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Influence of phosphorus and organic fertilizers on the growth and yield of Indonesian new superior variety of soybean in dry climate rice fields

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Abstract. The response of soybean crop to organic fertilizers has not been fully understood in Indonesia. This research aims to investigate the response of new superior variety of Anjasmoro soybean to phosphorus and organic fertilizers in the dry climate ricefields. The experiment was conducted in Sesela Village, West Nusa Tenggara Province, Indonesia from August - November 2015 using a randomized 2-factor design. The first factor was phosphorus fertilizer with 4 levels: 0 kg/ha, 36 kg/ha, 72 kg/ha and 108 kg/ha. The second factor was organic fertilizer with 4 levels of fertilizer dosage: 0 ton/ha, 2.5 tons/ha, 5 tons/ha and 7.5 tons/ha. Parameter observed were plant height, number of leaves, number of nodules, number of productive branches, number of pods, number of empty pods, dry weight, weight of 100 seeds, and production. The results showed that the optimum dose of organic fertilizer was 7.5 tons/ha with the highest number of pods of 100. This was confirmed by the regression value (R^2) of 0.97 which indicates that organic fertilizer affects the increase in the number of pods in a quadratic. Phosphorus fertilizer has an effect on the number of empty pods, number of productive pods, number of pods, productivity and production of soybean.

Keywords: Dry climate, organic fertilizer, phosphorous, soybean

1. Introduction

Soybean (*Glycine max* L.) is an important food commodity in Indonesia after rice and corn. Phosphorus (P) is one of the macro nutrients needed by plants in large quantities. The P element is absorbed by plants in the form of phosphate ions. A number of studies explain that P fertilization affects the growth and development of plants. This is because P plays a role in cell division, assimilation process, respiration, root growth, part of nucleic acids, and as a source of ATP and ADP [1]. Phosphorus can stimulate plant growth, root development, fruit and seed formation, especially cereal. Phosphorus is also important for cell division, flower formation, plant maturity processes, increase resistance to breeding, improve plant quality, and strengthen resistance to disease. Plants that experience a deficiency of P elements usually show symptoms such as stunted growth, purplish leaves, dwarf, shallow roots, and weakened stems. In legume plants, P is indirectly a nutrient that affects N



fixation activity by rhizobium bacteria. It can be seen from the reduced formation of root nodules by rhizobium with reduced P content in the soil [2].

P fertilization in soybean plants has very significant effect on the increasing yield. P fertilization of 67.5 kg/ha can increase soybean production to reach 1.5 ton/ha [3]. In addition, P increased the canopy weight, root weight and primary root diameter[4]. Furthermore to produce 1 ton/ha soybean dry seeds requires N nutrients as much as 22.5 kg N + 45 kg P₂O₅ + 25 kg K₂O in dry land. It was also reported that P fertilization at a dose of 72 kg/ha can increase the number of pods in saturated water cultivation [5]. Furthermore, Chesney [6] reported that soybean yield rose significantly in fertilizing 0, 29 and 59 kg/ha. It was concluded that phosphate is very important to get good seeds and the dose should not be less than 40-60 kg/ha [7]. Element P in soil comes from organic material (manure, plant remnants), chemical fertilizers and minerals in the soil [1]. On the other hand, the use of organic matter is very important in an effort to improve soil structure and aeration. Organic matter mixed with soil minerals has a large influence on the holding capacity of water therefore it can be utilized by plants in its growing period [8]. One of the important sources of organic matter that contains nutrients N, P, K, Ca, Mg, S, and Bo is mostly manure. Combination uses of P and organic fertilizers will provide optimal growth for plants [9]. Based on the above explanation, the combination uses of P and organic fertilizer on soybean in dry climate land of West Nusa Tenggara Province as one of the biggest production area in Indonesia is need to be investigated.

2. Materials and methods

2.1. Materials

The materials used in the field were soybean seed (Anjasmoro variety), fertilizer (urea, phosphor, KCl, and organic fertilizer called petroganik), pesticides (herbicide and insecticides), and chemicals for soil and plant nutrient analysis in the laboratory. Experiments in the field use the following tools: cow plows, hoes, sprayers, raffia ropes, ruler, cameras, hand counters, plastic bags, tarps, analytical scales, stationery and laboratory equipment for soil analysis and plant nutrient analysis.

