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Effect of Inorganic Fertilization Methods on Growth and Yield of Soybean on Alfisol

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ABSTRACT

The ever-increasing demand for soybeans has not been matched by increased yields. This is partly due to farmers not fertilizing properly. Many farmers apply urea, SP36, KCl, or compound NPK fertilizers at doses that are inappropriate for the plants' needs. Many even fertilize haphazardly. Appropriate fertilization methods are needed. This study aims to determine the effect of some of fertilization methods on soybean growth and yield on Alfisol. This study used a completely randomized block design (RCBD) with five treatments and five replications. PT0 (no fertilizer), PT1 (Farmer's Method: Urea, SP36, and KCl), PT2 (Balanced Fertilization Method: Urea, SP36, and KCl), PT3 (Farmer's Method: NPK Compound Fertilizer), PT4 (Balanced Fertilization Method: NPK Compound Fertilizer). The results of this study show that inorganic fertilizers given in a balanced manner can increase soybean yields from 2.28 g/plant to 13.82 g/plant. The results of this study indicate that the best treatment method, PT2 (Balanced Fertilization Method: Urea, SP36, and KCl), is able to support plant growth and increase soybean yields.

Keywords: Compound NPK; Marginal soil; Single fertilizer

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INTORDUCTION

Soybeans (*Glycine max*) are the world's leading vegetable protein and oil source (Triandita and Putri, 2019). In Indonesia, they are one of the primary food commodities after rice and corn. Various processed soybean products, such as tofu, tempeh, soy sauce, and tauco, are also increasingly in demand by the public. This high demand has prompted Indonesia to import soybeans from abroad. Imported soybeans are often considered to be of better quality than local soybeans, even though Indonesia has superior varieties that are just as good, one of which is the Grobogan variety. This variety is preferred because of its large pod size, similar to imported soybeans. In addition, Grobogan soybeans have high yield potential and can adapt to various environmental conditions (Sebastian & Banjarnahor, 2019).

Limited planting areas often hamper the ever-increasing demand for soybeans. One of the leading causes of the decline in soybean planting areas is converting agricultural land to non-agricultural land. No less than 67.28% of the national demand for soybeans must be met through imports because domestic production cannot meet demand (Junianto et al., 2019). This condition has prompted efforts to optimise soybean cultivation on marginal lands, including Alfisol soil. According to Syamsiyah et al. (2023), the main problem with Alfisol soil is inadequate nutrient availability, including low levels of available phosphorus (P). This soil generally lacks essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) due to low organic matter content and nutrients easily bound by aluminium (Al^{3+}) and iron (Fe^{3+}) ions.

Alfisol soil problems can be overcome through fertilisation to meet macro nutrient requirements such as N, P, and K. Farmers generally use inorganic fertilisers, both single (Urea, SP-36, KCl) and compound (NPK 16:16:16). However, fertilisation is often not adjusted to actual nutrient requirements, thereby disrupting plant growth and productivity. One essential approach to improving plant growth and yield is balanced fertilisation. With balanced fertilisation, macro and micro nutrients can be supplied according to plant requirements, preventing excess or deficiency. This method not only increases the efficiency of plant nutrient absorption but also maintains soil fertility in the long term and meets nutrient requirements during the plant's crucial vegetative and generative phases. Nutrients taken up by the roots are transported to the vegetative and generative parts of the plant to support maximum photosynthesis, thereby contributing to increased crop yields (Yusdian et al., 2023). This study aims to determine the effectiveness of several fertilisation methods on the growth and yield of soybean plants in Alfisol soil.

MATERIALS AND METHOD

Research Location

This study was conducted on Alfisol land in Kwangsan Village, Jumapolo, Karanganyar Regency, Central Java, at 285 metres above sea level.

Tools and Materials

The research tools consisted of hoes, measuring tapes, raffia ropes, stakes used for land cultivation, drills, plastic bags for sampling, and analytical scales for research treatments. The materials used in this study included urea, SP36, KCL, and 16:16:16 compound NPK fertilisers. The soybean seeds used in this study were Grobogan.

