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Improvement of Selected Soil Chemical Properties and Potassium Uptake by Mung Beans after Application of Liquid Organic Fertilizer in Ultisol

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ABSTRACT

Recently, application of liquid organic fertilizer (LOF) in organic farming practices is of importance to prevent further soil degradation due to prolong and massive use of synthetic fertilizers. LOF provides faster plant nutrient availability than solid organic fertilizer. However, quality of LOF is substantially dependent on its sources. Animal wastes from rabbit, goat, and cattle are scarcely used as sources of LOF production. The study aimed to determine soil chemical improvement and potassium uptake by mung beans as affected by LOF in Ultisol. The experiment was conducted at the Greenhouse, Faculty of Agriculture, employing Completely Randomized Design with two factors. The first factor was animal wastes, consisting of goat, rabbit, and cattle wastes. The second factor was LOF concentration, consisting of 0%, 25%, 50%, 75%, and 100% LOF. LOF was prepared by mixing altogether animal faeces, urine, soil, green biomass, EM-4 and fresh water to a total volume of 10 l in a plastic container. LOF was decanted to the polybag every week starting at one week after mung beans planting for four weeks to a total volume of 750 ml per polybag. Variables observed included soil pH, total soil organic-C, exchangeable K, soil nitrate-N, K concentration in plant tissue, K-uptake, and shoot dry weight of mung beans. The result showed that application of LOF from rabbit waste had the highest increment of soil pH as compared to the other treatments. However, exchangeable K was observed highest at the treatment of LOF from goat waste. Sources of LOF from animal wastes did not have an effect on K-uptake by mung beans. In addition, application of LOF up to 100% was able to improve soil chemical properties as indicated by the increase in soil pH and exchangeable K. So did the concentration and uptake of K, as well as shoot dry weight. Fertilization with LOF has benefit to the improvement of soil chemical properties leading to better K uptake.

Keywords: mung bean; liquid organic fertilizer; potassium uptake

INTRODUCTION

Highly responsive plant to fertilization has driven farmers to apply a high rate of synthetic fertilizer without considering organic matter application to the soil (Herdiyanti, 2015). Prolonged use of synthetic fertilizer brings about heavy metal accumulation in soil and plant (Savci, 2012). A study by Horrigen *et al*. (2002) indicated that excessive application of synthetic fertilizer led to soil deterioration such as nitrogen leaching, soil compaction, and soil organic matter reduction. Organic fertilizer is believed to be a reliable solution to improve soil properties.

Application of water hyacinth compost increases total soil organic carbon, exchangeable K, available P, microbial biomass carbon, soil pH and reduces exchangeable Al (Muktamar *et al*., 2016a). Another result indicates that poultry manure application in conservation tillage enhances soil organic carbon, total nitrogen, and soil enzymes at the soil surface (Mankolo *et al*., 2012). Also, an addition of manure and compost to soil considerably enlarges P and K uptake by sweet potato (Afandi *et al*., 2015). However, the weakness of solid organic fertilizer is a slow release of plant nutrients; therefore, supplementation of liquid organic fertilizer is necessary.

Liquid organic fertilizer is commonly produced by bio-activation of animal wastes incorporated with green biomass; consequently, the quality highly relies on its source. Wastes from goat, cattle, and rabbit can be used as main sources for LOF production. Goat faeces contains 2.45 % N, 1.10% P, and 3.5% K. Rabbit faeces has 2.6% N, 1.6% P, and 1.9% K while that of cattle comprises 2.0% N, 1.5% P, and 2,0 K (Balitbang Pertanian, 2013). Application of LOF from dairy cattle wastes as a complement of vermicompost significantly increases total soil nitrogen, nitrate-N, exchange-able K, and soil pH, even though does not influence available P and exchangeable Al (Muktamar *et al*., 2017a). Muktamar *et al*. (2015) also observe a prominent increase in nitrate-N, exchangeable K, available P, pH of mine spoiled soil after treatment of local based liquid organic fertilizer, leading to the improvement of *Leucaena* growth.

