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Soil Chemical Improvement under Application of Liquid Organic Fertilizer in Closed Agriculture System

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Soil degradation due to prolong and excessive application of synthetic fertilizer for last 3 decades has been acquired a lot of attention from soil scientists and practices. As the only sources of nutrients for organic farming, organic fertilizer is believed to improve soil properties. The study aimed to determine the improvement of soil chemical properties in closed agriculture system as influenced by the application of liquid organic fertilizer. The experiment was carried out at Closed Agricultural Production System (CAPS) Research Station in Air Duku Village, Bengkulu, Indonesia, employing Randomized Block Design (RCBD) with 2 factors. The first factor consisted of 3 varieties of sweet corn, i.e. Talenta, Jambore and Asian Honey. The second factor was the rates of liquid organic fertilizer (LOF), i.e. 0, 25, 50, 75, and 100 mg l^{-1}. LOF was applied at 2, 3, 4, 5, 6, and 7 weeks after planting with total volume of 600 ml per plant. At sweet corn harvesting, soil samples were collected at the depth of 0-20 cm. Samples were air-dried for 2 days, ground, and sieved with 0.5 mm screen and analyzed for selected soil chemical properties. The experiment pointed out that sweet corn varieties exhibited alike Total Organic Carbon (TSOC), NO_3-N, available P, exchangeable K, exchangeable Al and soil pH but Total Soil Nitrogen (TSN). Sweet corn variety of Asian Honey provided noticeably highest TSN as compared to other varieties. Another significant finding was that application of LOF substantially increased TSN, NO3-N, exchangeable K, and soil pH even though had no effect on TSOC, available P, and exchangeable Al. Liquid organic fertilizer is a useful tool for supplementation of solid organic fertilizer to improve soil quality and plant nutrient supply in closed agriculture system.

Keywords: Liquid Organic Fertilizer, Closed Agriculture System, Soil Chemical Properties.

Introduction

For decades, the use of synthetic fertilizers and pesticides in agriculture practices has prominently increased crop production in many parts of the world. However, prolong and excessive application of the agrochemicals has led to soil and environmental deterioration. Nitrogenous synthetic fertilizer has intensified soil acidity and decreased fungal and bacterial richness in soil (Barak *et al*., 1997; Wallenstein *et al*., 2006; Fang *et al*., 2012; Coolon *et al*.,

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2013). Awareness of soil degradation and environmental threat due to the conventional farming system has rooted to the development of sustainable agriculture system such as organic farming.

Organic farming which minimizes external input and outflow of agricultural wastes is often so-called closed agriculture system (DEFRA, 2012). Taking full advantage of internal agro-ecosystem resources, the system has higher efficiency in allocating energy than an open system. Sudjatmiko *et al.* (2014) noticed that this kind of system could maintain soil fertility after 5 years of operation.

Organic fertilizer has a vital role in organic farming practice, as the only fertilizer to provide plant nutrients and to improve soil quality. Muktamar *et al.* (2016a) pointed out that application of water hyacinth compost on 3 different tropical soils increased TSOC, Microbial Biomass Carbon (MBC), available P, exchangeable K, and soil pH but declined exchangeable Al. An earlier study also showed that organic farming exhibits higher TSOC, TSN, NH_4^+, MBC, and pH KCl (Wander *et al.*, 2007; Joergensen *et al.*, 2010). Slow release of plant nutrients is a weakness of solid organic fertilizer and supplementation of liquid organic fertilizer is often necessary to maintain nutrient availability mainly at the beginning of crop growth.

A number of studies have been carried out to determine the effect of liquid organic fertilizer on the growth and yield of crops. Application of 600 ml LOF per plant does not influence P and K uptakes and the growth of sweet corn (Muktamar *et al.*, 2016b; Fahrurrozi *et al.*, 2016), even though when total volume is increased to 950 ml per plant, LOF has significant upsurge on N, P, and K uptakes as well as the growth and yield of sweet corn (Muktamar *et al.*, 2017). Another study by Fahrurrozi *et al.* (2015) showed that Tithonia-enriched LOF did not exhibit a significant effect on carrot yields. The previous study by Sastro and Lestari (2011) confirmed that application of LOF from dairy cattle effluents pronouncedly increased growth and yield of sweet corn. Liquid fertilizer from cattle urine is also reported to be able to substitute synthetic N fertilizer on corn (Dordas *et al.*, 2008).