2.2. Methods

The experiments was conducted in ricefields at the end of the dry season II (August - November 2015), located in Sesela Village, West Lombok Regency, West Nusa Tenggara Province. Analysis of soil nutrient levels, water content, plant nutrients were carried out at soil laboratory of the Institute for Assessment of Agricultural Technology, West Nusa Tenggara Province and soil laboratory, Bogor Agricultural University. The experiment was arranged using a randomized block design of 2 factors, where first factor was P fertilizer dose consisting of 4 levels: 0, 36, 72, and 108 kg/ha. While second factor was organic fertilizer dosage consist of 4 levels: 0, 2.5, 5, and 7.5 tons/ha. The linear model used was: $Y_{(ij)k} = \mu + \alpha(i) + \beta(j) + \alpha\beta(ij) + \rho_k + \varepsilon_{(ij)k}$, where: Y_{ijk} = Observation value of p-fertilizer to organic fertilizer to -j on the k-block, μ = general average value, $\alpha(i)$ = the effect of i-p fertilizer, $\beta(j)$ = the effect of j-manure, $\alpha\beta(ij)$ = the effect of the interaction between p-i fertilizer and jth organic fertilizer, ρ_k = kth block effect, $\varepsilon_{(ij)k}$ = Effect of errors from jth and kth organic fertilizers. Data obtained were analyzed for variance, if significantly different continued with Duncan's Multiple Range Test (DMRT) at the level of 5%[10]. To see the response pattern a regression test was carried out.

3. Results and discussion

3.1. General condition of the experimental site

Based on nutrient status analysis prior to the experiment it is known that P content in the soil is very high, this has implications for the P available in the soil is also very high. Likewise with the total K and K available in the soil is also high. On the other hand, N content in the soil is in the low category 0.16%. A neutral category pH help plants absorb nutrients from the soil, help nutrients dissolve in

water, and help the development of microorganisms in the soil [1]. Soil has 42% sand, 42% dust, and 16% clay (table 1). This soil is a suitable land category based on physical and chemical properties for the growth and development of soybean plants. The research location is close to the water source (river is 200 meters from the planting area). Clay texture has advantages such as bonding and holding capacity of water is quite high.

Table 1. Physical and chemical properties at the site prior to the experiment

Parameters	Value	Criteria*
Physical properties:		
Soil texture (pipette):		Clay
- Sand	42	
- Dust	42	
- Clay	16	
Chemical properties:		
1. pH H ₂ O	6.44	neutral
2. pH KCl	6.44	neutral
3. C-organic (%)	0.20	low
4. N total (%)	0.16	low
5. C/N	11	medium
6. P available (ppm)	192.94	very high
7. K available (ppm)	575.83	very high
8. S available (ppm)	1.37	high
9. Fe available (ppm)	11.49	medium
10. Mg-dd (cmol/kg)	0.74	low
11. K-dd (cmol/kg)	0.99	high
12. Na-dd (cmol/kg)	0.12	low
13. Mg-dd	0,72	low
14. Cation exchange capacity	6.95	low

*= results of soil analysis at the IAAT West Nusa Tenggara Province (2015)

3.2. Plant height

Plant height observations at the ages of 2, 4, 6, 8, and 10 Weeks After Sowing (WAS) showed no significant difference but at the age of 12 WAS the highest plant height was found in treatment of P fertilizer 108 kg/ha and not significantly different from 36 and 72 kg/ha. This is caused by sufficient availability of P in the soil. Therefore it can increase P nutrient uptake for plants. The relationship between increasing P nutrient uptake and growth is related to photosynthesis (table 2). At an optimal photosynthesis, the distribution of photosynthate to the organs of plants that are needed will be greater therefore it become a source of energy for plant growth. Whilst treatment of organic fertilizer giving a very significant effect on plant height at aged 4, 6, 8 WAS (table 3).

