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Abstract. The study aimed to determine the effectiveness of P fertilization on soybean plants in coastal sands soil. Pot research in the field using complete randomized block design with four replications. Treatment factors include soybean cultivars namely Anjasmoro, Demas 1, Gema, and Gepak Ijo; and P fertilizer dosage consisted of 0, 36, 72, and 108 kg P_2O_5 ha^{-1} or equivalent to 0, 100, 200, and 300 kg SP36 ha^{-1}. Data were analyzed using variance analysis, continued with Duncan's Multiple Range Test at 5% error level. The results showed the interaction of soybean cultivars with P fertilizer dosage on all observed variables. The growth of leaf area and P uptake of soybean plants increased by P fertilization until the optimum dose depends on soybean cultivars. The dry weight of plants and soybean yields on Anjasmoro, Demas 1 and Gepak Ijo cultivars increased by fertilizing SP36 up to the optimum dose and no further increased or even decreased at higher P fertilizer doses. P fertilization on Gema cultivar showed ineffectiveness based on leaf area, plant dry weight and the yield of seeds which were actually inhibited by P fertilizer.

1. Introduction

Land availability has always been a major obstacle in national soybean production. This is because soybean is not a main crop in rice fields. Soybean cultivation in paddy fields through rice-rice-soybean cropping patterns contributed the most national soybean production because the harvested area reached 58%. The assembled technology in the form of high yielding and early maturing superior varieties has not been able to arouse the interest of farmers to grow soybeans in paddy fields [1,2].

Another problem is the unavailability of quality seeds in appropriate times because of the short storability of seeds [3]. Provision of seeds between fields and seasons can be done if there is a specific land that can be planted with soybeans before the planting season of soybean in the paddy fields. Alternative solution is through the development of soybeans in non-rice fields, both for production and supply of seeds. Therefore, one of the potential lands for the development of soybeans is coastal sandy land area.

Coastal sandy land area has sufficient groundwater resources, and is not affected by flooding and can be utilized throughout the year for crop cultivation [4]. However, coastal sandy land area has a major

obstacle, namely low nutrient availability, both macro and micro nutrients [5] also the in ability to store adequate nutrients [6].

Soybean plants need high N and P elements to produce quality seeds. The N nutrient requirements may mostly be met through N_2 fixation on the root nodules, while P can be met from soil P content, mineralization of organic matter and fertilizer P. Phosphorus enters the biosphere through absorption by microorganisms and plants, and otherwise through decomposition of materials organic, the phosphorus will be exchanged to the soil. Changes in organic matter contribute 20-80% of the total P in the soil [7].

Organic material in the form of manure is a production input that is always provided by farmers in coastal sandy land area along with land-processing activities. P fertilization both in the form of manure, mineral fertilizer, and sewage sludge can increase the availability of P in the soil [8], where the P element is likely to accumulate or leach depending on soil and environmental conditions [9]. Although P mobility in the soil is small because of the large P uptake capacity by soils, but leaching in water-soluble P in sandy soil with small cation exchange capacity occurs and has potentially cause the P contamination to surface water and groundwater [10].

According to this issue, the effectiveness of the use of P fertilizer on soybean plants in coastal sandy land is importantly studied. Phosphorus (P) is the second limiting factor for the growth and yield of soybeans after N. Phosphorus may be present in large amounts of soil, but less available because of its low solubility [11,12] and presence of dissolved P fixation. Al, Fe, Ca, K and Mg can react with P fertilizer and produce compounds that are not easily soluble.

In general, soybean plants require a number of nutrients both macro and micro nutrients to grow and develop normally and produce maximum according to their genetic potential. The study used several superior soybean cultivars which through previous research were known to be able to adapt in suitable to not adaptive to the environment, namely coastal sandy land. The study aimed to determine the effect of P fertilization on some soybean cultivars, as well as the optimum dose to obtain high yield of seeds in the coastal sandy land.

2. Materials and methods

This pot experiment was carried out on the sand land of Samas Beach, Srigading Village, Sanden District, Bantul Regency, Daerah Istimewa Yogyakarta. The study was conducted for 4 months, started from August to November 2017.