Study on the effect of LOF on soil quality is very limited. Therefore, the objective of the experiment was to determine the improvement of soil chemical properties in closed agriculture system as influenced by the application of liquid organic fertilizer.

Materials and Methods

A field experiment was conducted in sandy loam of Andept at Closed Agricultural Production System (CAPS) Research Station, located at Air Duku

Village, Rejang Lebong District, Bengkulu Province, Indonesia. The altitude of the experimental site is 1054 m above sea level. The site has continuously been cropped to organic vegetables since 2011. Every season, solid organic fertilizer at a rate of 15 Mg ha^{-1} was handed applied to the soil a week before crop planting. Initial soil characteristics at the experimental site are presented in Table 1.

Table 1. Initial soil characteristics

Soil Characteristics	Soil Depth (cm)			
	0-25	25-53	53-78	>78
TSOC (g kg^{-1})	20.1	11.5	14.3	11.9
TSN (g kg^{-1})	1.90	1.80	1.20	1.30
C/N Ratio	10.6	6.39	11.9	9.15
Available P (mg kg^{-1})	4.95	3.61	3.63	2.55
Exchangeable K (mg kg^{-1})	74.1	101.4	62.4	89.7
Exchangeable Ca (mg kg^{-1})	220	196	100	120
Exchangeable Mg (mg kg^{-1})	27.6	32.4	30.0	48.0
Soil pH	5.5	5.0	4.8	4.3
Cation Exchange Capacity (cmol kg^{-1})	31.76	24.72	23.32	27.14
Clay (%)	11.1	4.93	8.68	9.02
Silt (%)	34.94	6.19	7.51	7.81
Sand (%)	53.96	88.88	83.81	83.17
Texture Classification	Sandy Loam	Loamy Sand	Loamy Sand	Loamy Sand

The experiment was arranged in Randomized Completely Block Design (RCBD) with 2 factors and the treatment combination was replicated three times. The first factor consisted of 3 varieties of sweet corn, i.e. Talenta, Jambore and Asian Honey. The second factor was the rates of liquid organic fertilizer (LOF), i.e. 0, 25, 50, 75, and 100 mg l^{-1}. The LOF was produced in CAPS Research Station by mixing all together dairy cattle feces, dairy cattle urine, soil consisting of local microorganism, green leaves of *Tithonia diversifolia*, *effective microorganism*-4 (EM-4), sugar and fresh water as developed by Muktamar *et al.* (2016b). Nitrogen, P and K content of the LOF was 2.4%, 0.0144%, and 0.345%, respectively (Muktamar *et al.*, 2017). Phosphorus concentration of the LOF is considered very low.

The experimental site was cleared from weeds and harrowed to a depth 20 cm using hand tractor a week before planting. Fifteen soil-beds of 5x1 m in each replication were constructed just after soil tillage. Vermicompost was uniformly spread over at a rate of 15 Mg ha^{-1}. The experimental plots were separated by 0.5 m within the replication and 1 m between the replications. Two sweet corn seeds were grown at spacing of 70 x 20 cm. Thinning and replanting were carried out a week after planting when required. Weeds were bi-weekly controlled. When weeding, soil around the sweet corn stem was raised to avoid up-rooting and to strengthen the stem from strong wind which was often occurred at the experimental site.

Liquid organic fertilizer of 25, 25, 50, 100, 150, and 200 ml was sprayed to each plant using knapsack sprayer at week 2, 3, 4, 5, 6, and 7 after planting, respectively. The application was carried out at 09.00 to 11.00 in the morning when calm day and no rain. Excess LOF was decanted around the stem after sweet corn leaves had been wetted.

Composite soil samples at 0-20 cm depth were collected using soil probe at sweet corn harvesting. The samples were air-dried for 2 days, ground, and sieved with 0.5 mm screen and analyzed for selected soil chemical properties. Total soil organic carbon (TSOC) was analyzed using Walky and Black Method, TSN using Kjeldahl Method, N-NO_3 using Spectrophotometer after soil extraction with distilled water, available P with Bray I Method, exchangeable K using Flame-photometer after soil extraction with 1N NH_4Acetate, exchangeable Al using titration after soil extraction with 1N KCl, and soil pH with pH meter at 1:1 ratio of soil and distilled water (BPT, 2009).