At the level of P fertilizer 0 kg/ha, the response pattern of plant height (y) to organic fertilizer (x) is $Y = -2,094x^2 + 21,107x + 39,785$ and $R^2 = 0.9582$. the maximum plant height is obtained at the level of organic fertilizer 5.03 tons/ha with plant height 74.77 cm. At the level of P fertilizer 36 kg/ha the response pattern of plant height (y) to organic fertilizer (x) is $Y = -0.3187x^2 - 3.6021x + 91.411$ and $R^2 = 0.9952$ therefore the maximum plant height is obtained at the level of organic fertilizer 5.65 tons/ha with plant height 81.233 cm. At the P fertilizer level of 72kg/ha the response pattern of plant height (y) to organic fertilizer (x) is $Y = 0.0493x^2 - 0,6939x + 87.13$ and $R^2 = 0.7733$ therefore the minimum plant height is obtained at the level of organic fertilizer 6.48 tons/ha with plant height 88.751 cm. At the P fertilizer level of 108 kg/ha the response pattern of plant height (y) to organic fertilizer (x) is $Y = 0.1733x^2 - 1.8307x + 88.94$ and $R^2 = 0.9989$ therefore the minimum plant height is obtained at the level of organic fertilizer 5.38 tons/ha with plant height 84.11 cm. The results of the interaction of the

treatment of the use of P fertilizer and organic fertilizer significantly increased plant height at 12 WAS. It was clear that the application of P fertilizer at a dosage of 36 kg/ha had the highest plant height of 97 cm but did not significantly affect the treatment, and the lowest plant height was dosing P fertilizer 0 kg/ha and organic fertilizer 0 kg/h which is 38 cm (figure 1 and 2).

Table 2. Effect of P fertilizer on the average plant height at various ages of observations

Treatment P dosage (kg/ha)	Plant height (cm)					
WAS.....					
	2	4	6	8	10	12
0	14.36	51.93	87.05	85.68	85.39	73.12b
36	14.80	54.29	87.375	85.96	84.89	84.87a
72	14.87	53.13	87.80	87.09	85.55	86.21a
108	14.96	53.22	86.41	85.81	85.867	85.86a

Note: The values followed by different letters show a significantly different for the DMRT test at the 5% level

Table 3. Effect of organic fertilizer on the average plant height at various ages of observations

Organic fertilizer (ton/ha)	Plant height (cm)					
	2	4	6	8	10	12
0	14.91	56.07a	90.97a	90.21 a	87.89	76.33
2.5	14.97	53.62 a	86.37ab	86.38 ab	85.30	85.22
5	14.65	52.35ab	85.46b	84.57 b	84.65	84.65
7.5	14.49	50.535 b	85.45 b	83.41 b	83.86	83.89

Note: The values followed by different letters show a significantly different for the DMRT test at the 5% level

