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

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Abstract

This study aimed to analyze the content of nitrogen (N), phosphorus (P), and potassium (K) nutrients in soil planted with soybean as an intercrop in immature oil palm plantations (TBM). The research was motivated by the need to optimize land utilization and improve soil fertility in immature oil palm plantations through sustainable intercropping practices. The study was conducted on smallholder oil palm TBM land in Bukit Lawang Bahorok, Langkat Regency, from May 2025 to February 2026. The researchers used descriptive statistical analysis. Researchers planted soybean on five planting beds measuring 1 m × 10 m, using 1,500 seeds of the Grobogan variety. Observations involved laboratory analysis of soil nutrient content before and after soybean planting. The results showed that nitrogen (N) content increased from 0.07% to 0.09%, phosphorus (P) content increased from 19.78 ppm to 21.12 ppm, and potassium (K) content increased from 0.06 me/100 g to 0.18 me/100 g. The increase in nutrient content was influenced by soil biological activity, the decomposition of plant residues, and the ability of soybean plants to enhance soil fertility through nitrogen fixation. Soybean production during the study was 11 kg, with a seed failure rate of 18.27%. Based on these findings, it can be concluded that planting soybean as an intercrop in immature oil palm plantations positively affects soil nutrient content—particularly nitrogen, phosphorus, and potassium—thus supporting a more sustainable oil palm cultivation system.

Keywords: Immature Oil Palm Plantation, Intercrop, Nitrogen, Phosphorus, Potassium, Soil Nutrients, Soybean

1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) is a strategic commodity in Indonesia's plantation sector, contributing significantly to national economic growth. Its main product, crude palm oil (CPO), is a crucial raw material for the food, cosmetics, and renewable energy industries. The advantages of oil palm lie in its high productivity, long economic life, and ability to grow in a variety of tropical soils, making it a leading commodity that continues to be developed in various regions of Indonesia (Sipayung et al., 2017).

In its life cycle, oil palm goes through several growth phases, one of which is the Immature Plant (IMPAIRED PLANTS) phase, which is the period from planting until the plant begins to produce fruit. This phase generally lasts three to four years and is a crucial period because it determines the production potential of the Mature Plant (MTP) phase. During the MTP phase, vegetative plant growth is intensive. It requires sufficient macronutrient intake, especially nitrogen (N), phosphorus (P), and potassium (K) to support optimal root, stem, and crown development (Simbolon et al., 2017).

One of the fundamental problems with TBM (Cultivated Palm Oil Plantation) areas is the continued exposure of much of the soil surface due to the incomplete coverage of the oil palm canopy. This condition makes the soil susceptible to rainwater erosion, nutrient leaching, reduced organic matter, higher soil surface temperatures, and uncontrolled weed growth. If TBM areas are left without cover crops, soil degradation can occur more rapidly and impact the growth of young oil palm plants. In the long term, this condition can reduce plant productivity when entering the production phase.

To address these issues, companies and farmers

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generally use of legume cover crops (LCCs) such as Mucuna bracteata. These legumes suppress weed growth, improve soil structure, and increase nitrogen content through biological fixation. However, the use of conventional cover crops also faces several obstacles, such as the relatively high cost of seed procurement, the need for intensive maintenance, and the lack of direct economic benefits to farmers. In addition, some types of LCC have very fast growth, so they have the potential to compete with the main crops in space utilization and maintenance if not managed properly (Lubis et al., 2020).

Therefore, alternative ground cover crops are needed that not only function to maintain land quality but also provide additional economic value for farmers during the TBM period. One of the plants that has the potential to fulfill this function is soybeans (*Glycine max*). Soybeans are legumes that form root nodules through symbiosis with Rhizobium bacteria, allowing them to fix atmospheric nitrogen and increase nutrient availability in the soil. In addition, soybeans have a relatively short harvest period, light requirements that are suitable for TBM land conditions, and good economic value, so that they can be a source of additional income for farmers while waiting for oil palm plants to produce (Halimatussakdiah et al., 2022).

