

Effect of Various Levels of NPK Fertilizer on the Yield Attributes of Soybean (*Glycine max* L.) Varieties

Achmad Yozer Perkasa*, Utomo, Teguh Widiatmoko

Department of Agronomy, Jenderal Soedirman University, Jl. Dr Soeparno No. 61 Purwokerto, Indonesia 53123

*Corresponding author; email: achmadyozarp@yahoo.com

Abstract

Indonesian soybean production can only meet about 30% of national demand. Efforts to increase soybean production include the use of improved seed quality and fertilizer application. The aims of this research were to 1) examine the responses of six genotype soybeans to the application of different doses of NPK fertilizer; 2) determine the seed protein content of the six soybean genotypes following NPK application; 3) determine the interaction between soybean genotypes with NPK doses in affecting growth and yield. This research was conducted under a plastic house at the Faculty of Agriculture, University of Jenderal Soedirman, Central Java, Indonesia. The experiment was arranged in a randomized block design with three replications using six soybean varieties and four levels NPK fertilizer. Soybean varieties tested were "L/S: B6-G1" (V1), "L/S:B6-G3" (V2), "L/S:B6-G4" (V3), "Grobogan" (V4), "Burangrang" (V5), and "Argomulyo" (V6). Four levels NPK fertilizer tested were: without fertilizer (N0), 0.6 g per plant (N1) 1.2 g per plant (N2), and 18.g per plant (N3), or 0, 100, 200 and 300 kg.ha⁻¹. "L/S: B6-G1" had the greatest number of seeds per plant (184) following treatment with 300 kg.ha⁻¹ of NPK. The seed protein content increased with the increase doses of NPK. "Argomulyo" treated with NPK at 300 kg.ha⁻¹ had the highest seed protein content (34.5%). Soybean responses to NPK treatment differed with varieties, particularly in the number of flowers per plant, number of seeds per plant, grain weight per plant and seed protein levels.

Keywords: genotypes, soybean, NPK fertilizer

Introduction

Soybean has been cultivated in Indonesia for a long time, but there have been very little expansion of the soybean growing area for the last ten years. Soybean is rarely grown as a single crop in the

traditional farming systems. Soybean production in Indonesia in 2015 was 963,000 tons of dry beans with a productivity of 1.48 tons ha⁻¹ whereas the national soybean demand was 2.4 million tons (CBS, 2016). National shortage of soybean demand has been supplied through imports, i.e.1.7 million tons in 2010, and increased to 1.9 million in 2012 (CBS, 2013). According to El-Shemy (2011) every 100 g of soybean seeds have 330 calories, 35 g of protein, 18 g of fat, 35 g of carbohydrates, 227 mg of calcium, 585 mg of phosphorus, 8 mg of iron, 110 SI vitamin A, and 1 mg of vitamin B. One of the efforts to improve Indonesian soybean productivity is through breeding to obtain high yielding varieties (Sumarno and Adie, 2010). Faculty of Agriculture, Jenderal Soedirman University has produced improved soybean varieties; these varieties were grown in different geographical and environmental conditions to identify high yields varieties with consistent results prior to releasing them as the new varieties. The promising varieties that have been developed at Faculty of Agriculture, Jenderal Soedirman University are "L/S: B6-G1", "L/S:B6-G3", and "L/S:B6-G4". These lines are progenies of crosses between "Lokon" (male) and "Sindoro" (female). The new lines are expected to have a higher yield, early maturing and higher seed protein content, which are important for the manufacture of tempeh (Sunarto et al., 2008).

Fertilization with inorganic compound fertilizer NPK will supply the nutrient requirements for healthy soybean growth (Adisarwanto and Wudianto, 1999). The research objectives were to 1) examine the response of six genotype soybeans to the dose of NPK fertilizers; 2) determine the seed protein content of the six genotypes of soybean; 3) examine the interaction between soybean genotypes with dose of NPK fertilizer in affecting soybean growth and yield.

