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Residual effect of vermicompost on sweet corn growth and selected chemical properties of soils from different organic farming practices

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Abstract Solid organic fertilizer releases plant nutrient slowly, however, the residue in soil is available for the longer period. The he effect of vermicompost residue on sweet corn growth and selected chemical properties of soils from different organic farming practiceswas investigated. The first factor was soil from different organic farming practices (OFP), i.e., 0, 5, and 10 years of OFP and the second factor was rates of vermicompost, i.e., 0, 10, 20, and 30 Mg ha^{-1}. Result revealed that at the first and second plantings, vermicompost application considerably increased sweet corn growth and soil chemical properties, being the greatest was at the rate of 30 Mg ha^{-1}. Likewise, soil from 10 years of organic farming practice had higher total organic carbon and pH than the other practices. But, those of the second planting was shown significantly lower than those of the first planting, indicating that there was a depletion of nutrients after the second planting. The study confirmed that regular fertilization on organic farming practices is yet necessary to maintain the availability of plant nutrients.

Keywords: residue, vermicompost, organic farming, sweet corn

Introduction

The use of synthetic fertilizer to increase crop productivity has been widely reported to degrade soil quality such as increase in soil acidity and salinity (Hans *et al.*, 2015) and formation of Al-P (McDowel *et al.*, 2002), as well as a decline of microbial richness (Fang *et al.*, 2012) and microbial diversity in soil (Coolon *et al.*, 2013). Organic fertilizer is an alternative to substitute nutrient necessity from synthetic fertilizer.

Organic fertilizer has an advantage of improving soil fertility. Application of organic fertilizer exhibits an increase in total soil organic carbon (TSOC), microbial organic carbon (MBC), electrical conductivity (EC), total soil nitrogen (TSN), available P, exchangeable K, soil pH along with a reduction of

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exchangeable Al and bulk density (Butler *et al.*, 2009; Mankolo *et al.*, 2012; Jouquet *et al.*, 2011; Arthur *et al.*, 2012; Muktamar *et al.*, 2016). The improvement of the soil fertility leads to the enhancement of crop performances such as on sweet corn, mung beans, lettuce, soybean, and wheat (Anggita *et al.*, 2018; Muktamar *et al.*, 2017; Masarirambi *et al.*, 2012; Tagoe *et al.*, 2008; Ibrahim *et al.*, 2008).

Organic fertilizer, however, discharges plant nutrient slowly but persists residual effect of the longer period. After 16 years of compost application at rate 50 Mg ha^{-1}, the soil has 1.6 fold TSOC, greater microbial biomass, available P, K and Zn relative to no amended soil (Reeve *et al.*, 2012). Another study by Diaz *et al.* (2012) indicated that 3-12% of nitrogen supply from poultry manure applied at the first year was detected at the second but not at the following year. On the other hand, soil nitrate-N was not positively in noticing N supply from poultry manure in the second year of application. Another study by Yague and Quilez (2010) confirmed that there no residual effects of swine slurry were noticed after 2 years of application. Organic farming system exclusively obtains plant nutrients from organic fertilizer.

Soil organic matter in organic farming practice will accumulate over the years; however, its residual effects on soil properties and plant growth have been hardly evaluated. The study intended to investigate the effect of vermicompost residue on sweet corn growth and selected chemical properties of soils from different organic farming practices.

Materials and methods

Experimental Design and Soil Collection

A greenhouse experiment was carried out in 2016, employing Completely Randomized Design (CRD) with 2 factors. The first factor was soils from different organic farming practices (OFP) consisting of 0 (control), 5 and 10 years of OFP and the second factor was rates of vermicompost, i.e., 0, 10, 20, and 30 Mg ha^{-1}. The treatment combination was replicated 3 times. Selected soil chemical properties and sweet corn growth were examined for two plantings. Vermicompost was applied at the first planting. The experiment was repeated at the second planting without additional fertilizer to evaluate the residual effect of the compost.

