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Analysis of N, P, K Content in Soil Planted with Edamame Beans (*Glycine max* (L.) *Merr*.) As an Intercrop on Land Where Oil Palm Plants Have Not Yet Produced

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Abstract

Edamame beans (*Glycine max* (L.) Merrill) are legumes with potential as intercrops because they can help improve soil fertility through their effects on nitrogen (N), phosphorus (P), and potassium (K) content. This study aims to determine the changes in soil nutrient content—specifically nitrogen, phosphorus, and potassium—before and after planting edamame beans as intercrops on oil palm immature plants (TBM). The research was conducted on smallholder oil palm TBM land in Bukit Lawang Bahorok, Langkat Regency, from May 2025 to May 2026, using descriptive statistical methods. Edamame was planted on five beds measuring 1 m × 10 m, with 1,500 seeds of the Japanese variety Ryoko 75. During the study, no fertilizer or mulch was applied, but weeding was carried out periodically to maintain plant growth. Laboratory analysis of soil samples assessed the nutrient content of N, P, and K before and after planting. The results showed that nitrogen content decreased from 0.07% to 0.06%, while phosphorus content decreased from 19.78 ppm to 11.87 ppm. These decreases likely occurred because plants absorbed high levels of nutrients during vegetative and generative growth. Meanwhile, potassium content increased from 0.06 me/100 g to 0.15 me/100 g. The primary advantage of this system is its high productivity, yielding 3,068 kg of edamame without any fertilizer or mulch application, demonstrating excellent cost-efficiency. Based on these findings, it can be concluded that planting edamame beans as an intercrop on oil palm TBM land affects soil nutrient dynamics—particularly by increasing potassium content—though it did not significantly increase nitrogen and phosphorus levels during the study period. Therefore, it is highly recommended that farmers adopt this intercropping system to optimize land use and generate early income during the oil palm immature phase. However, a low-dose supplementary application of N and P fertilizers is advised to prevent soil nutrient depletion.

Keywords: Crop Yield, Decomposition, Leguminosae, Ryoko 75, Soil Fertility

1. Introduction

Oil palm is a plantation crop that farmers in the plantation sector highly seek after. According to Astuti et al. (2020), oil palm is a superior agricultural commodity that is crucial for Indonesia, both economically, socially, and environmentally. It contributes significantly to foreign exchange earnings, employment, and national energy needs. Oil palm is a highly valued crop because its high-quality oil is widely used in various industries.

The growth of oil palm is divided into two phases: the Immature Plant (IMPACT) and the Mature Plant (PM). During the IMPACT phase, oil palm plants are in the initial growth stage and last 0–3 years. Therefore, selecting superior oil palm seeds is essential. According to Waruwu et al. (2018), seed quality is a key factor in cultivating this plant. However, the performance of these superior seeds will not be optimal without proper land management during the IMPACT period. Without cover crops, IMPACT land faces major problems, including a high risk of erosion from direct exposure to sunlight and rainwater, significant nutrient leaching, and increased weed growth that competes with oil palm seeds for water and nutrients. Prime land

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management is essential in oil palm cultivation. The quality of oil palm seeds is influenced by genetic factors, the planting medium, and sufficient nutrient availability.

In addition to functioning as ground cover, a more efficient strategy can be implemented by planting intercrops that not only provide soil protection but are also able to generate additional economic value. Edamame beans (Glycine *max)* are one of the potential intercrops to plant between rows of oil palms in the TBM phase (Saragi *et al*. 2023) This plant has a short life cycle, good market value, and can fix nitrogen through symbiosis with rhizobium bacteria, thereby increasing the soil's N, P, and K content. Furthermore, using soybeans as an intercrop can help farmers generate income during the TBM period and improve land-use efficiency (Haitami et al., 2020).

Another way to ensure income continuity is to plant intercrops before the oil palms begin to produce (0-3 years), when the canopy and roots are still relatively undeveloped. Furthermore, some of the rejuvenated land will be open and receive full sunlight, allowing it to be used for intercropping. This pattern provides additional income for oil palm farmers before they produce. (Herman & Pranowo, 2010) .

