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Efficiency of Inorganic Fertilizer Utilization with Biofertilizer on the Growth and Production of Soybeans (*Glycine max* (L). Merrill.)

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ABSTRACT

Soybeans (Glycine max (L). Merrill.) are an important source of protein in Indonesia whose supply is still very low. One of the causes is low soil fertility so it needs to be fertilized. Continuous fertilization using inorganic fertilizers turns out to have a sustainable effect, namely increasing soil damage, so it needs to be made more efficient with biological fertilizers. The research aims to determine the response of soybean plants to the application of biological fertilizer as an efficient use of inorganics. The research was carried out in Lengkong Poncol Village RT/RW 001/011 Wetan, Serpong District, South Tangerang at an altitude of ± 25 m above sea level from January 2020 to April 2020. The research used a randomized complete block design (RCBD) with five treatments, as follows: NPK 100%, NPK 75% + Biofertilizer 100 mL, NPK 50% + Biofertilizer 100 mL, NPK 25% + Biofertilizer 100 mL, and Biofertilizer 100 mL. Observations were made on plant growth and soil analysis. The results of the research showed that the use of biological fertilizer to make the use of NPK fertilizer more efficient did not have a real effect on plant growth. It can be seen that the use of biological fertilizer by making NPK fertilizer more efficient gave the same results as using 100% NPK fertilizer and using 75% NPK fertilizer + fertilizer. biological 100 mL/plant affects plant height, pH value, and soil nitrogen content.

Keywords: biofertilizers, inorganic fertilizers, soybeans

INTRODUCTION

The increasing global population growth is directly proportional to the demand for food resources, with agricultural production being a significant source. According to (Ray *et al*., 2013) long-term projections for the harvest yields of maize, rice, wheat, and soybeans, representing two-thirds of total agricultural calorie requirements, indicate an annual increase of 1.3% for soybeans. However, this is categorized as insufficient to fully meet the food needs of the population by 2050.

Soybeans are a crucial plant-based protein source extensively utilized in Indonesian cuisine. Based on 2014 SUSENAS data released by BPS, the average annual per capita consumption of tempeh is 6.95 kg and tofu is 7.07 kg in Indonesia. To meet the raw soybean material requirements for these products, approximately 67.28% or 1.96 million tons need to be imported. This is due to the inability of domestic production to meet the demands of local tempeh and tofu producers. One factor contributing to the low soybean production is its non-native status in tropical regions, resulting in lower yields compared to Japan and China (Riniarsi, 2015). Additionally, the low fertility levels of Indonesian soil also contribute to the reduced soybean production.

Challenges faced in soybean farming on acidic land are associated with low soil fertility and high soil acidity levels (Hairiah *et al*., 2020). Soybean production can be improved on low-fertility soils through various approaches, including: (1) meeting nutrient needs in acidic status by adding fertilizer inputs, (2) mitigating the negative effects of soil physical and chemical properties by adding ameliorants or biological agents, (3) developing adaptive varieties for acidic environments, and (4) combining the previous three approaches (Wijanarko & Taufiq, 2004).

The management of agricultural land to enhance soil fertility is often achieved through fertilizer application. The majority of fertilizer applications use inorganic fertilizers due to their rapid provision of nutrients for plants. However, sustained use of inorganic fertilizers can impact soil fertility (Gusmini *et al*., 2022). Continuous use of inorganic fertilizers results in soil compaction due to the accumulation of residues that are difficult to decompose (Gusmini *et al*., 2021). Chemical substances are relatively more resistant to decomposition or breakdown compared to organic materials (Gusmini *et al*., 2021). Soil compaction can hinder plant nutrient absorption, disrupt root spreading and aeration (respiration), leading to suboptimal root function and subsequently reducing the plant's production capacity (Adrinal *et al*., 2021 ; Notohadiprawiro *et al*., 2006).

According to Sari & Alfianita (2018) the use of inorganic fertilizers can increase crop yields, but their continuous use can cause soil drying due to the accumulation of chemical residues that are suitable for decomposition. Inorganic fertilizers can also cause pollution to soil and water bodies so that in the long term they can degrade soil fertility. To overcome this, chemical fertilizers are substituted with organic fertilizers (Gusmini *et al*., 2021).

