International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 11(1): 55-64, February 2018
DOI: 10.30954/0974-1712.2018.00178.7

SOIL SCIENCE

Dynamics of Organic Carbon and Nutrients after Organic Waste Addition in an Acid Soil

Ermadani[1*], Hermansah[2], Yulnafatmawita[2] and Auzar Syarif[3]

[1]Graduate Program of Agricultural Sciences, Andalas University, Padang, Indonesia
[2]Department of Soil Science, Faculty of Agriculture, Andalas University, Padang, Indonesia
[3]Department of Agronomy, Faculty of Agriculture, Andalas University, Padang, Indonesia

*Corresponding author: ermadani_unja@yahoo.com (ORCID ID: 0000-0002-3364-9864)

Paper No. 650 Received: 06-09-2017 Accepted: 14-01-2018

ABSTRACT

Organic waste from agricultural industries such as effluent from palm oil mills contains high organic material and can be used as a source of organic material to improve soil quality. The incubation experiment was carried out to evaluate the effect of organic waste from a mixture of palm oil mill effluent with zeolite and chicken manure on pH, total organic C, labile organic C, humic acid C and nutrient in an acid soil. The treatment consisted of a control and the addition of organic waste at 5, 10, 15 and 20 t/ha arranged in a randomized block design with three replications. The incubation experiment was performed for 10 weeks. The addition of organic wastes significantly increased the soil pH, total organic C, labile organic C, humic acid C and nutrients (N, P, and K) and cation exchange capacity (CEC). The addition of organic waste also showed a significant decrease in the exchangeable Al, which is a toxic element found in acid soils. Changes in soil organic C, nutrients and other soil chemical properties showed different trends during incubation. Increased incubation time led to the decreasing trend in pH, total organic C, labile organic C and available P. In contrast, total N, humic acid C, exchangeable K, Al and cation exchange capacity tended to increase with increasing incubation time. The results of this study indicated that organic C, nutrients and other acid soil chemical properties could be improved by the addition of organic waste.

Highlights

- The addition of organic waste could ameliorate soil organic carbon and nutrients of acid soil
- The content of soil total organic C, labile organic C, pH, and available P showed the decreasing trend while soil humic C, total N, exchangeable K, exchangeable Al, and CEC had the increasing trend with the increasing incubation time.

Keywords: Organic waste, organic carbon, nutrients, acid soil

Soil organic carbon (C) is the main reservoir of carbon from the biosphere and acts as a key element of soil organic matter that plays a leading role in the biochemical cycles and the source of most of the major nutrients (Lal 2004; Stevenson *et al*. 2016). Soil organic carbon is a major source of energy for soil microorganisms (Lal 2016) and has a large contribution to soil cation exchange capacity (CEC) (Soares and Alleoni 2008; Murphy 2015), soil stability and ecological and environmental sustainability (Garcia- Gil *et al*. 2004). Because of its crucial role in determining soil properties, organic soil C is considered as a leading indicator for assessing soil quality or soil fertility (Yilmaz and Alagoz 2010; Ghosh *et al*. 2012).

Ultisol is the dominant soil in Indonesia covering a vast area of approximately 45.80 million hectares (Subagyo *et al*. 2004) and has a great potential for agricultural development. However, this soil is faced with low fertility problems due to the low content of organic matter and nutrients. Ultisol is characterized by low pH (4.20 - 4.70), organic C (0.80 - 1.18%), CEC (5.53 - 9.36 cmol/kg) and nutrients (Yuan *et* *al*. 2011; Kasno and Sutriadi 2012; Soelaeman and Haryati 2012). Aluminum (Al) toxicity and infertile soil condition are the two important factors that inhibit crop growth and reduce crop yield on acid soils such as Ultisol (Yuan *et al*. 2011). An effort to improve soil quality is to utilize organic waste as a source of organic matter and nutrients. The addition of organic materials is an important soil input to improve the chemical, physical and biological properties of the soil (Zhang *et al*. 2015). Dai *et al*. (2009) reported that biosolid compost increased the sequestration of C and improved soils physical and chemical properties and turf grass growth in which the total organic C, N, P and K in biosolid compost treatment were greater than inorganic fertilizer treatment.