Several previous studies have shown the benefits of using legume plants on plantation land. Research by Lubis et al. (2020) reported that using *Mucuna bracteata* as a ground cover crop can increase soil organic matter content and reduce erosion in young oil palm plantations. Simbolon et al. (2017) explained that the availability of macronutrients during the TBM phase significantly determines the vegetative growth of oil palm plants. Meanwhile, Halimatussakdiah et al. (2022) found that legumes can improve soil fertility through nitrogen fixation. However, most of these studies still focus on the use of conventional cover crops or discuss general aspects of plant growth. Research that specifically examines changes in the macronutrient content of N, P, and K in soil due to planting soybeans as intercrops on oil palm TBM land remains relatively limited.

Based on the above description, the novelty *of* this research lies in the use of soybeans as an intercrop with dual functions, namely as a ground cover crop and a productive crop that generates economic value. Furthermore, this research specifically analyzes changes in the macronutrient content of nitrogen (N), phosphorus (P), and potassium (K) in the soil before and after planting soybeans on oil palm plantations (TBM). Thus, this research not only evaluates the agronomic benefits of soybeans in improving soil fertility but also offers an alternative system for managing TBM land that is more productive and sustainable.

Based on this background, research is needed to analyze the macro-nutrient content of N, P, and K in soil planted with soybeans as intercrops in oil palm TBM land. The results of this study are expected to provide information on the potential to increase soil fertility through the integration of intercropping systems and support the sustainability of oil palm cultivation systems.

2. Material and Methods

This research was conducted in an Immature Oil Palm Plantation (TBM) area owned by a smallholder plantation located in Bukit Lawang Village, Bahorok District, Langkat Regency, North Sumatra Province. The research location is at coordinates around 3°32'–3°34' N and 98°06'–98°08' E with an altitude ranging between 80–120 meters above sea level (masl). The area has a tropical climate with relatively high rainfall, making it suitable for the cultivation of oil palm and legume intercrops such as soybeans. The research period ran from May 2025 to February 2026.

2.1. Tools and materials

The following were used in the implementation of the research:

Material: soybean seeds of the Grobongan variety. Tool: Hoe, rake, watering can, measuring tape, and hand sprayer. The method used in this research is a descriptive statistical method. Descriptive statistics are statistics used to analyze data by describing or depicting the data that has been collected without intending to make conclusions that apply to the public or generalizations (Sugiyono, 2019: 206).

The implementation of the research includes several stages, namely:

a. Soil Sampling

Sampling is done by:

1. Determine the location that will be used as the area for making beds.
2. Determine the center point of each bed.
3. Take soil samples by hoeing at the end of the bed, the middle, and the other end of each bed.
4. Mix all soil samples from each bed on a tarpaulin until evenly distributed.
5. The mixed soil sample was divided into four parts. The top-right and bottom-left sections were discarded, while the top-left and bottom-right sections were mixed again. This process was repeated until a total of 1 kg of soil sample was obtained.
6. The soil samples were then taken to the laboratory to be analyzed for the N, P, and K content of the soil before planting.

b. Bed Preparation

The bed size in this study was 1 m × 10 m. The beds were made on dead rails while still paying attention to the condition of the oil palm plantation discs. The location of

the beds is determined by paying attention to the position of the tips of the leaf stems and plant discs. The distance between the beds and the oil palm plants is set at around 2 m.

c. Weeding

Weeding is done manually using a scraper once a week.

d. Harvesting

Harvesting is carried out when the soybean plants are approximately 3 months old, with the characteristics of yellowing leaves, most of the pods are ripe, and are brownish in color. Ripe pods break easily when pressed.

Harvesting is done by uprooting or cutting the plants. Plant residues left in the soil can become organic matter that plays a role in increasing soil fertility, particularly the nutrient content of N, P, and K.