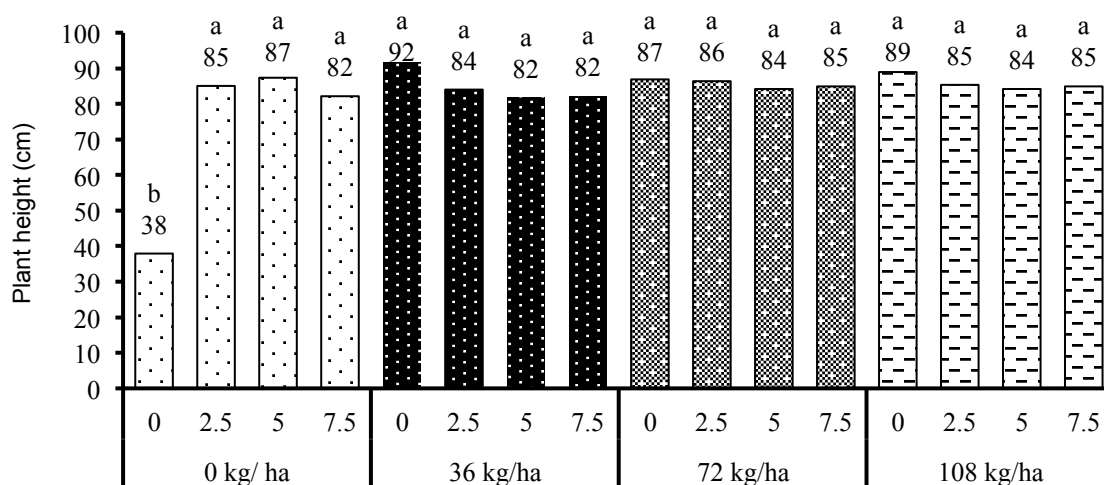


Figure 1. Effect of interaction on treatment of P fertilizer and organic fertilizer on plant height at 12 WAS. Note: The same letters at the same organic fertilizer dosage show no significant difference in the DMRT test $\alpha = 5\%$.

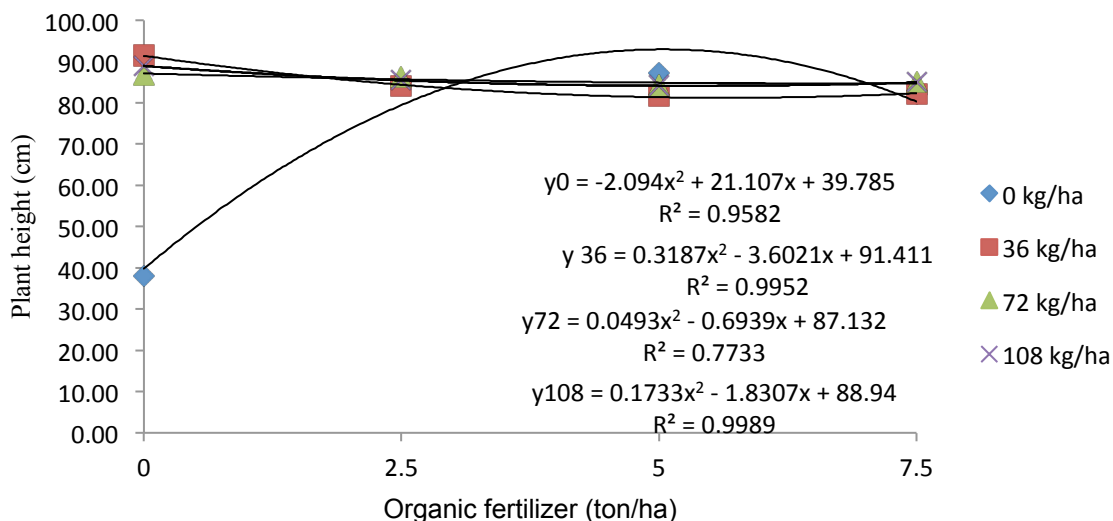


Figure 2. The response pattern of plant height in application of organic fertilizers and various dosage of P fertilizer.

3.3. Number of trifoliolate leaves

Phosphorus had an effect on the number of trifoliolate leaves at 2, 4, 6, 8, and 10 WAS. The highest number of trifoliolate leaves at various ages of observation was at P fertilizer treatment of 72 kg/ha and not significantly different from treatment without P fertilizer of 36 kg/ha and 108 kg/ha. Furthermore, for the treatment of organic fertilizer the effect was significant at the age of 6 WAS, the highest number of trifoliolate leaves was in the treatment of organic fertilizer 5 tons/ha and not significantly different between the other treatments. The average number of trifoliolate leaves is presented in table 4. The use of P fertilizer in various ages of observations with different doses showed an increase in the number of leaves at each age of observation. At different P doses the effect of using P fertilizer did not significantly affect the number of leaves. The influence of a single factor on the use of organic fertilizer gave a significant effect at the age of 6 WAS where the highest number of leaves was at the application of organic fertilizer at 5 tons/ha.

Table 4. Effect of P and organic fertilizers on the average number of trifoliolate leaves at various ages of observation.