Organic waste produced in large quantities from the agricultural industry can be an important source of organic material in improving soil quality. Serramia *et al.* (2013) reported that the application of olive oil processing waste raised humic acid C, which is an important indicator for soil C stabilization and soil sequestration. Coffee waste applied to the soil increases soil pH, organic C, total N, available P and CEC (Kasongo *et al*. 2011). One of the potential organic wastes from the agricultural industry is effluent generated from palm oil mills. This fresh effluent has high organic content with very high biological oxygen demand (BOD) value (21500-28500 mg/L) and low pH (pH 4.15-4.55) (Wong *et al*. 2009). With its high content of fresh organic material and acidity (low pH), it cannot be used directly to the soil. Low pH condition inhibits mineralization of organic matter by microorganisms (Rousk *et al*. 2009; Ye, *et al*. 2012). In addition, this effluent contains phenol compounds (Said *et al*. 2013; Saifuddin *et al*. 2014) that are toxic inhibiting the activity of enzymes involved in the cycle and mobilization of nutrients and decomposition of organic matter in the soil (Okolo *et al*. 2007; Baldrian 2009). Soil immobilization will occur with the addition of fresh organic matter directly to the soil (Wang *et al*. 2011).

However, through appropriate management, this organic waste can be used as a source of organic material for soil quality improvement. The reuse of agro-industry organic waste as a source of organic material for soil quality improvement is an environmentally friendly waste management effort. The objective of this study was to evaluate the effect of organic waste from a mixture of palm oil mill effluent with zeolite and chicken manure as a source of organic material on pH, total organic C, labile organic C, humic acid C and nutrients in an acid soil.

MATERIALS AND METHODS

Sampling Site and Soil Properties

The sampling site was dominated by grassland (*Imperata cylindrica*) and located in Mendalo Darat Village Muaro Jambi District, Jambi Province, Indonesia (103^0 32 ‘19.17” East; 01^0 36’ 17.76” South). The soil samples used in this incubation experiment were taken in March 2015 at a depth of 0-20 cm and the soil was characterized as Ultisol. The soil samples were air-dried for three days, ground and screened with a 2 mm sieve. Soil analysis was performed to determine soil properties and the results are presented in Table 1.

Table 1: Properties of soil prior to treatment

Properties	Value
pH	4.62
Organic C (%)	1.68
Total N (%)	0.124
Available P (ppm)	4.67
Exchangeable K (cmol/kg)	0.102
CEC (cmol/kg)	6.72
Exchangeable Al (cmol/kg)	2.59
Exchangeable H (cmol/kg)	0.78
Sand (%)	41.6
Silt (%)	30.28
Clay (%)	28.12
Texture class	Loam

Properties of Organic Waste

The organic waste used was a mixture of the fresh effluent of palm oil mill with zeolite and chicken manure. The fresh effluent was obtained in March 2015 from a palm oil mill located in Ladang Panjang Village, Muaro Jambi Province, Jambi Province. Properties of the fresh effluent are presented in Table 2. Properties of zeolite and chicken manure are presented in Table 3 and Table 4 respectively. The fresh effluent of palm oil mill (6 liters) plus zeolite (0.6 kg) and chicken manure (2 kg) were put into a plastic bucket (diameter 39 cm, height 41 cm). This mixture was stirred daily for one month. Properties of organic waste are presented in Table 4.

Table 2: Properties of fresh effluent

Properties	Value
pH	4.13
BOD (mg/L)	21720
COD (mg/L)	43490
Total N (mg/L)	560
Total P (mg/L)	96
Total K (mg/L)	819

Table 3: Properties of zeolite

Properties	Value
SiO_2 (%)	68.8
Al_2O_3 (%)	13.54
Fe_2O_3 (%)	1.43
CaO (%)	2.50
MgO (%)	0.82
Na_2O (%)	2.32
K_2O (%)	3.26
P_2O_5 (%)	<0.001
MnO (%)	0.019
H_2O (%)	6.98
CEC (cmol/kg)	106.48