The criteria for soybean plants that are ready to be harvested after 3 months are as follows:

1. The leaves have turned yellow and have even fallen off.
2. About 85% of the pods are ripe and brownish.
3. The pod skin is easy to remove.
4. The pods break easily if pressed or twisted.

e. Observation Parameters

Observations in this study were to observe the levels of nitrogen (N), phosphorus (P), and potassium (K) in the soil before and after soybeans were planted. The N, P, and K content in the soil where oil palms were planted were as follows:

Table 1. Range of Nutrient Content N , P, K

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

***Source**: East Java Agricultural Technology Assessment Center*

a. Nitrogen (N) nutrient content

Nitrogen (N) is a macronutrient that plants need to support vegetative growth. This element plays a role in the formation of chlorophyll, amino acids, and proteins, which function to stimulate the growth of stems and leaves. Plants that experience nitrogen deficiency generally show less than optimal growth and yellowish leaves. The nitrogen content in the soil is closely related to soil organic matter. The higher the organic matter content, the nitrogen content of the soil also tends to increase because the results of the decomposition of organic matter are able to provide nitrogen elements that can be utilized by plants (Okalia, 2022).

The range of N elements according to the East Java Agricultural Technology Assessment Center is:

Low <10 ppm
Moderate 15 ppm
High >15 ppm

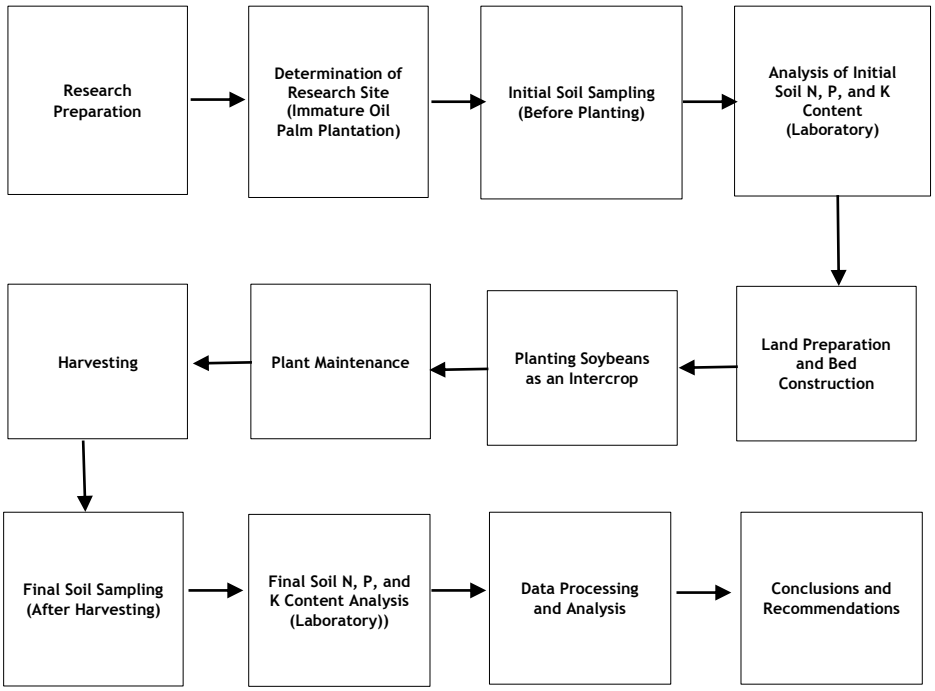


Figure 1. Research Flowchart

b. Phosphorus (P) nutrient content

The nutrient P (Phosphorus) is a nutrient that plays an important role in energy formation, cell division, tissue development, and plant root growth. Phosphorus is essential, especially during the early stages of growth, as it aids root system development and supports optimal plant

growth. Phosphorus availability in the soil is influenced by organic matter content and plant litter accumulation. Soils with high organic matter content generally have higher phosphorus levels because organic matter can contribute phosphorus to the soil through decomposition (Okalia, 2022).