Statistical analysis of data was carried out using PROC GLM SAS ver. 9.1.3. portable at $p<0.05$. If a significant F-test was obtained from an ANOVA, the differences among variety treatment means were separated using Duncan Multiples' Range Test at 95% confidence level and LOF treatment means were compared using polynomial orthogonal.

Results and Discussion

Soil Chemical Properties under Sweet Corn Varieties

Soil planted with three different varieties of sweet corn did not provide significant differences in selected soil chemical properties, but TSN as indicated in Table 2. However, in comparison to the initial content of selected soil chemical properties (Table 1), five years of solid organic fertilizer application to the soil unchanged content of TSOC and soil pH but slightly increased TSN, available P and exchangeable K. This indicated that during the seasons, decomposition of organic matter released nutrients and increased plant nutrient availability such as nitrogen, phosphorus, and potassium.

Table 2 also pointed out that soil cropped to sweet corn variety of Asian Honey exhibited highest TSN followed by Jambore and Talenta. Availability of nitrogen was followed by a prominent increase in N uptake by the variety as reported by Muktamar *et al.* (2016b). The difference in TSN might be attributed to the diversity of inherent characteristics of each variety to uptake N.

Study by Min *et al*. (2011) noted that five purple corn hybrids had different dry matter as well as N concentration and accumulation in above ground plant in seedling to maturity.

Table 2. Selected soil chemical properties under sweet corn cropping system.

Sweet corn Variety	Soil Chemical Properties						
	TSOC (g kg^{-1})	TSN (g kg^{-1})	N-NO3 ($mgkg^{-1}$)	Exch Al (mmol kg^{-1})	pH	P ($mgkg^{-1}$)	K ($mgkg^{-1}$)
Talenta	20.23 a	2.49 a	23.99 a	0.62 a	5.39 a	8.37 a	168.5 a
Jambore	18.88 a	2.59 a	21.53 a	0.63 a	5.58 a	7.52 a	166.4 a
Asian Honey	20.00 a	2.71 b	22.55 a	0.72 a	5.43 a	7.91 a	138.6 a

Means followed by the same letter within the column are significantly difference at $p<0.05$.

Liquid Organic Fertilizer Effect on Selected Soil Chemical Properties

Liquid organic fertilizer had no effect on TSOC, available P, and exchangeable Al, but prominently influenced on TSN, NO3-N, soil pH and exchangeable K. Figure 1 showed that an increase in the rates of LOF did not have any effect on TSOC. Although soil benefit of organic fertilizer is usually attributed to the addition of organic-C, it was found no significant treatment effects on soil organic matter. Organic matter from LOF decomposed much faster so that organic carbon remaining in the soil was in a lesser amount than solid organic fertilizer. Another reason would be the much lower organic-C content of LOF as compared to that of solid organic fertilizer. This result was in accordance to that concluded by Jokela *et al*. (2009). They reported that liquid dairy manure at 11.000 l ha^{-1} per year showed no significant effect on soil organic matter. A similar result also pointed out by Lithourgidis *et al. (*2007) where an application of liquid cattle manure had no effect on soil organic-C. However, Martinez-Alcantara *et al.* (2016) found out different result where an application of liquid organic fertilizer from corn residue or sheep feces resulted in an increase in soil organic matter.