Table 4: Properties of chicken manure and organic waste

Properties	Chicken manure	Organic waste
pH	7.20	6.91
Organic C (%)	21.91	20.01
Total N (%)	1.86	2.21
Total P (%)	1.33	1.46
Total K (%)	2.40	2.51
C/N	11.78	9.05
CEC (cmol/kg)	61.66	90.20
Moisture (%)	30.14	80.26

Experimental design

The incubation experiment was conducted from April to July 2015 and set in a completely randomized design with three replicates and five treatments consisting of an unamended control and four doses of organic waste (5, 10, 15 and 20 t /ha). The treatments were thoroughly mixed with 3 kg of air-dried fine soil (2 mm) and put into plastic pots (15 cm in height and 18 cm in diameter). The pots were incubated in a room at a temperature range of 24-30^0 C for 10 weeks. During the incubation time, the soil moisture was maintained at 80% field capacity by weighing every two days. The soils were rewetted by using distilled water.

Soil Analysis

Soils added with different rates of organic waste were sampled after incubation periods of 2, 4, 6, 8 and 10 weeks respectively. Each sample was about 100 g. The soil samples were dried, ground and screened to a 0.4 mm sieve. Soil analyses were performed to determine pH H_2O (1: 2), total organic C (Walkley and Black), humic acid (Tan, 1996), labile organic C (Weil *et al*. 2003), humic acid C (Walkley and Black), total N (Kjeldhal), available P (Bray 1), exchangeable Al (KCl 1M), exchangeable K and cation CEC (NH4OAc 1M pH 7).

Statistical Analysis

Statistical analysis of soil analysis data at each incubation interval was done by using analysis of variance (ANOVA) at $\alpha = 0.05$. The mean differences between treatments were assessed by Duncan's multiple-range test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Effect of organic waste on the dynamics of soil pH and exchangeable Al during incubation

The addition of organic waste significantly increased soil pH and lowered exchangeable Al when compared to control after 2 and 10 weeks of incubation (Table 5). The soil pH increased by 0.51-0.60 after 2 weeks of incubation and 0.12-0.44 after 10 weeks of incubation. Increased soil pH due to the addition of organic materials such as organic waste was similar to the results of several other studies. Tang *et al*. (2007) reported an increase in soil pH from the addition of organic fertilizers (cow manure and compost). Likewise, Yilmaz and Alagoz (2010) obtained an increase in soil pH with the addition of cow manure. The increase in soil pH could occur due to the consumption of H^+ ions by organic anions from organic matter (Hue 2011). Soil organic matter contains negatively charged sites to bind H^+ ions in acid soils (McCauley *et al*. 2017). However, soil pH tended to decrease with

Table 5: Soil organic C, nutrients and other soil chemical properties after 2 and 10 weeks of incubation with organic waste

Properties	Organic waste treatment (t/ha)				
	0	5	10	15	20
			Week 2		
pH	4.74 c	5.25 b	5.33 a	5.31 a	5.34 a
Exchangeable Al	2.64 a	1.68 b	1.55 bc	1.48 c	1.35 d
Total organic C	16.10 c	19.60 b	21.63 a	22.23 a	22.07 a
Labile organic C	0.30 c	0.40 b	0.42 b	0.49 a	0.51 a
Humic acid C	2.16 e	2.75 d	2.97 c	3.15 b	3.37 a
Total N	0.130 c	0.141 b	0.140 b	0.144 b	0.152 a
Available P	4.38 d	5.18 c	5.74 b	6.88 a	6.83 a
Exchangeable K	0.12 c	0.15 b	0.21 a	0.21 a	0.22 a
CEC	6.85 c	7.34 b	8.11 ab	8.00 b	8.48 c
			Week 10		
pH	4.59 b	4.71 b	4.96 a	5.03 a	5.01 a
Exchangeable Al	2.78 a	1.97 b	1.82 bc	1.67 cd	1.61 d
Total organic C	15.00 c	17.23 b	20.30 a	20.13 a	21.07 a
Labile organic C	0.24 d	0.37 c	0.37 c	0.42 b	0.46 a
Humic acid C	2.28 c	3.17 b	3.16 b	3.69 a	3.72 a
Total N	0.136 c	0.155 b	0.154 b	0.160 ab	0.162 a
Available P	3.87 d	4.88 bc	4.84 c	5.31 b	6.35 a
Exchangeable K	0.12 c	0.15 b	0.24 a	0.25 a	0.25 a
CEC	7.09 c	7.32 c	9.24 b	10.31 a	10.22 a

