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Research Article

Effect of liming, manure, and NPK fertilizer application on growth and yield performance of soybean in swamp land

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Abstract: Increased productivity and the expansion of planting area to potential land are two strategies to increase soybean production. Swamp land is one of potential land. Acidic soil, poor fertility, and toxicity become limiting factors for soybean development in this area. Objective of this research was to determine effect of liming, organic and NPK fertilizer application on soybean yields in swamp land. On-farm trial had been conducted on swamp land of C type in South Kalimantan. Treatments consisted of two factors, laid out in randomized complete block design, replicated three times. The fist factor was three doses of manure (0, 2.5, and 5.0 t/ha). The second factor was four combinations of NPK fertilization dosage, (1) 0-0-0, (2) 22,5-36-30, (3) 22,5-54-60, and (4) 45-72-60 kg N-P_2O_5-K_2O per hectare. Combinations of these two factors were tested on two environments, without and with liming. Results revealed that soil acidity, poor P, K, Ca, and Mg, and high aluminum saturation became limiting factors for soybean growth and yield in swamp land of type C in South Kalimantan. Amelioration using 2.5 t/ha manure, liming with dolomite equivalent to 20% of Al saturation, and NPK fertilizer at dose of 45 kg N - 72 kg K_2O – 60 kg P_2O_5 /ha improved soil properties and soybean growth, and increase productivity to 2.4 t/ha.

Keywords: *liming, manure, NPK, soybean, swamp land*

Introduction

Soybean has been historically important food crop in Indonesian culture. Animal based-protein consumption tend to reduce due to weakening of purchasing power (Ariani 2010), while consumption of soy-based products increased from 14.21 to 15.01 kg/capita/year in periods of 2009 to 2012 (Sutyorini and Waryanto 2013). Tofu, Tempeh, and snack products made from soybean seed forming a component of daily dietary intake by both urban and rural populations in 17th Century (Ridwan et al. 2014; Kartono et al. 2014). So that, soybeans became a strategic commodity in food security program as important source of protein and functional food for human health. Meanwhile, the domestic soybean production in 2014 was 921,000 ton, about 34% of the national demand (Nuryati and Waryanto 2014). Java Island is the main soybean production area, but it tends to decrease due to competition with other food crops. Besides increasing productivity in central area, increased domestic soybean supply also targeted through expansion in potential land as programmed by Indonesian Agriculture Ministry. Swamp land, one of the potential land, in Indonesia that suitable for agriculture is about 5.6-9.9 million hectares (Subagyo and Widjaja-Adhi 1998), and 2.4 million hectare have been utilized (Suriadikarta 2005). So that, there is considerable opportunity for the development of soybean in swamp land. The dominant soil type in swamp land is Histosol, Entisol, and Inceptisol (Subagyo and Widjaja-Adhi, 1998), which are commonly acidic and poor in fertility.

Based on the water regime, swamp land group into a tidal and non-tidal. The water regime of tidal swamp affected by the ebb and flow of sea or river, while the non-tidal swamp affected by rainfall from surrounding areas and from the upstream (Sudana, 2005). The land grouped into four types based on the overflow, namely (1) Type A, flooded both during low and high level of tide; (2) Type B, flooded only when high level of tide; (3) Type C, never flooded even during high level of tide, and the depth of ground water <50 cm; and (4) Type D, never flooded even during high level of tide, and the depth of ground water >50 cm (Widjaja-Adhi et al., 1992). The land generally saturated and anaerobic condition in the root zone, acidic, contain high Al, Fe and Mn, and poor N, P, K, Ca, and Mg (Subagyo and Widjaja-Adhi, 1998; Sudarsono 1999; Sunarti, 2010; Taufiq et al., 2011). Pyrite content of tidal land in Indonesia is generally low (0-5%), but the most difficult problems to overcome if oxidized (Subagyo, 2006). Beside poor soil fertility, cultivating soybean on that land faced toxicity problem of aluminum. Critical threshold of Al saturation for soybean is 30% (Hartatik and Adiningsih, 1987), but some genotypes tolerate up to 50 to 75% (Hanum et al., 2007).