The materials used were four superior soybean cultivars including: Anjasmoro, Demas 1, Gema, and Gepak Ijo, coastal sandy soil, bokashi made from banana pseudostem, ZA fertilizer, SP36, and KCl, insecticides, and fungicides. The equipment used include: ground sieves, polybags, water pumps, hoses, ovens, digital scales. Materials and tools for analyzing the content of P total plant tissues include: HNO_3, $HClO_4$, ascorbic acid, PO_4 standard, distilled water, digest tube, test tube, measuring pipette, and UV-VIS spectrophotometer.

The study was arranged in a factorial randomized complete block design (4 × 4) with 4 replications. The first factor was soybean cultivars consisting of Anjasmoro, Demas 1, Gema and Gepak Ijo. The second factor is the dose of P fertilizer (SP36) consisting of no fertilizer, doses of 100, 200, and 300 kg ha^{-1}, or equivalent to 0, 36, 72 and 108 kg P_2O_5 ha^{-1}. The experimental unit was 10 pots each with 2 plants per pot. The observed variables included plant leaf area, plant dry weight, P nutrient uptake, and soybean yield. Observation data were subjected to analysis of variance, and continued by Duncan's Multiple Range Test if the means were significantly different at 5% error level.

3. Results and discussions

The results showed that P fertilization had various effects among cultivars on the growth of leaf area, plant dry weight, P nutrient uptake, and soybean yield as presented in Table 1 to Table 4, and Figure 1.

Data on total leaf area of plants measured at age 4, 6 and 8 weeks after planting showed a variety among soybean cultivars, and affected by P fertilizer doses given as presented in Table 1. The leaf area of Demas 1 and Gepak Ijo cultivars were increased by P fertilization at the dose of 36 kg P_2O_5 ha^{-1} compared to plants with no P fertilizer P at age 4 weeks after planting. The leaf area of Anjasmoro was

increased at the dose of 72 kg P_2O_5 ha^{-1} (3.11 dm^2), while the development of leaf area of Gema cultivar was actually inhibited by P fertilization at the beginning of growth.

Table 1. Plant leaf area four soybean cultivars at treatment doses of P fertilizer in coastal sandy soil.

Treatment Factor		Plant Leaf Area (dm^2)		
		Plant Age (Weeks)		
Soybean Cultivars	Dose of P Fertilizer (kg P_2O_5 ha^{-1})	4	6	8
Anjasmoro	0	2.00 ^{e}	21.74 ^{de}	31.00 ^{e}
	36	2.23 ^{e}	22.09 ^{de}	41.50 ^{d}
	72	3.11 ^{cd}	24.42 ^{cd}	42.15 ^{d}
	108	2.52 ^{de}	18.11 ^{f}	33.13 ^{e}
Demas 1	0	4.42 ^{b}	26.21 ^{bc}	50.67 ^{c}
	36	5.48 ^{a}	26.35 ^{bc}	53.90 ^{bc}
	72	5.05 ^{ab}	28.87 ^{ab}	55.72 ^{b}
	108	4.95 ^{ab}	28.72 ^{ab}	49.75 ^{c}
Gema	0	3.16 ^{cd}	20.16 ^{ef}	31.22 ^{e}
	36	2.81 $^{c-e}$	23.30 ^{d}	31.43 ^{e}
	72	2.73 $^{c-e}$	24.23 ^{cd}	31.67 ^{e}
	108	2.63 ^{de}	18.77 ^{f}	25.07 ^{f}
Gepak Ijo	0	3.50 ^{c}	24.35 ^{cd}	50.79 ^{c}
	36	5.17 ^{ab}	26.33 ^{bc}	50.88 ^{c}
	72	5.28 ^{a}	29.77 ^{a}	57.85 ^{b}
	108	5.12 ^{ab}	29.91 ^{a}	63.73 ^{a}
Interaction (CxP)		(+)	(+)	(+)
C.V. (%)		13.35	7.42	7.10

- Numbers followed by the same letter in the same column show no significant difference in Duncan's Multiple Range Test at 5% error level.
- (+) / (-): interaction of soybean cultivars and P fertilizer doses was significant / no significant.