Means in the same columns followed by different letters are significantly different at $\alpha = 0.05$ by the Duncan's multiple range test

increasing incubation time (Fig. 1). Some studies also showed a decreasing trend in pH of soil amended with organic manure with an increasing incubation time (Yuan *et al*. 2011; Roy and Kashem 2014). The decrease in soil pH could be caused by the nitrification of NH_4^+-N to NO_3^- , which releases protons (H^+) during incubation (Wang *et al*. 2011; McCauley *et al*. 2017).

The addition of organic materials to acid soils decrease the soils Al content (Tang *et al*. 2007; Kasongo *et al*. 2011). With the addition of organic waste exchangeable Al decreased by 0.96-1.29 cmol/kg after 2 weeks of incubation and 0.81-1.17 cmol/kg after 10 weeks of incubation when compared with control (Table 5). The decrease in Al concentration by the addition of organic matter can occur because humic and low molecular weight aliphatic organic acid molecules of the organic matters form complex compounds with Al (Haynes and Mokolobate 2001; Yamaguchi *et al*. 2004; Hue, 2011). The carboxyl (-COOH) and phenolic hydroxyl (-OH) groups have a major role in the interaction of humic acid with metals (Shoba and Chudnenk, 2014). Shen and Shen (2001) reported that the concentration of Al-organic complexes increased with increasing doses of organic matter input such as pig manure and rice straw. The increased pH raises the ability of organic matter to form complex compounds with Al (Shen and Shen 2001).

However, the concentration of exchangeable Al showed an increasing trend with increasing incubation time (Fig. 1). This was likely because weakly organically bounded Al was released back to the soil solution that occupied the exchange complex. The concentration of weakly organically bounded Al is closely related to the total organic C content (Zołotajkin *et al*. 2011). The increased concentration of exchangeable Al may also be due to the decomposition of Al organic matter complexes (Xiao *et al*. 2014). Tang *et al*. (2007) reported that there was no significant difference in the treatment of cow manure and compost on exchangeable Al

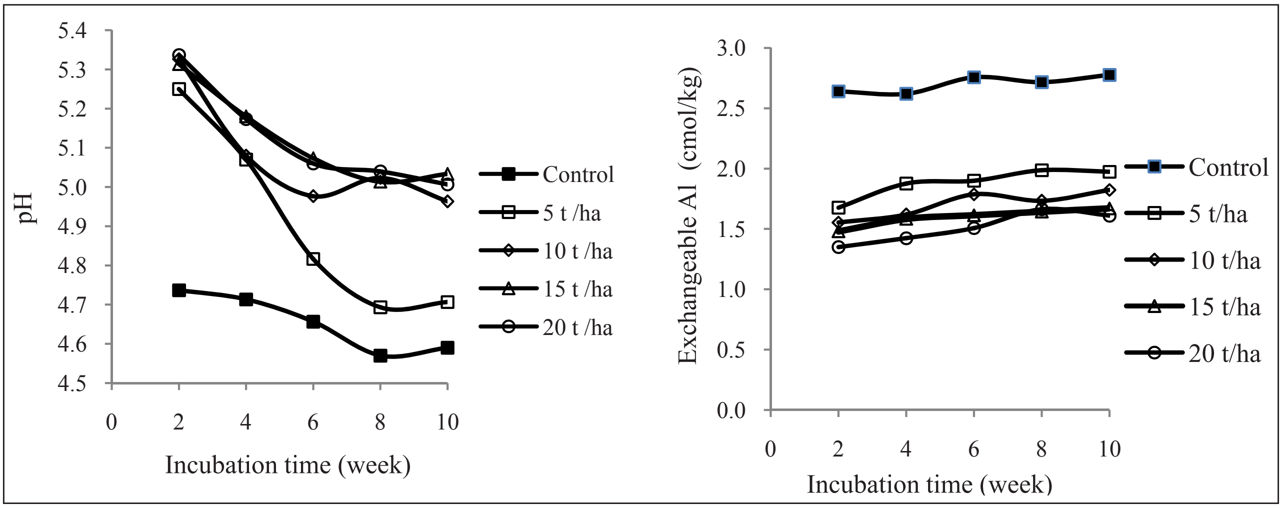

Fig. 1: Dynamics of soil pH and exchangeable Al during incubation with organic waste

after 30, 65 and 120 days of incubation. These results suggested that the effect of amelioration of organic amendment on the decrease of exchangeable Al soil was limited by a certain time.