Topsoil samples (0-25 cm) were collected from 3 locations in Air Duku Village, Rejang Lebong, Indonesia, representing the different duration of organic farming practices. Soil sample from 10 years of organic farming practice was collected from around 3^o 29’ 5.40” S and 102^o 37’ 16.49” E (1357 m above sea level), that of 5 years from around 3^o 27’ 37.3” S and 102^o 36’

55.35” E (1054 m above sea level), and control (conventional farming practice) from around 3^{o}28’75.42” S and 102^{o}37’3.72” E (1325 m above sea level). The soil sample was then air-dried, and sieved with 5 mm screen. Each soil sample was characterized for chemical properties.

Soil from 10 years of organic farming practice was classified as an Andept and contained 74.1 g kg^{-1} TSOC, 4.93 mg kg^{-1} available P, 2.7 mmol kg^{-1} exchangeable K, soil pH of 6.30 and CEC of 19.17 cmol kg^{-1}. Soil from 5 years of organic farming practice was Andept and had 65.5 g kg^{-1} TSOC, 4.67 mg kg^{-1} available P, 2.0 mmol kg^{-1} exchangeable K, soil pH of 6.00 and CEC of 17.98 cmol kg^{-1} while control contained 65.5 g kg^{-1} TSOC, 4.67 mg kg^{-1} available P, 2.0 mmol kg^{-1} exchangeable K, soil pH of 6.00 and CEC of 17.98 cmol kg^{-1}. Control was a soil which had never been associated with organic farming practice for years and received synthetic fertilizer every season. All soils had been cultivated to vegetable crops for years.

Greenhouse Experiment

Ten kg of each soil sample in a polybag was incorporated with vermicompost according to each treatment a week before planting. Two seeds of sweet corn were planted to each polybag. A week after planting, thinning was carried out by leaving the healthier and sturdy plant. The soil was maintained moist by watering when necessary. At tassel emergence, the sweet corn plant was cut and the shoot was oven-dried at 65-70^{o}C for 2 days and weighed for shoot dry weight. The soil sample was collected using a small probe, air-dried, sieved with 0.5 mm screen, and analyzed for selected soil chemical properties. Total soil organic carbon was analyzed using Walky and Black method, available P using Bray I method, exchangeable K using ammonium extraction method and analysis using Flame-photometer and soil pH using an electrometric method at the ratio soil and distilled water of 1:1 (BPT, 2009).

A week after the experiment completed, the second planting of sweet corn was carried out by implanting 2 seeds to each polybag. No additional fertilizer was applied at the second planting. The procedure and observed variables of the second experiment was similar to that of the first one.

Statistical Analysis

Data were assigned for analysis of variance using PROC GLM in SAS version 9.1.3. portable at $P< 0.05$. Treatment means were separated using Duncan's Multiple Range Test at the probability level of 5%.

Results

The result of ANOVA analysis indicated that soil chemical properties and the growth of sweet corn were different among soils from different organic farming practices for both plantings. Besides, there were prominent effects of vermicompost on the soil and plant variables. A significant difference was also observed between the two plantings.

Soil Chemical Properties and Sweet Corn Growth under Differences in Organic Farming Practices

Application of organic fertilizer for years in organic agriculture increases soil organic matter. After the first planting, soil from 10 years of OFP had greatest TSOC, available P and soil pH, followed by those of 5 years and control (Table 1). Nonetheless, lowest exchangeable K was observed in soil from 10 years of OFP. Total soil organic carbon, available P and soil pH are 35.6%, 11.0%, and 11.6% higher in soil from 10 years of OFP than control, respectively, indicating that carry over organic matter had occurred in the soil for 10 years.

Improvement of soil quality is expected to bring about the better growth of sweet corn. In this study, sweet corn height and shoot dry weight at the first planting were highest in 10 years of OFP as compared to those of 5 years and control (Table 1). Plant height was only 5.3% higher in 10 years of OFP than control while dry shoot weight was 51.3% heavier.