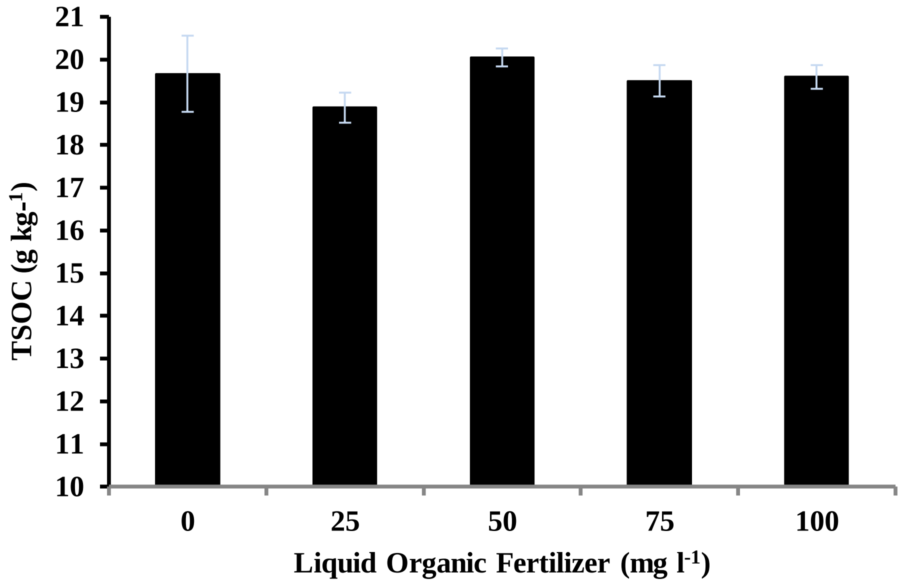

Figure 1. Liquid organic fertilizer effect on total soil organic carbon (TSOC)

Unchanged TSOC was followed by no effect of LOF on exchangeable Al (Figure 2). Soil organic matter decomposition releases organic acids such as humic and fulvic acids with high in functional groups of carboxyl and phenolic, forming organo-metallic (Sposito, 1984; Spark, 2003), bringing about lower exchangeable Al in the soil. However, it was not observed in this experiment. This might be related to the initial soil pH (5.5 at the depth of 0-25 cm). Most of the Al at soil pH of 5.5 or higher is in the form of $Al(OH)_3$ (Thomas and Hargrove, 1984), indicating low exchangeable Al. Muktamar *et al.* (2015) observed different finding where exchangeable Al prominently declined up to the depth of 30 cm after LOF application of 2000 ml. The results' differences might be due to that the researcher applied greater volume than that of the experiment.

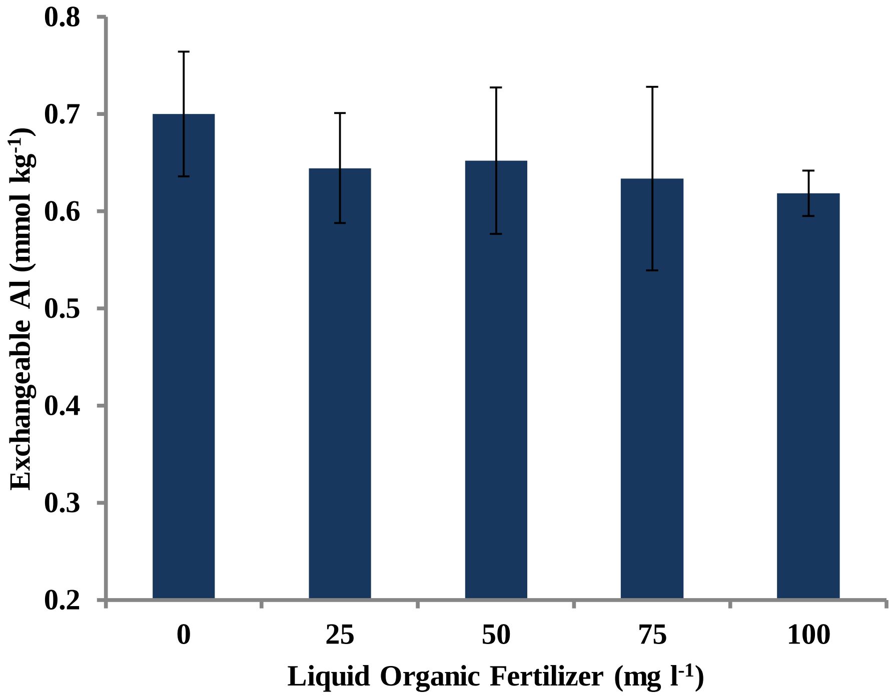

Figure 2. Effect of liquid organic fertilizer on exchangeable Al

Decomposition of organic matter releases plant nutrients such as N, P, and K. Application of LOF up to 100 mg l^{-1} did not significantly affect available P in the soil as shown in Figure 3. This might be associated with low P content of the LOF (144 mg l^{-1}), leading to low remaining P in the soil after its absorption by sweet corn. For future need, an addition of P sources on LOF production is necessary to increase its content. Laboski and Lamb (2003) found out a different result. Using liquid swine manure, they concluded that availability of phosphorus from the manure was larger than synthetic P fertilizer in soil tested in the experiment. The difference might be related to P content of the LOF where liquid swine manure contained 2.33% P as compared to only 144 mg l^{-1} of the LOF used in the experiment.