An alternative solution that can be used is to switch to fertilizers made from natural (organic) ingredients (Santoni *et al*., 2023). The use of in-situ organic fertilizer at the farmer level can also minimize the initial use of inorganic fertilizer in realizing organic farming (Darwis & Rachman, 2013). Therefore, it is necessary to streamline the use of inorganic fertilizers by adding the use of biological fertilizers in an effort to increase soybean productivity.

The application of inorganic fertilizers and the use of biological fertilizers are also needed in efforts to increase soybean productivity. According to (Latif, 2017), biofertilizer is a land rehabilitation effort by utilizing several active microorganisms and can have a symbiotic relationship with legume plants, so it is very good to use for soybean plants.

Biological fertilizers are an environmentally friendly nutrient management approach to reduce inorganic fertilizer inputs, enhance productivity and quality, and preserve soil fertility (Suwandi *et al*., 2017). The application of compost accompanied by biological fertilizers sprayed on plants has been shown to increase corn plant productivity, advocating for the use of organic materials such as compost (Kalay *et al*., 2020).

Research by Cahyadi & Widodo (2017) indicates that the combination of biological fertilizers with 0.5 to 1 dose of NPK can produce wet shoot weights, thereby reducing the use of inorganic fertilizers such as Urea, SP-36, and KCl by up to 50%. Given the above, this research is crucial to understand the response of soybean plants (*Glycine max* (L). Merrill.) to the application of biological fertilizers as an efficiency measure for inorganic (NPK) fertilizer use.

MATERIALS AND METHODS

The research was conducted in Lengkong Poncol Village RT/RW 001/011 Wetan, Serpong District, South Tangerang, at an altitude of approximately ±25 m above sea level from January 2020 to April 2020. Soil analysis was carried out at the Soil Chemistry Laboratory, Faculty of Agriculture, Universitas Andalas, Padang. The study employed a randomized complete block design (RCBD) with six treatments, as follows: NPK 100%, NPK 75% + Biofertilizer 100 mL, NPK 50% + Biofertilizer 100 mL, NPK 25% + Biofertilizer 100 mL, and Biofertilizer 100 mL. Each treatment was replicated four times, resulting in 20 experimental units, with each unit consisting of three plants, totaling 60 plants for investigation. Observations on plant growth were conducted when the plants were 2 to 5 weeks old after planting (WAP), encompassing plant height (cm), number of branches (per plant), flowering age (days), number of pods per plant, pod weight per plant (grams), and root length (cm). Soil analysis was performed on the initial soil before application and post-application, evaluating parameters such as pH, and the content of nitrogen (N), phosphorus (P), and potassium (K).

RESULTS AND DISCUSSION

Plant height

The analysis of variance in NPK efficiency, coupled with the introduction of biological fertilizer, revealed no significant impact on soybean plant height from 2 to 6 weeks after planting (WAP). However, at 3 WAP, there was a notable difference in soybean plant height compared to other weeks. The treatment with 75% NPK + 100 mL of biological fertilizer exhibited the tallest plants, underscoring the influence of both NPK and biological fertilizers on soybean growth. The reduction of inorganic fertilizer dosage by 25% proved effective in influencing plant height. According to Priambodo et al. (2019), halving the dosage of inorganic fertilizers can affect not only plant height but also nitrogen content and soil pH.

This study utilized a combination of inorganic and biological fertilizers, revealing a significant height difference at 3 weeks after planting (WAP). The biological fertilizer employed contains Rhizobium sp microorganisms at approximately 4.6 x 10-8 CFU mL^{-1}. These microorganisms engage in symbiosis with soybean roots, forming nodules or root nodules capable of fixing atmospheric and soil nitrogen. The resultant nitrogen serves as a crucial nutrient source for plant growth, influencing plant height.

Amin (2011) noted that plant height is affected by the soil's nitrogen content absorbed by the plant. Nitrogen plays a pivotal role in promoting a gradual increase in plant height. This aligns with Wang *et al*. (2020) research, which demonstrated that the application of nitrogen fertilizer significantly enhances the root biomass, plant height, root length, and root diameter of *Astragalus mongolica* plants.