Materials and Methods

The experiment was conducted in a plastic house at the

Faculty of Agriculture, Jenderal Soedirman University, North Village Karangwangkal of Purwokerto District, Banyumas, Central Java, Indonesia located 110 m above the sea level with the average temperature of 29°C, average rainfall of 284 mm per month, and an average humidity of 93%. The soil type was inceptisol. The study used three soybean lines, "L/S: B6-G1", "L/S:B6-G3", "L/S:B6-G4", and three released soybean varieties "Burangrang", "Grobogan" and "Argomulyo". Fungicide and insecticide were applied as required. Soybean plants were grown in 15-L polyethylene bags and arranged in a factorial randomized block design. Factors tested in this research are soybean varieties "L/S: B6-G1" (V1), "L/S:B6-G3" (V2), "L/S:B6-G4" (V3), "Burangrang" (V4), "Grobogan" (V5), and "Argomulyo" (V6), and four levels of NPK: 0, 0.6, 1.2, and 1.8 g per plant. All treatments were replicated three times, each treatment consist of three plants with a total of 216 plants. Variables scored were plant height, number of leaves per plant, number of flowers per plant, days to flowering, harvesting age, the number of productive branches per plant, number of branches per plant, number of pods per plant, number of seeds per plant, seed weight per plant, weight of one hundred seeds, and seed protein content. Data were analyzed using ANOVA to determine the effect of each treatment using SAS version 9.13. Significant effects were further tested using DMRT at 5%.

Results

Description of Soybean Varieties

The description of the soybean varieties of this study is in Table 1. "Argomulyo" and "Burangrang" have high resistance to leaf rust, whereas "Grobogan" has high adaptability to different climatic conditions (Arwin et al, 2012).

Growth and Yields of Six Soybean Genotypes





Soybean growth and yield as indicated by plant height, number of leaves per plant, number of flowers per plant, days to flowering, harvesting age, the number of branches per plant, number of productive branches per plant, number of pods per plant, number of seeds per plant, weight of seeds per plant, weight of one hundred seeds, and seed protein content, were significantly different amongst the six soybean variety. "L/S: B6-G4" was the tallest (101.7 cm at 10 weeks after planting) whereas "Grobogan" was the shortest (57.3 cm) (Table 2).

Genotype that had the greatest number of leaf is "L/S:B6-G4" had the highest number of leaves (24.8) and "L/S: B6-G3" had the fewest (15.6). Leaves are

crucial for the interception and conversion of solar light energy into growth and yield through photosynthesis.

"Burangrang" had the greatest number of flowers per plant, i.e. 59.4 whereas "L/S: B6-G1" had the fewest (34; Table 2). These results might be related to differences in the variety responses to day length and temperature range (Sunarto et al., 2008). The time to flower ranged from 29.5 to 34.3 days after planting. "L/S: B6-G3" was the earliest flowering variety (29 days after planting, dap) even though the time to flower was not significantly different to "Grobogan" (30.1 dap) and "Argomulyo" (30.8 dap) (Table 2). "Burangrang" was the latest flowering, i.e. 34.3 days after planting which was significantly later than "L/S: B6-G4" (33.1 dap) and "L/S:B6-G1" (32.3 dap). The duration of flowering is determined by the length of the vegetative phase, which determines the amount of sinks following photosynthesis (Paul and Foyer, 2001).

Table 1. Soybean variety description.

No	Variety	Morphology	Yield (t.ha ⁻¹)
1.	"L/S:B6-G1"	n.a.	2.2
2.	"L/S:B6-G3"	n.a.	2.2
3.	"L/S:B6-G4"		2.2
4.	"Grobogan"		2.7
5.	"Burangrang"		1.6–2.5
6.	"Argomulyo"		1.5–2.0

"Grobogan" has the earliest harvest age (78.9 dap) but it was not significantly different from the "L/S: B6-G3" (79.3 dap) and "Argomulyo" (79.3 dap). Harvesting was the latest in "L/S: B6-G1" (82.2 dap), which was significantly later than "L/S: B6-G4" (81.3 dap) and "Burangrang" (80.0 dap). According to Krisnawati and Adie (2007) the time to harvest of less than 80 days is considered early for soybean. The time to harvest of "L/S: B6-G1", "L/S: B6-G4" and "Burangrang" was more than 80 days (Table 2).