Potassium as a second most significant nutrient necessary for plant growth depends on its availability in soil. The study by Muktamar *et al*. (2017b) suggests that LOF application raises N, P, and K uptakes by sweet corn. Also, Fertilization with liquid organic fertilizer from coconut husk provides a considerable increase in K uptake and the growth of maize (Wijaya *et al*., 2017). The objective of the study was to determine soil chemical improvement and potassium uptake by mung beans as affected by LOF in Ultisol.

MATERIAL AND METHOD

Experimental design and treatment

The greenhouse study was conducted during the wet season of 2016, arranged in Completely Randomized Design with two factors. The first factor was animal faeces; i.e., goat, rabbit, and cattle while the second factor was the rate of its LOF consisting of 0, 25, 50, 75, and 100%. Treatment combination was replicated three times.

Soil collection and greenhouse experiment

Soil sample at 0-20 cm depth was compositely collected from Kandang Limun Village, Bengkulu located at 15 m above sea level. The sample, then, was air-dried for two days, sieved with 2 mm screen. 250 g of sample was separated for initial analysis of soil chemical properties. The top soil contained 3.2% total soil organic carbon (TSOC), 5.59 mg kg^{-1} nitrate-N, 0.11 cmol kg^{-1} exchangeable K, 21.46 cmol kg^{-1} cation exchange capacity, and soil pH of 3.50. The soil was classified as an Ultisol.

Liquid organic fertilizer was prepared by mixing altogether, 1 kg faeces (goat, rabbit, and cattle), 1 L animal urine (goat, rabbit, and cattle), 250 g soil, 500 g green biomass, 1 L bioactivator (EM-4) and fresh water to a volume of 10 L in plastic container (Muktamar *et al*., 2016b). The solution was incubated for four weeks and stirred every day to provide an aerobic condition. After incubation, the LOF was sieved with a cloth before the application. Nutrient content of LOF is shown in Table 1.

Growing media was prepared by incorporation of 10 kg of the soil sample, and 45.45 g of vermicompost as basal fertilizer, equivalent to 10 Mg $ha^{-1}$and altogether was placed in a polybag. No additional of synthetic fertilizer was applied. A week after application, two mung bean seeds; a variety of Vima-2 were put into planting hole in the polybag. Thinning was completed a week after planting by leaving the healthier one. During the study, the soil was retained in moist condition by watering when necessary.

Liquid organic fertilizer was applied for four weeks, starting at a week after planting. The LOF was dispensed to the polybag according to the treatment, as much as 150 ml for the second week and 200 ml for the remaining weeks; therefore, every plant received 750 ml of LOF. Freshwater at the same volume was also decanted to the control polybag.

After reaching maximum plant growth indicated by tassel emerging, the shoot was cut, cleaned, oven-dried at 65-70 ^{o}C, weighed for shoot dry weight and analyzed for K concentration in shoot using wet digestion method. Potassium uptake was calculated by multiplying its concentration and shoot dry weight. The fresh soil sample was collected for nitrate-N analysis using a spectrophotometric method, and the remaining was air-dried, sieved with a 0.5 mm screen. The soil was analyzed for TSOC (Walky and Black method), exchangeable K (Flame-photometry), and soil pH using an electrometric method at the ratio of 1:1.

Table 1. Nutrient content of liquid organic fertilizer from animal wastes

Animal waste	pH	C (%)	N (%)	P (mg kg^{-1})	K (%)
Goat	7.9	1.40	0.33	1455.12	0.37
Rabbit	7.8	0.98	3.71	63.31	0.41
Cattle	8.0	1.06	1.29	2022.05	0.28

RESULT AND DISCUSSION

Effect of LOF on selected soil chemical properties

Analysis of variance exhibits that the application of LOF from different animal wastes does not influence on TSOC and nitrate-N but does on soil pH and exchangeable K. Table 2 indicates that TSOC is similar among treatment of LOF from goat, rabbit and cattle wastes. So, does the increase in the rate of LOF. This result might have been a reflection of low C concentration in LOF as shown in Table 1. When compared to the initial content of carbon, it does not significantly increase, indicating that the LOF has a slight contribution on TSOC. This result is different from that reported by Siburian *et al*. (2016) where cattle waste based LOF up to 100% has a significant increase in soil carbon. The differences could be associated with the formula of LOF preparation.

