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Effect of phosphorus, organic and biological fertilizer on yield of mungbean (*Vigna radiata*) under two cropping patterns

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Abstract. *Suryantini. 2016. Effect of phosphorus, organic and biological fertilizer on yield of mungbean (Vigna radiata) under two cropping patterns. Nusantara Bioscience 8: 273-277*. The research investigated the effect of phosphorus rates, organic and biological fertilizer on productivity of mungbean grown after rice (cropping pattern: rice-rice-mungbean) and after soybean (cropping pattern: rice-soybean-mungbean). Treatment was arranged in a split plot design with three replications. The main plots were (i) without organic and biological fertilizer, (ii) organic soil treatment (OST) and (iii) phoshpate solubilizing biofertilizer (PSB). The subplots were phosphorus (P) fertilizer rates: 0, 100, 150 and 200 kg SP36/ha. The results revealed that the grain yield of mungbean grown after soybean was not affected by the application of OST or PSB, but it was increased by fertilizer P at 200 kg SP36/ha with an increase of 68%, from 0.60 t/ha (control) to 1.01 t/ha. Conversely, the grain yield of mungbean grown after rice was significantly affected by the interaction between fertilizer P and OST or PSB. The highest yield were obtained from the combination treatments of 150 kg SP36/ha + PSB and 150 kg SP36/ha + OST with an increase of 78% and 71% over control respectively. Increased grain yield was supported by the increase in number of pods, 100 seeds weight and plant P uptake.

Keywords: Bio fertilizer, mungbean, organic fertilizer, phosphorus fertilizer

INTRODUCTION

Mungbean (*Vigna radiata* L.) is a short-lived leguminous plant, and can be grown in various cropping patterns due to its ability to adapt to the poor environmental stresses such as low soil fertility and drought (Bourgault et al. 2010; Nair et al. 2012). In rainfed with the limited availability of water, mungbean becomes the primary choice of farmers to plant the next seasons after rice or after soybean. Rainfed is one of the potential land resources for the development of mungbean production in Indonesia. However, according to (BPS 2013) the average mungbean productivity is low-only about 1 t/ha.

Rainfed is a fluctuating hydrological environment of a completely flooded to dry conditions in a season or between seasons. These conditions reduce the content of soil organic matter, and increase the immobilization of nutrients such as phosphorus (Seng et al. 2004; Zhou et al. 2014). Phosphorus is one of the nutrients limiting plant productivity, because of its essential role in the process of flowering and seed formation. In rice plants phosphorus deficiencies at a moderate level generally do not appear but was able to decrease the number of pods and weight of 1000 seeds, and if very severe deficiencies can cause plants not flowering (Dobermann and Fairhurst 2000). The application of phosphorus to mungbean has been reported to increase plant dry matter, seed yield and P uptake (Shah et al. 2006; Iqbal et al. 2012).

One of the problems in phosphorus fertilization is rapidly immobile and less available for plant use after application to the soil. Some factors affecting the availability of phosphorus include the pH of the soil and the availability of Ca, Fe, Al and Mn (Hao et al. 2002; Anderson and Magdoff 2005). In addition, microbial activity in the soil also affects the availability of phosphorus. It was reported that through the process of carbohydrates oxidation by microorganisms, resulting organic acids that have a strong affinity with Al, Ca, Mg and Fe, it can release phosphorus which initially binds to these elements (Chen et al. 2006; Henri et al 2008). The use of biofertilizers containing P-solubilizing microbial is one of the ways to increase the availability of phosphorus. Turan et al. (2007) reported a greater increase in plant root and shoot weight as well as phosphorous uptake in treatments with PSB than without PSB.

The sufficient availability of organic matter in soil was also affects the supply of nutrients and their uptake by plants. The addition of organic matter to the soil can increase the cation exchange capacity of the soil and reduce the loss of nutrients were added through fertilization, thus increasing the availability of nutrients in the soil and fertilizer efficiency (Enujeke et al. 2013). Organic fertilizer was also reported to increase plant height, number of pods per plant and seed yield of mungbean as well as reduce the application rate of chemical fertilizers (Moller 2009; Abbas et al. 2011). Based on the above, this study aims to assess the effects of phosphorus, organic and P-solubilizing biofertilizer as well as their interaction on the productivity of mungbean under two cropping patterns ie after rice and after soybean.