Anjasmoro cultivar had the highest leaf area at 72 kg P_2O_5 ha^{-1} (24.42 dm^2) at the age of 6 weeks after planting. Demas 1 and Gepak Ijo cultivars also showed an increase in leaf area when given up to 72 kg P_2O_5 ha^{-1}. Gema cultivar at the age of 6 weeks after planting also showed increase in leaf width as affected by 36 kg P_2O_5 ha^{-1}, but not increased or even decreased higher doses of P fertilizer.

The highest leaf area at the age of 8 weeks is the Gepak Ijo cultivar when fertilized at a dose of 108 kg P_2O_5 ha^{-1}, with a leaf area 63.73 dm^2 and the lowest leaf area in Gema cultivar with the same dose was 25,07 dm^2. At a dose of 36 kg P_2O_5 ha^{-1}, the leaf area of Anjasmoro cultivar were effectively increased. An increase in fertilizer dose of P 72 kg P_2O_5 ha^{-1} not effectively increased leaf area, and at a dose of 108 kg P_2O_5 ha^{-1} actually decreases the leaf area. The leaf area of Demas 1 cultivar had only only increased in the application of P fertilizer up to dose of 72 kg P_2O_5 ha^{-1}. Gema cultivar showed the same leaf area between plants without P fertilizer compared to that fertilized at dose of 36 to 72 P_2O_5 ha^{-1}, and even decreased the leaf area at doses of 108 P_2O_5 ha^{-1}.

Sandy soil media in this study were given by organic material in the form of bokashi made from banana pseudo-stem as much as 36 t ha^{-1}, which in decomposition also can be as a source of P. P fertilization was effective only on soybean cultivars that adaptive to the environment of coastal sandy land, namely Anjasmoro, Demas 1, and Gepak Ijo; and not effective on non-adaptive cultivar namely Gema. Leaves as photosynthetic organs show that they are affected by P fertilization. The adequate of P will increase nitrogenase activity [13], and leaf photosynthesis [14], so that increase the growth of plant leaf area and plants can produce more dry matter.

Table 2. Plant dry weight four soybean cultivars in the treatment of P fertilizer in coastal sandy soil.

Treatment Factor		Dry Weight of Plants (g.pot^{-1})		
		Plant Age (Weeks)		
Soybean Cultivars	Dose of P Fertilizer (kg P_2O_5 ha^{-1})	4	6	8
Anjasmoro	0	1.43 ^{h}	15.29 ^{gh}	41.47 ^{h}
	36	1.74 ^{gh}	17.06 ^{fg}	47.19 ^{ef}
	72	2.05 ^{fg}	19.79 ^{e}	51.36 ^{cd}
	108	1.66 ^{gh}	14.41 ^{hi}	32.91 ^{i}
Demas 1	0	2.93 $^{b-d}$	21.03 ^{de}	54.62 $^{b-d}$
	36	3.57 ^{a}	22.93 $^{b-d}$	63.09 ^{a}
	72	3.13 $^{a-b}$	24.48 ^{ab}	63.19 ^{a}
	108	3.31 ^{ab}	25.29 ^{a}	56.20 ^{b}
Gema	0	2.12 $^{e-g}$	21.24 ^{de}	45.16 $^{f-h}$
	36	1.70 ^{gh}	20.85 ^{de}	46.53 ^{fg}
	72	1.56 ^{gh}	16.28 $^{f-h}$	43.05 ^{gh}
	108	1.43 ^{h}	12.49 ^{i}	30.46 ^{i}
Gepak Ijo	0	1.90 $^{f-h}$	17.53 ^{f}	50.94 ^{de}
	36	2.38 $^{d-f}$	21.84 $^{c-e}$	55.08 ^{bc}
	72	2.70 ^{cd}	23.42 $^{a-c}$	55.80 ^{b}
	108	2.60 $^{c-e}$	21.65 $^{c-e}$	55.41 ^{bc}
Interaction (CxP)		(+)	(+)	(+)
C.V. (%)		15.743	6.633	5.305

- Numbers followed by the same letter in the same column show no significant difference in Duncan's Multiple Range Test at 5% error level.
- (+) / (-): interaction of soybean cultivars and P fertilizer doses was significant / no significant.