Research Design

This study used a completely randomised design (CRD) with five treatments and five replicates. The research factors tested in this study were fertilisation methods, which included:

PT_0 : No fertilizer applied (control)

PT_1 : Single fertiliser application method which was used by local farmers (42 kg/ha Urea, 67 kg/ha SP36, and 69 kg/ha KCl, all applied at planting)

PT_2 : Split single fertiliser method, i.e., the same treatment as PT1 applied twice, with 2/3 of the dose applied at planting and 1/3 dose was applied at 30 days after planting.

PT_3 : Compound NPK fertiliser application method used by local farmers (160 kg/ha NPK 16:16:16 applied at planting

PT_4 : Split application of compound NPK fertiliser (160 kg/ha NPK 16:16:16 applied with 2/3 of the dose given at planting and 1/3 of the dose given at 30 days after planting)

Observation Parameters

Soybean plants were cultivated until harvest. Plant growth parameters included plant height, number of leaves per plant, dry weight of pods per plant, and dry weight of roots per plant. Crop yield parameters include total pods per plant, filled pods per plant, pod weight per plant, seeds per plant, seed weight per plant, seed weight per m², weight of 1000 seeds per plant, and seed moisture content per plant.

Soil Analysis

Analysis of pH H2O and KCl using the electrometric method, CEC and base saturation using the 1M NH4OAc extraction method, soil organic carbon content using the Walkey and Black method, total soil nitrogen content using the Kjeldahl method, total soil phosphorus using the 25% HCl method, available P in soil using the Olsen method, total K in soil using the 25% HCl method, Kdd and Fedd using the 1M NH4OAc extraction method, Aldd using the 1M KCl extraction method, Cadd using the 1M NH4OAc extraction method, and soil P retention analysis using the Blackmore method.

Data Analysis

Data analysis was performed using a one-way ANOVA test with the assistance of the SPSS programme. If there was a significant effect on the treatment (calculated F > Fα), it was followed by a DMRT (Duncan Multiple Range Test).

RESULT AND DISCUSSION

Initial Soil Analysis

Initial soil analysis is essential to determining the properties and characteristics of the soil at a given location. The purpose of initial soil analysis is to evaluate the characteristics of the soil before applying fertiliser. The results of the initial soil analysis are presented in Table 1 below.

Alfisol soil has a pH H2O value of 5.59, which means that the soil is acidic. The soil's pH KCl is 3.60, which is classified as low. The research results by Yanti and Kusuma (2021) prove that the pH H2O can be higher than the pH KCl because the acidity calculated from the pH H2O is active. The CEC and CEC of the soil are 15.63 cmol/kg and 31.85%, both of which are in the low category. The low CEC value is influenced by the low pH value as well. Base saturation is directly proportional to soil CEC. Soil organic carbon is also low, with a value of 1.27%. This result is supported by the opinion of Asrarudin et al. (2022), that Alfisol soil cannot increase the organic carbon value in the soil during the harvest phase.

Table 1. Initial Soil Analysis

No.	Parameter	Value	Unit	Category*
1	pH H_2O	5.59	-	Low (acidic)
2	pH KCl	3.60	-	Low
3	Cation Exchange Capacity (CEC)	15.63	cmol/kg	Low
4	Base Saturation	31.85	%	Low
5	Soil Organic C	1.27	%	Low
6	Soil Total N	0.11	%	Low
7	Soil Total P	9.51	mg/100 g	Very low
8	Available Soil P	2.66	ppm	Very low
9	Soil Total K	7.65	mg/100 g	Very low
10	Exchangeable K (K-dd)	0.31	cmol/kg	Low
11	Exchangeable Fe (Fe-dd)	0.11	ppm	Low
12	Exchangeable Al (Al-dd)	4.24	cmol/kg	High
13	Exchangeable Ca (Ca-dd)	3.45	cmol/kg	Low
14	Soil P Retention	92.72	%	High

*Assessment based on the Soil and Fertiliser Instrument Standards Testing Centre (2023).