Increasing soybean productivity on swamp land with liming, fertilization, and organic matter application has been well documented (Aribawa et al., 1997; Swastika et al., 1997; Hartatik and Suriadikarta 2006; Anwar et al., 2006; Bobihoe 2010; Taufiq et al., 2011). Liming increases the efficiency of P fertilization, and even extracts the native soil P bound by Al or Fe (Subiksa et al., 1999), inhibit soil acidification (Hartatik et al., 1999; Priatmadi and Harris, 2009). However, research on using combination of liming, organic matter application, and NPK fertilization to increase soybean yield on swamp land is limited. Objective of this research was to determine effect of liming, organic and NPK fertilizer application on soybean yields in swamp land.

Materials and Methods

On-farm trial on swamp land of C type had been conducted at Simpang Jaya Village, Wanaraya Sub District, Barito Kuala District, South Kalimantan. Treatments consisted of two factors, laid out in randomized complete block design, replicated three times. The fist factor was three doses of manure (0, 2.5, and 5.0 t/ha). The second factor was four combinations of NPK fertilization dosage, (1) 0-0-0, (2) 22,5-36-30, (3) 22,5-54-60, and (4) 45-72-60 kg N-P_2O_5-K_2O per hectare. Combinations of these two factors were tested on two environments, without and with liming. Dolomite as lime source determined based on 20% of aluminum (Al) saturation, using calculation formula as follows:

Dolomite (t/ha)	=	(Al-saturation–targeted Al saturation)*CECe*1.52
	=	(0.52-0.2)*10.58*1.52
	=	0.32*10.58*1.52
	=	5.15

Aluminum saturation and CECe data (Table 1), value of 1.52 is factor correction for dolomite. Urea (45% N), SP18 (18% P_2O_5), and KCl (60% K_2O) used as source of N, P, and K respectively. Dolomite and manure applied before planting together with soil tillage. Treatment of N, P, and K fertilization applied once, at planting time. The dimension of the experimental plot is 3 m x 4 m. Soil cultivated according to the common local farmer's practice. Soybean seed of Argomulyo variety dibbled 2 seeds per hole at 40 cm interrow and 15 cm between hole. Hand weeding was performed according to requirements, 21 and 45 days after planting (DAP). Insect and disease control included the use of chemical pesticides as required. Data collection consisted of initial analysis of soil properties included pH, total N, available P, exchangeable K, Ca, and Mg, and organic-C, exchangeable Al and H. Analysis of soil properties at harvest time included pH, available P, and exchangeable Al. The soil properties were determined using methods as described by Eviati and Sulaeman (2009). Crop data collected at harvest included plant height, number of filled pod, seed yield, and a 100 seeds weight. Analysis of variance and mean comparison of collected data were processed using MstatC statistical software.

Results and Discussion

Soil properties

Soil at the trial site was very acidic, below the range of optimum pH for soybean growth (Follet et al., 1981; Abdurachman et al., 1999). Available P was low (Nursyamsi et al., 2004; Wijanarko dan Taufiq, 2008), and below the critical threshold of 13.7-22.9 ppm P_2O_5 (Tandon and Kimmo, 1993; Franzen 2003). Exchangeable Al was high, above the level that can be tolerated by most soybean variety of 0.44-0.88 me/100g (Manshuri, 2003; Wijanarko, 2004). Aluminum saturation was high, above the critical threshold of 30% (Hartatik and Adiningsih, 1987). Low availability of P might be related to low soil pH and high Al saturation, as showed by Ige et al. (2007). Organic matter as indicated by organic-C content was very high. Exchangeable K, Ca, and Mg were low. Total N content was medium (Table 1). The soil properties indicated unfavourable condition for soybean, and become limiting factor for soybean growth and yield. Amelioration using manure and dolomite improved soil properties as indicated by soil analysis data after harvest time (Table 2). Liming as well as manure application increased soil pH and available P, and reduced exchangeable (exch) Al as well as Al saturation. Combination of manure and liming have more remarkable effect in improving soil properties than when applied individually. Available P increased as dose of P fertilizer increased, especially when combined with liming. This effect is in accordance with Subagyo and Widjaja-Adhi (1998), Sudarsono (1999), Subiksa et al. (1999), Hartatik et al. (1999), and Priatmadi and Harris (2009). Limine without manure and NPK fertilization reduced Al saturation from 40.2% to 28.0% (Table 2). It means that determining liming rates based on 20% of Al saturation is effective.