Based on Table 2, the dry weight of Anjasmoro cultivar increased when fertilized at dose of 36 and 72 kg P_2O_5 ha^{-1}, and at fertilizer doses of P 108 kg P_2O_5 ha^{-1} the plant dry weight decreased. Both Demas 1 and Gepak Ijo cultivars, with a P fertilizer dose of 36 kg P_2O_5 ha^{-1} had increased the dry weight of plants at 4 weeks, and an even higher increase in P fertilizer had not added to the plant dry weight. The response pattern Anjasmoro, Demas 1, and Gepak Ijo cultivars were P fertilization would increase the plant dry weight both at the age of 6 and 8 weeks after planting. The higher of fertilizer given, the lesser increase of plant dry weight. The effect of P fertilizer on the plant dry weight of Gema cultivar also had a negative effect, because it could limit its growth.

Nutrient uptake of plant organs (leaves and stems) and P nutrient uptake of plants from four soybean cultivars in the treatment of P fertilizer in coastal sandy soil observed at 8 weeks were presented in Table 3. Anjasmoro, Demas 1, and Gema at a dose of 36 kg P_2O_5 ha^{-1} increased its P nutrient uptake both in the leaves, stems and plants as a whole. However, the Gepak Ijo cultivar showed that the amount of P nutrient uptake was still the same with the treatment of without P fertilizer, which means it had not been effective in increasing nutrient uptake, but higher at a dose of P fertilizer 72 to 108 kg P_2O_5 ha^{-1}.

The highest P nutrient uptake of leaf organ was obtained from Gepak Ijo cultivar which was fertilized at doses of 72 and 108 kg P_2O_5 ha^{-1}, respectively 210.59 and 205.44 mg. Whereas the highest P uptake on stem organs in Demas 1 cultivar which was fertilized at a dose 36 kg P_2O_5 ha^{-1} (346.78 mg), which was also the highest P uptake in plants as a whole which was 618.28 mg. The availability of P come from bokashi made from banana pseudo stem, dissolution of P from soil media, and from SP36 fertilizer that seemingly had been excessive with the addition of P fertilizer at a dose of 72 and 108 kg P_2O_5 ha^{-1}, except for Gepak Ijo cultivar. According to [15], the efficiency of P uptake and soybean seed yields differed among cultivars, which reached optimum when fertilized at a dose 40 kg P_2O_5 ha^{-1} in Bromo and Kipas Putih Cultivars, while in Argomulyo, Malabar, and Wilis cultivars were obtained without P fertilizer.

Table 3. P nutrient uptake of plants four soybean cultivars in the treatment of P fertilizer in coastal sandy soil at 8 weeks after planting.

Treatment Factor		P Nutrient Uptake of Plants		
		Plant Organs		
Soybean Cultivars	Dose of P Fertilizer (kg P_2O_5 ha^{-1})	Leaf	Stem	Plant
Anjasmoro	0	129.86 ^{gh}	177.22 ^{e}	375.88 ^{h}
	36	150.25 $^{d-f}$	224.08 ^{d}	445.97 ^{ef}
	72	167.61 ^{c}	266.33 ^{bc}	505.66 ^{c}
	108	102.41 ^{i}	164.01 ^{e}	317.23 ^{i}
Demas 1	0	160.76 ^{cd}	246.11 ^{cd}	467.25 ^{de}
	36	186.82 ^{b}	346.78 ^{a}	618.28 ^{a}
	72	160.12 ^{cd}	279.68 ^{b}	499.52 ^{cd}
	108	130.52 ^{gh}	221.65 ^{d}	400.44 ^{gh}
Gema	0	140.16 ^{fg}	220.62 ^{d}	397.86 ^{gh}
	36	143.67 $^{e-g}$	262.30 ^{bc}	443.92 ^{ef}
	72	140.24 ^{fg}	233.91 ^{d}	418.45 ^{fg}
	108	122.84 ^{h}	167.00 ^{e}	323.46 ^{i}
Gepak Ijo	0	156.50 $^{c-e}$	158.38 ^{e}	386.94 ^{gh}
	36	157.12 $^{c-e}$	185.75 ^{e}	416.90 ^{fg}
	72	210.59 ^{a}	218.47 ^{d}	506.13 ^{c}
	108	205.44 ^{a}	285.91 ^{b}	561.33 ^{b}
Interaction (CxP)		(+)	(+)	(+)
C.V. (%)		5.870	8.118	5.143