Intercropping in oil palm plantations is a system of planting one season in rows between oil palm plantations to utilize empty areas during the 1- and 2-year TBM period. (Hartawan, 2016) . The use of TBM areas in oil palm has several advantages, namely in optimizing land use as indicated by the Land Equivalent Ratio (LER), producing diverse products, obtaining additional yields, improving land fertility, and preventing erosion.

Edamame beans are a type of plant that has a high protein content. According to Hanafi et al. (2025), Edamame is a type of soybean originating from Japan and has a higher market value than regular soybeans. Edamame has been cultivated in China since 200 BC. It also contains higher levels of carbohydrates and protein than regular soybeans. (Prakoso et al., 2022) Other advantages of edamame beans include larger seeds, a sweeter flavor, and a softer texture than regular soybeans. This has led to increased demand for edamame pods, especially domestically.

Several previous studies have explored the potential of edamame as an intercrop. For example, research by Siregar and Lubis (2021) focused on the use of edamame as an intercrop in young rubber plantations, relying on high-dose organic fertilizer applications to maintain soil fertility. Meanwhile, Pratama et al. (2023) tested edamame cultivation between oil palm plantations (TBM). However, they relied heavily on the use of black-silver plastic mulch and intensive NPK fertilization to achieve optimal results.

The fundamental difference and novelty *of* this research lies in the testing of the Japanese variety Ryoko 75 as an intercrop on smallholder oil palm plantations without the use of fertilizer or mulch (zero input). This research not only measures edamame productivity under minimal-input conditions but also analyzes the dynamics of changes in soil macronutrients (N, P, K) before and after planting. This is important to demonstrate cost-effectiveness for smallholder farmers and to assess how much natural edamame residues improve oil palm soil fertility.

This study aims to determine the content of soil nutrients N, P, and K in the soil before and after planting edamame beans in TBM land.

2. Material and Methods

This research was conducted in the TBM area of the people's oil palm plantation in Bukit Lawang Bahorok, Langkat Regency. Geographically, the research location is at coordinates 3°32'45.2" North Latitude (N) and 98°07'12.0" East Longitude (E), with an altitude ranging from 100 to 108 meters above sea level (masl). The research was conducted from May 2025 to May 2026.

2.1. Tools and materials

The following tools and materials were used in carrying out the research: Material: Ryoko 75 Japanese Edamame seeds, as many as 1500 seeds, weighing 1 kg. Tools: Hoe, rake, watering can, measuring tape, and hand sprayer. The method used in this study was descriptive statistics. According to Sihombing et al. (2023), descriptive statistics are statistics used to analyze data by describing or depicting the data that has been collected without intending to draw conclusions that apply to the general public.

The implementation of the research includes several stages, namely:

2.2. Soil Sampling

Sampling is done by:

1. Determine the location point where the bed will be made.
2. Determine the center point of the bed.
3. Take soil samples by hoeing the end of the bed, the middle of the bed, and the end of the bed again in the middle of the entire bed.
4. Mix the soil sample in each bed on the tarpaulin until evenly distributed.
5. The soil sample was divided into four parts, discarding the top-right and bottom-left corners, and mixing the top-left and bottom-right corners again. This process was repeated until 1 kg of soil remained.
6. Soil samples were taken to the laboratory to determine the N, P, and K content in the soil before planting edamame beans.

2.3. Bed Preparation

The bed size in this study was 1m × 10m. The beds were made in dead space, observing the oil palm discs. The bed's location was measured by observing the leaf tips and discs. The distance between the beds and the oil palm plants was 2 m.