Treatment	Number of trifoliolate leaves				
WAS.....				
P Fertilizer (kg/ha)	2	4	6	8	10
0	9.73	14.73	16.67	22.92	20.92
36	10.28	15.28	15.94	24.48	20.93
72	10.45	14.97	16.69	24.54	21.33
108	9.92	14.97	16.60	24.64	21.12
Organic Fertilizer (ton/ha)WAS.....				
0	10.38	15.38	16.23 ab	23.72	20.04
2.5	10.63	15.60	16.49 ab	23.16	21.42
5	9.51	14.51	17.46 a	25.06	21.58
7.5	9.85	14.93	16.23 ab	24.64	21.25

Note: The values followed by different letters show a significantly different for the DMRT test at the 5% level

3.4. Branches, root nodules, root length, and leaf area

Application of P fertilizer had an effect on the number of branches, number of nodules, and root length. The highest number of branches at harvest was at P fertilizer of 108 kg/ha, the highest number of root nodules was at P fertilizer of 72 kg/ha and the highest root depth was at P fertilizer of 0 kg/ha and not significantly different with treatments of 36 and 72 kg/ha but significantly different with treatments of 108 kg/ha (figure 3). The highest root depth was at no P fertilizer application but it was not significantly different from 36 and 72 kg/ha. The average number of branches, number of root nodules, and root length is presented in table 5.

The higher dose of P fertilizer given, the more branches are, due to the availability of P in sufficiently available conditions in the soil, which will affect the vegetative generative processes [11]. In general, the function of P is to accelerate the growth of branches and will accelerate the growth of young plants into mature plants and accelerate the growth of seedling roots. Adequate supply of P results in increased root growth therefore uptake of water and nutrients increases because the application of sufficient amounts of P fertilizer will greatly assist in the process of growth and plant metabolism such as cell division, respiration and photosynthesis [12].

The use of P fertilizer had no significant effect on leaf area but the use of organic fertilizer significantly affected leaf area at the age of 8 WAS (table 5). The best leaf area is in the application of P fertilizer at 108 kg/ha, and is significantly different from 36 and 72 kg/ha. The results of the interaction between P and organic fertilizers significantly affect the depth of the root. The highest root depth was found in giving phosphorus fertilizer 72 kg/ha and without organic fertilizer. Root depth is the ability of roots to develop in search of nutrients needed by plants, at P fertilizer 72 kg/ha provides the ability to develop roots and provides space for roots to absorb more nutrients therefore it will help the growth and transport of elements nutrients in plants [13].

Table 5. Effect of P and organic fertilizers on leaf area, number of branches, number of root nodules and root length at harvest

Treatment	Leaf area 8 WAS	Number of branches	Number of Root nodules	Root length
P fertilizer (kg/ha)				
0	82.50	4.39	1.17	18.14a
36	98.33	4.24	1.14	17.04ab
72	97.90	4.55	1.23	17.65ab
108	93.27	4.56	1.14	16.32b
Organic fertilizer (ton/ha)				
0	85.79 ab	3.88	19.02	16.78
2.5	95.79 ab	4.38	19.63	17.11
5	78.10 b	4.34	18.21	17.87
7.5	112.31 a	4.13	21.56	17.40

Note: The values followed by different letters show a significantly different for the DMRT test at the 5% level