The number of productive branches in soybean is affected by nutrient uptake and light reception. The number of productive branches was the greatest in "L/S: B6-G4" (Table 2) whereas "L/S: B6-G4" has the greatest number of pods per plant (63.4) (Table 3). The differences in the number of pods per plant amongst soybean genotypes were likely caused by different plant morphologies, which could obviously be seen in the plant height, the number of trifoliolate leaves per plant, and the number of flowers per plant. Number of seeds ranged from 72.3 to 122.0 seeds per plant. "L/S: B6-G1" had the greatest number of seeds per plant (122.0), which were significantly greater than "L/S: B6-G4" (103.4), "Burangrang" (92.4), and "Argomulyo" (94.6). "L/S: B6-G3" had the fewest number of seeds of plants of 72.3. The number of seeds per plant correlated with the large number of productive branches and number of pods per plant. In this study the soybean variety that has a large number of productive branches and number of pods per plant is "L/S: B6-G4". According to Somaatmadja (1985) the yield per plant is correlated to the number of pods, number of seeds and seed weight per plant.

"B6-G3" had the greatest 100-seed weight (18.6 g). These results were possibly related to a number of factors that determine the size of soybean seeds, including genetic factors. According to Adie (2005) the weight and size of the seeds is the quantitative nature of the genetic factors that in certain circumstances may change according to the growing environments.

Differences in levels of soybean protein are closely related to genotype tested and micro-climatic conditions at the time of the study. The seed protein content was the highest in "Argomulyo" (34.4%) whereas "L/S: B6-G4" had the lowest (33.3%) (Table 3). Growing environment such as temperature might also indirectly affect the seed protein levels through the increase in plant's respiration and photo respiration (Lakitan, 2007).

The results showed that NPK doses significantly increased all soybean growth attributes (Table 2 and 3) except for the time to flower and time to harvest (Table 2). Increased doses of NPK increased the average plant height from 59.7 to 73.4 cm, and number of leaves per plant from 16.5 in control to 21.6

Table 2. Matrix of analysis variance of the soybean varieties

No.	Variable	V	N	V x N
1	Plant height (cm)	**	**	ns
2	Number of leaf per plant	**	**	ns
3	Number of flowers per plant	**	**	*
4	Days to flowering	**	ns	ns
5	Harvesting (days after planting)	**	ns	ns
6	Number of productive branches per plant	**	**	ns
7	Number of branches per plant	*	**	ns
8	Number of pods per plant	**	**	ns
9	Number of seeds per plant	**	**	*
10.	Seed weight per plant (g)	**	**	**
11.	One hundred seed weight (g)	**	ns	ns
12.	Protein content (%)	**	**	**

Note: V= varieties or lines; N = dose of NPK fertilizer; V x N= interaction of varieties with NPK doses; ** = highly significant; * = significant; ns = not significant according to DMRT at 5%.

There were significant differences in seed weight between the varieties tested. Seed weight per plant of "L/S: B6-G1" was 19.3 g and "L/S: B6-G4" had 16.3 g, which were significantly greater than "L/S: B6-G3" (12.4 g), "Grobogan" (12.2 g), "Burangrang" (12.4 g), and "Argomulyo" (13.1 g; Table 3). According to Krisnawati and Adi (2007) seed weight per plant are closely related with the yield components including the number of pods per plant and seed size. The weight of 100 g seeds ranged between 13.7-18.6 g with "L/S:

at NPK 300 kg.ha⁻¹ (Table 2). Increased plant height is related to the roles of NPK in promoting plant growth.

The results of this study demonstrated that the number of productive branches and the number of branches per plant were clearly affected by the doses of fertilizers (Table 2). The highest NPK doses of 1.8 g per plant, or 300 kg.ha⁻¹, resulted in the greatest number of fruits per plant, the greatest number of productive branches and total number of branches

per plant (Table 2).

Different doses of NPK fertilizer resulted in different soybean yields (Table 3). The seed weight per plant was the greatest (19.1 g per plant) when applied with the highest NPK, and the seed weight per plant was gradually decreased with the decrease of NPK doses (Table 3). As for other legumes, NPK played significant roles in the development of soybean pods, seed formation, protein levels, and root growth (Rismunandar, 1993).

plant (Figure 1), number of seeds per plant (Graph 2), seed weight per plant (Figure 3), and seed protein content (Figure 4).

The results of this study demonstrated that the responses to NPK doses vary with soybean varieties (Figure 1). Increases in the dose of NPK fertilizer resulted in the higher seed yield per plant, but the increase was significantly increased in V1 only (Graph 2). NPK has important roles in cell division, energy transformation, and fat metabolism (Hardjowigeno, 1995) which eventually affected seed production.