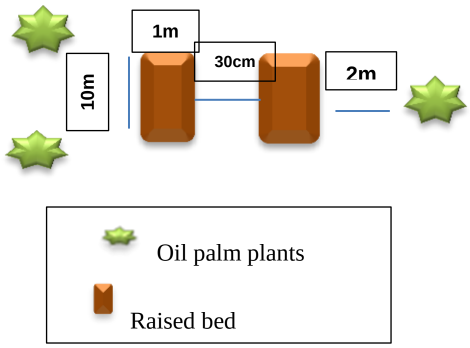

Figure 1. Planting Distance

2.4. Planting

Planting began on December 14, 2025. Seeds were planted using a single system at a depth of 2-3 cm. of planted 1-2 seeds per hole. The planting distance for edamame beans used can be seen in Figure 2 below.

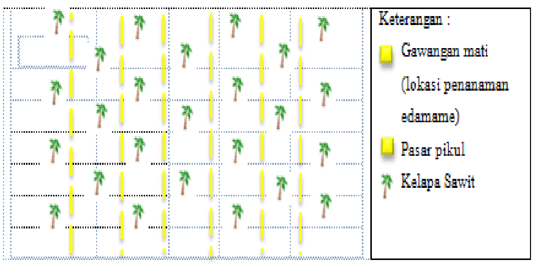

Figure 2. Overview of edamame planting location

2.5. Watering

According to (Argeshwara, DK, Rosyidin, ZU, Wibawa, AP, Handayani. AN, & Hadi, MS, 2023) The growth phase of edamame bean plants is important to get enough water at the age of 20-25 days after planting (DAP), flowering period (35-40 DAP) and during the pod formation and seed filling period (50-60 DAP). For plants aged 0-14 days, water once a day in the afternoon; after 14 days, water every 2 days.

2.6. Weeding

Weeding is done manually using a scraper and is done once a week.

2.7. Harvesting

Harvesting is carried out when the edamame plants are approximately 3 months old, characterized by yellowing leaves, leaf fall, most of the pods having ripened, and a brownish-yellow color. Ripe pods break easily when pressed. Harvesting is carried out at 70 days of age by uprooting the plants. The remaining plant matter in the soil can become organic matter, which plays a role in increasing soil fertility, particularly the nutrient content of N, P, and K.

2.8. Observation Parameters

Edamame beans are planted between oil palm plants using beds. The number of beds used in this study was 5 beds. Each bed is made with 150 planting holes. Each hole is planted with 2 edamame seeds.

The observations made were the levels of N, P, and K in the soil before and after. The levels of N, P, K in the soil of oil palm plants were as follows:

Soil fertility in the agricultural sector is very important for the continuity of plant growth. Soil fertility refers to the soil's capacity to produce desired plant products in its surrounding environment. Geographical location and different soil types influence soil fertility. Plants will grow healthily if their nutrient content is adequate. Macronutrients in soil include N (nitrogen), P (phosphorus), and K (potassium). NPK is the dominant nutrient in soil for plant survival.

Table 1. Range of nutrients N, P, K

Nutrient	Low	Currently	Tall
N (ppm)	<10	15	>15
P(ppm)	<2	3	>3
K(ppm)	<12	21	>21

2.8.1. Nitrogen (N) nutrient content

Nitrogen (N) is needed by plants for growth, especially in the formation or growth of vegetative parts of plants such as stems and leaves. Nitrogen deficiency in the soil can disrupt plant growth and development, and reduce crop yields.

Nitrogen (N) is a component of amino acids (proteins), nucleic acids, nucleotides, and chlorophyll; this makes plants greener, speeds overall growth, and increases protein content in the harvest (Okalia et al., 2022). The range of N nutrients according to the East Java Agricultural Technology Assessment Center is:

Low : <10 ppm
Medium: 15 ppm
Tall : >15 ppm

2.8.2. Phosphorus nutrient content (P)

Phosphorus (P) can stimulate root development, improve yield quality, and accelerate the maturity period. Nutrient P functions as a storage and distribution source of energy for all plant metabolic activities. Its positive effects include stimulating root growth, promoting tissue development, stimulating flower formation and fruit ripening, and increasing disease resistance (Okalia et al., 2022). The range of P nutrients according to the East Java Agricultural Technology Assessment Center is:

Low : < 2
Middle : 3
Tall : >3

2.8.3. Potassium (K) nutrient content

The element Potassium (K) plays a role in the formation of protein and carbohydrates and improves the quality of seeds or fruit. Potassium is a macronutrient that plays a role in various physiological processes, including photosynthesis, assimilate translocation, starch formation, and enzyme activity. The presence of organic matter and land management can influence potassium content in soil. Soil with a higher potassium content can support optimal plant growth and development (Okalia et al., 2022).