After second planting, soil from 10 years of OFP contained highest TSOC and soil pH as compared to those of other OFP (Table 1). However, available P and exchangeable K were similar among the OFP, followed by no significant difference in plant height and shoot dry weight. Table 1 also indicated that soil chemical properties from each soil declined significantly after the second planting. The reduction of TSOC was 14.2%, 13.7%, and 15.5% for 10, 5, 0 years of OFP, respectively as compared to that of first planting. A higher reduction was noted at control than other OFP. Similar fashion was observed for soil pH and available P. Significant decline in soil chemical properties led to the restricted growth of sweet corn. The plant looked stunting and severe deficient of plant nutrient as indicated in plant height and shoot dry weight. The green biomass drastically dropped as much as 179% and 246% for 5 and 10 years of OFP, respectively.

Table 1. Selected soil chemical properties and shoot dry weight under different organic farming practices

Organic Farming Practices (years)	Soil chemical properties								Sweet corn performance			
	TSOC (g kg^{-1})		Soil pH		P-Bray (mg kg^{-1})		Exchangeable-K (mmol kg^{-1})		Plant height (cm)		Shoot dry weight (g plant^{-1})	
	1st planting	2nd planting	1st planting	2nd planting	1st planting	2nd planting	1st planting	2nd planting	1st planting	2nd planting	1st planting	2nd planting
0	56.5 a	49.0 a	5.42 a	4.77 a	3.92 a	1.16 a	1.77 a	1.57 a	186.3 a	107.7 a	108.8 a	69.2 a
	A	B	A	B	A	B	A	B	A	B	A	B
5	62.1 a	54.6 a	5.66 ab	4.87 ab	3.46 a	1.09 a	1.52 a	0.92 a	164.4 b	98.8 a	120.1 a	67.1 a
	A	B	A	B	A	B	A	B	A	B	A	B
10	76.6 b	67.1 b	6.05 b	5.02 b	4.35 a	1.42 a	1.45 a	1.07 a	196.1 a	94.4 a	164.6 b	66.8 a
	A	B	A	B	A	B	A	B	A	B	A	B

Means within a column followed by the same small letters and means within the row at the same variable followed by the same capital letters are not significantly different using Duncan test at 5%.

Residual Effect of Vermicompost on Selected Soil Chemical Properties and Sweet Corn Growth

Application of vermicompost on soil from different organic farming practices had a prominent effect on soil properties and sweet corn growth for both plantings. Figure 1 indicates that TSOC increases significantly after first and second plantings under application of vermicompost up to the rate of 30 Mg ha^{-1}. Total soil organic carbon is 54.5% and 41.1% higher at the application of 30 Mg ha^{-1} than control for first and second plantings, respectively. However, TSOC declines significantly after second planting. The soil characteristic dropped from 81.5 to 66.1 g kg^{-1} after second planting for vermicompost rate of 30 Mg ha^{-1}. Figure 1 also shows that the reduction of TSOC is more extensive at the rate of 30 Mg ha^{-1} than other treatments.

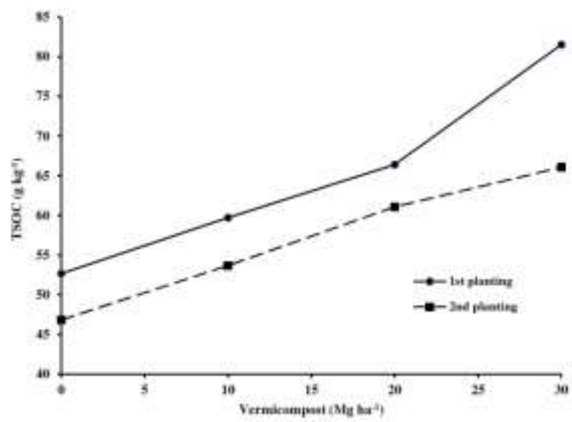

Figure 1. Total soil organic carbon after 1st and 2nd planting as affected by vermicompost

An increase in soil organic matter due to the application of vermicompost is followed by significantly higher soil pH as seen in Figure 2. At the first planting, soil pH is approximately 7% higher at the rate of 30 Mg ha^{-1} than control. But, this is not in the case of the second planting, where soil pH is not significantly affected by the application of vermicompost. It is also detected from Figure 2 that soil pH decreases sharply after the second planting as compared to that of first planting. More extensive reduction of soil pH is noticed at the higher rate of vermicompost than the lower one. Soil pH declines from 6.24 to 4.9 at the rate of 30 Mg ha^{-1} while 5.4 to 4.9 at control.