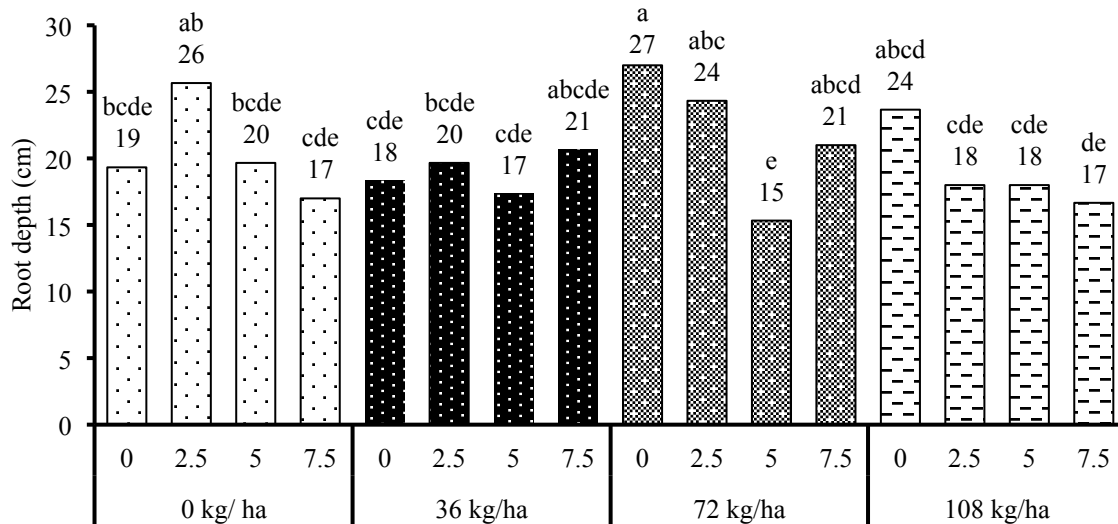


Figure 3. Effect of interaction treatment of P and organic fertilizers on root depth at harvest. Note: The same letters at the same organic fertilizer dosage show no significant difference in the DMRT test $\alpha = 5\%$

Root depth at harvest shows the interaction between the treatment of P and organic fertilizer. The depth of the deepest roots is found in a combination of 36 kg/ha of phosphorus fertilizer and without organic fertilizer. At the P fertilizer level of 0 kg/ha the response pattern into the root (y) of organic fertilizer (x) is $Y = -0.36x^2 + 2.1803x + 20.116$ and $R^2 = 0.70$ therefore the maximal root is obtained in 3.02 tons/ha of organic fertilizer with root 23.42 cm. At P 36 kg/ha the response pattern into the root (y) of organic fertilizer (x) is $Y = 0.08x^2 - 0.4133x + 18.8$ and $R^2 = 0.32$ therefore the minimum root is obtained in level of organic fertilizer 2.58 tons/ha with root 18.26 cm. At P 72kg/ha the response pattern into the root (y) of organic fertilizer (x) is $Y = 0.3334x^2 - 3.5802x + 28.05$ and $R^2 = 0.70$ therefore the minimum root is obtained at the level organic fertilizer 5.36 tons/ha with root 18.35 cm. At P 108 kg/ha the pattern of response into the root (y) of organic fertilizer (x) is $Y = 0.1734x^2 - 2.1402x + 23.317$ and $R^2 = 0.916$ therefore the minimum root is obtained in level of organic fertilizer 6.17 tons/ha with root depth of 16.12 cm (figure 4).

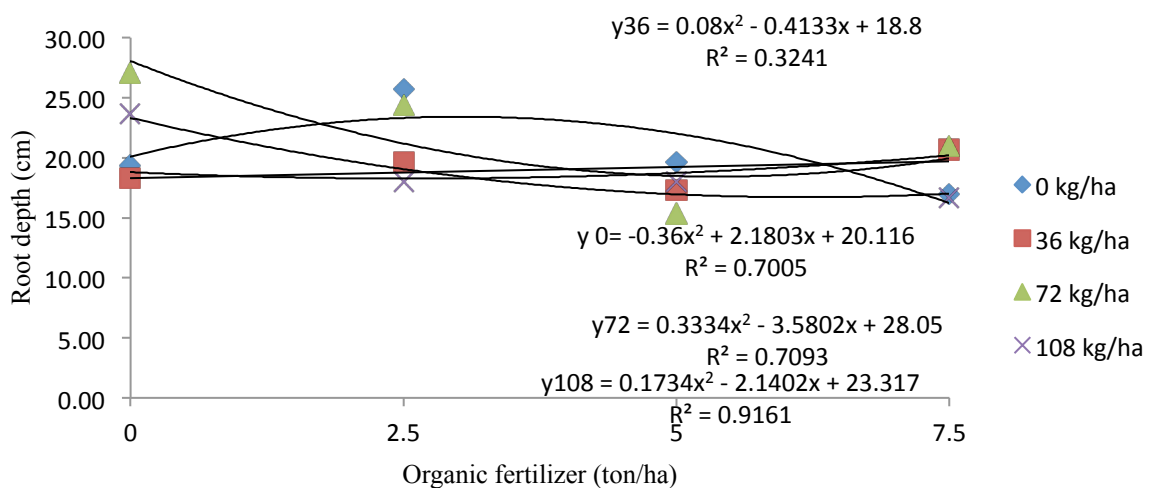


Figure 4. Response pattern of root depth in application of organic fertilizer and various dosage of P fertilizer