The range of P nutrients according to the East Java Agricultural Technology Assessment Center is:

Low : <12
Medium: 21
High : >21

2.9. Research flowchart

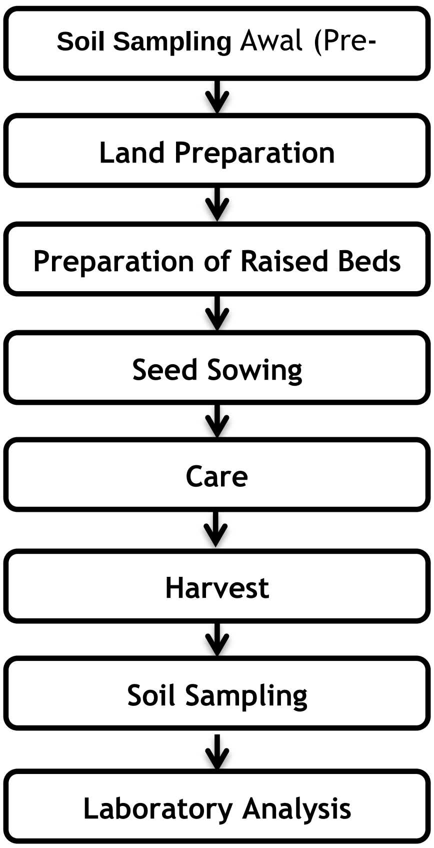

Figure 3. Research Flow Diagram

3. Results and Discussion

Based on 3 months of planting, edamame bean production reached up to 3 kg. During the maintenance of edamame beans for 3 months, fertilization was not carried out for the reason of determining the NPK nutrient content in the soil after planting edamame beans, so that planting edamame beans does not increase farmer costs. Table in shows edamame bean production.

3.1. NPK Content Results

Based on the results of laboratory analysis of the soil's macronutrient content before and after planting edamame beans as intercrops on oil palm TBM land, data were obtained on changes in nitrogen (N), phosphorus (P), and potassium (K) content, indicating the dynamics of soil fertility.

3.1.1. Nitrogen (N) content

Based on the laboratory results, nitrogen (N) content before and after planting was higher than before planting. The comparison of N elements can be seen in the Table 5.

Based on the laboratory analysis results in Table 6, that soil nitrogen (N) content of the soil decreased by 0.01% from 0.07% before planting to 0.06% after edamame was cultivated as an intercrop in the oil palm TBM land. This decrease indicates that the use of edamame in the intercropping system did not directly increase soil nitrogen reserves during the observation period. This is likely because plants absorbed most of the soil nitrogen to support vegetative growth. The use of Rhizobium bacteria in legumes plays a role in biological nitrogen fixation. However, environmental conditions, nutrient availability, and the level of competition with the main crop can affect its effectiveness (Indah Cahyani Zega & Natalia Kristiani Lase, 2025).

This quantitative decrease in N nutrients is in line with findings in soybean intercropping in young oil palm land, which reported a decrease in total soil N of 0.02% (from 0.11% to 0.09%) due to the rate of nitrogen accumulation in the intercrop biomass being much faster than the rate of natural N fixation by root nodules during one short cropping cycle. The decrease in N stores due to this cropping interaction is also in line with an intercropping study published in the Journal of Tropical Plant Agronomy (JUATIKA) by Sutriana et al. (2022)**.** In their research on intercropping land productivity, without additional nutrients or adequate organic fertilizer application, intensive intercropping cultivation stimulates competition for root uptake of macronutrients (N, P, K) in the root zone, which can deplete soil nitrogen to between 0.01% and 0.03%, depending on plant density.

