importance of early identification and preventive action in maintaining crop health. The findings support the implementation of Integrated Pest Management (IPM) as a sustainable approach to reduce dependence on chemical inputs and preserve ecological balance. Future research is recommended to evaluate the long-term effectiveness of IPM components used in local farming systems, assess the contribution of natural enemies in regulating pest populations, and explore the potential of resistant varieties to enhance resilience against major pests and diseases.

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INCIDENCE AND INTENSITY OF PESTS AND DISEASES ATTACKING RICE PLANTS (*Oryza sativa* L.) IN WEDOMARTANI VILLAGE

(INSIDENSI DAN INTENSITAS HAMA DAN PENYAKIT YANG MENYERANG TANAMAN PADI (Oryza sativa L.) DI DESA WEDOMARTANI)

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Abstract

The increasing food needs of the Indonesian population underline the critical role of rice (*Oryza sativa* L.) in national food security, but production is often constrained by attacks from pests and diseases. This study aimed to determine the incidence and intensity of key pests (grasshoppers and rice bugs) and diseases (blast and tungro) in a rice field in Wedomartani Village through the application of a systematic W-pattern sampling technique. Observations were conducted four times over a 5-day interval, with samples taken from 50 rice plants. The quantitative approach used formulas to calculate the percentage of Disease Incidence and Disease Severity. The results showed a consistently increasing pattern of infestation for all pests and diseases throughout the observation period. Grasshopper incidence reached 100% by the third observation, with a peak intensity of 34.22% (moderate category) at the fourth observation. Rice bug incidence peaked at 98%, with an intensity of 18.22% (low category). Both blast and tungro incidence reached 100%, with blast severity peaking at 26.22% (moderate category) and tungro severity reaching 50.67% (moderately high category). The high levels of incidence and intensity are primarily supported by environmental conditions conducive to pest and disease development, such as high humidity for blast and the availability of preferred food sources for rice bugs. These findings affirm the urgent need for comprehensive Integrated Pest Management (IPM) strategies, including synchronized planting, field sanitation, and biological control, to secure optimal rice production in the area.

Keywords: *Grasshopper, Rice Bug, Tungro, Blast, Integrated Pest Management.*

Abstrak

Peningkatan kebutuhan pangan penduduk Indonesia menggarisbawahi peran penting padi (*Oryza sativa* L.) bagi ketahanan pangan nasional, namun produksinya sering terhambat oleh serangan hama dan penyakit. Penelitian ini bertujuan untuk mengetahui insidensi dan intensitas hama utama (belalang dan walang sangit) serta penyakit (blas dan tungro) pada pertanaman padi di Desa Wedomartani melalui penerapan teknik sampling sistematik pola W. Pengamatan dilakukan empat kali dengan interval 5 hari, dengan sampel diambil dari 50 tanaman padi. Pendekatan kuantitatif digunakan untuk menghitung persentase Insidensi Penyakit dan Keparahan Penyakit. Hasil penelitian menunjukkan pola serangan yang terus meningkat untuk semua hama dan penyakit selama periode pengamatan. Insidensi belalang mencapai 100% pada pengamatan ketiga, dengan intensitas puncak 34,22% (kategori sedang) pada pengamatan keempat. Insidensi walang sangit mencapai puncaknya pada 98%, dengan intensitas 18,22% (kategori rendah). Insidensi blas dan tungro sama-sama mencapai 100%, dengan keparahan blas mencapai puncak 26,22% (kategori sedang) dan keparahan tungro mencapai 50,67% (kategori sedang-tinggi). Tingginya tingkat insidensi dan intensitas ini utamanya didukung oleh kondisi lingkungan yang kondusif bagi perkembangan hama dan penyakit, seperti kelembaban tinggi untuk blas dan ketersediaan sumber makanan yang disukai bagi walang sangit. Temuan ini menegaskan perlunya strategi Pengendalian Hama Terpadu (PHT) yang komprehensif, termasuk penanaman serentak, sanitasi

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lapangan, dan pengendalian hayati, untuk mengamankan produksi padi yang optimal di wilayah tersebut.

Kata Kunci: *Belalang, Walang Sangit, Tungro, Blast, Pengendalian Hama Terpadu*

Introduction

The food needs of the Indonesian people continue to increase every year in line with the growing population. One of the main food commodities that plays an important role in supporting national food security is rice *(Oryza sativa* L.). According to the Central Statistics Agency (2022), the total rice production in Indonesia in 2021 was 54.42 million tons of milled dry grain (GKG), a decrease of 233.91 thousand tons from the 2020 production. One of the reasons for the decline in milled dry grain yield was the attack of plant pests and diseases. Losses due to pests and diseases can reach significant levels if proper control measures are not taken. One of the factors that causes ineffective control is the lack of accurate field data on the population and intensity of pest and disease attacks.

To support successful pest control, appropriate identification and monitoring activities are required through the application of sampling techniques. Sampling techniques serve to obtain representative data on the types, populations, and distribution of pests in crop fields (Eliott *et al.,* 2020). This data forms the basis for developing more effective and efficient control strategies in accordance with the principles of Integrated Pest Management (IPM).

The principles of Integrated Pest Management (IPM) include efforts to grow healthy crops, preserve and utilize natural enemies, conduct regular monitoring of pests, and place farmers as the main actors in the implementation of IPM. This principle aims to reduce pest populations to below the economic threshold, maintain ecosystem sustainability, and ensure optimal crop productivity (Sudewi *et al.,* 2020). To support the application of this principle, this study aims to identify the major pests and diseases that commonly affect rice crops and to describe the sampling techniques used to assess their incidence and intensity in the field.

Plant pests include various pests and diseases that can reduce rice productivity. Locusts and green leafhoppers are important pests that can damage plant tissue and transmit diseases. Locusts damage rice by eating the leaves, and they usually appear continuously from the beginning of planting until harvest season (Sarumaha, 2020). Green leafhoppers damage rice plants by sucking fluids from leaf tissue; this activity not only weakens the plants but also acts as the main vector for the spread of the tungro virus (Muzam and Nugroho, 2020). In addition to pests, blast disease (*Magnaporthe oryzae*) and tungro caused by the Rice Tungro Virus (RTV) are also serious threats at certain growth stages. To accurately detect the presence of these pests, sampling techniques are used as a systematic approach capable of producing representative data. Within the framework of Integrated Pest Management (IPM), sampling data serves as an important basis for determining the level of infestation and the need for control.

Materials and Methods

This study used a field survey design with both quantitative and qualitative approaches. The survey was conducted to identify the level and type of pest and disease attacks on rice plants. The quantitative approach was used to calculate the percentage of pest and disease attacks on rice plants, while the qualitative approach was used to describe the symptoms of pest and disease attacks on rice plants and the organisms that cause them.

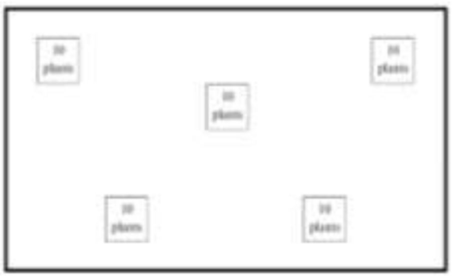

Figure 1. Sampling pattern

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The research population used is rice plants in a field in Wedomartani, Ngemplak, Sleman. The sample was taken using a systematic sampling technique with a W pattern. The observer walked across the field following a W-shaped path, and samples were taken at regular intervals along this path. A total of 50 rice plants located along the W transect line were selected as observation units, ensuring that the samples represented different sections of the field.

Observations of pests and diseases on rice plants were conducted from October to November, with an interval of 5 days, and were carried out four times. Each observation aimed to record the presence, population, and intensity of pest and disease symptoms at different growth stages of the rice plants. For rice bug and grasshopper pest observation, visual inspection was used to directly record the presence of pests by examining the leaves, stems, sheaths, and panicles for signs of feeding damage such as chew marks, discoloration, wilting, or deformation. For disease observation, visual inspection was also performed to identify the presence and severity of blast and tungro symptoms on leaves, stems, and other affected plant organs.

The collected data were analyzed descriptively to determine the incidence of pests and diseases (%) and the intensity of pests and diseases (%) using the IRRI scale (0-9). Based on Hafidhi *et al.* (2020), to quantify mean pest population and disease attack levels, the following formulas were used:

- The pest and disease incidence (%) was calculated using the formula:

  Pest and disease incidence (%) = $\frac{Number\ of\ affected\ plants}{Total\ number\ of\ observed\ plants}$ x 100

- The Pest and disease intensity (%) was determined using the IRRI 0–9 scale following the formula:

  Pest and disease intensity (%) = $\frac{(\sum(ni \times vi))}{(N\ x\ Vmax)}$ x 100

  Description:
  ni = number of plants in the i-th score category
  vi = intensity score
  N = total number of observed plants
  Vmax = maximum score (i.e., 9)

Assessment of plant damage due to pest attacks based on Wagiyanti et al. (2024) is described as follows:

Table 1. Description of plant damage

Scale	Description
0	no damage
1	damage of 1-25% (light)
2	damage of 25-50% (moderate)
3	damage of 50-75% (heavy)
4	damage of 75-100% (failure)

Assessment of disease severity is carried out using the Standard Evaluation System for Rice by IRRI (2013), with a description of disease symptom scores as follows:

Table 2. Description of tungro symptom severity score

Scale	Description
1	no symptoms
3	1-10% plant height reduction, with no distinct leaf discoloration
5	11-30% plant height reduction, with no distinct leaf discoloration
7	31-50% plant height reduction, with yellow to orange leaf discoloration
9	more than 50% height reduction, with yellow to orange leaf discoloration

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Table 3. Description of blast symptom severity score

Scale	Description
0	no disease
1	1 –5% attack of leaf area
3	> 5 –≤ 11% attack of leaf area
5	> 11 –≤ 25% attack of leaf area
7	> 25 –≤ 75% attack of leaf area
9	> 75 –≤ 100% attack of leaf area

Results and Discussion

Incidence of Pest and Disease in Rice

Table 4. Pest Incidence of Rice Bug and Grasshopper (%)

Pest	Obervation			
	1	2	3	4
Grasshopper	70%	92%	100%	100%
Rice Bug	26%	52%	68%	98%

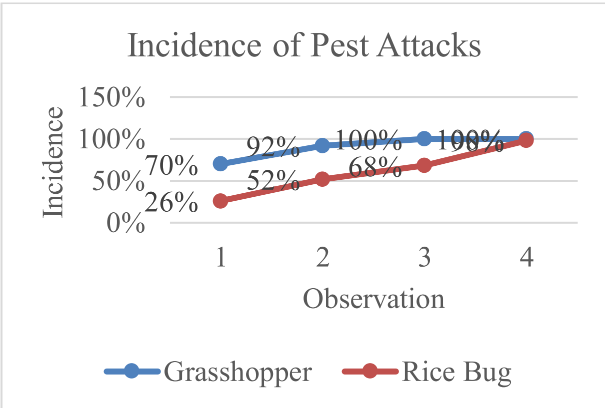

Figure 1. Pest Incidence

The incidence of grasshopper (*Valanga nigricornis*) infestation in rice showed a clear increasing pattern throughout the observation period. Based on Table 1, the first observation recorded 70% of plants being attacked, which increased to 92% in the second observation and reached the highest level of 100% in both the third and fourth observations. This increase in incidence indicates that the grasshopper population developed rapidly as the availability of fresh foliage increased during the vegetative phase of the rice crop. This finding is consistent with Anjani and Pribadi (2021), who reported that grasshoppers generally attack rice plants continuously from planting until harvest.