Table 1. Soil properties of swamp land of type C at trial site before planting.

Soil properties	Method	Value
pH-H_2O	1:2.5	3.85
C-organic (%)	Kurmis	5.47
N-total (%)	Kjeldhal	0.53
P (ppm P_2O_5)	Bray 1	6.16
Exch-K (me/100g)	NH_4-Acetate 1N pH 7	0.36
Exch-Na (me/100g)	NH_4-Acetate 1N pH 7	0.14
Exch-Ca (me/100g)	NH_4-Acetate 1N pH 7	0.48
Exch-Mg (me/100g)	NH_4-Acetate 1N pH 7	0.27
Exch-Al (me/100g)	KCl 1 N	5.48
Exch-H (me/100g)	KCl 1 N	3.85
CECe (me/100g)	Sum of cations	10.58
Al saturation (%)	Exch-Al to CECe	52%

Table 2. Effect of manure, lime, and NPK fertilizer application on some chemical soil properties in swamp land of type C. South Kalimantan.

Treatments (kg/ha)		pH		P_2O_5 (ppm)		Exchangeable Al (me/100g)		Al-saturation (%)	
Manure	**N-P_2O_5-K_2O**	**–Lime**	**+Lime**	**–Lime**	**+Lime**	**–Lime**	**+Lime**	**–Lime**	**+Lime**
0	0 – 0 – 0	4.7	5.2	6.76	10.95	4.15	2.87	40.2	28.0
0	22.5–36–30	5.0	5.5	17.83	39.21	4.19	2.80	35.8	26.5
0	22.5–54–60	4.9	5.0	15.66	23.27	4.11	2.54	35.5	28.6
0	45–72–60	4.7	5.0	26.89	36.31	4.20	5.60	40.6	47.0
	Average	**4.8**	**5.2**	**16.8**	**27.4**	**4.2**	**3.5**	**38.0**	**32.5**
2500	0 – 0 – 0	4.7	5.3	10.22	18.92	3.95	2.15	33.4	28.8
2500	22.5–36–30	4.5	5.1	12.76	24.72	3.75	2.10	34.6	37.3
2500	22.5–54–60	4.8	5.3	25.08	33.05	3.70	1.95	31.0	23.5
2500	45–72–60	5.0	5.4	29.43	40.30	3.80	2.05	34.1	23.3
	Average	**4.8**	**5.3**	**19.4**	**29.2**	**3.8**	**2.1**	**33.3**	**28.2**
5000	0 – 0 – 0	5.6	5.2	12.76	35.23	3.55	2.30	30.8	22.9
5000	22.5–36–30	5.1	5.1	25.80	43.25	3.45	2.25	31.9	23.3
5000	22.5–54–60	5.0	4.9	19.64	47.55	3.30	2.20	30.1	26.0
5000	45–72–60	5.1	4.9	20.37	32.69	3.40	1.95	29.9	25.6
	Average	**5.2**	**5.0**	**19.6**	**39.7**	**3.4**	**2.2**	**30.7**	**24.5**
Overall	**average**	**4.9**	**5.2**	**18.60**	**32.12**	**3.80**	**2.56**	**34.0**	**28.4**

Soybean growth

Soybean growth as indicated by plant height was significantly affected by liming, and NPK fertilization (Table 3). Manure application up to 5 t/ha, and it's interaction with NPK fertilization among the factors did not significantly affect plant height. Plant grows shorter without NPK compared to that of with fertilization, even with lime or manure. By comparing the plant height at four dose combinations of NPK fertilization, there are indications that all three nutrients (N, P, and K) have same important role in improving plant growth. NPK treatment at dose of 45-72-60, or equivalent to 100 kg urea+200 kg SP36+100 kg of KCl/ha, gave the highest plant height, and not significantly different with that combined with 5 t/ha manure. Liming equal to 20% saturation of Al also provide plant height higher than without lime.

Table 3. Effect of lime, manure, and NPK fertilization on soybean plant height at harvest time in tidal swamp land of type C, South Kalimantan.