Table 1. Soybean plant height on NPK efficiency with the addition of biological fertilizer

Treatment	Plant height (cm)				
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP
NPK 100%	16.06	25.25b	41.95	58,67	73,19
NPK 75% + Biofertilizer 100 mL	15.13	22.05a	35,79	52,57	65,2
NPK 50% + Biofertilizer 100 mL	15.72	24.17ab	38,85	56,3	69,06
NPK 25% + Biofertilizer 100 mL	15.94	24.47b	38,9	57,59	70,95
Biofertilizer 100 mL	16.21	25.97b	42,19	58,69	70,39

Note: Numbers in the same column followed by the same letter are not significantly different based on the HSD test at the 5% level.

Number of branches

The variance analysis results indicate that the inclusion of biological fertilizer with NPK fertilizer does not have a noteworthy impact on the number of branches in soybean plants, as detailed in Table 2. Across all treatments, there was no significant difference observed in the number of branches. The quantity of branches is closely tied to the development of flowers and pods, where a higher number of branches correlates with increased flower formation. This aligns with findings from the research conducted by Xu et al. (2021), which asserts that a greater number of branches is positively associated with the number of pods per plant. The augmentation of branch count can indirectly contribute to enhanced soybean plant yield.

The number of branches is not significantly different because the plant height also does not show a significant difference so it has an impact on the number of branches produced. According to Muzammil *et al.* (2011), providing fertilizer containing nitrogen is also associated with an increase in plant height, as taller plants have the potential to produce more branches. However, based on the results of the conducted research, it is evident that plant height is not correlated with the number of branches.

Table 2. Number of soybean branches on NPK efficiency with the addition of biological fertilizer

Treatment	Number of branches (fruit)				
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP
NPK 100%	0.67	2.27	5.87	6.20	0.67
NPK 75% + Biofertilizer 100 mL	1.53	3.67	5.60	6.13	1.53
NPK 50% + Biofertilizer 100 mL	0.67	3.27	5.53	6.47	0.67
NPK 25% + Biofertilizer 100 mL	0.73	3.00	5.40	5.80	0.73
Biofertilizer 100 mL	0.4	2.87	5.47	6.47	0.40

Note: Numbers in the same column followed by the same letter are not significantly different based on the HSD test at the 5% level.

Flowering age

Based on the results of the analysis of variance, it is evident that the response of soybean plants to the efficiency of NPK fertilizer doses with the addition of biological fertilizer did not have a significant effect on the flowering age and root length of soybean plants (Table 3).

Table 3. Flowering age and root length of soybeans on NPK efficiency with the addition of biological fertilizer

Treatment	Flowering age (days)	Root length (cm)
NPK 100%	35.47	63.99
NPK 75% + Biofertilizer 100 mL	35.27	62.66
NPK 50% + Biofertilizer 100 mL	34.87	61.88
NPK 25% + Biofertilizer 100 mL	34.33	63.53
Biofertilizer 100 mL	34.33	65.65

Note: Numbers in the same column followed by the same letter are not significantly different based on the HSD test at the 5% level.

Pods

The response of soybean plants to the efficiency of NPK fertilizer doses with the addition of biological fertilizer did not have a significant effect on soybean pods (Table 4). The efficiency of using inorganic fertilizer and adding biological fertilizer does not affect the pods of soybean plants. Reducing NPK fertilizer has been proven to be able to match the flowering age and root length of soybean plants with the use of 100% NPK. According to Swanda *et al*. (2015), the microbial content in biological fertilizer can accelerate the rate of decomposition and fix nitrogen, acting as solvents for P and K nutrients in the soil. Biofertilizers are highly effective in providing nutrients and improving soil properties to support plant growth and yields.

Table 4. Soybean pods on NPK efficiency with the addition of biological fertilizer

Treatment	Pods			
	Number of pods	Pithy pods	Empty pods	Weight 100 Items
NPK 100%	92.27	233.3	7.23	12.23
NPK 75% + Biofertilizer 100 mL	98.67	239.33	8.53	12.19
NPK 50% + Biofertilizer 100 mL	87.67	209.07	8	11.18
NPK 25% + Biofertilizer 100 mL	93.8	232.1	6.33	12.37
Biofertilizer 100 mL	95.6	238.07	7.53	13.02

Note: Numbers in the same column followed by the same letter are not significantly different based on the HSD test at the 5% level.