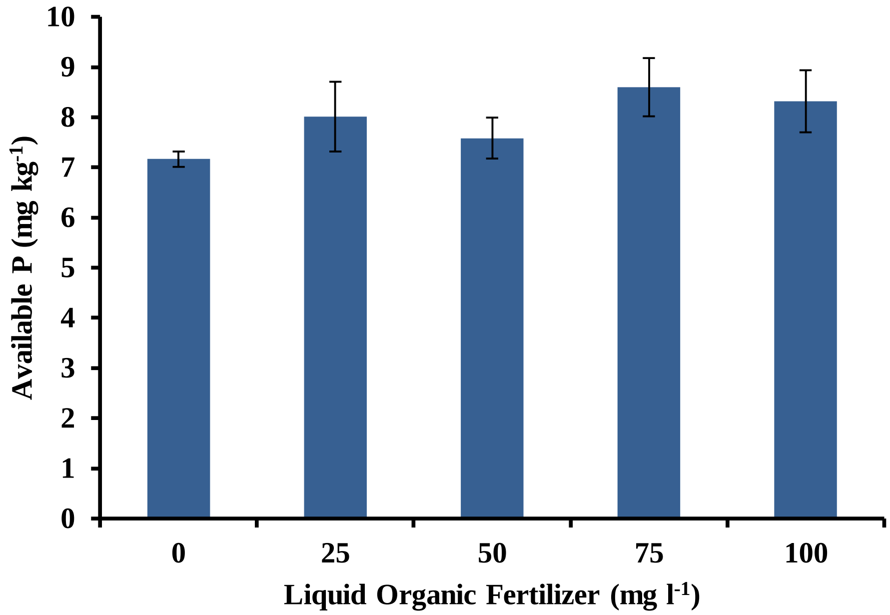

Figure 3. Soil available P as affected by liquid organic fertilizer

It is observed from Figure 4 that increasing rates of LOF application linearly enhanced total soil nitrogen (TSN), being the concentration of 100 mg l^{-1} provided 6.6% higher than control. This might be attributed to the content of N in LOF (2.4%). Incubation study conducted by Hartz *et al.* (2010) confirmed that liquid organic fertilizer from plant material had up to 92% of initial N of mineral form. When compared to the initial content of TSN, application of organic fertilizer at a rate of 15 Mg ha^{-1} for 5 years was able to maintain TSN content in soil and addition of LOF had contributed to a slight increase in such important element for plant growth.

Increase in TSN is followed by an increase in NO_3-N as seen in Figure 5. Nitrate-N is linearly related to TSN (R^2=0.855), supporting the claim that decomposition of organic N in soil provided a prominent contribution to NO_3-N. Even though there was a small increment of TSN as LOF rates increased, NO_3-N raised more than 50% at a rate of 100 mg l^{-1} in comparison to the control. Again, this also shows the significant support of TSN on the availability of NO_3-N to plant growth. This finding is consistent with that found out by Lithourgidis *et al.* (2007). Column study by Muktamar *et al*. (2015) also confirmed that application of LOF in mine spoiled soil increased NO_3-N up to the depth of 30 cm, indicating that the anion was easily leached to a deeper part of the soil.