MATERIALS AND METHODS

The study was conducted on paddy fields under different cropping patterns, namely rice-rice-mungbean (after rice field) and rice-soybean-mungbean (after soybean field), during the dry seasons of 2012. Both fields was located adjacent in a village of Pasuruan district the eastern part of Java island, Indonesia. Treatment was arranged in a split plot design with three replications. The main plots were (i) control, (ii) a commercial organic soil treatment (OST), and (iii) P-solubilizing biofertilizer (PSB). The subplots were phosphorus fertilizer rates: 0, 100, 150 and 200 kg SP36/ha. The chemical properties and moisture content of the soils are presented in Table 1. In both fields the total N and available P were low while the exchangeable K was medium. The soil after rice had around neutral pH and low organic-C while the soil after soybean had a moderately acidic pH and very low organic-C.

Soil organic treatment (OST) at recommended dose of 50 kg/ha was incorporated into the soils during seed bed preparation. The synthetic inoculant of PSB was collected from Indonesian Legumes and Tuber Crops Research Institute Malang, Indonesia ILETRI), it was applied by inoculating the seeds before sowing at a dose of 5 g inoculant/kg seed (10^9 CFU/g inoculant). Basal fertilizers (50 kg Urea + 75 kg KCl)/ha and various phosphorus fertilizer rates were applied at planting by drilling. Mungbean (cv. Walet) was sown with spacing of 40 cm x 10 cm, 2 plants per hill. The plot size was 20 m^2 (4 m x 5 m). After planting soil was irrigated provide moisture for the microbes were introduced. Pest and disease control based on monitoring conducted intensively.

Data were collected at the vegetative phase (45 DAP) from sample of 5 plants per plot for plant dry weight and P content in the plants. P content in plant tissue (after drying fresh samples at 75-80 ˚C for 48 hours) was determined using wet digestion, ie 1 g of plant tissue destruction in nitric acid (HNO3) and concentrated hypoclorate (HClO4) then heated to obtain a solution (extract) clear. After the preparation of plant tissue extract, the amount of phosphorus were measured by spectrophotometer (Aliehyaei and Behbahani, 1993).

At harvest samples of 10 plants per plot were measured for number of pods per plant and 100 seed weight, while the harvested plots of 3 m x 4 m was observed for grain yield. Analysis of variance (ANOVA) for all data was performed using MSTAT-C software (Analytical Software, Tallahassee, Florida, USA). Significant different between treatments were further analyzed using Duncan's Multiple Range Test (DMRT) for mean separation.

RESULTS AND DISCUSSION

The data in Table 2 shows a significant interaction between fertilizer P and OST or PSB on plant dry weight of mungbean in both fields (after rice and after soybean). On mungbean grown after soybean, the application of 100 kg SP36/ha or OST increased plant dry weight from 7.4 g/plant (control) to 12.1 and 12.4 g/plant respectively, while the application of PSB did not increase plant dry weight. The highest plant dry weights (13.8 g) was obtained in the treatment of 200 kg SP36/ha + OST, but the value was not significantly different from those obtained with 100 kg SP36/ha or OST only.