- Numbers followed by the same letter in the same column show no significant difference in Duncan's Multiple Range Test at 5% error level.
- (+) / (-): interaction of soybean cultivars and P fertilizer doses was significant / no significant.

In general, P nutrient uptake of stem organs in the observation of 8 weeks for four soybean cultivars grown in coastal sandy soil with treatment of P fertilizer was greater than that of leaf organ. However, by investigating at the proportion of the Gepak Ijo cultivar, the P uptake of leaf organ was still high, that was still at 85.99%; compared with the proportion of P uptake of leaf with P uptake of stem in Anjasmoro cultivars (66.15%); Demas 1 (58.33%); and Gema (61.88%). Remobilization of P in the Gepak Ijo cultivar, from the leaf organ to the reproductive organ showed the slowest pattern, because the P element absorbed by the plant was still mostly accumulated in the leaves. According to [16] in P-efficient cultivars, it would increase P accumulation in both leaf and stem organs at low to moderate dose P application, and will decrease in P application at high doses.

Soybean seed yield is the weight of the seeds including all seeds which are whole or broken and damaged. Soybean seeds are weighed after drying up to about 12% moisture content. Soybean seed yield data from the four cultivars in the treatment of P fertilizer in coastal sandy land was presented in Table 4.

The yield of the seeds of Demas 1 cultivar in the treatment of P 0, 36 and 72 kg fertilizer P_2O_5 ha^{-1} were the highest, respectively 45.31; 48.38; and 46, 88 $g.pot^{-1}$. The seed yield of Demas 1 cultivar slightly decreased at the dose reaching to 108 kg P_2O_5 ha^{-1} which was 43.54 $g.pot^{-1}$. The effect of P fertilizer with various doses has the same effect in increasing the yield of Anjamoro cultivar. Showing the dose of P fertilizer to produce high seeds is enough at a dose of 36 kg P_2O_5 ha^{-1}, or equivalent to SP36 100 kg ha^{-1} fertilizer. Fertilization of P with various doses also did not affect the seeds yield of Gema cultivar. In accordance with the cultivar groups that were not responsive to the provision of bokashi made from banana pseudo stem with low grain yield [7]. The seed yield of Gepak Ijo cultivar showed higher amount in the treatment of P fertilizer dosage starting from 72 to 108 kg P_2O_5 ha^{-1}, which was 38.05 and 37.92 $g.pot^{-1}$ compare to other treatments.

Table 4. The Seed yield of four soybean cultivars in the treatment of P fertilizer in coastal sandy soil at harvest time.

Treatment Factor	Seed Yield (g.pot^{-1}) Dose of P Fertilizer (kg P_2O_5 ha^{-1})				Mean
Soybean Cultivars	0	36	72	108	
Anjasmoro	15.78 ^{d}	39.16 ^{b}	38.36 ^{b}	37.97 ^{b}	32.82
Demas 1	45.31 ^{a}	48.34 ^{a}	46.88 ^{a}	43.54 ^{ab}	46.02
Gema	11.72 ^{d}	11.81 ^{d}	11.74 ^{d}	9.77 ^{d}	11.26
Gepak Ijo	28.67 ^{c}	31.19 ^{c}	38.05 ^{b}	37.92 ^{b}	33.96
Mean	25.37	32.62	33.76	32.30	31.01 (+)
C.V. = 11.937%					

- Numbers followed by the same letter show no significant difference in Duncan's Multiple Range Test at 5% error level.
- (+) / (-): interaction of soybean cultivars and P fertilizer doses was significant / no significant.