The rapid rise in incidence to 100% by the third observation suggests that environmental conditions at the study site were highly favorable for grasshopper development. The abundance of weeds provided an ideal food source and breeding habitat. Open field conditions also facilitated the movement and spread of grasshopper populations. Additionally, non-synchronous planting resulted in rice plants at varying growth stages within the same area, allowing grasshoppers to continuously find suitable food throughout the cropping period, thereby accelerating population growth. Climatic factors such as optimal rainfall, as well as suitable temperature and humidity, also played a significant role in supporting this population outbreak (Yudiawati *et al.,* 2025).

The incidence pattern of rice bug (*Leptocorisa acuta*) attacks increased more gradually. In the first observation, the infestation level was relatively low at 26%, then rose to 52% in the second observation. The incidence continued to increase as the crop entered the generative phase, reaching 68% in the third observation and surging to 98% in the fourth observation, which coincided with the grain-filling stage. This pattern is typical for rice bugs, as this pest is most active and damaging during the

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panicle formation to grain-filling stages, when the nutrient content of the developing grains is at its optimal level (Ishak *et al.,* 2024).

The high incidence of rice bug infestation in this study may also be influenced by environmental and agronomic conditions. The presence of wild grasses around the study area provides an alternative habitat where rice bugs can shelter and reproduce before moving onto rice plants. Another contributing factor may be the irregular planting schedule in the surrounding fields, which results in rice plants entering the generative phase earlier in some areas and attracting rice bug populations migrating from other fields. Rice bugs that have developed functional wings are capable of flying from harvested fields to unharvested ones in search of food sources (Sumini *et al.,* 2019).

Table 5. Disease Incidence of Blast and Tungro (%)

Disease	Obervation			
	1	2	3	4
Tungro	76%	100%	100%	100%
Blast	78%	96%	100%	100%

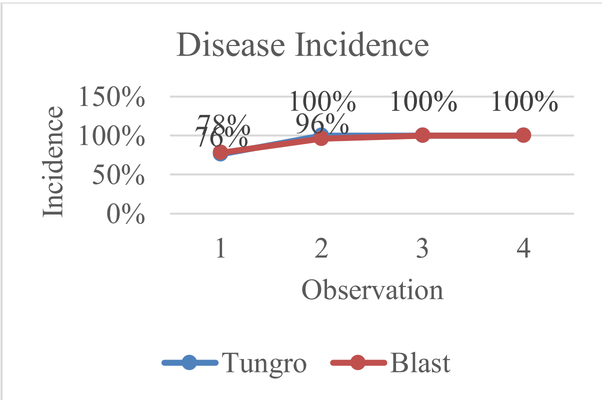

Figure 2. Disease Incidence

Field observations showed typical blast lesions such as spindle-shaped spots with grey centers and brown margins, which were widely distributed across leaves during the peak incidence period (IRRI, 2025). Based on Table 2, blast incidence showed a consistently high level of infection across all observations. At the first observation, 78% of plants exhibited blast symptoms, increasing to 96% at the second observation and reaching 100% at the third and fourth observations.

The increasing incidence up to the third observation indicates that disease development intensified as the crop entered the late vegetative to maximum tillering stage, which is known to be the most vulnerable phase to *Pyricularia oryzae* infection. This pattern is consistent with findings by Akhsan & Palupi (2015), who reported that blast intensity increases progressively during the vegetative phase, as young rice tissues are more susceptible to infection and microclimatic humidity increases as tillers develop. Their study also showed that the longer the crop remains in the field, the higher the blast intensity and spore abundance of *Pyricularia grisea*, indicating that disease development is strongly influenced by crop growth stage and environmental conditions.

The high incidence recorded in this study can be explained by environmental conditions that favor blast development. This disease commonly appears under high humidity, moderate temperatures ranging from 20–28°C, and shaded or poorly aerated areas where leaf surfaces remain moist for longer periods. Such conditions likely supported the rapid increase in incidence observed from the first to the third observation. This explanation is consistent with the findings of Suganda *et al.* (2016), who reported that blast incidence can rise sharply when environmental conditions are conducive, particularly under humid conditions. The literature also states that incidence levels above 90% fall into the “very high” category, confirming that field conditions strongly supported blast development during the observation period.

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Plants with tungro exhibited the characteristic yellow–orange discoloration and stunted growth commonly associated with tungro virus infection (IRRI, 2025). Based on Table 2, tungro incidence also increased during the observation period, although the pattern differed from that of blast. At the first observation, 76% of plants showed the characteristic yellow–orange tungro symptoms. This figure increased to 100% at the second observation and remained stable at 100% in the subsequent observations.

The observed pattern, in which an initial increase is followed by stabilization, indicates that tungro transmission occurred early in the growth period and reached saturation once most plants had been infected. This pattern is consistent with the epidemiology of tungro disease, which depends on the presence of the green leafhopper (*Nephotettix virescens*) as its vector. Unlike blast, tungro does not spread rapidly unless vector populations are high and actively feeding. The increase from 76% to 100% likely reflects early vector activity, after which transmission stabilized because vector abundance did not increase further. This explanation aligns with the findings of Yuliani (2014), who reported that tungro incidence often increases gradually and tends to plateau once the majority of plants in the field have been infected. In addition, rice plants in the vegetative phase are known to be more susceptible to tungro infection, which supports the infection pattern observed in this study.

Intensity of Pest and Disease in Rice

Table 6. Pest Intensity of Grasshopper Rice Bug (%)

Pest	Obervation			
	1	2	3	4
Grasshopper	8.00%	15.11%	25.33%	34.22%
Rice Bug	2.89%	7.56%	11.11%	18.22%

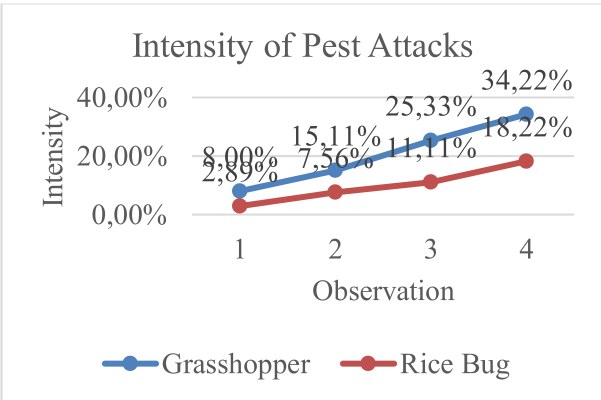

Figure 3. Intensity of Pest Attacks

Based on the observations, the intensity of grasshopper (*Valanga nigricornis)* infestation showed an increasing pattern as the plants aged. At the first observation, the intensity of leaf damage was 8.00%, which falls into the low category and is characterized by small bite marks on the leaf edges forming serrated patterns (Nurhadiah *et al.,* 2023). The intensity increased to 15.11% at the second observation and then rose significantly to 25.33% at the third observation. The highest value was recorded at the fourth observation with an intensity of 34.22%, which falls into the moderate category, defined as 25–50% damage intensity (Deptan, 2007).

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Figure 4. Grasshopper (*Valanga nigricornis*)

Figure 5. The Symptoms of Plant Damage Caused by Grasshoppers

This consistent upward trend indicates that the population and feeding activity of grasshoppers increased as the plants grew older. According to Nurhadiah *et al.* (2023), grasshoppers tend to attack rice during the vegetative phase, when leaf development and growth are relatively rapid, resulting in higher levels of damage. This condition can be influenced by various factors, such as the abundance of food sources in the field and environmental conditions. The life of insects is influenced by physical, biotic, and chemical environmental factors. Physical factors such as temperature, humidity, rainfall, and wind play significant roles. If all these factors support insect development, insect populations will increase (Wardani, 2017).

Based on the observations, the intensity of rice bug (*Leptocorisa acuta)* infestation also showed an increasing trend as the plants aged. At the first observation, the intensity was 2.89%, which is categorized as low. This low value occurred because, during the early growth stage of rice, panicles that serve as the main food source for rice bugs were not yet available. According to Ningsih *et al.* (2024), rice bugs typically feed by sucking the sap from rice grains in the milk stage, resulting in empty and unfilled grains. The intensity increased to 7.56% at the second observation and further increased to 11.11% at the third observation. The highest intensity occurred at the fourth observation, reaching 18.22%.

Figure 6. Rice Bug (*Leptocorisa acuta*)

Figure 7. The Symptoms of Plant Damage Caused by Rice Bug

This increase aligns with the rice plant entering the generative stage, during which panicles begin to form and food sources for rice bugs become more abundant. According to Erdiansyah *et al.* (2021), intensity increases because rice bug feeding activity is most intense during the grain-filling phase up to the full-grain stage, when the nutrient content of the panicles is at its highest. The highest value of 18.22% indicates that although the infestation is still in the moderate category, it is significant enough to affect grain quality. Several factors support the presence and development of rice bugs in the field, including varietal characteristics such as the number of tillers and grain color, as well as environmental and climatic conditions (Paputungan, 2020).

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Table 7. Disease Intensity of Blast and Tungro (%)

Disease	Obervation			
	1	2	3	4
Blast	10.00%	16.44%	23.33%	26.22%
Tungro	12.44%	32.44%	39.56%	50.67%

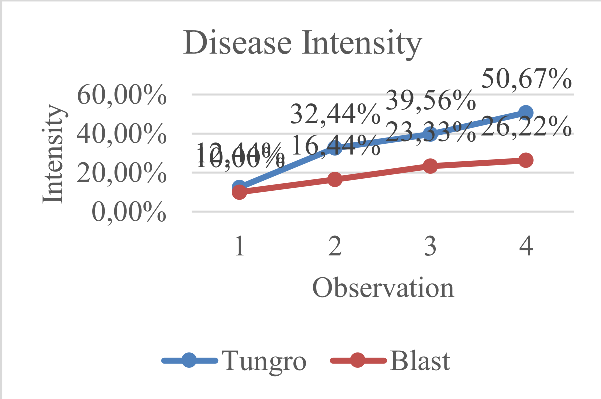

Figure 8. Disease Intensity

Based on the observations, the intensity of blast showed a gradual increasing pattern throughout the four observation periods. At the first observation, the blast severity reached 10.00%, which falls into the low category based on the IRRI scale. The intensity then increased to 16.44% at the second observation and continued rising to 23.33% at the third observation. The highest recorded value appeared at the fourth observation with an intensity of 26.22%, placing it in the moderate category according to IRRI severity levels (IRRI, 2013).