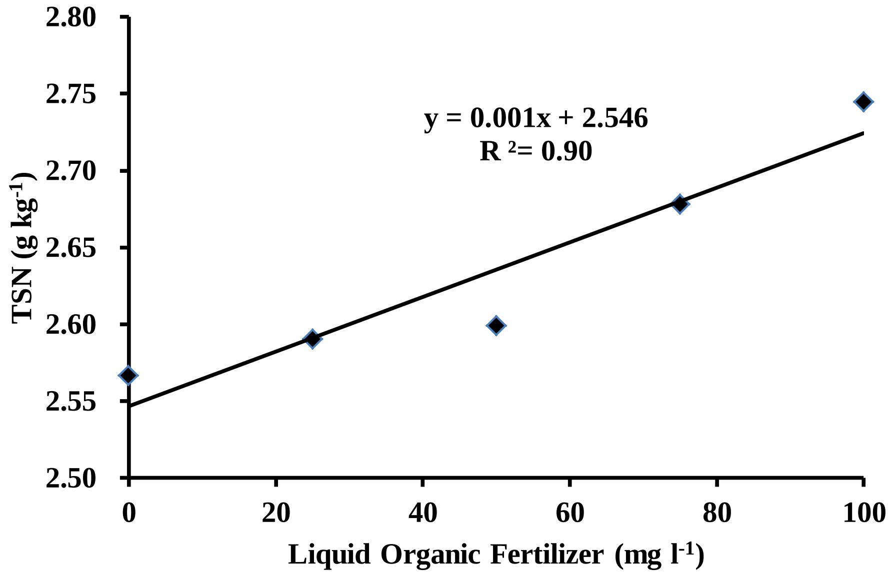

Figure 4. Total soil Nitrogen (TSN) as affected by Liquid Organic Fertilizer.

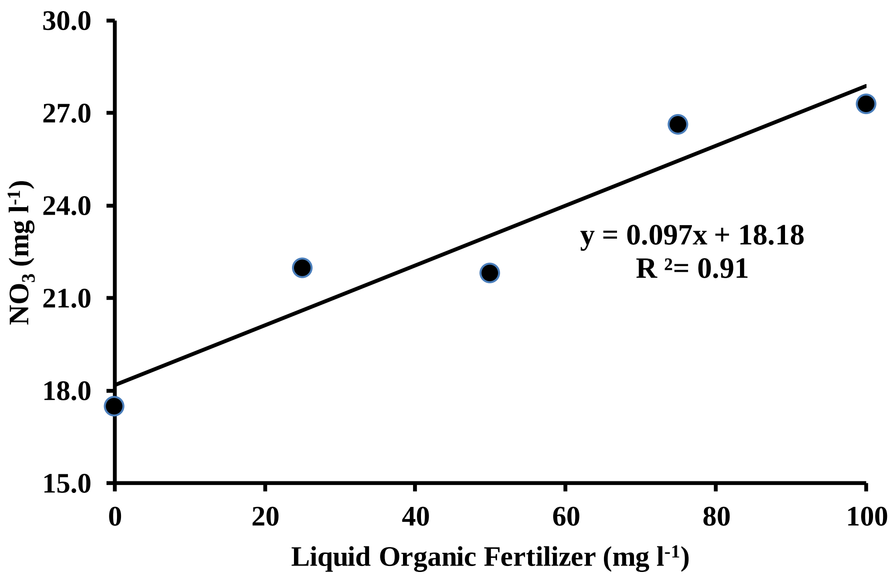

Figure 5. Nitrate-N in soil as influenced by liquid organic fertilizer

There was a significant effect of LOF on exchangeable K as presented in Figure 6. Increase more than 60% of exchangeable K was observed when soil was fertilized with LOF at a rate of 100 mg l^{-1} in comparison to that of the control. The higher increment is noted at the high concentration of LOF between 80 to 100 mg l^{-1}. This finding is different from that reported by Jokela *et al*. (2009). They found out that liquid dairy manure had no effect on all soil quality indicators. A study by Martinez-Alcantara *et al*. (2016) also resulted in no significant effect of LOF on soil K.