The increased plant dry weight due to P fertilization may be attributed to increased leaf area, plant height and branching (not observed), as revealed by Dobermann and Fairhurst (2000) that the vegetative growth phase such as the formation of leaves and stems is supported by phosphorus. While organic fertilizers capable of creating a good soil environment, such as maintaining soil moisture and increasing the availability of nutrients including phosphorus (Mohammadi, 2009; Ayeni, 2014). Crop response to phosphorus and organic fertilizer might be due to low levels of phosphorus and organic-C in the soils (Table 1). Whereas the low soil moisture content on land formerly used for soybean (Table 1) may be the cause of ineffectiveness of PSB. Soil moisture strongly supports the effectiveness of microbes, otherwise drought can cause a decrease in the population and the effectiveness of microbes introduced into the soil (Sinegani and Maghsoudi 2011; Reuben et al. 2013). This condition was different from that of mungbean grown after rice, flooding during the previous growing season seems to leave enough soil moisture (Table 1), it causes P fertilizer, organic fertilizer OST and PSB capable of increasing the dry weight of mungbean plants, and the highest was obtained in the combined treatment of 150 kg SP36/ha with OST or PSB. Similar results were also reported by Reddy and Swamy (2000) and Kumawat et al. (2009) on mungbean and blackgram (*Vigna mungo* L.).

Similar to plant dry weight, plant height was influenced by the interaction between fertilizer P with OST or PSB (Tabel 3). On mungbean grown after soybean, the application of 100 kg SP36/ha or OST increased plant height from 40.1 cm (control) to 50.1 and 50.7 cm respectively, while the application of PSB did not increase plant dry weight. Increasing dose of fertilizer P to 200 kg SP36/ha as well as its combination with OST or PSB does not add to an increase in plant height. In field after rice, either SP36, OST, as well as PSB were able to increase the plant height, and the highest was obtained in the combined treatment of 150 kg SP36/ha with OST or PSB. Similar report by Walpola and Yoon (2013) that Co-inoculation of both PSB and P fertilizer exhibited the highest growth performances of mung bean. Enhanced plant growth after inoculation of PSB can be attributed to the ability of the bacteria to make P available for plant uptake and to produce plant growth-promoting substances (Linu et al., 2009; Viruel et al., 2014). A similar increase in growth of mung bean plants due to inoculation of PSB was observed by Walpola and Yoon (2013) and Rani et al. (2016).

Mungbean although drought tolerant, it requires adequate of water especially in the phase of flowering until pod filling (Ranawake et al. 2011), otherwise it will result in a decrease in yield. This can be seen from the grain yield of mungbeans grown after soybean which was low, averaging less than 1 t/ha, and there was no interaction between fertilizer P and OST or PSB on grain yield and yield components (Table 3). The application of OST increased the average number of pods per plant from 8.9 pods/plant (control) to 10.8 pods/plant, but the increase was not followed by an increase in grain yield. This may be due to an increase in the number of pods is only about 21% and is not followed by an increase in 100 seeds weight. In field after soy, 100 seeds weight was not significantly different between treatments (Table 3).The application of OST as much as 50 kg/ha seems less than optimal to increase mungbean productivity on land with very low organic matter content (Table 1). Similarly, fertilizer P did not increase grain yield except at the highest dose (200 kg SP36/ha) with an increase of 57.7%, i.e. from 0.71 t/ha (without P fertilizer) to 1.12 t/ha. This increase was supported by an increase in average number of pods from 9.1 pods/plant (without P fertilizer) to 11.7 pods/plant, an increase of 28.5%. Possibly because of the very low soil P levels (Table 1) then its required high doses of P to increase grain yield.

The opposite was mungbean grown after rice, its grain yield on average was higher than mungbean grown after soybean, which was about 1.4 t/ha. The interaction between P fertilizer and OST or PSB on number of pods, 100 seeds weight and grain yield were also significant (Table 4). The grain yield increased with OST or PSB, ie from 0.98 t/ha (control) to 1.30 t/ha and 1.43 t/ha, respectively or increased by 32.7% (0.32 t/ha) and 45.9% (0.45 t/ha) over control, and was at par with 100 kg SP36/ha fertilization. The highest yield, however, was obtained from the combination treatments of 150 kg SP36 + PSB followed by 150 kg SP36/ha + OST, which increase by 77.6% and 71.4%, respectively as compared to control. While increase in the dose of P fertilizer up to 200 kg SP36/ha, did not give benefit in increasing yield. Increase in grain yield was supported by an increase in the number of pods per plant and 100 seed weight that showed the same pattern of increase with an increase in grain yield (Table 4).