Figure 9. The Symptom of Rice Blast Disease

This upward trend aligns with the typical behavior of blast, which often intensifies under conducive environmental conditions. Blast development is strongly supported by high humidity, frequent leaf wetness, and temperatures ranging from 20–28°C, conditions proven to increase sporulation and lesion expansion (Prasad *et al.,* 2022). Furthermore, plants at the late vegetative to maximum tillering stage are known to be more vulnerable due to higher physiological susceptibility (Raveloson *et al.,* 2016). The moderate severity observed in this study is consistent with reports stating that field-level blast commonly ranges between 10–35% under natural tropical conditions (Agha *et al.,* 2023). According to Marzougui *et al.* (2021), progressive increases in blast severity are typical during periods of high rainfall and humidity, which enhance conidia germination and infection efficiency. The rise in severity from the first to fourth observation thus reflects a pattern commonly reported in blast epidemiology across rice-growing regions.

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Based on the observations, tungro severity exhibited a consistent upward pattern from the first to the fourth observation. At the first observation, the disease intensity was 12.44%, categorized as low. This value then increased substantially to 32.44% at the second observation, followed by 39.56% at the third observation, and reached its highest point at 50.67% during the fourth observation. These values indicate that tungro progressed from low to moderately high severity based on standard symptom scoring guidelines (Bangladesh Rice Research Institute, 2019).

Figure 10. Symptoms of Tungro Disease

This steady increase aligns with the known epidemiological pattern of tungro, where symptom development typically intensifies gradually because the virus depends on green leafhopper (*Nephotettix* spp.) activity for transmission. Although vector abundance was not directly measured, tungro progress commonly reflects the feeding and movement behavior of the leafhopper population (Cabauatan *et al.,* 2022). According to Yuliani *et al.* (2023), tungro spread often remains moderate unless leafhopper populations surge, as the virus is not airborne and relies entirely on vector-mediated transmission. The rising intensity through the vegetative phase is consistent with observations by De Costa *et al.* (2021), who reported that tungro symptoms become more severe as plants age due to cumulative viral replication and systemic spread. The intensity values in this study, peaking above 50%, also fall within the range documented in recent field surveys in Southeast Asia, where tungro severity can reach 40–60% under moderate vector pressure (Herlina *et al.,* 2022).

Application of Integrated Pest Management (IPM) on Rice Plants in Wedomartani

The implementation of Integrated Pest Management (IPM) in Wedomartani is carried out through several complementary strategies. Crop rotation serves as a crucial measure to break the life cycle of pests and pathogens while improving soil conditions, enabling rice plants in the following season to grow more healthily and vigorously. Farmers also use selective seeds to reduce the risk of seed-borne diseases and enhance plant resistance to pest attacks. Pest and disease control in the field is conducted using sulfur and silica, both of which are considered environmentally friendly inputs. Sulfur helps suppress the development of pathogenic fungi, while silica strengthens plant tissues, making them more resistant to piercing-sucking pests. Its occurrence is associated with environmental conditions such as the presence of weeds around the field and asynchronous planting patterns. These findings indicate that farmers in Wedomartani have implemented IPM principles effectively to reduce pest and disease pressure while minimizing excessive reliance on synthetic pesticides.

Integrated Pest Management (IPM) has begun to be implemented in Wedomartani Village, but only a few farmers have adopted it due to various limitations. One of the main obstacles is the farmers' limited understanding of IPM concepts and techniques, which leads them to prefer using chemical pesticides that are considered more practical. In addition, limited access to IPM-supporting resources and technologies, such as biological control agents or pest monitoring tools, also becomes a significant barrier. Economic factors also play a significant role, as limited capital makes it challenging for farmers to implement environmentally friendly control methods, leading them to opt for cheaper and more immediate solutions.

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The infestation of grasshoppers and rice bugs in rice can be controlled more effectively through the implementation of Integrated Pest Management (IPM). Cultural practices are highly recommended, such as synchronized planting to break the pest life cycle and reduce the continuous availability of food sources. Field sanitation, including the removal of weeds and alternative host plants, is also essential to reduce pest habitats. Biological control is another important component of IPM, utilizing natural enemies of grasshoppers and rice bugs such as insect predators (spiders and orthopteran predators from the families Gryllidae and Tettigonidae) as well as entomopathogenic fungi like *Beauveria bassiana* and *Metarhizium* spp. (Wardoyo, 2025).

IPM implementation to control blast and tungro can be carried out by selecting resistant or tolerant varieties as the first and most effective step in managing rice diseases. Field sanitation and crop rotation are also crucial to reducing sources of disease inoculum. The proper and timely application of fungicides, especially when environmental conditions favor disease development, such as high humidity for blast, is necessary to keep infections under control. Routine monitoring systems and early preventive actions can significantly suppress the spread of diseases (Wardoyo, 2025).

Conclusion

This study showed that four major rice pests and diseases, such as grasshoppers, rice bugs, blast, and tungro, were present throughout the entire observation period. The incidence of grasshoppers and blast increased to 100% starting from the third observation, while tungro reached 100% from the second observation, and rice bugs reached 98% in the fourth observation. The intensity of attacks also increased as the rice plants developed. The highest intensities were recorded in the fourth observation, namely 34.22% for grasshoppers (moderate category), 18.22% for rice bugs (light category), 26.22% for blast (moderate category), and 50.67% for tungro (heavy category). Overall, the results indicate that pest and disease pressure in the study area was high and increased consistently throughout the observation period.

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DEVELOPMENT AND EVALUATION OF A MODULAR HYDROPONICS WITH PELTIER COOLING SYSTEM FOR ROMAINE (*Lactuca sativa*) PRODUCTION

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Abstract

This study evaluated the quantitative performance of the fabricated modular hydroponics system integrated with a Peltier module as a rootzone cooling device to regulate and enhance the production of romaine lettuce. The experimental design fabricated and installed two treatment systems with identical modular hydroponics to compare the growth and yield results of conventional lettuce production without rootzone cooling (Treatment 1) and hydroponics with rootzone cooling (Treatment 2). The nutrient solution temperature was maintained between 20 to 22 ºC during daytime. Other water quality parameters including pH and electrical conductivity were also maintained within the recommended range during the 30 days growing period. The results of the statistical analysis using paired samples t-Test demonstrated significant differences at 5% level for yield performances. The analysis comparing the weight difference between the two treatments yielded a t-statistic of 2.654 with a p-value of 0.0139, where Treatment 2, significantly outperformed Treatment 1 in yield and efficiency. The final yield was 1390grams, this is significantly higher than Treatment 2, 1159grams. Economic feasibility yields a benefit-to-cost ratio of 1.85 and a return on investment of less than 2 years, justifying the P12,828.76 cost of initial investment. The results confirm that the integration of Peltier module in rootzone temperature management is a robust and economically viable strategy for maximizing the yield of romaine lettuce in modular hydroponics system.

Keywords : *modular hydroponics, rootzone cooling, Peltier module, romaine lettuce*

Introduction

Lettuce is considered to be one of the most important crops in the market that is used for salad, and since a lot of people have learned to appreciate the benefits that they can get from the green plants, especially the health benefits, lettuce has become popular and in demand in the markets. But lettuce production faces problems during its growing period in temperate areas of the Philippines. According to the Philippine Statistic Authority (PSA, 2021), the volume of lettuce production in Region III, increased from 1.86 cubic meters in the year 2018 to 7.02 cubic meters in the year 2019 to 7.58 cubic meters in the year 2020, representing an 8.0% change from the years 2019 to 2020. Due to the increase in demand for salad vegetables in the Philippines, lettuce nowadays has a high market potential, and since the demand for lettuce continues to increase, its continuous production is in need.

Planting lettuce in soil-based system is currently experiencing challenges such as natural disasters, climate change, and land infertility that are a product of using chemicals as well as pesticides (Nisha et al., 2018). Another problem is the weather conditions in the Philippines. Due to the tropical weather, growing lettuce in the lowland areas of the Philippines is seen to be impractical, yet the desire to produce is essential due to the rising demand (Capuno et al., 2014). Due to climate change, there are also threats in the form of rising temperatures, frequent dry periods, and the unpredictability of the weather patterns.

These are the serious problems in conventional soil-based agriculture that make the production of lettuce a real challenge.
With these, alternative ways of planting might be considered, like the hydroponic system. Hydroponic farming may be one of the current alternatives that can meet the need for fresh, secure, and nutritious vegetables. The plant that uses the hydroponic system grows faster and bigger because receiving nutrients from its surroundings requires less energy. As water becomes scarce and vital as a source, the implementation of hydroponics as well as other water-saving methods for crop production is necessary nowadays and become more popular over time. Hydroponics requires far less water than soil farming (Arya et al., 2018). Hydroponics, which grows in environmentally controlled horticulture, is becoming a more popular technique for producing products around the world. Its numerous methods involve sustainability and growth efficiency by regulating climatic and system parameters (Zajkowski and Short, 2021). Hydroponics application of cooling systems to help lettuce receive the required temperature can provide conducive growing environment at its best. The Peltier cooling system is one of the alternative technologies that can be used to regulate the water temperature when growing lettuce in lowland areas of the Philippines.

This study aimed to develop and evaluate a modular hydroponics system with the use of a Peltier cooling system for romaine lettuce (*Lactuca sativa*) production. Particularly, this study aimed to (1) set-up and fabricate the modular hydroponics with Peltier cooling system; (2) evaluate the growth and yield performance of the lettuce grown in the Peltier-cooled modular hydroponics system; and (3) perform simple cost analysis.

Materials and Method

A. Conceptual Framework of the Study

The concept of the study (Fig. 1) shows the application of a Peltier cooling system in a modular hydroponics system wherein vertical and intensified farming technique was used to intensify the planting density of the romaine lettuce. This helped to increase production thus may result to increase rate of recovering capital cost. The water together with the nutrient solution was cooled using the Peltier cooling system, and was recirculated throughout the modular hydroponic system, which cooled the rootzone area of the lettuce and provided a prolific environment for lettuce production. This will provide needed data to analyze the objectives of the study

INPUT	PROCESS	OUTPUT
1. Materials used for modular hydroponics with Peltier cooling system for lettuce production.	1. Fabrication and Installation.	1. Fabricated modular hydroponics with the use of Peltier cooling system.
2. Thermometer, pH and EC pen type meter.	2. Water quality parameters, lettuce growth and yield monitoring.	2. Data gathered for the water parameters, growth and yield of lettuce.
3. Water with added nutrient solution.	3. Water monitoring.	3. Data for water and area productivity.
4. Production, operating cost, and area productivity and	4. Recording of the production and operating cost of the system, and computation of area productivity.	4. Simple cost analysis and area productivity.

Figure 1. Conceptual Framework of the study using Input-Process-Output Flow Diagram.