3.1.2. Phosphorus (P) Content

Based on laboratory results, phosphorus (P) content before and after planting was lower than before planting. The comparison of P elements can be seen in the Table 6.

Based on the laboratory analysis data in Table 7, it is known that the soil phosphorus (P) decreased by 7.91 ppm from 19.78 ppm before planting to 11.87 ppm after cultivating edamame beans as an intercrop in oil palm TBM land. This decrease in phosphorus content indicates that the availability of P in the soil decreased during the cultivation period, likely due to a high level of phosphorus uptake by edamame plants to support vegetative and generative growth. Phosphorus is an essential macronutrient that plays a vital role in energy transfer (ATP), root system development, and flowering and seed formation in plants (Sagala et al., 2024).

Table 2. Observation Results of Edamame Beans

Number of Beds	Number of Seeds / Bed	Number of Holes / Beds	Number of Living Plants/Holes	Number of Dead Plants / Holes	Average Branch / Bed	Production (kg)
Bed 1	300	150	59	91	1	0.565 kg
Bed 2	300	150	72	78	1	0.678 kg
Bed 3	300	150	80	70	1	0.370 kg
Bed 4	300	150	68	82	1	0.820 kg
Bed 5	300	150	59	91	1	0.635 kg
Amount	**1,500**	**750**	**338**	**412**	**5**	**3,068**

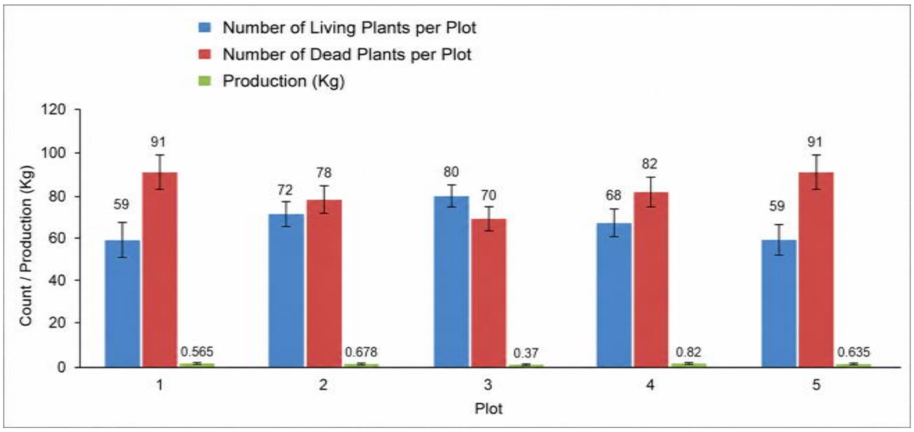

Figure 4. Edamame Bean Production Diagram

Table 3. *N*, P, K Content Before Planting Edamame Beans

No. Lab	No. Sort	On a Dry Weight Basis 105°C		
		N (%)	P (ppm)	K me/100g
2478/25	1	0.07	19.78	0.06

Table 4. *N*, P, K Content After Planting Edamame Beans

No. Lab	No. Sort	On a Dry Weight Basis 105°C		
		N (%)	P Bray II (ppm)	K me/100g
234/26	1	0.06	11.87	0.15