Number of pods showed an increase in the fertilization of 100 kg SP36/ha but not significantly different compared to control, while at the dose of 150 kg SP36/ha significantly increased the number of pods 37% compared to control. However, the highest number of pods obtained at fertilization SP36 150 kg/ha in combination with OST or PSB to increase 72.7% and 89.9% compared to control, is at par with the number of pods on the fertilization of 200 kg SP36/ha. The use of 100 kg SP36/ha, OST and PSB also increase the 100 seeds weight from 4.9 g (control) to 5.3 g, 5: 57 g and 5.5 g respectively. But the highest of 100 seeds weight obtained at fertilization SP36 150 kg/ha in combination with OST or PSB which increased 23% and 27% compared to control.

Table 1. Chemical properties and moisture content of the experimental soils

Soil	Moisture (%)	pH (H_2O)	C-organic (%)	N (%)	P2O5 (ppm)	K (me/100 g)
After rice	25.4	6.90	1.43	0.08	9.2	0.55
After soybean	18.2	6.65	0.95	0.14	7.0	0.51

Table 2. Effect of organic soil treatment (OST), P solubilizing biofertilizer (PSB) and P fertilizer (SP36) on plant dry weight of mungbean grown after soybean (A) and after rice (B)

P fertilizer	Plant dry weight (g/plant)		
SP36 (kg/ha)	Control	OST	PSB
After soybean			
0	7.4 d	12.4 ab	9.5 bcd
100	12.1 abc	9.9 bcd	9.5 bcd
150	10.7 bc	11.4 bc	7.1 d
200	9.3 cd	13.8 a	9.2 d
CV (%): 15,0			
After rice			
0	9.0 e	11.9 cd	13,0 cd
100	12.2 cd	11.7 cd	13.6 bc
150	13.6 bc	15.4 ab	16.0 a
200	11.3 d	11.8 cd	13.6 bc
CV (%): 14.7			

Note: The numbers in the same column followed by the same letter are not significantly different (P = .05).

Table 3. Effect of organic soil treatment (OST), P solubilizing biofertilizer (PSB) and P fertilizer (SP36) on plant height of mungbean grown after soybean (A) and after rice (B)

P fertilizer	Plant height (cm)		
SP36 (kg/ha)	Control	OST	PSB
After soybean			
0	44.1 d	50.7 ab	45.8 cd
100	50.1 ab	47.4 bc	48.6 bc
150	47.7 bc	46.8 bc	45.2 cd
200	48.0 bc	51.3 a	45.7 cd
CV (%): 15,0			
After rice			
0	49.0 e	53.5 d	55.0 cd
100	53.0 d	56.6 bc	57.4 bc
150	53.8 d	60.4 ab	62.3 a
200	55.7 cd	57.4 bc	58.6 abc
CV (%): 14.7			

Note: The numbers in the same column followed by the same letter are not significantly different (P = .05).

Table 4. The effect of organic fertilizer (OST), P solubilizing biofertilizer (PSB) and P fertilizer (SP36) on the number of filled pods and grain yield of mungbean grown after soybean

Treatment	Filled pods number/ plant	100 Seed Weight (g)	Grain yield (t/ha)
Organic/biofertilizer			
Control	8.9 b	4.95 a	0.81 a
OST	10.8 a	5.06 a	0.88 a
PSB	9.4 b	4.83 a	0.84 a
SP36 (kg/ha)			
0	9.1 b	4.83 a	0.71 b
100	9.3 b	4.94 a	0.76 b
150	10.9 a	5.06 a	0.99 b
200	11.7 a	5.18 a	1.12 a
CV (%)	14.5	10.11	20.0

Note: The numbers in the same column followed by the same letter are not significantly different (P = .05)

Table 5. The effect of organic soil treatment (OST), P solubilizing biofertilizer (PSB) and P fertilizer (SP36) on the number of filled pods and grain yield of mungbean grown after rice