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B. Recirculating Hydroponics and Cooling System

The recirculating hydroponics system was composed of hydroponic channel, net cup, distribution pipe, drainage pipe, water reservoir, and the steel frame. The material used for the hydroponic channel was the tubular polyvinyl carbon (PVC) pipe having a dimension of 100 x 10 x 6 cm, each channel has a hole with a center-to-center distance with 20 cm each. The holes distance that was based on the planting distance of the romaine lettuce. The net cup was placed inside the hole which served as an anchorage for the lettuce to stay in place and with perforations that allows the lettuce to absorb the nutrients inside the hydroponic channel. The net cup used has a dimension of 5.1 cm height and 2.5 cm in diameter. The distribution pipe conveyed the water from the water tank into the hydroponic channel. It was made of ½ inch PVC pipe. The drainage pipe carried the water directly from the bottom of the hydroponic system returning it back to the water reservoir and it was also made of ½ inch PVC pipe. The nutrient solution container used was an ice chest available in the market with a dimension of 50 x 38 x 35 cm. Placed inside the ice chest was the Peltier cooling system.

The whole cooling system was enclosed in a plastic container with a dimensions of 43 x 30 x 24 cm. The cooling system consists of two pieces fans, heatsink, cold radiator, 2 pieces of Peltier module, and temperature setter that was attached to the side of the container. A heatsink and a fan were attached to the hot side of the Peltier module to remove the excess heat. The cold part of the Peltier was attached to a radiator which allows the water to cool down up to the set temperature. The cooling system was connected to a 12V power supply that is powered by electricity. The overall capacity of the fabricated Peltier cooling system is 0.012 cubic meter The capacity of the ice chest was 70 liters and the capacity of the cooling system inside was 12 liters. With the use of the temperature setter, the temperature was set to 20ºC to meet the needed rootzone temperature of lettuce. The Peltier module control was set to automatically turned-on when the temperature reaches 22ºC and it automatically turned-off when the temperature becomes 20ºC. A digital thermometer was used to double check that it reached the set temperature. The submersible water pump installed in the system assisted the nutrient solution circulation. It pushed the nutrient solution upward into the distribution pipe until it reached the top of the hydroponic system and then the water directly flows down to the drainage pipe by gravity force until it reached the water reservoir.

C. Experimental Design and Statistics

The design of the modular hydroponics system set-up was replicated. Two treatments were used for the study, the recirculating hydroponics system without cooling system and with cooling system, as Treatment 1 and 2, respectively. The data that was gathered and analyzed using the data analysis tool. The t-Test was used to evaluate if there was a significant difference between the two treatments that was used for the study.

D. Lettuce Production, Data Gathering and Monitoring

The romaine lettuce seeds were grown in seedling foam and were watered using sprinkler daily until the seeds germinated and ready to be transferred to the system. After 14 days from sowing and when three to four leaves emerged in all seedlings, the seedling foam was transferred carefully to the net cup and was transplanted into the hydroponics system. The hydroponic system set-up was grown for 30days inside a 300 x 300 x 220 cm greenhouse with an insect net.

The cooling system undergone calibration, pre-tested and recirculated for 24 hours before transferring the seedling on it. This is to ensure that the nutrient solution and the system was stable. The water temperature, pH and electrical conductivity (EC) were also tested before transferring the seedlings to the system. A simple water management was practiced during the conduct of the study. When the water level on the tank drops to 4 liters, additional water with nutrient solution will be added. The water parameters were checked every time that there was an addition of water to check the water quality by manual dosing. The quality of water inside the water reservoir was checked before starting to operate the Peltier cooling system, and it was done to maintain the good quality of water. The water quality parameters were checked using the pH-meter, EC-meter, and thermometer.

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In terms of the water quality, the water parameters were checked three times daily every 8:00 a.m., 2:00 p.m., and 6:00 p.m. The temperature of the water that was set on the Peltier cooler was 20ºC, while the pH was maintained between 6.0-7.0, and the EC was 1.2-1.8 mS/cm.

The plant growth parameters were measured every three days from transplanting until harvesting. This includes the length, width, and height. The lettuce was marked as sample and were measured on the longest and widest part of the leaf, and for the height from the bottom part to the top of the lettuce. The lettuce was harvested after 30 days and each was measured using a digital weighing scale.

Results and Discussions

A. Objective 1 – Modular Hydroponics System Design and Fabrication

The fabricated design of the modular hydroponic system applied with recirculating nutrient solution cooling system was used in rearing the romaine lettuce for 30days. The modular hydroponic system with peltier nutrient solution cooling system shown in Figure 2, were tested and calibrated for seven days to ensure that it is working properly. During the pre-testing, the highest ambient temperature taken was 35ºC and the lowest was 26ºC. In terms of the relative humidity (RH), the highest was 67%, and the lowest was 53%. The recorded water parameters showed that the highest temperature taken at Treatment 1 was 32ºC, while the lowest was 23ºC. For Treatment 2, the highest temperature taken was 25ºC and the lowest was 19ºC. In terms of pH level, Treatment 1 and Treatment 2 had an average pH level of 6, while in terms of EC of water, Treatment 1 has an average EC of 1.3 mS/cm and Treatment 2 had an average EC of 1.2 mS/cm.

The ambient temperature recorded the temperature comparison inside and outside the greenhouse at 8:00 a.m., 2:00 p.m., and 6:00 p.m. The average ambient temperature at 8:00 a.m. was 33.66ºC, 38.96ºC, at 2;00p.m., and 30.12ºC at 6:00 p.m. Ambient temperature influences the speed at which the plants process the energy, and changes in temperature had a direct effect on the process of photosynthesis, which will influence the growth and development of plants (Chia and Lim, 2022). The RH inside and outside of the greenhouse, taken every 8:00 a.m., 2:00 p.m., and 6:00 p.m. Observation showed that the average RH at 8:00 a.m. was 55%, while at 2:00 p.m. the average was 39%, and at 6 p.m. the average RH was 62%. The RH affects the leaf transpiration rate and can influence the water balance in the crop. An RH that is below the optimum level increases the resistance of the stomata, which leads to a reduction in carbon dioxide uptake as well as the photosynthesis rate (Chia and Lim, 2022).

Figure 2. The modular hydroponics and the peltier cooling system

The nutrient solution temperature was monitored and recorded and found that the average temperature for Treatment 1 was 27.2ºC, while at 2:00 p.m. it was 35.1ºC, and 30.4ºC at 6:00 pm. For the average temperature of Treatment 2, it was 20.8 ºC , 29.4ºC, and 26.8ºC, respectively. The nutrient solution tank temperature and the yield performance of the lettuce showed that providing a cooling system affected the production of lettuce. One of the important hydroponic characteristics was the necessity and ability to control the temperature of the nutrient solution. Growth and development can be affected when the temperature is above or below the optimum level. Having high temperatures in the root zone will result in reduced leaf, stem, and fresh and dry weight (Thakulla et al., 2021).

The daily pH taken on the water tank for both treatments for Treatment 1, the average pH at 8:00 a.m. and 2:00 p.m. was 6.46, while at 6:00 p.m. it was 6.49; while in Treatment 2, the average pH level was 6.29, 6.35, and 6.36, respectively. The pH recorded data showed that Treatment 1 had a higher pH level with an average of 6.47 level compared to Treatment 2, which has a pH level of 6.33. The behavior of pH was affected by the daytime temperature, and lower temperatures had a more stable pH compared to higher temperatures (Sulit, 2019).

The daily average EC of the nutrient solution for Treatment 1, was 1.4 mS//cm and 1.5 mS/cm for Treatment 2. High electrical conductivity decreases the possibility of water absorption by the plant as well as photosynthesis (Cometti et al., 2013). High fertilization can result in marginal leaf burn (Henry et al., 2018). The recommended range of EC was between 1.2 and 1.8 mS/cm was attained throughout the duration of the study.

B. Objective 2 – Growth and Yield Performance of Lettuce

The growth parameters, such as plant height, leaf length, and width, were measured and recorded. . Figure 3 presented that Treatment 1 and Treatment 2 have a significant difference in terms of leaf length, width and length, showing that the application of rootzone cooling for modular hydroponics helps the romaine lettuce leaf, as Treatment 2, to have better growth compared to the Treatment 1 that does not have a cooling system.

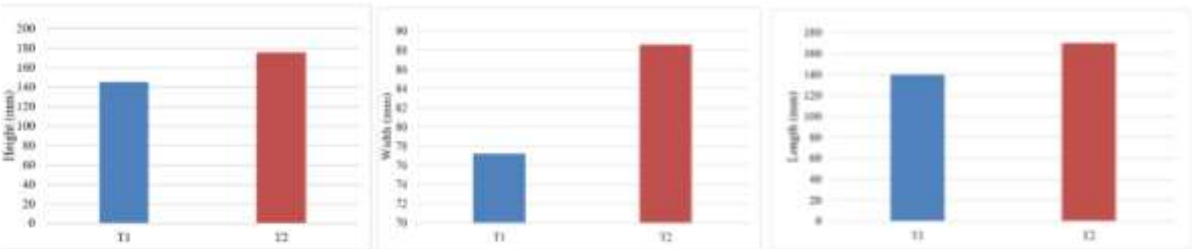

Figure 3. Average plant height, width and length of romaine lettuce

In terms of the yield of the lettuce, the result of the paired samples t-test calculation as showed in Table 1. Since the calculated p-value is approximately 0.0139 which is less than the standard significance level of 0.05, the result is statistically significant. This means that there is a statistically significant different in weight between Treatment 1 and Treatment, with Treatment 2 having a significantly higher mean weight of 54.8 grams compared to Treatment 1 (46.8 grams). T-test performed was shown in Table 4, and it showed that the two treatments had a significant difference in terms of their yield performance, and the treatment with rootzone cooling can produce a higher yield compared to the conventional hydroponics. Further checking of the results using traditional t-distribution table to find the critical value using the degrees of freedom and significance level at 0.05, two-tailed, gave a critical value (t_{crit}) of ±2.064. Since the calculated absolute t-statistic (|2.654|) is greater than the critical value (2.064), this confirms the finding of a significant difference.

Table 1. Paired samples T-test results of yield performance of lettuce

Group	N	Mean	SD	t	df	p-value
Treatment 1	25	46.8	9.92	2.654	24	0.0139*
Treatment 2	25	54.8	9.90			

*significant at 5%level

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Results of the experimental study shows significant effect of the provision of temperature control on lettuce production under lowland tropical condition with limited time of operation as well as limited temperature window and control. A similar study by Niam and Suhardiyanto in 2019 proved that treatment with rootzone cooling on leafy vegetables has higher yields than the treatment without rootzone cooling, the study revealed that 25ºC has 37.7% higher yields and 30ºC has 61.4% higher yields compared to the treatment that has no rootzone cooling.

