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Growth, yield and movement of phosphate nutrients in soybean on P fertilizer, straw mulch and difference of plant spacing

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Abstract. Soybean is one of the plants that require much amounts of phosphate. P nutrient, microclimate modification and plant spacing arrangement is the efforts to improve grain yield. The objective of the research was to study the effect of P fertilization, mulching straw and plant spacing on growth, yield and movement of P nutrient on soybean. The study was conducted at Cengkeh Turi Binjai using factorial randomized block design with 3 factors. The first factors was P fertilizer 0, 100, and 200 kg/ha, the second factor was thickness of rice straw mulch 0 and 5 cm, and third factors was plant spacing 30 cm x 15 cm, 40 cm x 20 cm, and 50 cm x 25 cm. The results of the research showed that phosphate fertilizer (200 kg/ha) significantly increased levels of phosphate in the shoot. Plant spacing (50 cm x 25 cm) increased root volume. The interaction of phosphate fertilizer (200 kg/ha) and spacing (50 cm x 25 cm) increased the phosphate level by 93.33% in shoot. Plant spacing (50 cm x 25 cm) produced the largest of 100 grains weight as compared to other plant spacing.

1. Introduction

Soybean yield potential is genetically determined. The agronomically important traits affect the enhancement of grain quantity and quality. However, the majority of agronomic and genetic traits such as complex metabolic, biological, and pharmaceutical pathways are polygenetic traits and are produced in a complex pathway [1], but actual yield potential depends on environmental conditions and management practices. Higher levels of soybean production may require higher levels of some nutrients appropriate environmental conditions to achieve yield goals. Obtaining maximum yield is only possible when the plant's nutritional requirements are met and environmental stress is limited. Maintaining a fertile growing environment is a risk management strategy that produces higher yield and healthier plants that are often better suited to withstand the yield-robbing effects of biotic and abiotic stress. Soybean respond to fertile soils [2]. A well planned soil fertility program is a management strategy that leads to profitable soybean production.

Soybean is one of the leguminous plants that require more P than others. Plants require adequate P from the very early stages of growth for optimum crop production [3]. Restricted early-season P supply frequently limits crop production, and P fertilizer is commonly applied to ensure that sufficient P is available to optimize crop yield and maturity. Therefore it is important that P management balances the goal of providing sufficient P to the crop to optimize crop yield with the goal of avoiding excess P and environmental risk. Management of the cropping system to improve the availability of P to the crop early in the growing season may improve P nutrition while reducing the potential for excess accumulation of P in soils and risk of movement of P into water systems.

Some studies, Fonseka et al. [4], Ifenkwe and Allen [5], in which the relation between plant spacing and growth were examined, the results showed an increase in plant spacing to be accompanied by an increased stem length. The increased branching at the wider spacing did not compensate for fewer plants/m^2. They attributed increased branching at wider spacing to the availability of more space at lower plant densities. More space meant that plants were able to exploit the available nutrients in the soil and the photosynthetic active radiation for growth than plants at close spacing. In other words, the growth rate was increased. Setting plant spacing per unit area will reduce the effect of plant competition that will occur.

Several studies on plant spacing showed that the closer the spacing, it will cause competition plant height, number of branches and leaf area. Crop productivity could be greatly influenced by even a small change in soil water storage [6].

Mulches are essential components for up land agriculture, limit the negative effects of soil cultivation and increase the stability of natural environment Owing to a protective layer produced by these mulches the development of weeds is restrained and the water resistance of soil aggregates is improved [7].

Management of soybean cultivation practices through phosphor nutrient management, plant spacing, and mulching, is believed to increase soybean production and not damage the environment.In this context, this study analyzed the effect of different plant spacing, phosphor fertilizer, and mulching on growth, development and yield of soybean.

2. Material and Methods

The experiment was conducted in Cengkeh Turi - Binjai. This study used randomized block design (RBD) with three factors. The first factor is Phosphate fertilizer which consists of three levels (0, 100, and 200 kg TSP/ha). The second factor is Straw Mulch, consists of two levels of thickness 0, 5 cm. The third factor is Plant spacing which consists of three levels were: (30x15cm; 40x20cm; 50x25cm). The soybean cultivar used was Grobogan, a genotype which have large seed, adapted and widely grown in Sumatera Utara climate. Data were subjected to analysis of variance and means were compared by *Duncan Multiple Range Test* ($p<0.05$) using the SAS statistical software.