The range of N elements according to the East Java Agricultural Technology Assessment Center is:

Low <2 ppm
Moderate 3 ppm
High >3 ppm

c. Potassium (K) nutrient content

Potassium (K) is a macronutrient that plays a vital role in various plant physiological processes, such as photosynthesis, translocation of photosynthetic products, starch formation, and enzyme activation. Furthermore, potassium helps increase plant resilience to environmental disturbances and supports the absorption of water and other nutrients. The presence of organic matter and land management can influence potassium content in the soil. Soil that has good organic matter content generally tends to have a higher potassium content so that it can support optimal plant growth and development (Okalia, 2022).

The range of N elements according to the East Java Agricultural Technology Assessment Center is:

Low <12 ppm
Moderate 21 ppm
High >21 ppm

If P and K data are also analyzed in the PPKS laboratory, the methods usually listed are:

- N Total: Kjeldahl Method
- P Available: Bray II Method (according to your results table it says "P Bray II")
- K Exchange: Extraction of NH_4 OAc pH 7 and read with AAS/Flame Photometer

3. Results and Discussion

The results of the analysis of soil nutrient content before planting soybeans, based on the results of the PPKS laboratory analysis, are presented in Table 2.

Table 2. N, P, K Content Before Planting Soybeans

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

Source: PPKS 2025

Table of presents the results of the soil nutrient content analysis after planting soybeans, based on the results of the PPKS laboratory analysis, as presented in Table 3. Comparison of the soil nutrient content of N, P, and K before and after planting soybeans can be seen in Figure 2.

Based on Table 2, Table 3, and Figure 2, changes in the N, P, and K content of the soil after soybean planting are visible. Nitrogen (N) content increased from 0.07% to 0.09%, while phosphorus (P) content decreased from 19.78 ppm to 19.13 ppm. Meanwhile, potassium (K) content increased from 0.06 me/100 g to 0.30 me/100 g. These changes indicate that each nutrient responds differently to soybean planting.

Table 3. N, P, K Content After Planting Soybeans

No Lab	No. Sort	On a Dry Weight Basis 105°C		
		N (%)	P Bray II (ppm)	K me/100g
234 / 26	1	0.09	19.13	0.30

Source : PPKS 2026

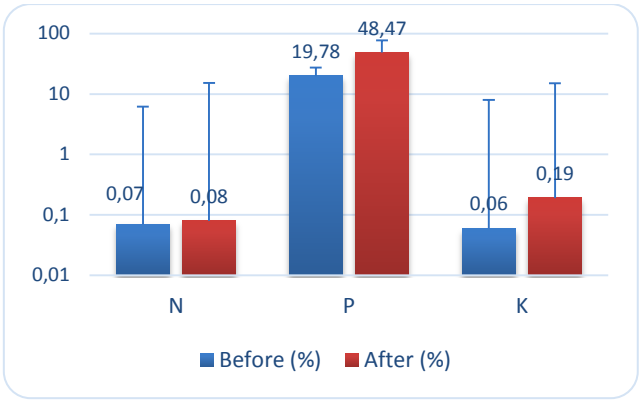


Figure 1of nutrients before and after planting soybeans.

3.1. Soil Nitrogen (N) Content Before and After Soybean Planting

Based on laboratory analysis, soil nitrogen (N) content before planting soybeans was 0.07%, while after planting it increased to 0.09%. Thus, there was an increase in N content of 0.02%. This increase indicates a change in soil nitrogen content after soybean cultivation as an intercrop on oil palm TBM land.

The increase in N content can be attributed to the characteristics of soybeans as a legume that has a symbiotic relationship with nitrogen-fixing bacteria in root nodules. Through nitrogen fixation, atmospheric nitrogen can be utilized in the plant system; thus, the presence of soybean plants can influence nitrogen dynamics in the soil. Bachtiar et al. (2019) showed that Rhizobium inoculation of soybean plants can increase nitrogen uptake efficiency. This indicates that the activity of microorganisms associated with soybean roots plays a role in the process of nitrogen supply and utilization.