C. Objective 3 – Cost Analysis

The cost analysis of the two treatments in terms of benefit-to-cost ratio and return on investments was summarized in Table 2. The investment cost includes the operational cost and the fixed capital investment (FCI). The operational cost was computed at ₱6469.19 which includes the seed cost, electricity, nutrient solution, and water cost projected for one year lettuce production. The material cost was divided based on the life span of the materials used, and the lowest life span was five years, and the total FCI was ₱4040.00, which resulted to a total investment cost of ₱10,509.19. The fixed cost was computed as the sum of the average interest on investment (AIOI) and the depreciation cost. The AIOI was ₱427.91, while the depreciation cost was ₱1891.65, and with that the total fixed cost was ₱2319.57. The total cost was ₱12,828.76 which was computed by adding the investment cost and fixed cost.

The gross income after 1 year was attained after multiplying the total yield (kg) by the market price of romaine lettuce and computed with 10 cycles every year for planting intensity; that includes the one (1) week fallow period in between the production for sterilization purposes of the system. The amount computed for the gross income was ₱7460.83. The net income was computed with the used of the gross income subtracted by the FCI, and the computed net income was ₱3420.83.

Table 2. Benefit-to-cost ration and return on investments of the lettuce production

	T2	T1
Present value of benefits	₱7460.825	₱6,172.63
Present value of cost	₱4,040.00	₱4,794.80
Benefit-cost ratio	**1.846738861**	**1.626600875**
Average net income	₱4,420.83	₱3,377.83
Fixed capital investment	₱4040	3794.8
Return of Investment	**85%**	**63%**

The present value of the benefit was the gross income, which is ₱7460.83, and the present value of the cost was the computed FCI, which was ₱4040.00 and with that, the computed BCR was 1.85. The BCR should be equal or greater than 1, therefore the study was beneficial. The ROI was obtained with the use of the average net income and the FCI, and with that the ROI of the study was 85%. The comparison of cost analysis was shown also in the table and it showed that despite having a lesser cost of Treatment 1, Treatment 2 still has higher BCR and ROI.

Conclusion and Recommendations

Based on the findings, the results demonstrates that the modular hydroponics system with the application of Peltier device as rootzone cooling system, Treatment 2, offers significant advantages over the conventional uncooled system, Treatment 1, for romaine lettuce production. The statistical analysis confirmed a significant difference, where Treatment 2 presented a higher growth performance and total yield. The system based on the presented analysis demonstrated an economically viable alternative of crop production as based on the benefit-to-cost ratio. The return on investment validated the financial justification for the initial cost of the system with a short payback period of one year and eight months. This constitute to the possibility of integration of Peltier cooling device successfully in mitigating rootzone temperature stress, leading to a substantial improvement in both farm productivity and economic feasibility of romaine lettuce cultivation in modular hydroponics.

This study suggests to add sensory evaluation of the harvested romaine lettuce for better comparison in terms of the taste and quality of the produce. Further analysis on the effects of rootzone cooling on the physico-chemical characteristics of the lettuce leaves as well as the evapotranspiration process may also be investigated. The capacity of the modular hydroponic system can also be further intensify the production and to try other high valued crops for possible crop rotation.

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PENGARUH WAKTU PERENDAMAN EKSTRAK BAWANG MERAH DAN JUMLAH RUAS STEK PADA PERTUMBUHAN BIBIT KOPI ROBUSTA (*Coffea canephora*)

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Abstract

Robusta coffee production in Buleleng, Bali, faces a challenge due to the difficulty for farmers to independently produce high-quality seedlings. Vegetative propagation via cuttings is preferred, but poor rooting is a common issue, making the application of Plant Growth Regulators (PGRs) essential. This study addressed the research gap on optimizing the use of natural PGRs from a 75% red onion (Allium cepa) extract, which contains Auxin and Gibberellin. The experiment used a Factorial Completely Randomized Block Design (CRBD) with two factors: Soaking Time (L: 0, 15, 30, 45 minutes) and Cutting Node Number (R: 1, 2, 3 nodes). Results showed that both single factors and their interaction had a very significant effect (P<0.01) on almost all growth variables, including shoot length, shoot diameter, and root metrics, but not on the number of leaves. The analysis determined that the optimal treatment combination was L2R1 (30 minutes soaking time and 1 cutting node). This specific combination maximized the absorption of growth hormones, minimizing nutrient competition and evaporation for the 1-node cutting. L2R1 resulted in the highest values for shoot length (9.30 cm), shoot diameter (3.00 mm), and crucially, dry root weight (0.33 grams). This optimal combination provides a practical, effective, and efficient guide for farmers to produce high-quality Robusta coffee seedlings.

Keywords: Robusta Coffee, Cutting Number, Red Onion Extract, Growth.

Pendahuluan

Kopi merupakan salah satu komoditas perkebunan unggulan Indonesia. Komoditas ini memiliki peranan strategis dan signifikansi ekonomi yang tinggi, baik sebagai sumber devisa negara melalui ekspor maupun sebagai penopang utama perekonomian daerah dan sumber pendapatan bagi jutaan petani. Produksi kopi komersial didominasi oleh dua jenis utama di Indonesia: Kopi Arabika (*Coffea arabica*) dan Kopi Robusta (*Coffea canephora*). Jenis yang paling banyak dibudidayakan di Kabupaten Buleleng, Bali, adalah Kopi Robusta secara spesifik. Secara geografis dan suhu untuk tumbuh, jenis kopi yang paling banyak dibudidayakan di Kabupaten Buleleng adalah kopi robusta dengan 76 persen luas lahan dari total 11.033,87 hektar (Sumiarta, 2021). Salah satu daerah penghasil kopi robusta terbesar di provinsi Bali adalah Kecamatan Busungbiu khususnya Desa Sepang dan Pucaksari dengan luas lahan masing-masing 1.340 ha dan 909 ha (BPS, 2014). Berdasarkan data laporan Badan Pusat Statistik (BPS, 2022) Provinsi Bali, produksi kopi robusta di Kabupaten Buleleng mengalami penurunan di tahun 2021–2022. Penurunan ini mengindikasikan adanya permasalahan mendasar yang perlu diatasi untuk menjaga keberlanjutan dan meningkatkan daya saing komoditas ini.

Salah satu faktor utama yang berkontribusi pada penurunan produksi dan rendahnya mutu hasil adalah kendala dalam ketersediaan dan penyediaan bibit kopi yang bermutu secara mandiri oleh petani. Ketersediaan bibit unggul yang memadai adalah prasyarat yang tidak dapat diabaikan untuk mencapai hasil produksi yang maksimal dan berkelanjutan. Perbanyakan tanaman pada tanaman kopi robusta dapat dilakukan secara generatif (*seedling*), dan vegetatif (stek) namun, pengembangan kopi

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robusta secara generatif tidak disarankan karena akan membentuk populasi baru dengan sifat daya hasil yang bervariasi (Erdiansyah *et al.*, 2014). Perbanyakan vegetatif dengan metode stek menjadi alternatif yang lebih disukai. Metode stek dipilih karena beberapa keuntungan, seperti: memungkinkan tanaman lebih cepat berbuah, menghasilkan sifat turunan yang identik dengan induknya (*true-to-type*), dan bahan stek cukup melimpah. Selain itu cara berbanyakan vegetatif mempunyai beberapa keuntungan antara lain, lebih cepat berbuah, sifat turunan sama dengan induk, bahan stek cukup melimpah, sistem perakaran yang cukup kokoh menyerupai tanaman yang berasal dari perbanyakan generatif (Muningsih *et al*., 2019). Keberhasilan stek juga dipengaruhi oleh umur dan jenis klon, serta perlakuan yang diberikan pada bahan tanam. Penelitian terdahulu menunjukkan bahwa hasil pertumbuhan bibit kopi yang paling baik adalah pada perlakuan stek 1 ruas diikuti dengan perlakuan stek 2 ruas dan stek 3 ruas, pertumbuhan yang kurang baik pada perlakuan stek 4 ruas (Muningsih *et al*., 2018).

Perbanyakan stek menawarkan banyak keunggulan. Namun, tantangan yang sering dihadapi adalah rendahnya persentase stek yang hidup karena sulitnya pertumbuhan akar di tahap awal. Stek yang berhasil tumbuh akar seringkali memiliki akar yang sedikit dan pendek, tanpa akar tunggang, sehingga tanaman mudah roboh. Perlakuan dengan menggunakan Zat Pengatur Tumbuh (ZPT) eksogen menjadi sangat penting untuk mengatasi permasalahan perakaran ini. Zat Pengatur Tumbuh (ZPT) merupakan senyawa organik yang memiliki fungsi penting dalam mengatur, merangsang, atau bahkan menghambat berbagai proses fisiologis pada tanaman (Wiryanata *et al*., 2025). Terdapat kecenderungan untuk mengganti ZPT sintetis (seperti auksin, contohnya Rootone F, yang relatif mahal dan sulit didapat) dengan ZPT alami dalam praktik pertanian organik modern. Penggantian ini bertujuan untuk menghindari risiko residu kimia pada tanah dan tanaman. ZPT alami memiliki keunggulan karena bersifat ramah lingkungan, mudah didapat, dan aman digunakan (Sutriono & Rumondang, 2020). Ekstrak umbi bawang merah (*Allium cepa*) merupakan salah satu sumber ZPT alami yang potensial. Bawang merah, selain sebagai rempah unggulan, memiliki kandungan hormon pertumbuhan alami seperti Auksin dan Gibberellin, serta Rhizokalin.

Bawang merah merupakan salah satu rempah-rempah unggulan di Bali yang sangat fluktuatif harga maupun produksinya (Wiryanata dan Owa, 2021). Secara umum bawang merah memiliki kandungan hormon pertumbuhan berupa hormon Auksin dan Gibberellin, sehingga dapat memacu pertumbuhan bibit (Marfirani, 2014). Hormon ini membantu merangsang terbentuknya akar, baik akar primer maupun akar sekunder. Menurut Nengsih dan Deska W. (2021) perlakuan (750 gram bawang merah pada 1 liter aquades) memberikan hasil peningkatan presentase stek hidup 47,37%, presentase stek tumbuh tunas dan akar 83,51%, Panjang tunas 106,06%, jumlah akar 98,03%, dan berat kering akar 225,27%. Menurut Kumara, Arimbawa dan Sutedja (2020) Pemberian konsentrasi ekstrak bawang merah 75% memberikan pertumbuhan setek kopi robusta yang terbaik yaitu pada koefisien partisi fotosintat akar serta berbeda nyata dibanding dengan pemberian perlakuan konsentrasi yang lainnya

Efektivitas ZPT, baik sintetis maupun alami, sangat dipengaruhi oleh sejumlah faktor. Faktor-faktor tersebut mencakup jenis tanaman, jumlah ruas stek, konsentrasi larutan, dan lama perendaman (Lakitan, 2000). Pemberian ZPT pada konsentrasi yang berlebihan dapat mengganggu fungsi sel dan menghambat pertumbuhan. Konsentrasi yang terlalu rendah mungkin tidak memberikan pengaruh yang berarti. Konsentrasi dan lama perendaman yang tepat diperlukan agar penyerapan ZPT berlangsung dengan optimal. Penelitian terdahulu oleh Irmayanti *et al.* (2021) menunjukkan bahwa lama perendaman ZPT alami ekstrak bawang merah selama 30 menit menghasilkan pertumbuhan tunas dan akar yang tertinggi. Terdapat kesenjangan penelitian (*research gap*) berdasarkan kondisi ini. Belum ada informasi yang memadai mengenai kombinasi optimal antara konsentrasi ekstrak bawang merah dan lama perendaman stek yang secara spesifik memberikan hasil pertumbuhan terbaik pada perbanyakan kopi robusta. Penelitian ini dilakukan untuk mengisi kesenjangan tersebut. Penelitian ini diharapkan dapat memberikan panduan praktis bagi petani kopi robusta di Buleleng dalam memproduksi bibit unggul secara mandiri.