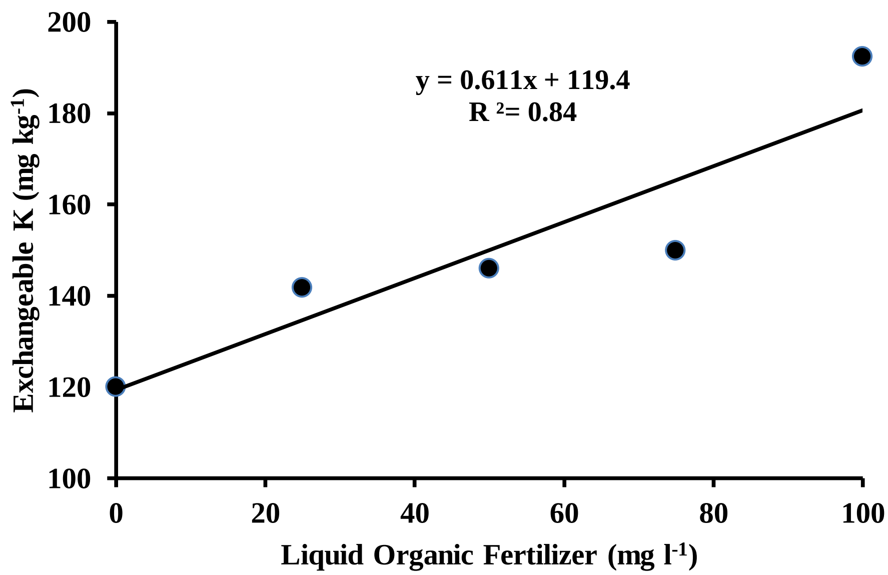

Figure 6. The effect of liquid organic fertilizer on exchangeable K.

A similar pattern with exchangeable K was found in soil pH as shown in Figure 7. A significant increment of soil pH was observed at the high concentration of LOF. The fertilizer was able to increase soil pH up to 0.3 unit when LOF concentration was raised from 0 – 100 mg l^{-1}. In this experiment, an increase in soil pH was not directly related to exchangeable Al; however, accumulation of humic substances from the application of solid organic fertilizer for 5 years might have led to an increase in soil pH through the formation of organo-complex in soil (Muktamar *et al*., 1998). A similar result was summarised by Muktamar *et al*. (2015) that LOF stimulated an increase in soil pH to a deeper part of the soil. Another earlier study by Martinez-Alcantara *et al*. (2016) noticed different finding where soil pH was not affected by LOF.

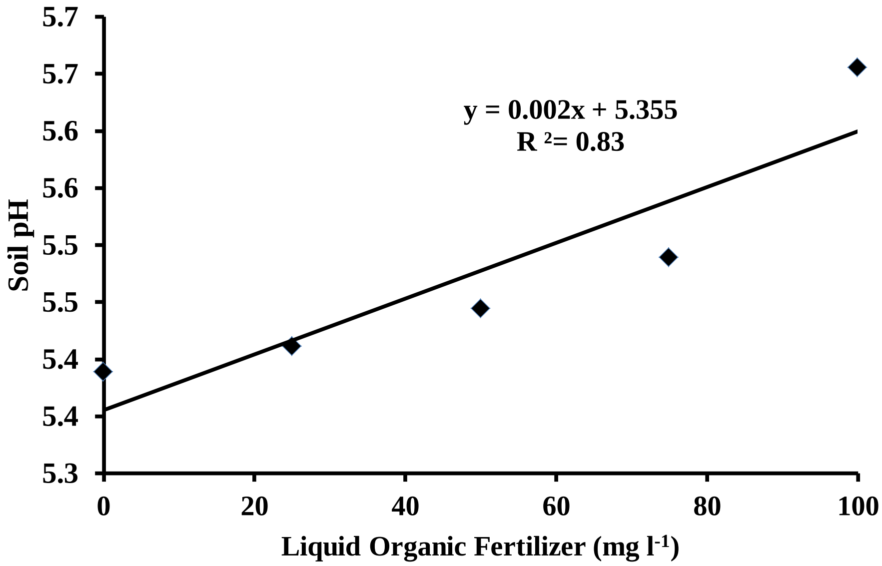

Figure 7. Liquid organic fertilizer effect on soil pH.

Conclusion

Application of LOF as a supplement to solid organic fertilizer provided a significant improvement on soil chemical properties and contributed to the availability of plant nutrient. The prominent increase in TSN, NO_3-N, exchangeable K and soil pH is a benefit from the application of the LOF, even though TSOC, available P, and exchangeable Al were not affected by the LOF. Additional P source on LOF production is required to meet the need of P for plant growth and development. Clearly, LOF can be a useful tool to improve soil quality and nutrient sources for plant growth in closed agriculture system.

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