In addition to nitrogen fixation, the increase in soil N after soybean planting may also be related to residual plant biomass. Roots, leaves, stems, and other plant parts left in the field after cultivation can undergo decomposition. This process allows some of the nutrients contained in plant tissue to return to the soil. Thus, the increase in N from

0.07% to 0.09% can be attributed to interactions among soybean root activity, soil microorganisms, and the return of plant biomass to the soil.

The results of this study are in line with the research of Tistama et al. (2016), which shows that the use of soybean plants as intercrops on plantation land can bring about changes in several indicators of soil fertility. These similarities suggest that the presence of intercrops from the legume group can contribute to soil nitrogen dynamics. However, the magnitude of N changes in this study cannot be directly compared quantitatively with previous studies due to differences in research locations, soil conditions, cultivation duration, and plant management.

Thus, the increase in N content in this study indicates that planting soybeans on oil palm TBM land may contribute to changes in soil nitrogen content. However, this increase should be interpreted as a change in the N content observed at the research location because this study used one soil analysis result before and one after planting.

3.2. Phosphorus (P) Content of Soil Before and After Soybean Planting

Laboratory analysis showed that soil phosphorus (P) content before soybean planting was 19.78 ppm, while after planting it was 19.13 ppm. Thus, P content decreased by 0.65 ppm. Unlike nitrogen, the phosphorus content in this study did not increase after the soybean cultivation period.

The decrease in P content may be related to the soybean plant's phosphorus needs during growth. Phosphorus is a nutrient that plays a role in root development, energy transfer, cell division, and the formation of flowers, pods, and seeds. Therefore, during vegetative to generative growth, soybean plants can absorb P available in the soil. Sagala et al. (2024) showed that phosphorus availability is related to the growth and productivity of soybean plants. This condition shows that the plant's need for P can influence changes in the P content available in the soil.

In addition to plant uptake, soil P content is also influenced by transformation processes and its availability in the soil. Not all phosphorus contained in the soil is in a form that plants can directly absorb. Some phosphorus can be in bound, so soil conditions and microbial activity influence its availability. Therefore, changes in P content after soybean planting may be the result of interactions between plant uptake and the dynamics of phosphorus availability in the soil.

The results of this study differ from those of Tistama et al. (2016), which showed an increase in phosphorus content in soybean intercropping systems on plantation land. These differences in results may relate to initial soil conditions, land characteristics, length of cultivation period, plant management, and the availability of phosphorus sources. Research by Harahap et al. (2024) also showed that phosphorus management through fertilizer application was related to soybean growth and yield. Meanwhile, in this study, no additional fertilizer was applied during soybean cultivation, so the observed changes in P content were more likely related to soil conditions and processes occurring during the study period.

0.65 ppm decrease in P indicates that the plants likely utilized some soil phosphorus during growth. Although this change is relatively small, it shows that phosphorus management remains essential if soybeans are to be cultivated sustainably as an intercrop on oil palm plantations. Monitoring of P content in the next planting period is necessary to ensure that phosphorus availability for plants is maintained.

3.3. Potassium (K) Content of Soil Before and After Soybean Planting

Laboratory analysis showed that the potassium (K) content of the soil before planting soybeans was 0.06 me/100 g and increased to 0.30 me/100 g after planting. This increased K content of 0.24 me /100 g. This increase indicates that the soil K content changed after the land was used for soybean cultivation.

Potassium is a macronutrient that plays a role in various plant physiological processes, including water balance regulation, enzyme activation, and the translocation of photosynthesis products. The increase in potassium in this study may be related to plant root activity and the return of plant biomass to the soil. Plant remains in the form of roots, stems, leaves, and other plant parts can undergo decomposition so that the nutrients contained in the plant tissue can return to the soil. Peniwiratri et al. (2023) showed a relationship between soil biological activity and nutrient availability, including potassium.