Soil pH and Nitrogen

The initial soil pH content was around 5.28 (acid). After fertilizer application, the pH increased to slightly acidic, this is presented in Table 5.

Soil pH has increased, which of course will affect the availability of nutrients, thereby affecting the growth of soybean plants. According to (Lubis et al., 2015), an elevated pH can enhance root nodule weight at the end of the plant's vegetative period, increase the number of root nodules at the end of the plant's generative period, elevate plant nitrogen and phosphorus levels, and boost plant nitrogen and phosphorus uptake. The higher the nitrogen uptake by plants, the higher the soil pH will be.

The nitrogen content in Table 5 shows that the initial soil was 0.161% (low) and after fertilizer application it was not able to increase the nitrogen content. The treatment of 75% NPK fertilizer + 100 mL biological fertilizer managed to increase the nitrogen content in the soil to 0.189%. However, other treatments experienced a reduction due to the utilization of nitrogen by plants and microbes. (Kalay *et al*., 2020) stated that nitrogen in the soil can be used by plants and microbes for their growth. Nitrogen is a vital element playing a role in the formation of chlorophyll, protoplasm, proteins, and nucleic acids, all of which are crucial for the growth and development of living tissues. The use of biological fertilizer can increase soil nitrogen, although not significantly, but the loss of nitrogen is substantial, caused by absorption by plants, utilization by microbes, and leaching

Table 5. Soil pH and nitrogen on NPK efficiency with the addition of biological fertilizer

Treatment	pH		Nitrogen (%)	
	Beginning	End	Beginning	End
NPK 100%	5.28	6.23	0.161	0.112
NPK 75% + Biofertilizer 100 mL	5.28	5.91	0.161	0.189
NPK 50% + Biofertilizer 100 mL	5.28	5.54	0.161	0.084
NPK 25% + Biofertilizer 100 mL	5.28	5.57	0.161	0.07
Biofertilizer 100 mL	5.28	6.23	0.161	0.119

Soil phosphorus and potassium

Table 6 presents the soil phosphorus and potassium content following the efficient application of NPK fertilizer supplemented with additional fertilizer. Both NPK efficiency and the incorporation of biological fertilizer influence soil phosphorus levels, with the application of 100% biological fertilizer exhibiting the highest value compared to other treatments. This demonstrates that the utilization of biological fertilizer enhances the availability of phosphorus in the soil.

The introduction of biofertilizers to the soil has been shown to elevate phosphorus availability. Typically derived from organic materials inoculated with microbes, biofertilizers enable the conversion of organic materials into inorganic forms. One such microbe commonly used in biofertilizers is phosphate solubilizing bacteria, which possesses the ability to fix phosphate (Pratiwi *et al*., 2018).

The availability of K elements in all treatments decreased from the initial soil analysis. This was a very significant decrease in all treatments where the highest K element value was found in the 100% biological fertilizer treatment and the lowest in the 100% NPK treatment. The decrease in K can be caused by potassium being absorbed by plants for growth and lost due to leaching by water. As per the findings of Al Mu'min *et al*. (2016), plants can absorb only a minimal quantity of potassium from the soil, primarily due to the limited availability of potassium and its depletion through processes such as harvesting, water leaching, and soil erosion

Table 6. Soil phosphorus and potassium on NPK efficiency with the addition of biological fertilizer

Treatment	Phosphorus (ppm)		Potassium (Cmol.kg^{-1})	
	Beginning	End	Beginning	End
NPK 100%	9.08	133.03	0.82	0.51
NPK 75% + Biofertilizer 100 mL	9.08	139.27	0.82	0.54
NPK 50% + Biofertilizer 100 mL	9.08	115.51	0.82	0.52
NPK 25% + Biofertilizer 100 mL	9.08	126.06	0.82	0.56
Biofertilizer 100 mL	9.08	145.13	0.82	0.62

CONCLUSION

The research findings yield several conclusions: (1) Incorporating biological fertilizer to enhance the efficiency of NPK fertilizer does not significantly impact plant growth. It is evident that utilizing biological fertilizer to optimize NPK fertilizer results in outcomes comparable to using 100% NPK fertilizer. (2) The application of 75% NPK fertilizer alongside 100 mL of biological fertilizer per plant influences plant height, pH value, and soil nitrogen content.

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