Based on the yield of soybean seed presented Table 4, soybean cultivar response curves could be made on P fertilizer dose as in Figure 1. The effect of P fertilizer dose would cause an increase in quadratic pattern in each cultivar with increased yields that varied depending on the cultivar.

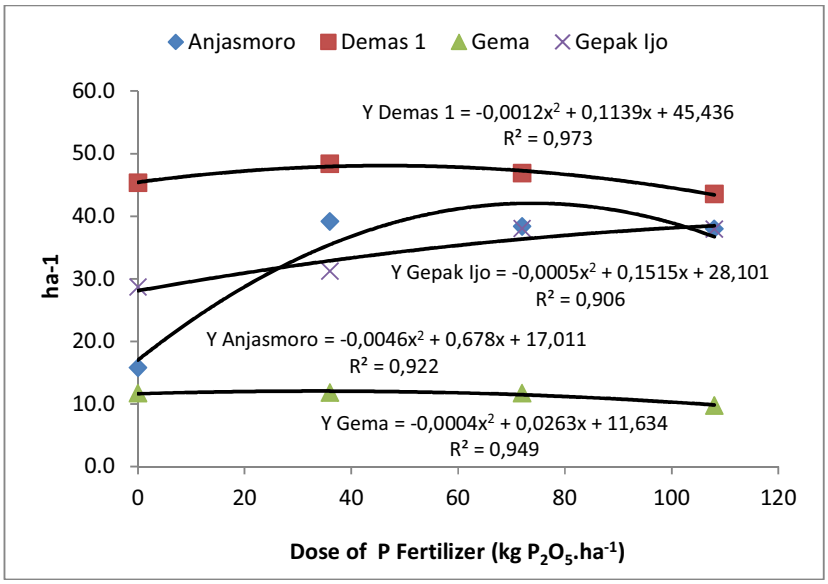

Figure 1. Seed yield (g pot^{-1}) of four soybean cultivars at the level of P fertilizer application on the coastal sandy soil.

Based on the regression line equation of the soybean cultivar response curve to the P fertilizer dose (Figure 1), the optimum dose of P fertilizer for each cultivar could be determined. Anjasmoro cultivar with regression equation Y Anjasmoro = -0.0046x^2 + 0.678x + 17.011 (R^2 = 0.922), showed that at a dose of 73.70 kg P_2O_5 ha^{-1} would get maximum seed yield of 41.99 g. pot^{-1}. The optimum dose of P fertilizer for Demas 1 cultivar with the equation of the Y Demas 1 regression line = -0.0012x^2 + 0.1139x + 45.436 (R^2 = 0.973) is 47.46 kg P_2O_5 ha^{-1} with a maximum seed yield of 48.14 g. pot^{-1}. The optimum dose of P fertilizer for Gema cultivar with the equation line regression Y Gema = -0,0004x^2 + 0,0263x + 11,634 (R^2 = 0,949) was 32,88 kg P_2O_5 ha^{-1} with maximum seed yield 12,07 g.pot^{-1}. The optimum

dose of P fertilizer for Gepak Ijo cultivar with the regression line equation Y Gepak Ijo = $-0.0005x^2 + 0.1515x + 28.101$ ($R^2 = 0.906$) was 151.50 kg P_2O_5 ha^{-1} with maximum seed yield of 41.00 g. pot^{-1}.

4. Conclusion

P fertilization effectively increased the growth of leaf area, plant dry weight, and soybean yield on Anjasmoro, Demas 1 and Gepak Ijo up to the optimum dose and depended on their soybean cultivars. The optimum dose of P fertilizer for Anjasmoro cultivar was 73.70 kg P_2O_5 ha^{-1} and for Demas 1; Gema; and Gepak Ijo cultivars; were 47.46; 32.88; and 151.50 kg P_2O_5 ha^{-1}; respectively. Demas 1 cultivar could produce the highest seed yield despite low P fertilization. P fertilization was not effective on Gema cultivars because the growth and yield of the seeds were suppressed when given with P fertilizer.

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