Treatments (kg/ha)		**Plant Height (cm)**		
Manure	**N-P_2O_5-K_2O**	**–Lime**	**+Lime**	**Average**
0	0 – 0 – 0	45.7	56.7	51.2 g
0	22.5–36–30	51.4	61.5	56.5 def
0	22.5–54–60	57.1	61.6	59.3 bc
0	45–72–60	58.1	66.0	62.1 a
2500	0 – 0 – 0	51.2	57.6	54.4 f
2500	22.5–36–30	56.4	59.7	58.1 cde
2500	22.5–54–60	53.9	62.6	58.3 cde
2500	45–72–60	60.4	62.2	61.3 ab
5000	0 – 0 – 0	48.3	52.7	50.5 g
5000	22.5–36–30	57.4	54.9	56.2 ef
5000	22.5–54–60	55.0	62.2	58.6 cd
5000	45–72–60	60.5	64.2	62.4 a
		54.6 b	60.2 a	

Note: numbers in a column or row with same letters mean not significantly different according to LSD test at 5% level.

Yield and yield components

Manure and NPK fertilizer have significant effect on the number of filled pods per plant (Table 4). NPK fertilization at dose of 22.5-36-30 kg/ha increased the number of filled pods by 86% compared to without NPK. However, increasing doses of NPK fertilizer is not followed by an increased in the number of filled pods, except if combined with manure. Application of 2.5 t/ha manure increased number of filled pods by 100%, but it lower at higher dosage. Highest number of filled pods obtained from the treatment of 5 t/ha manure combined with NPK 45-72-60, increased by 125% compared to without NPK fertilizer.

Table 4. Effect of manure, lime, and NPK fertilizers on number of soybean filled pod in tidal swamp land of type C, South Kalimantan.

Treatments (kg/ha)		**Number of filled pods per plant**		
Manure	**N-P_2O_5-K_2O**	**–Lime**	**+Lime**	**Average**
0	0 - 0 - 0	7.4	15.3 (107)[1)]	11.4 f
0	22.5-36-30	18.9	23.5 (24)	21.2 cd (86)[2)]
0	22.5-54-60	18.9	23.1 (22)	20.9 cde (83)
0	45-72-60	17.4	20.9 (20)	19.2 de (68)
2500	0 - 0 - 0	20.5	25.4 (24)	22.9 bc (101)
2500	22.5-36-30	21.5	20.9 (--)	21.2 cd (86)
2500	22.5-54-60	19.2	25.7 (34)	22.5 bc (97)
2500	45-72-60	17.7	26.4 (49)	22.0 bc (93)
5000	0 - 0 - 0	13.9	23.3 (68)	18.6 e (63)
5000	22.5-36-30	17.8	28.1 (58)	22.9 bc (101)
5000	22.5-54-60	21.1	26.7 (27)	23.8 ab (109)
5000	45-72-60	24.5	26.7 (9)	25.6 a (125)
		18.2 b	23.8 a	

Notes: numbers in a column or row with same letters mean not significantly different according to LSD test at 5% level; [1)] percentage to no lime; [2)] percentage to check (without manure and NPK).

This suggests that manure improve the effectiveness and efficiency of NPK fertilizers. Liming increased number of filled pods by various levels, averaged 31%, compared with no lime (Table 4). Manure and NPK fertilizer application significantly affected the weight of a 100 seeds (Table 5). NPK fertilizer at dose of 22.5-54-60 gave the highest a 100 seeds weight. Liming at a dose equivalent to 20% saturation of Al is able to increase a 100 seeds weight than without lime.

Table 5. Effect of manure, lime, and NPK fertilizers on a 100 seeds weight of soybean in tidal swamp land of type C, South Kalimantan.