Application of LOF also has no considerable effect on nitrate-N content in the soil. Even though the nitrate-N content in LOF from rabbit waste is higher than the other animal wastes, the residual nitrate-N in soil is about the same, indicating there is a loss of nitrate-N from the soil. The previous study by Muktamar *et al*. (2015) demonstrates that nitrate -N moves downward to the lower part of soil profile after application of LOF. Loss of nitrate-N is a weakness of LOF application directly to surface soil. Foliar LOF application might be a solution to lessen the loss of the plant nutrient. In comparison to initial content, increase in nitrate-N is less than 1.5 mg kg^{-1} from both vermicompost and LOF.

Table 2. Total soil organic carbon as affected by LOF

LOF Concentration (%)	Types of waste			Average
	Goat	Rabbit	Cattle	
		(%)		
0	3.21	3.51	3.57	3.43
25	3.17	3.58	4.02	3.59
50	3.32	3.60	3.52	3.48
75	3.70	3.54	3.70	3.65
100	4.19	3.70	3.66	3.85
Average	3.52	3.59	3.69	

Table 3. Nitrate-N concentration in the soil as influenced by LOF

LOF Concentration (%)	Types of waste			Average
	Goat	Rabbit	Cattle	
		(mg kg^{-1})		
0	6.62	6.41	6.98	6.67
25	6.67	8.12	7.46	7.41
50	7.62	7.25	6.72	7.20
75	7.60	7.69	5.99	7.09
100	7.68	7.40	5.15	6.74
Average	7.24	7.37	6.46	

Although TSOC does not differ among source and concentration of the LOF, soil pH profoundly raises with increasing the rate of LOF as shown in Figure 1. The pH increase might have been related to the formation of an organo-metal complex between Al/Fe with the organic functional group (Muktamar *et al*., 1998; Spark, 2003). Reduction of Al/Fe hydrolysis due to organo-complex formation leads to increase in soil pH. This result is an agreement with that noted by Muktamar *et al*. (2017a) where LOF linearly increases soil pH even though does not influence exchangeable Al. Figure 1 also shows that LOF from rabbit waste provides more significant increment than that the other two animal wastes as indicated by the slope of the line. Nevertheless, LOF from goat and cattle wastes has a similar effect on soil pH. When compared to the original pH, application of 100% LOF raises soil pH nearly 27%, 60%, and 46% for LOF from goat, rabbit, and cattle, respectively.

Similar fashion to soil pH, exchangeable K as a reflection of its availability to plant enhances prominently as LOF concentration increases (Figure 2). The increase might have been attributed to the contribution by LOF; higher rate provides greater K to the soil. Addition of organic fertilizer to the soil enhances soil organic matter, contributing to the accumulation of K leftover in the soil (Leiwakabessy *et al.,* 2003). A different case of soil pH, the higher K increment is observed in LOF from goat waste than those other animal wastes, shown by the slope of the regression line. This result indicates that the LOF delivers faster K to the soil. In contrast, LOF from cattle waste has an insignificant increment of K to the soil. Muktamar *et al*. (2015) observed similar result where exchangeable K increased significantly to 20-25 cm depth by application of 100% LOF. Another study by Zaintun (2010) also confirmed an increase in K availability and base saturation of soil after application of LOF.