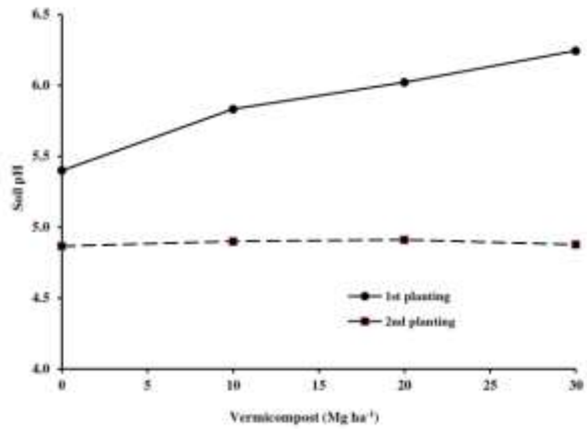

Figure 2. Soil pH after 1st and 2nd plantings as influenced by vermicompost.

Greater TSOC is followed by the higher content of soil available phosphorus (Figure 3). The increment is associated with soil organic matter decomposition during the experiment. A similar trend to TSOC, soil available phosphorus has a prominent increase for both plantings. But, a significant reduction of the soil characteristic is observed after second planting. The decline is more prominent at the higher rate of vermicompost than lesser rate.

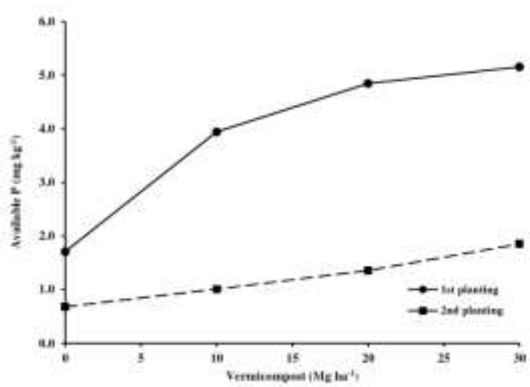

Figure 3. Soil available P after 1st and 2nd plantings as affected by vermicompost

A similar trend to available P, exchangeable K for both plantings pronouncedly increases as rates of vermicompost higher (Figure 4). After first planting, exchangeable K enhances by 240% when the rate of vermicompost is increased from 0 to 30 Mg ha^{-1}. Nonetheless, there is a considerable decline of exchangeable K after second planting and more prominent at the highest rate of vermicompost.

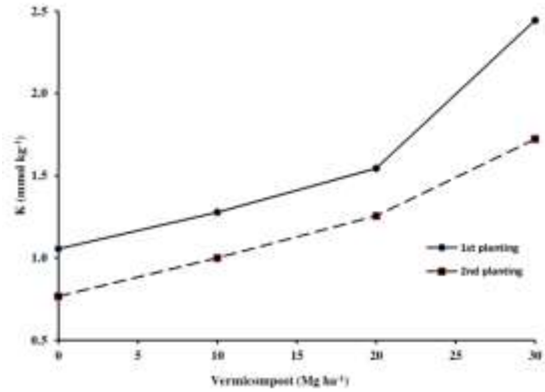

Figure 4. Exchangeable K after 1st and 2nd plantings as influenced by vermicompost

Improvement of soil chemical properties due to the application of vermicompost is followed by taller plant and higher biomass as indicated in Figure 5 and 6. Application of 30 Mg ha^{-1} vermicompost exhibits taller sweet corn as much as 85% and 35% as compared to that of control for first and second plantings, respectively while shoot dry weight increases by 21% and 180%. However, after the second planting, the growth of sweet corn drastically declines as indicated in Figure 5 and 6. Plant height lowers as much as 203.2% and 47.7% when fertilized with 30 Mg ha^{-1} and control, respectively, indicating more prominent effect at the higher rate of vermicompost. In addition, shoot dry weight is reduced as much as 44.5% and more than 3 fold for application of 30 Mg ha^{-1} and control, respectively.