3.5. Soybean yield

The application of P fertilizer had an effect on the number of empty pods, number of productive pods, number of pods, production per plot and production per hectare. Table 6 shows that the more doses of P fertilizer are given, the higher the number of productive pods, the total number of pods, and the higher production of production and plot production but not significantly different between treatments. The components of the results obtained are quite high compared to the potential possessed by the Anjasmoro variety. This is presumably due to the availability of sufficient water for the growth and development of soybean plants and the intensity of radiation which is quite high. With both of the above, it can anticipate drought stress which can reduce soybean yield to 55% [14].

Table 6. Effect of application of P and Organic fertilizers on the number of empty pods, number of productive pods, number of pods, and yield per plot

Treatment	Number of empty pods	Number of productive pods	Total number of pods	Yield/plot
P fertilizer (kg/ha)				
0	0.92	85.23	86.15	2.23a
36	0.89	83.38	85.13	2.22a
72	1.10	84.34	85.20	2.22a
108	0.84	89.95	90.79	2.21a
Organic fertilizer (ton/ha)				
0	0.89	85.01	85.65	2.19a
2.5	0.85	86.19	87.04	2.23a
5	1.17	85.93	87.09	2.22a
7.5	0.84	85.78	87.48	2.21a

Note: The values followed by different letters show a significantly different for the DMRT test at the 5% level

The results of the interaction of P and organic fertilizers significantly increase the number of crop pods. The highest number of pods is found at a dose of P 108 kg/ha and organic fertilizer 5 tons/ha. And the lowest is found in plants with phosphorus fertilizer 108 kg/ha and without the use of organic fertilizers. It can be seen that by giving P fertilizer at 108 kg/ha can help the process of growth and development because P elements play a lot in the process of cell division and photosynthesis. If the photosynthesis process can run optimally, the process of forming photosynthate yields to organs such as seeds will increase, this will cause a greater number of plant pods (figure 5).

At the level of P fertilizer 0 kg/ha the response pattern of the number of pods (y) to organic fertilizer (x) is $Y = 0.2027x^2 + 21.107x + 39.785$ and $R^2 = 0.654$ therefore the maximum number of pods obtained at the level of organic fertilizer is not reaching with the number of pods 80.779. At the P 36 kg/ha, the response pattern of the number of pods (y) to organic fertilizer (x) is $Y = -0.33747x^2 - 3.9421x + 891,961$ and $R^2 = 0.99$ therefore the maximum number of pods is obtained at the level of organic fertilizer 5.26 tons/ha with a minimum number of pods of 79.5856 at the P fertilizer of 72kg/ha. The response pattern of the number of pods (y) to organic fertilizer (x) is $Y = -1.0080x^2 + 9.68x + 75.7$ and $R^2 = 0.91$ therefore the maximum number of pods is obtained at the organic fertilizer 4.80 tons/ha with number of pods 98.94. At P fertilizer 108 kg/ha the response pattern of number of pods (y) to organic fertilizer (x) is $Y = 0.2174x^2 - 3.8183x + 93.905$ and $R^2 = 0.99$ therefore the minimum number of pods is obtained at the level organic fertilizers that have not reached the minimum conditions with the number of pods have not been able to reach a minimum condition (figure 6). Based on the regression results, figure 6 shows that the optimum dose of organic fertilizer is

7.5 tons/ha with the highest number of pods 100. This is reinforced by the regression value (R^2) 0.97 which indicates that organic fertilizers affect the increase in the number of pods squared. Figure 6 shows the optimum number of doses for increasing soybean production in dry climate ricefields is without the use of P fertilizer and 5 tons/ha dose of organic fertilizer. This is because P is available in the soil high enough to provide an element of P which will help the process of growth and development of soybean plants.