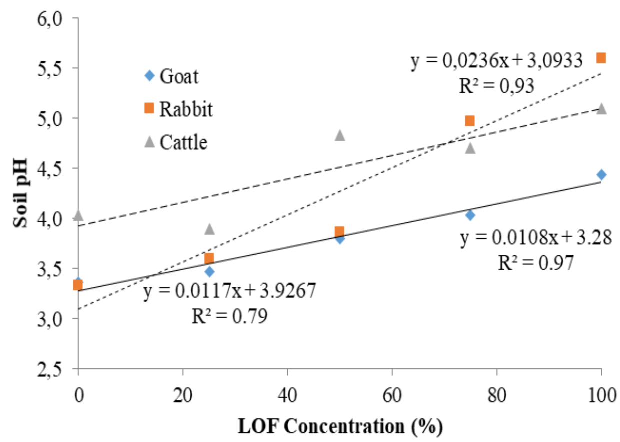

Figure 1. Effect of liquid organic fertilizer on soil pH

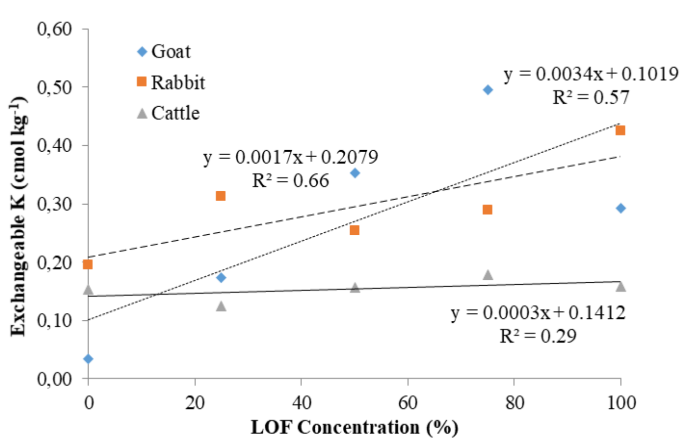

Figure 2. Exchangeable K as influenced by liquid organic fertilizer

Effect of LOF on Potassium uptake

Nutrient uptake by the plant is highly dependent on its availability in soil. The significant difference of exchangeable K in soil among treatment of different LOF sources leads to the considerable difference of K content in mung bean tissue. Greatest K content in the plant tissue is observed in LOF from goat waste followed by that of cattle and rabbit. However, treatment of LOF from rabbit and cattle provides similar K content of the tissue (Figure 3). Potassium content in mung bean tissue fertilized with goat waste based LOF exhibits 27.6 % dan 30.4% higher than those of rabbit and cattle; however, K uptake of mung beans is not significantly different among the sources of LOF.

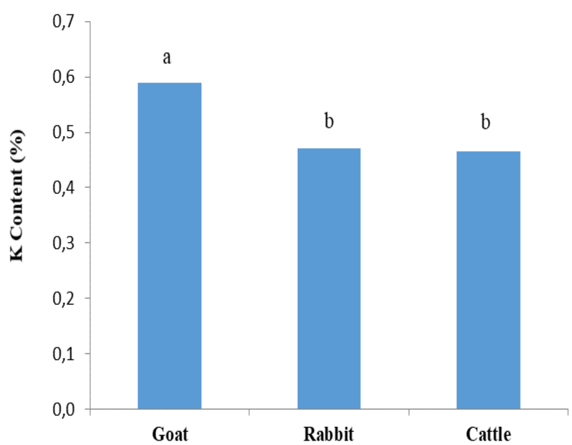

Figure 3. Potassium content in mung bean tissue under different sources of LOF

Increasing rate of LOF linearly heightens the content and uptake of K by mung beans as indicated in Figure 4. The upsurge is associated with the availability of K in soil (Figure 2). Higher availability of the nutrient in soil promotes more significant absorption by the plant. Organic matter can supply an adequate amount of available K for plant growth (Havlin *et al*., 2005). Potassium content and uptake escalate by more than three-fold as fertilizer rate increases from 0% to 100%, promoting the growth of mung beans. A similar result is noted by Muktamar *et al*. (2017b) where N, P, and K uptakes by sweet corn linearly increase as the rate of LOF is raised up to 100%.