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Metode Penelitian

Metode penelitian ini secara komprehensif menjelaskan aspek-aspek kunci yang diperlukan untuk mereplikasi percobaan perbanyakan kopi robusta secara stek. Bahan-bahan yang digunakan telah terperinci meliputi stek entres kopi robusta Klon BP 308 (tunas ortotrop), bahan pendukung seperti bawang merah, bambu, dan plastik, serta kebutuhan media tanam yaitu pasir, tanah top soil, dan cocopeat. Kelengkapan bahan kimia seperti Furadan dan wadah tanam seperti polybag ukuran 15 cm x 15 cm juga dicantumkan dengan jelas, memberikan gambaran utuh tentang kebutuhan material. Alat-alat yang digunakan pun tercakup secara spesifik, mulai dari alat pertanian seperti cangkul dan parang, alat pengukuran seperti jangka sorong dan timbangan digital, hingga alat dokumentasi, memastikan setiap tahapan penelitian dapat dilakukan dengan presisi dan terekam dengan baik.

Rancangan percobaan mengaplikasikan Rancangan Acak Kelompok Lengkap (RAKL) faktorial, sebuah desain yang kuat untuk penelitian pertanian yang melibatkan dua atau lebih faktor. Faktor pertama adalah pengaruh lama perendaman ekstrak bawang merah (L) dengan konsentrasi tetap 75%, terdiri dari empat taraf waktu perendaman: 0, 15, 30, dan 45 menit. Faktor kedua adalah pengaruh jumlah ruas (R) yang terdiri dari tiga taraf: 1, 2, dan 3 ruas stek. Kombinasi dari kedua faktor ini menghasilkan 12 unit perlakuan dengan tiga kali pengulangan, total unit percobaan menjadi 36. . Penjelasan mengenai pembuatan ekstrak bawang merah 75% juga diberikan secara kuantitatif, yaitu menghaluskan 750 gram umbi dan menambahkan akuades hingga volume total 1 liter.

Prosedur penelitianmelibatkan serangkaian langkah operasional yang esensial untuk validitas hasil, namun prosedur penanaman dan pemeliharaan perlu diperjelas lebih lanjut. Cara penanaman stek, perlakuan perendaman yang diikuti dengan penanaman dalam media campur (pasir, top soil, cocopeat) di polybag, dan pemasangan sungkup untuk menciptakan mikroklimat kelembapan tinggi harus dirinci. Detail penting lainnya adalah mengenai kondisi lingkungan tempat stek diletakkan, termasuk perlakuan naungan waring, frekuensi penyiraman, serta protokol perawatan dan pengendalian hama/penyakit. Dasar pengelompokan pada RAKL menjadi krusial; perbedaan intensitas cahaya atau kelembapan antar blok harus dijelaskan sebagai variabel yang dikontrol oleh pengelompokan untuk mengurangi variabilitas galat. Detail teknis dalam pembuatan ekstrak, seperti penggunaan blender atau ulekan untuk menghaluskan dan penggunaan kain saring untuk memisahkan ampas, juga penting untuk memastikan replikasi yang akurat. Parameter pengamatan (misalnya persentase hidup, jumlah dan panjang akar/tunas, waktu muncul akar) yang akan dicatat dan dianalisis juga perlu ditambahkan untuk melengkapi metode ini.

Hasil dan Pembahasan

Berdasarkan hasil analisis ragam diperoleh hasil signifikansi pengaruh lama perendaman ekstrak bawang merah (L) dan jumlah ruas stek (R), serta kombinasinya (L x R) seperti disajikan pada tabel 1.

Tabel 1. Signifikansi pertumbuhan bibit kopi robusta pada perlakuan lama perendaman ekstrak bawang merah dan jumlah ruas stek.

No.	Variabel	Faktor R	Faktor L	Faktor R X L
1.	Panjang tunas (cm)			
	45 hst	**	**	**
	59 hst	**	**	**
	73 hst	**	**	**
	87 hst	**	**	**
2.	Diameter tunas (mm)			
	45 hst	**	**	**
	59 hst	**	**	*
	73 hst	**	**	**
	87 hst	**	**	**

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3.	Jumlah daun (helai)			
	45 hst	tn	tn	tn
	59 hst	tn	tn	tn
	73 hst	tn	tn	tn
	87 hst	tn	tn	tn
4.	Luas daun total (cm)			
	45 hst	**	**	**
	59 hst	**	**	**
	73 hst	**	**	**
	87 hst	**	**	**
5.	Berat basah tunas (g)	**	**	**
6.	Berat kering tunas (g)	**	**	**
7.	Panjang akar (cm)	**	**	**
8.	Berat basah akar (g)	**	**	**
9.	Berat kering akar (g)	**	**	**
10	Volume akar (ml)	**	**	**

Keterangan: (R)= Jumlah Ruas; (L)= Lama Perendaman Ekstrak Bawang Merah; (RxL)= R interaksi L; (*)= berbeda nyata (5%); (**)= berbeda sangat nyata (1%); (tn)= berbeda tidak nyata

Seperti disajikan pada tabel 1, perlakuan lama perendaman ekstrak bawang merah berpengaruh sangat nyata terhadap semua variabel pertumbuhan stek kopi Robusta kecuali pada variabel jumlah daun. Hal ini disebabkan karena Auksin yang terkandung pada ekstrak bawang merah yang lama perendamannya sampai 30 menit bekerja dengan maksimal ke bagian jaringan tubuh tanaman dan diserap secara merata sehingga mampu merangsang pemanjangan sel dan perkembangan sel, yang di perkuat oleh faktor lingkungan seperti tersedianya air yang cukup pada media tanam, akan mempercepat terjadinya proses fisilogis yang menyebabkan pembelahan sel menjadi lebih cepat sehingga pertumbuhan panjang tunas pada stek berkembang secara maksimal, semakin panjang tunas yang dihasilkan, maka akan semakin besar pula diameter tunas tersebut. Meningkatnya diameter tunas berpengaruh juga terhadap berat basah tunas dan berat kering tunas. Disamping itu juga karena bawang merah mengandung auksin, thiamin, dan giberlin dimana Auksin berperan dalam memacu pertumbuhan akar dan tunas, sedangkan Thiamin (B1) merupakan vitamin yang bersifat esensial bagi metabolisme tumbuhan yang memiliki fungsi mempercepat pembentukan primodial akar, dan hormon giberlin berfungsi untuk menginduksi pertumbuhan dan pemanjangan stuktur tanaman. Hal ini sejalan dengan penelitian Aisyah *et al.* (2016) yang menyatakan bahwa pemberian zat pengatur tumbuh dengan konsentrasi dan lama perendaman yang tepat akan memberikan pengaruh terhadap pertumbuhan dan perkembangan tanaman. Dengan adanya Auksin, maka Ca^{2+} terlepas dari pektin dan senyawa pektin menjadi larut, sehingga dinding sel menjadi lunak. Lunaknya dinding sel mengakibatkan terjadinya peningkatan penyerapan air. Berat basah akar menunjukkan adanya kandungan bahan organik hasil metabolisme sel dan kandungan air di sel akar, semakin banyak air yang diserap oleh akar, maka akan semakin tinggi pula bobot basah akar begitupun sebaliknya. Hal ini sesuai dengan pernyataan Lakitan (2012), bahwa berat basah sangat dipengaruhi oleh kadar air pada jaringan stek, sedangkan bobot kering dipengaruhi oleh serapan unsur hara serta kandungan cadangan makanan pada stek. Besarnya bobot kering akar sangat berhubungan dengan tingginya volume akar dan panjang akar pada tanaman.

Tabel 2 data ini menyajikan hasil pengamatan pertumbuhan bibit di bawah berbagai kondisi perlakuan. Perlakuan utama melibatkan lama perendaman (L0-L3) dan posisi ruas (R1-R3) pada beberapa parameter pertumbuhan. Parameter pertumbuhan yang diamati meliputi panjang tunas, diameter tunas, jumlah daun, total luas daun, berat basah dan kering tunas, berat basah dan kering akar, volume akar, serta panjang akar. Pengukuran dilakukan secara bertahap pada 45, 59, 73, dan 87 hari setelah tanam (hst). Data mencerminkan adanya perbedaan signifikan antar perlakuan untuk sebagian besar variabel, mengindikasikan respon pertumbuhan yang bervariasi terhadap faktor perlakuan.

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Tabel 2. Pengaruh lama perendaman ekstrak bawang merah (l) dan jumlah ruas stek kopi robusta (r) terhadap panjang tunas per tanaman , diameter tunas per tanaman, jumlah daun per tanaman, total luas daun, berat basah tunas, berat kering tunas, berat basah akar, berat kering akar, volume akar, dan panjang akar.

Perlakuan	Panjang tunas per tanaman (cm)				Diameter tunas per tanaman (mm)				Jumlah daun per tanaman (helai)				Total luas daun (cm²)			
	45 hst	**59 hst**	**73 hst**	**87 hst**	**45 hst**	**59 hst**	**73 hst**	**87 hst**	**45 hst**	**59 hst**	**73 hst**	**87 hst**	**45 hst**	**59 hst**	**73 hst**	**87 hst**
L0 (Kontrol)	0,56 c	0,94 b	1,82 d	2,54 d	0,48 c	0,79 c	1,14 c	1,50 c	1,11 a	2,56 a	4,33 a	6,44 a	1,02 b	2,12 b	5,79 c	9,05 c
L1 (15 Menit)	0,67 b	1,02 b	3,42 c	4,34 c	0,74 b	1,01 b	1,34 b	1,73 b	1,33 a	2,44 a	4,78 a	6,78 a	0,97 b	2,18 b	5,89 b	9,28 b
L2 (30 Menit)	0,99 a	1,54 a	5,47 a	6,67 a	0,98 a	1,26 a	1,59 a	2,06 a	1,67 a	2,78 a	4,67 a	6,89 a	1,06 b	2,25 b	5,92 b	9,46 b
L3 (45 Menit)	0,70 b	1,07 b	4,16 b	5,19 b	0,70 b	0,99 b	1,31 b	1,67 b	1,22 a	2,56 a	4,67 a	7,22 a	1,69 a	2,74 a	6,18 a	9,77 a
BNT 5%	**0,09**	**0,17**	**0,5**	**0,42**	**0,09**	**0,11**	**0,12**	**0,12**	**tn**	**tn**	**tn**	**tn**	**0,10**	**0,16**	**0,13**	**0,21**
R1 (Ruas 1)	0,89 a	1,41 a	4,14 a	5,07 a	0,81 a	1,11 a	1,48 a	2,02 a	1,50 a	2,83 a	4,67 a	6,42 a	1,05 b	2,20 b	5,88 b	9,19 b
R2 (Ruas 2)	0,68 b	1,04 b	3,38 b	4,53 b	0,66 b	0,92 c	1,22 c	1,62 b	1,42 a	2,58 a	4,83 a	7,08 a	1,00 b	2,18 b	5,85 b	9,36 b
R3 (Ruas 3)	0,62 b	0,98 b	3,63 b	4,46 b	0,71 b	1,01 b	1,35 b	1,58 b	1,08 a	2,33 a	4,33 a	7,00 a	1,50 a	2,59 a	6,11 a	9,63 a
BNT 5%	**0,08**	**0,15**	**0,43**	**0,37**	**0,08**	**0,09**	**0,10**	**0,11**	**tn**	**tn**	**tn**	**tn**	**0,09**	**0,14**	**0,11**	**0,18**