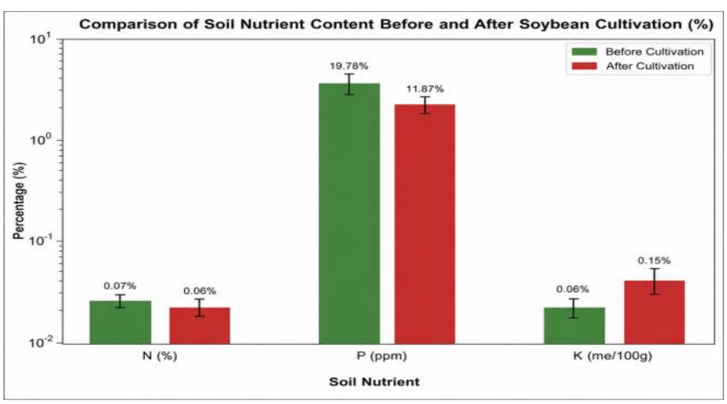

Figure 5. Diagram of Laboratory Results Before and After Planting Edamame Beans

Table 5. nitrogen content

Parameter	Before Planting	After Planting
Nitrogen (N)	0.07	0.06

Table 6. Contents phosphorus

Parameter	Before Planting	After Planting
Phosphorus (P)	19.78	11.87

Quantitatively, the decrease in available P of 7.91 ppm in this study is quite massive when compared to studies with additional inputs in intercropping areas, where the decrease in nutrient P can usually be suppressed to only around 2.15–3.40 ppm through the help of organic mulch applications that maintain soil moisture and the activity of P-solubilizing microbes. A study (Rastono & Muzadi, 2025) in the Journal of Tropical Plant Agronomy (JUATIKA) emphasizes the high deficit in soil available P due to intercrop exploitation without external nutrient inputs. They reported that in soils with high absorption capacity, the availability of active phosphorus in the root zone (such as Alfisol/Ultisol soils) can decrease sharply to reach around 6.20–8.40 ppm during the flower formation and pod/fruit filling phases of plants, if not assisted by biological inoculants such as Phosphate Solubilizing Bacteria (PBS) or Arbuscular Mycorrhizal Fungi (AMF) to decompose latent soil phosphate.

3.1.3. Potassium (K) content

Based on laboratory results, potassium (K) content before and after planting was higher than before planting. The comparison of K elements can be seen in the following table:

Table 7. Potassium content

Parameter	Before Planting	After Planting
Potassium (K)	0.06	0.15

Based on the laboratory analysis data presented in Table 8, there is a change in soil potassium (K) content from 0.06 me/100 g before planting to 0.15 me/100 g after cultivating edamame beans as an intercrop on oil palm TBM land. This change shows an increase in potassium content of 0.09 me /100 g, which indicates that the edamame cultivation system has a positive contribution to the dynamics of potassium availability in the soil. Potassium is a macronutrient that plays an important role in regulating water balance, enzyme activation, translocation of photosynthesis products (assimilates), and increasing plant resistance to environmental stress (Sihaloho et al., 2025).

The quantitative increase in soil exchangeable K of 0.09 me/100 g reinforces the general finding that annual legume intercropping can boost soil potassium by between 0.05 and 0.12 me/100 g. This significant increase is driven by the decay of edamame leaf litter (plant residues) that fall before harvest. Because potassium of highly mobile and easily leached from dead plant tissue, the vegetative decomposition of edamame Ryoko 75 quickly returns K elements to the *topsoil layer* of the oil palm TBM land. A recent publication in the Journal of Tropical Plant Agronomy (JUATIKA) by Agriani et al. (2025) supports the dynamics of physicochemical improvements in plantation land due to this plant integration**.** Their research on the impact of agroforestry systems and intercropping on oil palm land quantitatively shows that the return of plant residue biomass between oil palms significantly affects topsoil nutrient retention. Rapid mineralization of intercrop litter can provide an additional supply of instantly exchangeable potassium to the soil colloidal complex, ranging from 0.07 to 0.13 me/100 g.

3.2. Pests on Edamame Bean Plants

During the implementation of research on cultivating edamame beans as an intercrop in oil palm TBM land, pest attacks were found that affected plant growth and yield. Pest attacks are one of the limiting factors in edamame production because they can reduce harvest quality and quantity. In edamame beans, pests are especially problematic during the TBM period, when pest attack rates are still low (1%-20%).