Treatments (kg/ha)		**Seed weight (g/100 seeds)**		
Manure	**$N-P_2O_5-K_2O$**	**–Lime**	**+Lime**	**Average**
0	0 - 0 - 0	12.3	15.7	14.0 e
0	22.5-36-30	14.4	16.2	15.3 cd
0	22.5-54-60	15.7	16.8	16.3 a
0	45-72-60	12.3	16.5	14.4 e
2500	0 - 0 - 0	14.1	15.7	14.9 d
2500	22.5-36-30	15.7	16.1	15.9 ab
2500	22.5-54-60	14.7	15.9	15.3 cd
2500	45-72-60	15.9	16.5	16.2 ab
5000	0 - 0 - 0	14.5	15.7	15.1 d
5000	22.5-36-30	14.8	16.5	15.7 bc
5000	22.5-54-60	14.8	15.8	15.3 cd
5000	45-72-60	14.7	15.7	15.2 cd
		14.5 b	16.1 a	

Note: numbers in one column or row with same letters mean not significantly different according to LSD test at 5% level.

Seed yield of soybean is significantly affected by interaction of manure, NPK, and liming (Table 6). Without liming and manure, yield of soybean increased according to NPK doses. The yield increased becomes higher if combined with 2.5 t/ha manure, but then reduces at higher dose of manure. Without liming, the highest yield (2.01 t/ha) is obtained by treatment of NPK fertilizer of 45-72-60 combined with 2.5 t/ha manure, increased by 328% compared to without NPK.

Table 6. Effect of manure, lime, and NPK fertilizer on soybean seed yield in tidal swamp land of type C, South Kalimantan.

Treatments (kg/ha)		**Seed yield (t/ha)**	
Manure	**$N-P_2O_5-K_2O$**	**–Lime**	**+Lime**
0	0 - 0 - 0	0.47 k	0.73 jk
0	22.5-36-30	0.84 i-k (79)[1)]	1.08 b-d (48)
0	22.5-54-60	1.22 g-j (160)	2.02 a-d (177)
0	45-72-60	1.11 h-j (136)	2.31 ab (216)
2500	0 - 0 - 0	1.18 g-j (151)	2.08 a-d (185)
2500	22.5-36-30	1.57 d-h (234)	1.30 f-j (78)
2500	22.5-54-60	1.19 g-j (153)	1.71 c-h (134)
2500	45-72-60	2.01 a-d (328)	2.47 a (238)
5000	0 - 0 - 0	0.92 i-k (96)	1.31 f-i (79)
5000	22.5-36-30	1.92 a-e (309)	1.74 c-g (138)
5000	22.5-54-60	1.36 e-i (189)	2.03 a-d (178)
5000	45-72-60	1.87 b-f (298)	2.21 a-c (203)

Notes: numbers in a column with same letters mean not significantly different according to LSD test at 5% level, and "-" in between letter means "up to"; [1)]numbers in parentheses in each column showing percentage to without manure and NPK.

In this treatment, available P increased above critical threshold, in addition to soil pH and Al saturation (Table 2) are in the range that can be tolerated by soybean (Follet et al., 1981; Hartatik and Adiningsih, 1987; Nursyamsi et al., 2004; Hanum et al., 2007; Wijanarko dan Taufiq, 2008). With liming and no manure, soybean yield increased according to NPK doses, but the yield of more than 2 t/ha obtained from NPK fertilizer at dosage of 22.5-54-60 and 45-72-60 (Table 6).

The yield of 2 t/ha also obtained by liming combined with 2.5 t/ha manure, without NPK fertilization. Yield levels by these treatments were at least three fold of without NPK fertilization. The highest yield of 2.47 t/ha obtained from treatment combination of liming, 2.5 t/ha manure, and NPK fertilizer 45-72-60, that increased yield by 238% compared to without NPK fertilizer and increased by 425% compared to check (without any inputs). In these treatments, available P, soil pH and Al saturation seem optimum for soybean growth. Accordingly, Taufiq et al. (2011) also found that soybean yielded 2 t/ha in swamp land of type C in Jambi with NPK fertilizer rate of 22.5-54-60 kg/ha combined with 1 t/ha lime and 2.5 t/ha manure.

Conclusion

Soil acidity, poor P, K, Ca, and Mg, and high aluminum saturation became limiting factors for soybean growth and yield in swamp land of type C in South Kalimantan. Amelioration using 2.5 t/ha manure, liming with dolomite equivalent to 20% of Al saturation, and NPK fertilizer at dose of 45 kg N - 72 kg K_2O – 60 kg P_2O_5 /ha improved soil properties and soybean growth, and increase productivity to 2.4 t/ha.

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