The results of this study can also be compared with those of Harahap et al. (2024), which showed that potassium availability is related to soybean growth and production. Potassium is required for various plant physiological processes, making its availability a factor supporting growth and yield formation. In this study, the increase in K content after the cultivation period indicates a change in soil K availability, even without additional K fertilizer.

The increase in K in this study differed from the decrease in phosphorus. This difference indicates that changes in each nutrient do not always follow the same pattern throughout the cultivation period. K content can be influenced by nutrient return through plant residues and decomposition processes. At the same time, P can decrease due to plant utilization and the dynamics of its availability in the soil. The differences in the characteristics of each of these elements may explain why N and K levels increased while P levels decreased.

Thus, the increase in K content from 0.06 me/100 g to 0.30 me/100 g indicates a change in soil potassium content after soybean planting. These results suggest that the

presence of soybean plants and residual plant biomass may influence soil K dynamics in oil palm TBM land. However, as with N and P, these results represent changes in values observed at the research location and cannot yet be used to conclude a statistical effect because the research did not use repeated laboratory analyses.

3.4. Comparison of N, P, and K Content Before and After Soybean Planting

Based on the analysis results, planting soybeans as intercrops on oil palm TBM land showed different patterns of changes in nutrient content. The N content increased by 0.02 %, from 0.07% to 0.09%; the P content decreased by 0.65 ppm, from 19.78 ppm to 19.13 ppm; while the K content increased by 0.24 me/100 g, from 0.06 me/100 g to 0.30 me/100 g. These differences in response indicate that the dynamics of soil nutrients are influenced by the characteristics of each element and the biological processes that occur during plant cultivation.

The increase in N corresponds to the characteristics of soybeans as a legume that can associate with nitrogen-fixing bacteria, while the increase in K may be related to nutrient return through residual plant biomass and decomposition processes. Conversely, the decrease in P indicates that plant phosphorus requirements during growth can affect soil P availability. These results show that soybean planting does not automatically increase all soil nutrients, but produces different responses for each parameter.

Compared with previous research, the results of this study show both similarities and differences. The increase in N is in line with research related to the role of soybeans and Rhizobium in nitrogen dynamics, while the change in K is in line with research showing the importance of K in supporting soybean growth. Meanwhile, the decrease in P in this study differs from previous research that showed an increase in P in intercropping systems. This difference may be influenced by initial soil conditions, study location, cultivation period, crop management, and nutrient input use.

Overall, the research results show that the use of soybeans as intercrops on oil palm TBM land results in changes to the N, P, and K content of the soil. These changes demonstrate the potential for utilizing the space between rows of immature oil palm plants and provide information on the dynamics of soil fertility during intercropping cultivation. However, further research with a larger number of samples and replications is needed to determine the consistency of changes in nutrient content and to statistically test the effect of soybean planting on soil chemical properties.

4. Conclusion

Based on the results of research on the analysis of the nutrient content of nitrogen (N), phosphorus (P), and potassium (K) in soil planted with soybeans as intercrops in oil palm TBM land, the following conclusions can be drawn: Nitrogen (N) increased by (0.02 %) from 0.07% to 0.09% in the low category. Phosphorus (P) decreased by (0.65 ppm) from 19.78 ppm to 19.13 ppm in the low category. Potassium (K) increased by (0.24 me/100 g) from 0.06 me/100 g to 0.30 me/100 g in the low category.

Suggestion

Fertilization needs to be carried out during the soybean plant maintenance period so that plant productivity is more stable with maximum results, and the soil phosphorus (F) content remains balanced and does not decrease after planting. It is necessary to select intercrops that can increase the N, P, and K nutrient content of the soil so that they can help improve soil fertility on oil palm TBM land sustainably.

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