Perlakuan	Berat Basah Tunas (g)	Berat kering tunas (g)	Berat Basah Akar (g)	Berat kering akar (g)	Volume Akar (ml)	Panjang Akar (cm)
	87 hst	**87 hst**	**87 hst**	**87 hst**	**87 hst**	**87 hst**
L0 (Kontrol)	0,24 d	0,05 c	0,24 c	0,06 c	1,90 c	9,44 c
L1 (15 Menit)	0,38 c	0,10 b	0,37 b	0,10 b	2,45 b	11,72 b
L2 (30 Menit)	0,83 a	0,18 a	0,55 a	0,16 a	2,99 a	12,89 a
L3 (45 Menit)	0,49 b	0,10 b	0,36 b	0,10 b	2,53 b	9,86 c
BNT 5%	**0,04**	**0,03**	**0,06**	**0,04**	**0,35**	**0,73**
R1 (Ruas 1)	0,63 a	0,15 a	0,51 a	0,16 a	2,78 a	11,64 a
R2 (Ruas 2)	0,43 b	0,09 b	0,37 b	0,10 b	2,43 b	10,57 b
R3 (Ruas 3)	0,41 b	0,08 b	0,26 c	0,07 b	2,20 b	10,72 b
BNT 5%	**0,03**	**0,03**	**0,05**	**0,04**	**0,31**	**0,63**

Penelitian ini membandingkan pengaruh durasi perlakuan dan posisi ruas stek terhadap pertumbuhan tanaman, menunjukkan perlakuan L2 selama 30 menit secara signifikan menghasilkan panjang tunas tertinggi yaitu 6,67 cm dan diameter tunas terlebar 2,06 mm pada 87 hari setelah tanam (hst) dibandingkan kontrol L0 dan perlakuan lainnya. Jumlah daun, total luas daun, dan berat basah tunas menunjukkan peningkatan seiring waktu, tetapi perlakuan L3 (45 menit) menghasilkan total luas daun tertinggi 9,77 cm² pada 87 hst, meskipun L2 memberikan berat kering tunas, berat basah akar, berat kering akar, dan volume akar tertinggi. Posisi ruas R1 menghasilkan panjang dan diameter tunas yang superior dibandingkan R2 dan R3, dengan panjang tunas mencapai 5,07 cm dan diameter tunas 2,02 mm pada 87 hst. Ruas R3 menghasilkan total luas daun tertinggi 9,63 cm² pada 87 hst, namun R1 menunjukkan berat kering tunas, berat basah akar, berat kering akar, dan volume akar tertinggi. Kedua faktor, durasi perlakuan dan posisi ruas, secara nyata memengaruhi parameter pertumbuhan vegetatif dan akar, dengan perlakuan L2 dan ruas R1 umumnya memberikan hasil yang optimal pada sebagian besar parameter.

Tabel 3 menyajikan data hasil penelitian mengenai pengaruh perlakuan kombinasi antara lama perendaman ekstrak bawang merah (L) dan jumlah ruas (R) terhadap berbagai parameter pertumbuhan tanaman. Parameter yang diamati meliputi panjang tunas, diameter tunas, jumlah daun, total luas daun,

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berat basah dan kering tunas, berat basah dan kering akar, volume akar, dan panjang akar. Pengukuran dilakukan pada beberapa fase pengamatan yang berbeda, diakhiri pada umur 87 hari setelah tanam (hst). Analisis data memberikan informasi signifikan mengenai potensi kombinasi perlakuan tersebut dalam mengoptimalkan pertumbuhan vegetatif dan perkembangan akar.

Tabel 3. Pengaruh kombinasi antara lama perendaman ekstrak bawang merah dan jumlah ruas (L x R) terhadap panjang tunas per tanaman , diameter tunas per tanaman, jumlah daun per tanaman, total luas daun, berat basah tunas, berat kering tunas, berat basah akar, berat kering akar, volume akar, dan panjang akar pada umur 87 hst.

No	Perla-kuan	Panjang tunas per tanaman (cm)				Diameter tunas per tanaman (mm)				Jumlah Daun (helai)				Total Luas Daun (cm^2)			
		45 hst	**59 hst**	**73 hst**	**87 hst**	**45 hst**	**59 hst**	**73 hst**	**87 hst**	**45 hst**	**59 hst**	**73 hst**	**87 hst**	**45 hst**	**59 hst**	**73 hst**	**87 hst**
1	L0R1	0,57 d	1,03 b	1,92 c	2,5 e	0,50 d	0,87 c	1,17 c	1,47 c	,00 a	3,00 a	4,67 a	6,00 a	0,90 c	2,11 b	5,76 b	8,87 c
2	L1R1	0,77 b	1,13 b	2,47 c	3,37 d	0,77 c	1,03 b	1,40 b	1,83 b	,67 a	2,33 a	5,33 a	6,33 a	1,02 b	2,17 b	5,89 b	8,92 c
3	L2R1	1,50 a	2,3 a	7,87 a	9,30 a	1,20 a	1,50 a	1,97 a	3,00 a	,00 a	3,33 a	4,33 a	7,00 a	1,18 b	2,14 b	5,91 b	9,52 b
4	L3R1	0,73 b	1,17 b	4,3 b	5,10 b	0,77 c	1,03 b	1,37 b	1,77 b	,33 a	2,67 a	4,33 a	6,33 a	1,09 b	2,37 b	5,96 b	9,44 b
5	L0R2	0,53 d	0,87 d	1,23 d	2,53 e	0,37 e	0,63 d	1,00 c	1,33 c	,33 a	2,33 a	4,33 a	6,33 a	0,97 c	2,05 c	5,71 c	9,05 c
6	L1R2	0,57 d	0,97 b	4,00 b	5,05 b	0,63 c	0,90 c	1,20 c	1,67 b	,33 a	3,00 a	5,00 a	7,67 a	1,00 c	2,16 b	5,91 b	9,41 b
7	L2R2	0,87 b	1,23 b	4,50 b	5,50 b	0,93 b	1,13 b	1,37 b	1,73 b	,67 a	2,33 a	5,00 a	6,33 a	0,93 c	2,29 b	5,90 b	9,42 b
8	L3R2	0,73 b	1,1 b	3,77 b	5,03 b	0,70 c	1,00 b	1,30 b	1,73 b	,33 a	2,67 a	5,00 a	8,00 a	1,12 b	2,22 b	5,89 b	9,55 b
9	L0R3	0,57 d	0,93 bc	2,30 c	2,60 e	0,57 d	0,87 c	1,27 b	1,70 b	,00 a	2,33 a	4,00 a	7,00 a	1,08 b	2,15 b	5,90 b	9,18 c
10	L1R3	0,67 bc	0,97 b	3,80 b	4,60 c	0,83 b	1,10 b	1,43 b	1,70 b	,00 a	2,00 a	4,00 a	6,33 a	1,02 b	2,27 b	5,88 b	9,58 b
11	L2R3	0,60 d	1,1 b	4,03 b	5,20 b	0,80 b	1,13 b	1,43 b	1,43 c	,33 a	2,67 a	4,67 a	7,33 a	1,05 b	2,32 b	5,95 b	9,44 b
12	L3R3	0,63 c	0,93 bc	4,40 b	5,43 b	0,63 c	0,93 c	1,27 b	1,50 c	,00 a	2,33 a	4,67 a	7,33 a	2,85 a	3,63 a	6,69 a	10,33 a
BNT 5%		**0,16**	**0,30**	**0,86**	**0,73**	**0,16**	**0,18**	**0,21**	**0,22**	**n**	**tn**	**tn**	**tn**	**0,17**	**0,28**	**0,23**	**0,37**

No	Perlakuan	Berat basah tunas (g)	Berat kering tunas (g)	Berat basah akar (g)	Berat kering akar (g)	Volume akar (mm)	Panjang akar (cm)
		87 hst	**87 hst**	**87 hst**	**87 hst**	**87 hst**	**87 hst**
1	L0R1	0,29 e	0,06 c	0,21 d	0,06 c	2,41 c	8,07 e
2	L1R1	1,28 a	0,08 c	0,36 bc	0,11 b	2,46 c	11,93 b
3	L2R1	0,67 b	0,35 a	1,11 a	0,33 a	4,41 a	16,17 a
4	L3R1	0,61 b	0,11 b	0,34 c	0,12 b	1,84 cd	10,40 c
5	L0R2	0,55 c	0,04 c	0,32 c	0,06 c	2,05 c	9,47 d
6	L1R2	0,45 d	0,15 b	0,41 b	0,14 b	3,21 b	12,53 b
7	L2R2	0,44 d	0,07 c	0,27 c	0,08 b	1,77 d	11,10 c
8	L3R2	0,43 d	0,10 b	0,48 b	0,11 b	2,69 b	9,17 d
9	L0R3	0,38 d	0,06 c	0,20 d	0,07 bc	1,24 d	10,80 c
10	L1R3	0,32 e	0,07 c	0,33 c	0,06 c	1,67 d	10,70 c
11	L2R3	0,27 e	0,11 b	0,27 c	0,08 b	2,81 b	11,40 b
12	L3R3	0,16 f	0,10 b	0,25 cd	0,08 b	3,07 b	10,00 c
BNT 5%		**0,07**	**0,05**	**0,10**	**0,07**	**0,61**	**1,27**

Pada tabel, data menunjukkan variasi dalam berbagai perlakuan yang mempengaruhi berbagai parameter pertumbuhan tanaman. Perlakuan L0R1 menghasilkan panjang tunas yang meningkat dari 0,57 cm pada 45 hst menjadi 2,5 cm pada 87 hst, dengan diameter tunas juga meningkat dari 0,50 mm menjadi 1,47 mm pada 87 hst. Jumlah daun dan luas daun per tanaman juga mengalami peningkatan,