Table 2. Analysis of the Effect of Fertilisation Methods on Soybean Plant Growth

Treatment	Plant height (cm)	Number of leaves	Fresh biomass weight (g)	Dry biomass weight (g)
PT0	33.11a	9.27a	5.29a	1.34a
PT1	47.64b	19.06bc	7.64b	3.06c
PT2	47.56b	19.66c	6.80ab	2.59bc
PT3	34.47a	14.52b	5.97a	1.96ab
PT4	37.93a	16.32bc	6.15ab	1.98ab

Note: Numbers followed by different letters in the same column indicate significant differences at the 5% level according to the DMRT test.

Table 3. Analysis of the Effect of Fertilisation Methods on Soybean Crop Yield/Plant

Treatment	Total number of pods	Number of filled pods	Pod weight (g)	Number of seeds per plant	Seed weight per plant	Seed moisture content (%)
PT0	8.34a	6.70a	10.44a	15.34a	2.28a	0.97a
PT1	27.28c	19.08c	24.58d	57.94c	14.52c	1.23b
PT2	27.26c	18.24c	23.22cd	56.16c	13.82c	2.27b
PT3	14.62b	12.92b	17.48b	32.96b	6.72b	1.00a
PT4	18.02b	13.66b	18.14bc	31.38b	7.34b	1.00a

Note: Numbers followed by different letters in the same column are significantly different at the 5% level according to the DMRT test.

The total nitrogen content of the soil is low, at only 0.11%. The soil's total phosphorus and potassium contents are also very low, at 9.51 mg/100 g and 7.65 mg/100 g, respectively. The available phosphorus content of the alfisol soil is 2.66 ppm, which is very low. According to Abel et al. (2021), the total N content in the soil comes from the decomposition of organic matter. Research by Darlita et al. (2017) states that the difference in the values of total soil P and available soil P is due to phosphorus content. Soils in tropical climates are more prone to decreased total K content due to repeated rainfall and high temperatures.

K-dd, Fe-dd, and Ca-dd values are low at 0.31 cmol/kg, 0.11 ppm, and 3.45 cmol/kg, respectively. Based on previous research by Sihaloho et al. (2024), plants can deplete the available K content in the soil, which affects the K-dd parameter. The Fe-dd parameter also influences soil pH. According to Karnilawati et al. (2022), low Ca-dd can occur due to a reduction in base cations caused by leaching or absorption by harvested plants. The parameters with high values are Al-dd and soil P retention, with values of 4.24 cmol/kg and 92.72%, respectively. In dry and acidic soils, low P availability is related to Al-dd. High P retention values can be caused by several factors, such as high content of non-crystalline clay minerals (allophane, imogolite, and ferrihydrite) in the soil.

The Effect of Fertilisation Methods on Soybean Plan Growth

An analysis of soybean plant growth parameters was conducted to evaluate the effectiveness of various fertilisation treatments. The parameters observed included plant height, number of leaves, wet pod weight, and dry pod weight.

This study produced different soybean growth results for each treatment. Regarding plant height, the best treatment was PT1 (Farmer Method (Urea, SP36, and KCL), averaging 47.64 cm/plant. According to Dahlia and Setiono (2020), plant height will increase with the addition of N elements. Regarding the number of leaves, the treatment with the highest average yield was 19.66/plant in PT2 (single fertiliser method (Urea, SP36, and KCL) applied twice in split doses). The analysis results in the study by Yuriansyah et al. (2023) stated that the number of leaves will increase if the plants have good genetic traits supported by favourable environmental conditions.

In terms of wet and dry weight of root system, the treatment with the highest yield was PT 1 (single fertiliser method (Urea, SP36, and KCL) applied at planting), with an average value of 7.64 g/g/ g/plant and 3.06 g/g/ g/plant. According to Siregar and Nuraini (2021), shoot weight is an indicator of N uptake closely related to forming N-fixing root nodules. Appropriate fertilisation will enable plant roots to absorb nutrients well, thereby assisting the plant's metabolic processes in its development and influencing its total shoot weight.

The Effect of Fertilisation Methods on Soybean Yield

The evaluation of soybean yield under various fertilisation treatments by observing several harvest yield parameters, including total pod number, number of filled pods, pod weight, number of seeds, seed weight, and seed moisture content. The data from these observations illustrate the effect of each treatment on the components of soybean crop yield.