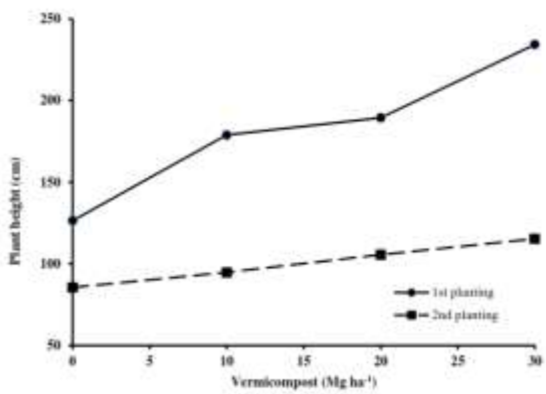

Figure 5. Sweet corn height after 1st and 2nd plantings as influenced by vermicompost

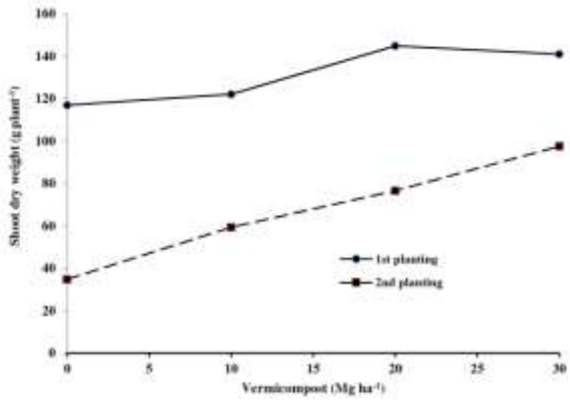

Figure 6. Shoot dry weight of sweet corn after 1st and 2nd plantings as affected by vermicompost

Discussion

Organic farming practice is highly dependent its plant nutrients on organic fertilizer, bringing about an accumulation of organic matter in the soil. This study shows that a more prolonged period of organic practices contains higher organic matter as indicated by TSOC content in soil (Table 1). Accumulation of TSOC is associated with the increase in organic matter from the organic amendment. A number of studies confirm that an application of organic fertilizer accumulates TSOC in soil (Brown and Cotton, 2011; Arthur *et al.*, 2012; Muktamar *et al.*, 2016).

Decomposition of soil organic matter releases plant nutrients and accumulates organic acids primarily humic and fulvic acids. The result of the experiment shows that after the first planting, soil from 10 years of OFP exhibits the highest available P (Table 1) as compared to the others, but exchangeable K is highest in control. The result indicates higher supply K from synthetic fertilizer and less mobile in soil than P; therefore, soil from the conventional farming system has higher K. Also, the primary source of P in soil is primarily from soil organic matter. Previous study by Edmeades (2003) indicated that long-term application of manure accumulated soil nutrients, particularly N and P. Highest pH in soil from 10 years of OFP might be attributed to accumulation of humic and fulvic acids in soil, leading to the formation of alumino-organic complex (Spark, 2003) and rising of soil pH. Earlier studies showed similar result where an addition of organic material increased soil pH (Muktamar *et al.*, 2015, Anggita *et al.*, 2018; Ifansyah, 2013).

Improvement of soil properties is followed by an increase in sweet corn growth as indicated by its height and shoot dry weight (Table 1). Tallest sweet corn and greatest shoot dry weight were attained in 10 years of OFP. This result might have been related to the content of TSOC, available P and K as well as higher soil pH (Table 1). The previous study confirmed that after 3 years of application, turkey manure had an effect on sweet corn grain yield (Diaz *et al.*, 2012).