Armyworm (Spodoptera litura) is a major pest of edamame plants because it attacks the leaves, the site of photosynthesis. Edamame is a plant that is highly susceptible to attack during the vegetative through early generative phases.

Armyworm (*Spodoptera litura*) attacks on edamame plants significantly affect growth and production yields. The larvae of this pest attack leaves by consuming leaf tissue, causing defoliation (leaf damage) and reducing the leaf surface area available for photosynthesis. This decrease in photosynthetic activity directly disrupts the energy formation and assimilation needed for vegetative and generative plant growth (Novitasari et al., 2025). Furthermore, at high levels of attack, armyworms can cause leaves to be stripped of their veins, resulting in physiological stress, stunted growth, and failure to form flowers and pods. As a result, edamame pod number and weight of edamame pods decrease significantly, and under severe attack, yield losses of up to 60–80% can result in crop failure (Ningrum et al., 2024).

Figure 5. Armyworm

a. Sengkal Caterpillar (Chrysodeixis chalcites)

The leafhopper (Chrysodeixis *chalcites*) is a leaf-eating pest that can be detrimental to oil palm plants. Although fireworms and bagworms are more often the main concern, leafhoppers also contribute to leaf damage. According to Muharram et al. (2024), the leafhopper (Chrysodeixis chalcites) is also a group of leaf-eating pests that attacks oil palm plants during the TBM phase. This pest damages leaves by reducing the leaf surface area that functions in the process of photosynthesis, thereby inhibiting the plant's vegetative growth. Defoliator pest attacks during the TBM phase require attention because this phase is a critical stage of plant organ formation. Recent studies on oil palm plants show that pest attacks during the pre-production phase (TBM) contribute to the level of plant damage and affect overall plant development (Muharram et al., 2024).

Figure 6. Inchworm

b. Green Grasshopper (Oxya chinensis)

Green grasshopper (*Oxya chinensis*) is one of the harmful pests in oil palm plants. This pest is classified as greedy and can cause serious damage to leaf blades. According to Muharram et al. (2024), green grasshoppers such as Oxya chinensis attack leaves by biting the leaf blades. Grasshopper damage can reduce effective leaf area, inhibiting the process of photosynthesis and plant growth. Environmental conditions, such as weed presence of weeds and season, generally influence pest attacks in the TBM phase. Recent research shows that the presence of plant pest organisms in the TBM phase can increase the level of plant damage, especially in environmental conditions that support pest development.

The green grasshopper (Oxya chinensis) is a leaf-eating pest found on soybean (edamame) plants and can damage leaves. This insect has biting-chewing mouthparts that create holes in the leaves, reducing leaf surface area. This damage reduces the plant's photosynthetic capacity, thus stunting growth. Furthermore, grasshoppers, such as *Oxya chinensis,* have been reported as a pest found in soybean plantations, with varying levels of infestation across various varieties. Grasshopper attacks can cause defoliation, which can reduce plant growth, especially during the vegetative phase when leaves are still actively photosynthesizing (Jati et al., 2021).

Figure 7. Green Grasshopper

c. Conclusion

Based on the conducted research, it can be concluded that the soil nutrient content experienced changes after planting edamame beans on oil palm TBM land. Nitrogen (N) content decreased by 0.01%, falling into the low category. Phosphorus (P) content also decreased by 7.91 ppm, although it remained in the high category. Meanwhile, potassium (K) content increased by 0.09 me/100 g, but it remained in the low category. These changes in nutrient content indicate that planting edamame beans affects soil fertility, particularly for the elements N, P, and K.

Based on the results of this study, it is recommended that fertilization be carried out during the maintenance period of edamame bean plants to maintain stable plant productivity and achieve maximum yield. Fertilization is also necessary to ensure that the nitrogen (N) and phosphorus (P) content in the soil remains balanced and does not decline after planting. Additionally, selecting intercrops that can enhance the soil's N, P, and K nutrient content is important to help sustainably improve soil fertility in oil palm TBM land.

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