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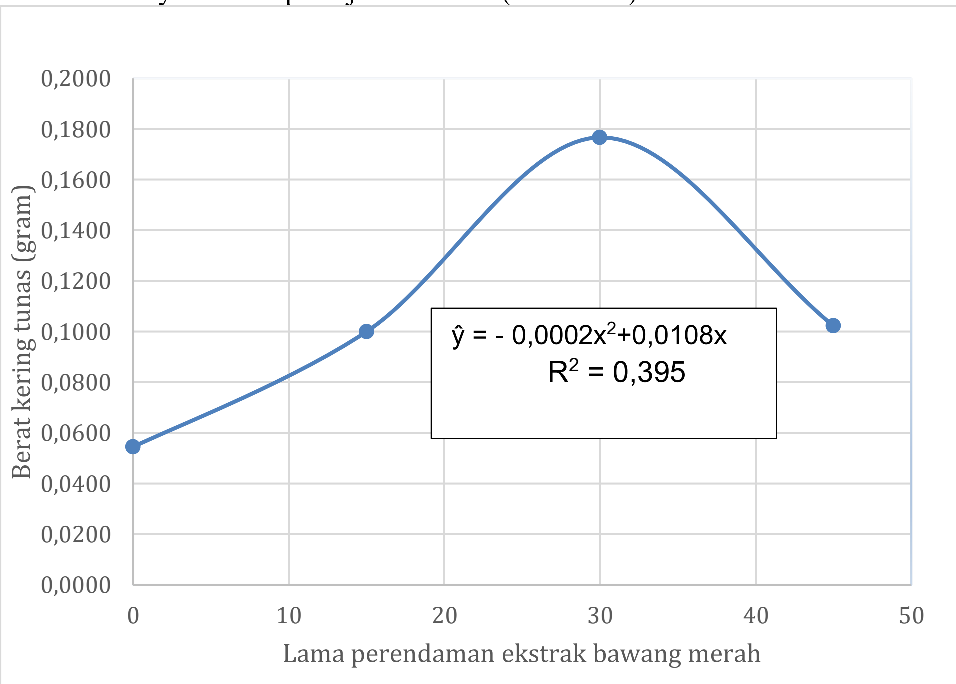
di mana jumlah daun pada 87 hst tercatat sebesar 6 helai dan luas daun 6,00 cm². Berat basah tunas juga menunjukkan peningkatan signifikan, mulai dari 0,90 g pada 45 hst hingga 8,87 g pada 87 hst, begitu juga dengan berat kering tunas yang bertambah dari 0,21 g pada 45 hst menjadi 0,06 g pada 87 hst. Perlakuan lain, seperti L1R2, memberikan hasil yang serupa dalam peningkatan panjang tunas dan diameter, serta jumlah daun. Perlakuan L2R1 bahkan menunjukkan hasil terbaik dengan panjang tunas mencapai 7,87 cm pada 73 hst dan diameter tunas 1,97 mm. Berat basah akar juga meningkat pada perlakuan ini, dengan berat basah akar mencapai 2,00 g pada 87 hst dan volume akar yang tercatat 2,41 mm. Peningkatan ini juga tercermin pada parameter lain, seperti panjang akar, yang tercatat 8,07 cm pada perlakuan L0R1 dan 16,17 cm pada perlakuan L2R1. Secara keseluruhan, berbagai perlakuan yang diterapkan pada setiap waktu pengamatan menunjukkan adanya perubahan signifikan pada berbagai parameter pertumbuhan tanaman, mencerminkan pengaruh positif dari perlakuan yang berbeda terhadap perkembangan tanaman.

Berdasarkan hasil analisis regresi pada berat kering tunas yaitu lama perendaman optimum di dapat pada lama perendaman 30 menit dengan nilai regresi (R = 0,395). Hal ini didukung oleh sebagian besar variabel lainnya kecuali pada jumlah daun (Gambar 1).



Gambar 1. Uji Regresi lama perendaman ekstrak bawang merah terhadap variabel berat kering tunas.

Hasil sidik ragam menunjukkan bahwa perlakuan jumlah ruas stek berpengaruh sangat nyata terhadap semua variabel pengamatan kecuali pada variabel jumlah daun. Hal ini terjadi karena stek 1 ruas memiliki jalur tercepat dalam proses pengiriman unsur hara dimana unsur hara yang sudah masuk ke jaringan akar tanaman, akan diangkut melalui pembuluh xylem dan floem. Pembuluh xilem mengangkut air dan mineral dari akar ke daun, sedangkan floem mengangkut nutrisi dari daun ke bagian tumbuhan lainnya. Hal ini menyebabkan pada perlakuan jumlah stek 1 ruas dapat menumbuhkan tunasnya lebih cepat, dan berpengaruh pada petumbuhan panjang tunas, diameter tunas, serta pada berat basah tunas dan berat kering tunas. Bintoro *et al* (2014), menyatakan bahwa semakin banyak kebutuhan akan bahan makanan maka akan terjadi persaingan. Semakin sedikit jumlah ruas yang dimiliki, maka persaingan untuk mendapatkan kebutuhan akan bahan makanan juga lebih sedikit, tetapi jika jumlah ruas yang dimiliki dalam skala jumlah yang banyak maka persaingan antar tunas yang tumbuh akan semakin besar untuk mendapatkan bahan makanan dan akan menghambat perkembangan tunas. Selain itu, panjang stek 1 ruas mengalami sedikit penguapan dibandingkan

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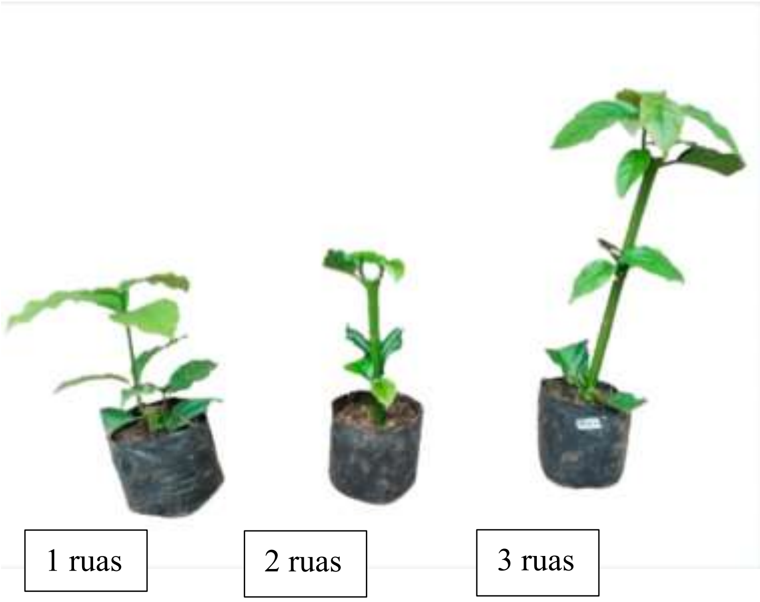
dengan panjang pada stek 2 ruas dan stek 3 ruas, hal ini dikarenakan semakin panjang ruas batang, akan terjadi banyaknya penguapan atau transpirasi yang akan mengakibatkan melambatnya pertumbuhan stek kopi robusta.

Hasil analisis sidik ragam menunjukkan bahwa interaksi antara lama perendaman ekstrak bawang merah dan jumlah ruas berpengaruh nyata terhadap semua variabel pengamatan kecuali pada variabel jumlah daun. Hal ini karena kedua perlakuan ini mampu bekerja secara bersama-sama untuk memberikan respon terhadap pertumbuhan stek bibit kopi Robusta, dimana pada perlakuan bahan stek sudah memiliki hormon pertumbuhan alaminya sendiri, namun dalam jumlah yang sedikit dan dalam kondisi tertentu tidak mampu memproduksi hormon secara maksimal. Maka dari itu, diperlukan ZPT atau hormon auksin tambahan yang diberikan dari luar yang sesuai dengan kebutuhan optimum stek kopi Robusta yaitu dengan lama perendaman ekstrak bawang merah 30 menit, sehingga pada perlakuan ini, dapat memberikan rangsangan yang mampu memacu pada proses pertumbuhan akar dan tunas pada stek. Sitorus, Irmansyah & Sitepu (2015) dalam penelitiannya menjelaskan bahwa untuk mempercepat tumbuhnya suatu tanaman perlu dibantu dengan pemberian ZPT auksin dari luar. Hal ini dapat dibuktikan degan kedua perlakuan ini pada semua parameter berpengaruh sangat nyata terhadap (panjang tunas, diameter tunas, total luas daun, berat basah tunas, berat kering tunas, berat basah akar, berat kering akar, panjang akar dan volume akar) kecuali pada parameter jumlah daun.

Hasil sidik ragam menujukkan bahwa pada perlakuan lama perendaman ekstrak bawang merah dan jumlah ruas stek tidak berpengaruh nyata terhadap variabel jumlah daun, dapat dilihat pada Gambar 1.



Gambar 2. Jumlah daun pada perlakuan lama perendaman ekstrak bawang merah selama 30 menit pada berbagai perlakuan jumlah ruas stek 1 ruas, stek 2 ruas, dan stek 3 ruas.

Pada gambar 2 menunjukkan bahwa jumlah daun pada masing-masing perlakuan jumlah ruas stek satu, dua, dan tiga pada lama perendaman ekstrak bawang merah 30 menit tidak berbeda nyata. Hal ini disebabkan karna pada tanaman kopi,daun tumbuh pada batang, cabang dan ranting. Pada bagian batang dan cabang daun yang tumbuh berselang-seling, sedangkan pada bagian ranting daun tumbuh pada bidang yang sama.

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Kesimpulan

Kesimpulan dari penelitian ini menegaskan bahwa penggunaan Zat Pengatur Tumbuh (ZPT) alami dari ekstrak bawang merah sangat penting dan berhasil dalam meningkatkan perbanyakan vegetatif bibit kopi Robusta. Hasil analisis menunjukkan bahwa perlakuan tunggal maupun kombinasinya memiliki pengaruh yang sangat nyata (meningkatkan) pada hampir semua variabel pertumbuhan bibit kecuali jumlah daun karena kandungan hormon dalam ekstrak bawang merah 75% memacu pemanjangan sel, perkembangan, dan pembentukan akar serta tunas secara maksimal. Perlakuan terbaik secara keseluruhan yang terbukti paling optimal adalah kombinasi L2R1, yaitu perendaman stek selama 30 menit dalam ekstrak bawang merah dengan menggunakan stek 1 ruas. Kombinasi optimal L2R1 ini menghasilkan nilai tertinggi pada parameter krusial seperti panjang tunas (9,30 cm), diameter tunas (3,00 mm), dan terutama berat kering akar (0,33 gram), yang secara signifikan meningkatkan kualitas bibit dibandingkan perlakuan kontrol. Sebagai implikasi praktis dan rekomendasi dari penelitian, temuan ini memberikan panduan yang praktis, efektif, dan efisien bagi petani kopi robusta, khususnya di Buleleng, untuk memproduksi bibit unggul secara mandiri, sehingga dapat mengatasi tantangan ketersediaan bibit bermutu dan mendukung keberlanjutan

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