3. Results and Discussion

The result of statistic analysis showed that the application of P fertilizer and straw mulch did not affect on root volume, except the plant spacing. The increase in plant spacing will increase soybean root volume (Table 1).

Table 1. Root volume of soybean on plant spacing and straw mulch treatment

Plant spacing	Thickness of Straw Mulch (cm)		Average
	0	5	
30 cm x 15 cm	2.83	3.67	3.25c
40 cm x 20 cm	4.22	4.94	4.58b
50 cm x 25 cm	7.00	7.78	7.39a
Average	4.69	5.46	

The number followed by the same letters on the same row are not significantly different according to Duncan Multiple Range Test (DMRT) at 5% level.

Individual plant growth and development is directly influenced by the space available to plants. Plant spacing would be good for root growth. Roots will grow and expand in all directions. In addition, with a more extensive root growth, competition between plant roots decreases thus expanding the water and nutrient uptake. Nutrient and water availability will increase the volume of plant roots. Regular spacing will provide space to grow plants that are uniform so that the process of making food by the plant will be the same. The effect of different plant spacing on growth, development and yield of stems and roots of commercial cassava grown in a subtropical environment also found by N.A. Streck et al [8].

Although statistically mulching does not effect on root volume parameter, however, mulching with a thickness of 5cm increases root volume. The yield differences were caused by the effects of the mulches on the temperature and water content of the soil surface. Ground that given mulch straw has a higher soil moisture than without mulch. Observations during the vegetative growth period obtained an average moisture content of 82% in mulched soil and 75% of non-mulch. The mean temperature also has a difference, 28 on mulch and 31 on non-mulch. Differences in temperature and humidity on mulch-weighted soil were also found Mbagwu [9]. Maximum daily soil temperature was lowest on the straw plots (32·5°C), about equal on the bare and white polythene treatments (38·6°C vs 39·8°C) and highest on the black polythene plots (45·0°C). Maximum daily soil temperature was lowest on the straw plots. (32·5°C), about equal on the bare and white polythene treatments (38·6°C vs 39·8°C) and highest on the black polythene plots (45·0°C). And the research of Bunna *et al* [10] found that The positive effect of straw mulch on grain yield was related to increased crop establishment and reduced weed biomass, particularly under weedy conditions. The effect of mulch on yield may be considered through its effect on improved crop establishment and reduced weed biomass, and also its effect on mungbean growth directly through favourable water and perhaps temperature conditions, or indirectly through increased crop establishment and reduced weed growth. Their contribution to yield is analysed below.

The high moisture of the soil on mulched straw will help the availability of water for nutrient and root growth. The relatively constant temperature on the ground given mulch will also help the process of nutrient uptake.

Table 2. Soybean root dry weight on phosphate fertilizer, straw mulch and plant spacing treatment

Phosphate Fertilizer (kg/ha)	Thickness of Straw Mulch (cm)	Plant Spacing			Average
		30 cm x 15 cm	40 cm x 20 cm	50 cm x 25 cm	
0	0	1.10	1.13	0.90	1.04
	5	0.90	1.13	0.93	0.99
100	0	1.32	1.23	0.97	1.18
	5	0.83	0.87	1.30	1.00
200	0	1.03	1.03	1.23	1.10
	5	1.27	1.20	1.33	1.27
Average		1.06	1.10	1.11	

Phosphate fertilization, straw mulching and plant spacing did not significant effect on root (Table 3) and shoot growth (Table 4).

The results of this study indicate the root growth pattern has decreased at larger plant spacing (Table 2), different from the shoot growth, the extension of the plant spacing will increase the shoot growth, although statistically not significant effect (Table 3). roots and shoots are two sinks that compete during the plant life cycle [11]. Data of weight per plant and weight per root in table 4 can be explained by the hypothesis of Aguiar et al. [12] who found that, under conditions of lower densities (wide spacing), the sink of roots exceeds that of shoot tips.