Table 3. Effects of NPK doses on growth of several soybean varieties

Treatment	Plant height (cm)	No of leaves per plant	No of seed pods per plant	Time to flowering (dap)	Time to harvest (dap)	No of productive branches per plant
<i>Varieties</i>						
"L/S: B6-G1"	69.1b	21.0b	34.0d	32.3b	82.2a	2.4b
"L/S: B6-G3"	58.9bc	15.6c	45.2bc	29.5d	79.3c	2.4b
"L/S: B6-G4"	101.7a	24.8a	39.9cd	33.1b	81.3ab	3.3a
"Grobogan"	57.3c	16.7c	47.6b	30.1cd	78.9c	2.3b
"Burangrang"	67.3bc	16.8c	59.4a	34.3a	80.0bc	2.5b
"Argomulyo"	59.6bc	19.0b	44.4bc	30.8c	79.3c	2.6b
<i>NPK doses (g per plant)</i>						
0	59.7b	16.5c	33.8c	32.1a	80.1a	2.0b
0.6	71.1a	18.5b	45.3b	31.4a	79.6a	2.7a
1.2	71.7a	19.4b	47.0b	31.4a	80.2a	2.7a
1.8	73.4a	21.6a	54.2a	31.9a	80.7a	3.0a

Note: Values followed by the same letter are not significantly different according to DMRT at 5%; dap: day after planting.

Table 3 shows that the number of pods and seeds per plant was the greatest (60.9 and 120, respectively) with the highest NPK dose, and the fewest without NPK (40.7 and 73.7, respectively). N, P and K have important roles in increasing the number of cells and chlorophyll, hence increased photosynthesis products, which resulted in the increase in the number of pods and seeds. The highest NPK dose also resulted in the greatest 100-seed weight (16.0 g) and the highest seed protein content (33.9%). The uptake of phosphorus during vegetative stage will be residing in the meristem tissues for protein synthesis, whereas during generative stage will accumulate in the fruit and seeds (Junkazayama, 2009).

Interaction between Soybean Varieties with NPK Doses

Different soybean varieties responded differently to NPK doses particularly in the number of flowers per

The seed protein content was the highest in "Argomulyo" (34.5%) fertilized with NPK at 1.8 g per plant, and it was significantly higher than those in other genotypes at the same dose of fertilizer. "L/S: B6-G1" had the lowest seed protein content of 33.2%. Phosphate plays important roles in plant growth as it is a constituent of ATP, ADP, NAD, NADPH. According to Gardner et al. (1991), nitrate reduction process that occurs before the production of amino acids requires electrons, and the main donor of electrons are nicotinamide adenine dinucleotide is (NADH) or nicotinamide adenine dinucleotide phosphate (NADPH), which are photosynthesis products. Protein content was positively associated with the N₂ fixation activity at all stages of the reproductive cycle, and different soybean genotypes could have different ability to fix nitrogen and to assimilate nitrates (Fabre and Planchon, 2000).

Table 4. Effects of NPK doses on yields of several soybean varieties

Treatment	Number of branches per plant	Number of pods per plant	Number of seed per plant	Seed weight per plant (g)	100-seed weight (g)	Seed protein content (%)
Varieties						
“L/S: B6-G1”	69.1b	21.0b	34.0d	19.3a	16.4b	33.3d
“L/S: B6-G3”	58.9bc	15.6c	45.2bc	12.4c	18.6a	33.5c
“L/S: B6-G4”	101.7a	24.8a	39.9cd	16.3b	15.6bc	33.3e
“Grobogan”	57.3c	16.7c	47.6b	12.2c	15.5bc	34.2b
“Burangrang”	67.3bc	16.8c	59.4a	12.6c	14.5cd	34.2b
“Argomulyo”	59.6bc	19.0b	44.4bc	13.1c	13.7d	34.4a
Dose of NPK (g per plant)						
0	59.7b	16.5c	33.8c	10.7c	15.6a	33.8c
0.6	71.1a	18.5b	45.3b	13.0b	15.5a	33.8b
1.2	71.7a	19.4b	47.0b	14.3b	15.8a	33.9a
1.8	73.4a	21.6a	54.2a	19.11a	16.0a	33.9a

Note: Figures followed by the same letter are not significantly different according to DMRT at 5%.