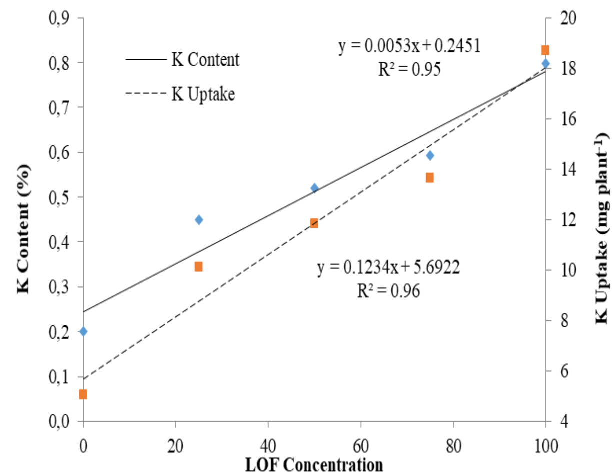

Figure 4. Potassium content and uptake by mung beans as influenced by LOF concentration

Improvement of soil chemical properties and K absorption stimulates the growth of mung beans. Shoot dry weight is the reliable indicator of plant growth. Liquid organic fertilizer from goat waste provides greatest shoot dry weight, followed by those of cattle and rabbit. The difference might have been related to the content of K as indicated in Figure 3 where mung beans fertilized with LOF from goat waste has highest K content. Shoot dry weight treated with LOF from goat leftover is 39.5% larger than that of the rabbit.

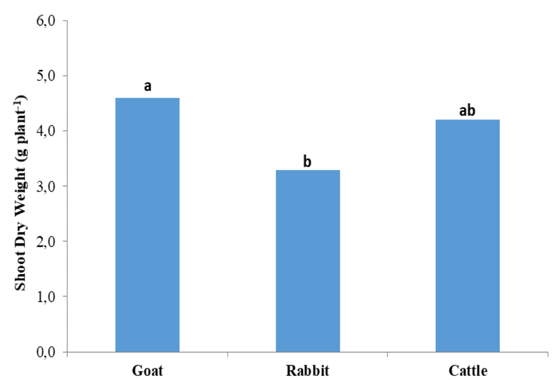

Figure 5. Shoot dry weight of mung beans under different sources of LOF

Similar fashion to K content and uptake under the different rate of LOF, increase in shoot dry weight of mung beans is also observed as seen in Figure 6. Shoot dry weight of mung beans is 30.9% and 61.4% greater when the plant was supplemented with 50% and 100% of LOF, respectively as compared to that control. The field experiment on Inceptisol carried out by Muktamar *et al*. (2017b), and Fahrurrozi *et al*. (2016) find out a similar pattern. The result demonstrated that application of LOF up to 100% had the substantial increase in sweet corn shoot dry weight. Apparently, the benefit of supplementation of LOF to mung beans growth is to improve soil chemical properties leading to better uptakes of plant nutrient. As a result, improvement of mung beans growth is achieved significantly.

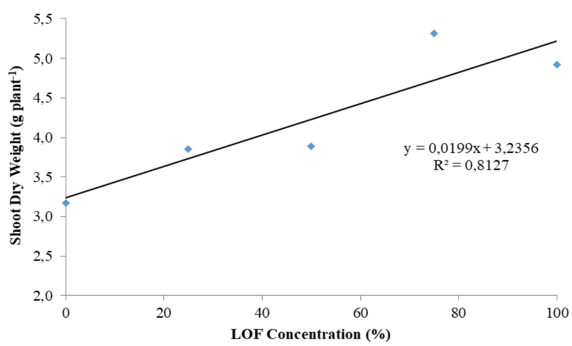

Figure 6. Effect of LOF concentration on shoot dry weight of mung beans

CONCLUSION

Application of LOF from animal waste provides an improvement of soil chemical properties and uptake of K by mung beans, initiating the improvement of its growth. Fertilization with LOF from rabbit waste exhibits the highest increment of soil pH; however, that of goat achieved greatest exchangeable K. Besides, total soil organic carbon and nitrate-N is similar among the LOF from animal wastes. The rate of LOF does not influence the two soil properties but linearly enhances soil pH and exchangeable K. Improvement of the soil chemical properties leads to increase in K content and uptakes of mung beans. Fertilization with LOF from rabbit waste has highest K content as compared to the other residues. Similarly, a linear increase in content and uptake of K by mung beans is observed with increasing LOF rates. In summary, application of LOF to an Ultisol enhances soil chemical properties, promoting better K uptake by mung beans.

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