Effect of organic waste on dynamics of soil total organic C, labile organic C and humic acid C during incubation

Total organic C, labile organic C and humic acid C in organic waste treatments were significantly higher than in the control (Table 5). The addition of organic waste increased total organic C, labile organic C and humic acid C by 15-40%, 54-92% and 39-63% respectively after 10 weeks of incubation. Total organic C showed a tendency to decrease with increasing incubation time (Fig. 2). After 2 weeks of incubation, the total organic C content ranged from 16.10 to 22.07 g/kg and decreased to 15.00 and 21.07 g/kg after 10 weeks of incubation (Table 5). Similar results were reported by several other researchers. Gulser *et al*. (2010) reported that the increase in organic soil C content occurred with the addition of tobacco waste and the organic C content decreased and was almost constant after 80 days of incubation. Serramia *et al*. (2013) also reported that organic matter application increased total organic C after 90 days of incubation and tended to decrease after 150 days of incubation. The decrease in the amount of soil organic C with increasing incubation time indicates the presence of an unstable organic C fraction that decomposes to CO_2 (Follett *et al*. 2007).

Increased doses of organic waste addition showed a tendency to increase organic labile C content (Table 5). The labile organic C content showed an increasing trend after 2 weeks of incubation and decreased after 4 weeks of incubation and tended to remain constant after 8 weeks of incubation (Fig. 2). The labile organic C fraction is related to the biological activity of microorganisms and includes biological metabolization compounds (Oyonarte *et al*. 2007).

The results of Masunga *et al*. (2016) found that the microbial biomass C on soils with organic matter input (crop residues, manure, and compost) decreased after 68 days of incubation. This fraction is an easily decomposed fraction and shows a rapid response to soil management (Lucas and Weil 2012). The decrease in labile organic C after 4 weeks of incubation was possibly due to reduced dissolved substrates such as dissolved C and N as a source of energy for microorganisms. The fraction of labile organic C or active organic C comprises of simple carbohydrates, amino acids, amine/amide sugars and C compounds containing hydroxyl, ketone, carboxyl and aliphatic compounds (Weil *et al*. 2003).

The content of humic acid C increased with increasing doses of organic waste addition and showed an increasing trend with increasing incubation time (Table 5; Fig. 2). Usman *et al*. (2004) also found that humic acid C significantly increased by the addition of sewage sludge and compost wherein the content of humic acid C tended to increase with increasing incubation time. Humic acid content increases due to the humification process (Huang *et al*. 2006). Increased fraction of humic acid C is associated with soil C stabilization