After second planting, however, there was a considerable reduction of TSOC, available P, exchangeable K, and soil pH. (Table 1) At the same time, there was a substantial increase in soil acidity where after first planting was not detected (data are not shown), initiating a significant decline of soil pH. Total soil organic carbon, available P and exchangeable K after second planting are lower than those of initial soil, indicating there is a depletion of those nutrients. After the second planting, up to 10 years accumulation of organic matter has not been sufficient to support sweet corn growth and no residue of applied vermicompost is detected, even sweet corn had absorbed nutrients initially present in the soil. This result confirms that the effect of vermicompost lasts only one growing season. The previous study detected that application of compost on corn grain lasted at least one growing season (Eghball *et al.*, 2004)..

Application of vermicompost exhibits a substantial increase in TSOC, available P and exchangeable K as well as soil pH for both plantings (Figures 1, 2, 3, and 4). As the rate of vermicompost higher, the soil properties significantly increase, being the highest in the rate of 30 Mg ha^{-1}. This result is associated with the addition of soil organic matter, from which the decomposition releases plant nutrient and leaves organic acid, predominantly humic and fulvic acid. A number of studies discover that addition of organic matter to soil enhances TSOC, N, P, K, soil pH, and microbial biomass carbon (Muktamar *et al.*, 2015; Muktamar *et al.*, 2016; Laudicina *et al.*, 2011). As a consequence, there is also prominent increase in sweet corn growth for both plantings as rates of vermicompost get higher, indicated by plant height and shoot dry weight of sweet corn (Figure 5 and 6).

After the second planting, however, a drastic decrease of soil properties and sweet corn growth is observed (Figures 1, 2, 3, 4, 5, and 6). The reduction is more prominent at the higher rate of vermicompost than at the lower one. Sweet corn faced a severe deficiency of plant nutrients even though the high rate of the amendment exhibited less severe than the lower rate. Nonetheless, the residual effect of vermicompost is detected in second planting. Diaz et al. (2012) also found that the residual effect of turkey manure on grain yield of corn lasted for two seasons even though the yield pronouncedly declined. Also, the possibility is an effect of growing season where lower yield in continuous corn has often occurred. However, another study by Eghball *et al.* (2003) found that residual effects of manure lasted at least one growing season.

In summary, total soil organic carbon, available P, exchangeable K and pH is highest in soil from 10 years of OFP. Accumulation of organic matter for ten years is only sufficient for one planting of sweet corn indicated by no sweet corn growth differences among soils. Effect of vermicompost on soil properties and sweet corn growth lasts in second planting even though there is a considerable reduction of the variables. Therefore, continuous fertilization with an organic amendment in the organic farming system is mandatory to maintain soil productivity as well as to provide plant nutrients.

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References

Anggita, T., Muktamar, Z. and Fahrurrozi, F. (2018). Improvement of selected Soil chemical properties and potassium uptake by mung beans after application of liquid organic fertilizer in Ultisol. Terra Journal of Land Restoration. 1:1-7.

Arthur, E., Conelis, W. and Razzaghi, F. (2012). Compost amendment to soil affects soil properties and greenhouse tomato productivity. Compost Science and Utilization. 20:215-221.

Balai Penelitian Tanah (BPT) (2009). Petunjuk Tehnis Analisis Kimia Tanah, Tanaman, Air, dan Pupuk. Edisi II. Badan Penelitian dan Pengembangan Pertanian. (in Indonesian).

Brown, S and Cotton, M. (2011). Changes in soil properties and carbon content following compost application: Results on farm sampling. Compost Sci. and Utilization. 19: 87-96.

Butler, T. J., Weindorf, D. C., Han, K. J. and Muir. J. P. (2009). Dairy manure compost quality effects on corn silage and soil propertiesCompost Science and Utilization. 17:18-24.

Coolon, J. D., Jones, K. L., Todd, T. C., Blair, J. M. and Herman, M. A. (2013). Long-term nitrogen amendment alters the diversity and assemblage of soil bacterial communities in Tallgrass Prairie. PLoS ONE 8(6): e67884. doi:10.1371/journal.pone.0067884.

Diaz, D. A. R., Sawyer, J. E. and Barker, D. W. (2012). Residual poultry manure N supply to corn the second and third years after application. Soil Science Society of America Journal. 76:2289-2296.