Pod filling in soybean plants is one of the key factors determining crop yield, as it directly affects the number and weight of seeds produced. The results of the analysis of variance show that the Farmer's Fertilisation Method (Urea, SP36, and KCL) (PT 1) increases the total number of pods/plant, filled pods/plant, and pod weight/plant in soybean plants compared to other fertilisation methods. Pod formation is related to the absorption of phosphorus in the soil. According to Jamili et al. (2017), plants can utilise soluble phosphorus for various metabolic processes, including photosynthesis.

This process is essential, especially in CO2 fixation, which ultimately contributes to plant carbohydrate formation and pod formation.

Fertilisation applied according to the precise needs of the plant will optimise nutrient absorption efficiency so that plants can avoid nutrient deficiencies or excesses, especially during critical periods. In this way, nutrient availability is maintained during the pod filling phase, which is crucial to ensure that the pods develop well and are not empty. According to Febrianti et al. (2022), the availability of macro and micro nutrients plays a vital role in determining the number of fresh pods per plant, so there is a positive relationship between adequate nutrition and increased pod weight. Optimal nutrient uptake will increase the effectiveness of photosynthesis in plants, and the formation of assimilates in the form of carbohydrates and proteins will also increase, which are then translocated into food reserves, namely pods. Ultimately, this affects the pod weight per plant (Margenda et al., 2020). The parameters of total pods, filled pods, and pod weight of soybean plants generally increased in the single fertiliser treatments of urea, SP36, and KCl compared to the NPK pearl compound fertiliser. NPK compound fertiliser contains fixed amounts of N, P, and K nutrients, so it cannot be adjusted to the needs of soybean plants at each growth stage. As a result, the number of pods produced was lower than treatments using single fertilisers such as urea, SP-36, and KCl.

The number of plant seeds is the total number of seeds per plant samples in each treatment block. The number of seeds per plant is one of the most critical parameters in determining soybean productivity. The results of the analysis of variance show that the recommended methods based on the Farmer Method (Urea, SP36, and KCL) (PT1) and the Urea, SP36, and KCl split fertilisation method (PT2) increase the number of seeds and seed weight per soybean plant compared to other treatments. The availability of N, P, and K nutrients influences the high or low seed weight. Adequate supply will support the rate of photosynthesis. If the photosynthesis process runs well, pod filling will be optimal, and the resulting seed weight will increase. The recommended fertilisation method based on the Farmer Method (urea, SP36, and KCL) (PT1) showed the highest seed weight, indicating that the fertilisation system had sufficient nutrient supply. Still, the split application of N, P, and K fertilisers (PT2) also produced high seed weight, which was not significantly different from PT1. In a study by Timotiwu et al. (2020), it was shown that split fertiliser application can increase the total number of pods, the number of filled pods, the weight of 100 seeds, and the dry weight of seeds (t/ha) compared to a single application of fertiliser at the beginning of planting.

The moisture content of soybeans is the percentage of moisture in the beans. According to Izzati (2024), moisture content is a key indicator of various storage parameters studied. Moisture content is related to germination, plant respiration, and the growth of microorganisms that damage soybeans. The moisture content of soybeans can determine the rate of change and damage to soybeans. The results of the variance analysis show that the recommended fertilisation method based on the split (split) fertilisation methods of urea, SP36, and KCL produced the highest moisture content in the seeds compared to other treatments. An increase in seed weight increases contact between the seeds and air humidity. This causes an increase in moisture content in the seeds during storage, which can decrease seed germination (Meyer et al., 2007 in Hartawan et al., 2011). The NPK Mutiara compound fertiliser treatment resulted in lower seed moisture content than the single fertiliser treatment. Low moisture content is insufficient to ensure that the physiological quality of the seeds is well maintained (Hartawan et al., 2011).

CONCLUSION

This study concluded that the use of fertilisation methods by farmers, particularly the use of single fertilisers such as urea, SP36, and KCL, applied once at planting (PT1) and split application at planting and 30 days after planting (PT2), had a significant effect on improving soybean growth, as seen from the parameters of plant height, wet plant biomass, dry plant biomass, and also has a significant impact on crop yield, as seen in the total number of pods, filled pods, pod weight, number of seeds, and seed weight of soybean plants compared to the fertilisation method using compound NPK fertiliser.

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