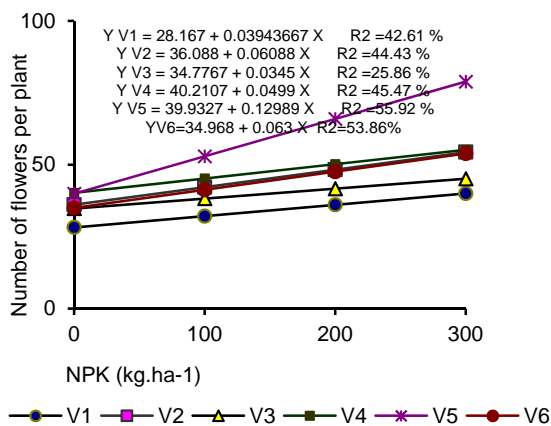


Figure 1. Interaction between soybean varieties with NPK dose in affecting number of flowers per plant

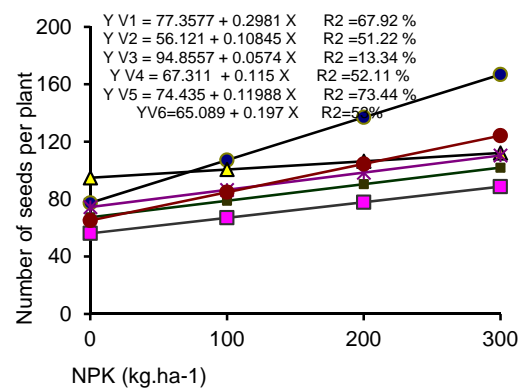


Figure 2. Interaction between soybean varieties with NPK dose in affecting number of seeds per plant

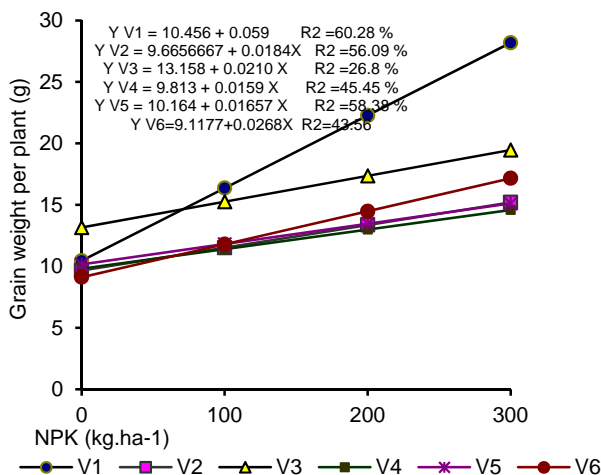


Figure 3. Interaction between soybean varieties with NPK dose in affecting grain weight per plant

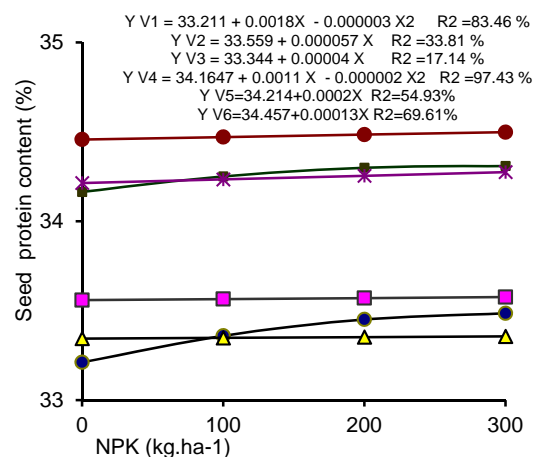


Figure 4. Interaction between soybean varieties with NPK dose in affecting seed protein content

Conclusion

Soybean genotypes had different responses to the increase of NPK doses. "L/S: B6-G1" fertilized with 1.8 g per plant NPK produced 184 pods and 32.5 g of seeds per plant, which was 46% greater than the released variety "Argomulyo". "Argomulyo" treated with NPK of 1.8 g per plant, however, had the highest seed protein content of 34.5%. The increase in NPK doses increased the seed protein content in all soybean genotypes. There were positive interactions between the six soybean genotypes with doses of NPK in affecting the number of flowers per plant, number of seeds per plant, seed weight per plant and seed protein content. Further field research should be conducted using "L/S: B6-G1" and "L/S: B6-G4" in different locations to determine their growth, yield and adaptability.

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