The wide plant spacing will increase the weight of 100 soybean seeds, while the application of P fertilizer and straw mulch does not affect (Table 4). Narrow spacing (30x15cm), which produce lower shoot dry weight than in wide spacing. This lower shoot growth will result in lower assimilate accumulation, so the biomass for seed filling is lower, and produce smaller seed yields.

Table 3. Shoot dry weight of soybean on phosphate fertilizer, rice straw mulch and spacing treatment

Phosphate Fertilizer (kg/ha)	Thickness of Straw Mulch (cm)	Plant spacing			Average
		30 cm x 15 cm	40 cm x 20 cm	50 cm x 25 cm	
0	0	10.10	15.07	12.40	12.52
	5	14.60	12.00	10.77	12.46
100	0	9.50	14.27	14.27	12.68
	5	10.93	12.43	10.70	11.36
200	0	12.97	14.27	13.43	13.56
	5	13.90	14.20	16.03	14.71
Average		12.00	13.71	12.93	

Table 4. Weight of 100 seeds of soybean on the of plant spacing and phosphate fertilizer treatment

Phosphate Fertilizer (kg/ha)	Plant Spacing			Average
	30 cm x 15 cm	40 cm x 20 cm	50 cm x 25 cm	
0	19.97	21.09	22.08	21.05
100	17.76	20.34	22.40	20.17
200	20.99	22.28	22.79	22.02
Average	19.57b	21.24ab	22.42a	

The number followed by the same letters on the same column are not significantly different according to Duncan Multiple Range Test (DMRT) at 5% level.

This result confirms the individual advantage for plants with larger area for exploration and is according to Barros et al. [13] who reported that the yield per cassava plant is greater in plants with wider plant spacing. And research of Onat, *et al* [14] found that The average pod yield was significantly affected by the row distance and plant spaces. Increasing the plant spaces from 5 cm to 25 cm, the pod yield per plant was increased from 24.5 g to 96.2 g in a two year average. In this equation, the pod yield per plant was decreased when the plant density increased, whereas plant number per hectare was increased when the plant density increased.

The increase of phosphate fertilizer 200 kg/ha at plant spacing of 50 x 25cm resulted in the highest P content on shoot, while the lowest rate was obtained on soybean without P fertilizer with narrow spacing (Table 5). P fertilization may improve P nutrition and crop yield potential [3].

Table 5. P content of soybean shoot on phosphate fertilizer and plant spacing treatment

Phosphate Fertilizer (g/plot)	Plant Spacing			Average
	30 cm x 15 cm	40 cm x 20 cm	50 cm x 25 cm	
0	0.15h	0.15h	0.16g	0.15
10	0.19f	0.22e	0.24d	0.21
20	0.26c	0.28b	0.29a	0.28
Average	0.20	0.22	0.23	

The number followed by the same letters on the same column and row are not significantly different according to Duncan Multiple Range Test (DMRT) at 5% level.

The results of this study indicate the highest root volume obtained in plants that have a wide spacing. In this condition the plant has the potential to have a higher root proliferation. An increase in P fertilizer dosage will cause an increase in total P of soil that affects its availability. This condition is suspected to cause why soybean with fertilization of phosphat 200 kg/ha at wide plant spacing yields higher P levels. When compared with no fertilizer P, the fertilized plant will increase P levels to 93.3%. As described by Deressegn and Telele [15] that Plant spacing have effect on the crop growth, yield components and yield of soybean due to competition effect of the plant such as light, nutrients and water, the rate and extent of vegetative growth and development of crops particularly that of leaf area index, plant height, root length and density, yield components and yield the major problems in the country. With the rise of density, the dry matter produced in both sole cropping (monocultures) and intercropping increased. High plant density particularly as to forage crops, creates a suitable microclimate and results in the rise of total dry matter yield.

4. Conclusion

Phosphate fertilizer (200 kg/ha) significantly increased levels of phosphate in the shoot. Plant spacing (50 cm x 25 cm) increases root volume. The interaction of phosphate fertilizer (200 kg/ha) and spacing (50 cm x 25 cm) increased the phosphate level by 93.33% in shoot. Plant spacing (50 cm x 25 cm) produces the largest of 100 grains weight as compared to other plant spacing.

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