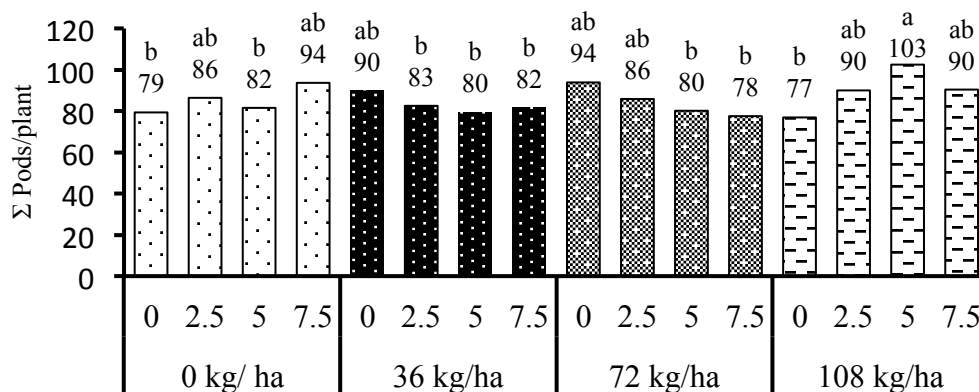


Figure 5. Effect of interaction treatment of P and organic fertilizers on number of pods per plant. Note: The same letters at the same organic fertilizer dosage show no significant difference in the DMRT test $\alpha = 5\%$.

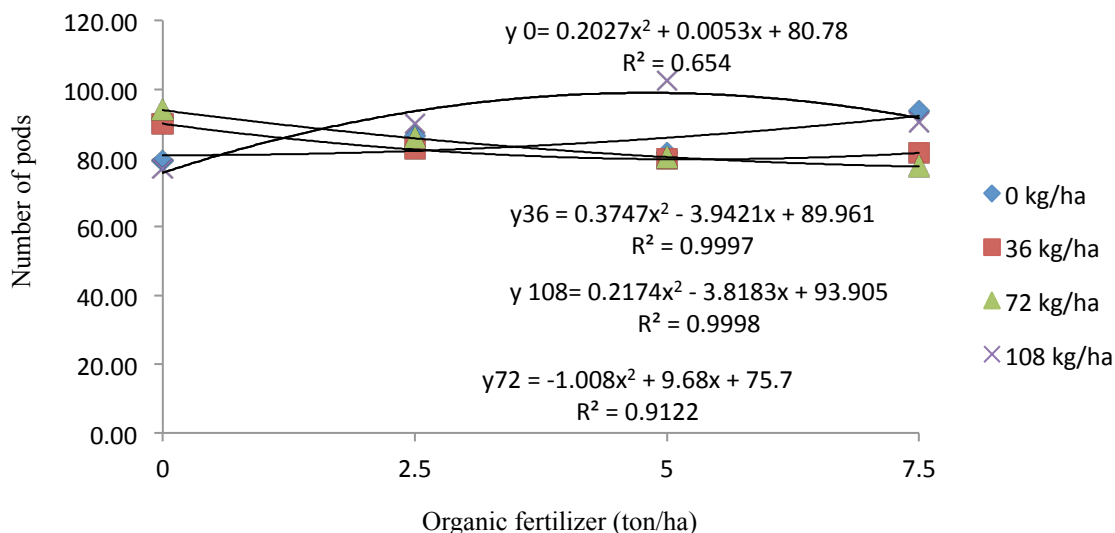


Figure 6. Response pattern of number of pods in application of P and organic fertilizers.

4. Conclusion and Recommendation

Based on the results of the study, it was found that all treatments of P fertilizer and organic fertilizer gave a significant effect on plant height, weight of 100 seeds, number of pods, wet weight, and root depth. The effects of different P and organic fertilizers application have a significant effect on the amount of productivity between each treatment in dry climate ricefields. The interaction of the combination of P and organic fertilizer treatments can increase and significantly influence the number of plant pods, weight of planting seeds, P nutrient content in leaves, root depth of soybean plants, and

productivity. The optimum dose combination of P and organic fertilizer treatments is 72 kg/ha and organic fertilizer 7.5 tons/ha can increase the number of filled pods in dry climate ricefields.

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