Organic/ bio fertilizer	SP36 (kg/ha)	Filled pods number/plant	100 Seed weight (g)	Grain yield (t/ha)
Control	0	9.9 d	4,90 e	0.98 d
	100	12.5 cd	5,30 d	1.37 c
	150	13.6 bc	5,38 d	1.45 bc
	200	16.1 ab	5,35 d	1.24 cd
OST	0	13.7 bc	5,57 cd	1.30 c
	100	13.6 bc	5,66 bc	1.28 c
	150	17.1 a	6,04 ab	1.68 ab
	200	13.1 bcd	5,74 bc	1.30 c
PSB	0	15.0 abc	5,50 cd	1.43 bc
	100	15.2 abc	5,86 abc	1.50 bc
	150	17.8 a	6,23 a	1.74 a
	200	14.5 abc	5,74 bc	1.50 bc
CV %		12.7	10.00	15.8

Note: The numbers in the same column followed by the same letter are not significantly different (P = .05)

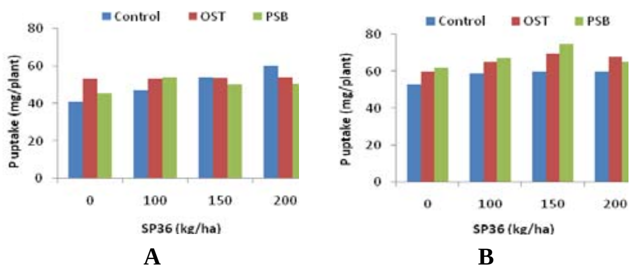

Figure 1. Phosphorus uptake by mungbean grown in paddy field after soybean (A) and after rice (B)

These results were consistent with previous findings on paddy field at Pasuruan, East Java with a very low of soil P content (1.29 ppm) the application of P fertilizer up to 200 kg SP36/ha did not increase grain yield of soybean, but a combined treatment of PSB + 150 kg SP36/ha was able to increase yield by 40% compared to control (Suryantini 2000). Furthermore, it was reported that the effectiveness of PSB and its interaction with P fertilizer was specific location which was influenced by the levels of P and pH of the soil. P-solubilizing biofertilizers are generally most effective in alkaline and acid soils, and when the soil P level is very low, its use was less useful unless accompanied by P fertilization (Suryantini 2001). Similarly, on the field after rice which was slightly acid and had moderate P levels (Table 1), the application of PSB was able to increase yield of mungbean. However, when PSB was used in combination with P fertilizer, a higher yield increased was obtained.

Difference yield of mungbean between cropping patterns or among treatments seems to be related to the differences in plant P uptake. In general, mungbean grown after rice showed the average higher P uptake than mungbean after soybean (Figure 1). PSB treatment on mungbean grown after rice was effective in increasing P uptake, followed by OST (Figure 1b). Increased in P uptake due to PSB inoculation may be caused by the increased availability of P in soil as reported by Wang et al. (2014) that inoculation with P-solubilizing bacteria increased the availability of P in the soil. The increase in P uptake and its reflection on yield as an effect of PSB inoculations may be caused by its ability to solubilize insoluble inorganic phosphates. Conversely, mungbean grown after soybean showed no effect of PSB on P uptake, whereas fertilizer P at the highest dose (200 kg/ha) or OST without fertilizer P showed higher P uptake compared to control (Figure 1.A). While Increased in P uptake due to OST application may be caused of organic matter in soil improves soil physical properties (Abbasi et al. 2009). increases P solubility and decreases P fixation (Khiari and Parent, 2005), and thus improves P availability to plants . It was also reported that the combined use of inorganic and organic fertilizers enhanced phosphorus availability, due to the dissolution of sparingly soluble P sources and reduced P retention (Kang et al. 2009). Therefore, fertilization P accompanied with organic or biological fertilizer has great potential for improving mungbean yield through improvement of the soil physical properties and nutrient supply. But specifically for the use of biological fertilizer such as PSB requires soils with sufficient moisture for optimal effectiveness.

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