Eghball, B., Ginting, D. and Gilley, J. E. (2004). Residual effects of manure and compost application on crop production and soil properties. Agronomy Journal. 96:442-447.

Ermiades, D. C. (2003). The long-term effects manures and fertilizers on soil productivity and quality: A review. Nutrient Cycling in Agroecosystem. 66:165-180.

Fang Y., Xun, F., Bai, W., Zhang, W. and Li, L. (2012). Long-term nitrogen addition leads toloss of species richness due to litter accumulation and soil acidification in a Temperate Steppe. PLoS ONE 7(10): e47369. doi:10.1371/journal.pone.0047369.

Han, J., Shi, J., SeSeng, L., Xu, L. and Wu, L. (2015). Effects of nitrogen fertilization on the acidity and salinity of greenhouse soils. Environmental Science and Pollution Research. 22:2976-2986.

Ibrahim, M., Anwar-Ul-Hassan, Iqbal, M. and Valeem, E. E. (2008). Response of wheat growth and yield to various levels of compost and organic manure. Pakistan Journal of Botany. 40:2135-2141.

Ifansyah, H. (2013). Soil pH and solubility of aluminum, iron, and phosphorus in Ultisol: Roles of humic acid. Journal of Tropical Soils. 18:203-208.

Laudicina, V. A., Badalucco, L. and Palazzolo, E. (2011). Effects of compost input and tillage intensity soil microbial biomass and activity under Mediterranean condition. Biology and Fertility of Soils. 47:63-70.

Jouquet, E. P., Bloquel, E., Doan, T. T., Ricoy, M., Orange, D., Rumpel, C. and Duc, T. (2011). Do compost and vermicompost improve macronutrient retention and plant growth in degraded tropical soils? Compost science and utilization. 19:15-24.

Mankolo, R., Reddy, C., Senwo, Z., Nyakatawa, E. and Sajjala, S. (2012). Soil biochemical change induced by poultry litter application and conservation tillage under cotton production system. Agronomy 2:187-198.

Masarirambi, M. T., Mbokazi, B. M., Wahome, P. K. and Oseni, T. O. (2012). Effects of kraal manure, chicken manure and inorganic fertilizer on growth and yield of lettuce (*Lactuca sativa* L. var Commander) in a semi-arid environment. Asian Journal of Agricultural Sciences. 4:58-64.

McDowel, R. W., Brooks, P. C., Mahieu, N., Poulton, P. R., Johnston, A. E. and Sharpley, A. N. (2002). The effect of soil acidity on potentially mobile phosphorus in a grassland soil. Journal of Agricultural Science. 139:27-36.

Muktamar, Z., Hasibuan, S. Y. K., Suryati, D. and Setyowati, N. (2015). Column study of downward movement and selected soil properties'changes in mine spoiled soil as influenced by liquid organic fertilizer. International Journal of Agricultural Technology. 11:2017-2027.

Muktamar, Z., Justisia, B. and Setyowati, N. (2016). Quality enhancement of humid tropical soils after application of water hyacinth (*Eichornia crassipes*) compost. Journal of Agricultural Technology. 12:1211-1227.

Muktamar, Z., Sudjatmiko, S., Chozin, M., Setyowati, N. and Fahrurrozi. (2017). Sweet corn performance and its major nutrient uptake following application of vermicompost supplemented with liquid organic fertilizer. International Journal on Advance Sci. Engineering Information Technology. 7:602-608.

Reeve, J. R., Endelman, J. B., Miller, B. E. and Hole, D. J. (2011). Residual effects of compost on soil quality and dryland wheat yield sixteen year after compost application. Soil Science Society of America Journal. 76:278-285.

Spark, D. (2003). Environmental Soil Chemistry. 2nd ed. Academic Press. London.

Tagoe, S. O., Horiuchi, T. and Matsui, T. (2008). Effects of carbonized and dried chicken manures on the growth, yield, and N content of soybean. Plant and Soil. 306:211-220.

Yague, M. R. and Quilez, D. (2010). Cumulative and residual effects of swine slurry and mineral nitrogen in irrigated maize. Agronomy Journal. 102:1682-1691.

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