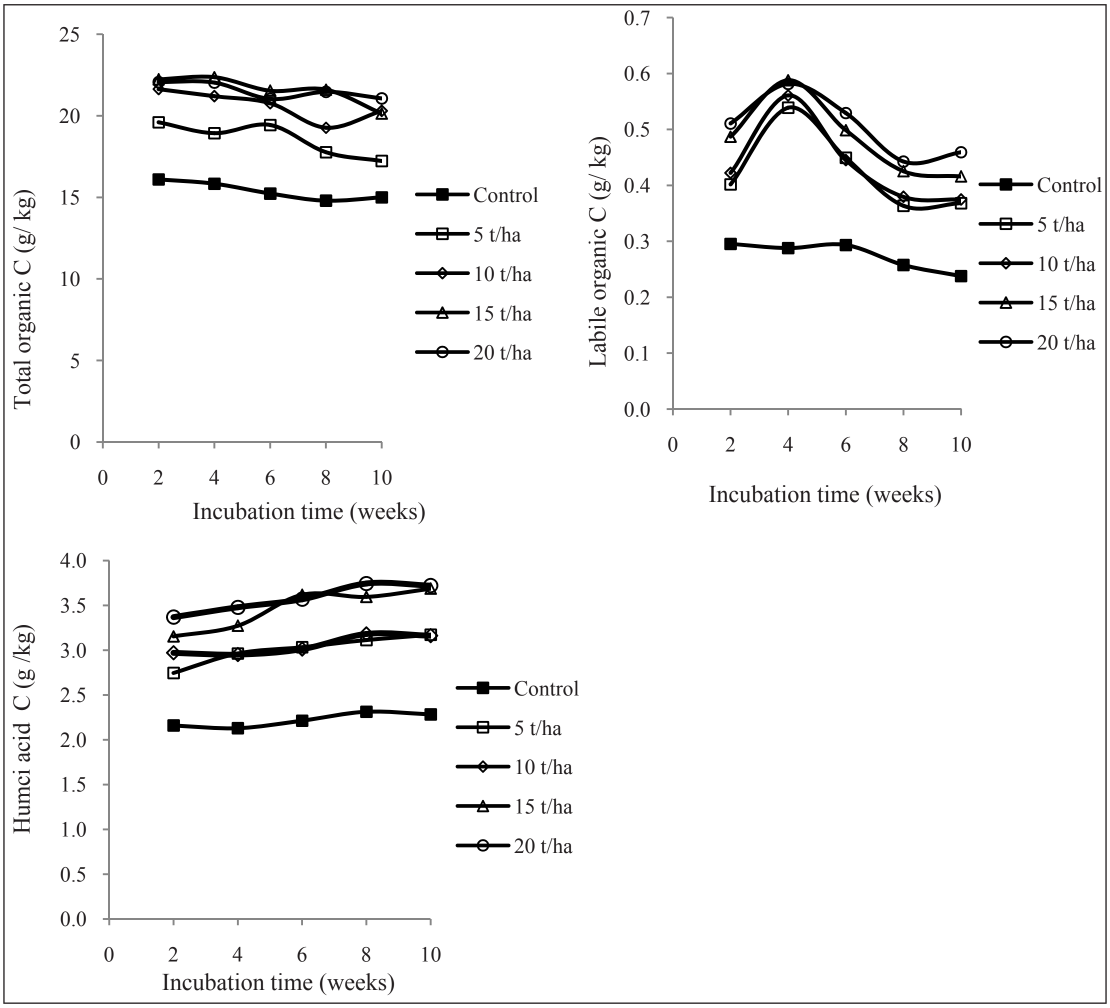

Fig. 2: Dynamics of soil total organic C, labile organic C and humic acid C during incubation with organic waste

and an indicator of C sequestration process in the soil (Serramia *et al*. 2013).

Effect of organic waste on dynamics of soil total N, available P, exchangeable K and CEC during incubation

The addition of organic waste caused a significant increase in total N content, available P and exchangeable K when compared to control (Table 5). Some researchers also reported an increase in total N of soil by the addition of organic fertilizer (Whalen *et al*. 2008; Wang *et al*. 2016; Kasongo *et al*. 2011). The main source of N is soil organic matter and with increasing soil organic matter the contents of organic C and N in the soil increases (Ryals *et al*. 2014). The total N content of soil shows an increasing trend with increasing incubation time (Fig. 3). This increase was due to increased soil mineral N (NH_4^+ and NO_3^-) during incubation (Wang *et al*. 2011). Khoi *et al*. (2006) reported that the amount of mineral N (NH_4^+ + NO_3^-) that was released and accumulated in the soil from the decomposition of organic matter increased with increasing incubation time and this was due to greater immobilization of microbe N with increasing incubation period. The results of Vel Murugan and Swarnam (2013) also showed an increase in the soil mineral N content with increasing incubation time on soils amended with vermicompost and chicken manure. Masunga *et al*. (2016) reported an increase in NO_3^- and a decrease in NH_4^+ during 97-day incubation on soils added with organic matter. Flavel and Murphy (2006) found that the increase in total N of soil was in conjunction with the increase of NO_3^- on soil incubated 150 days with compost.

Available P was significantly higher in organic waste treatment compared to control (Table 5). Available P in the control was 4.38 ppm (week

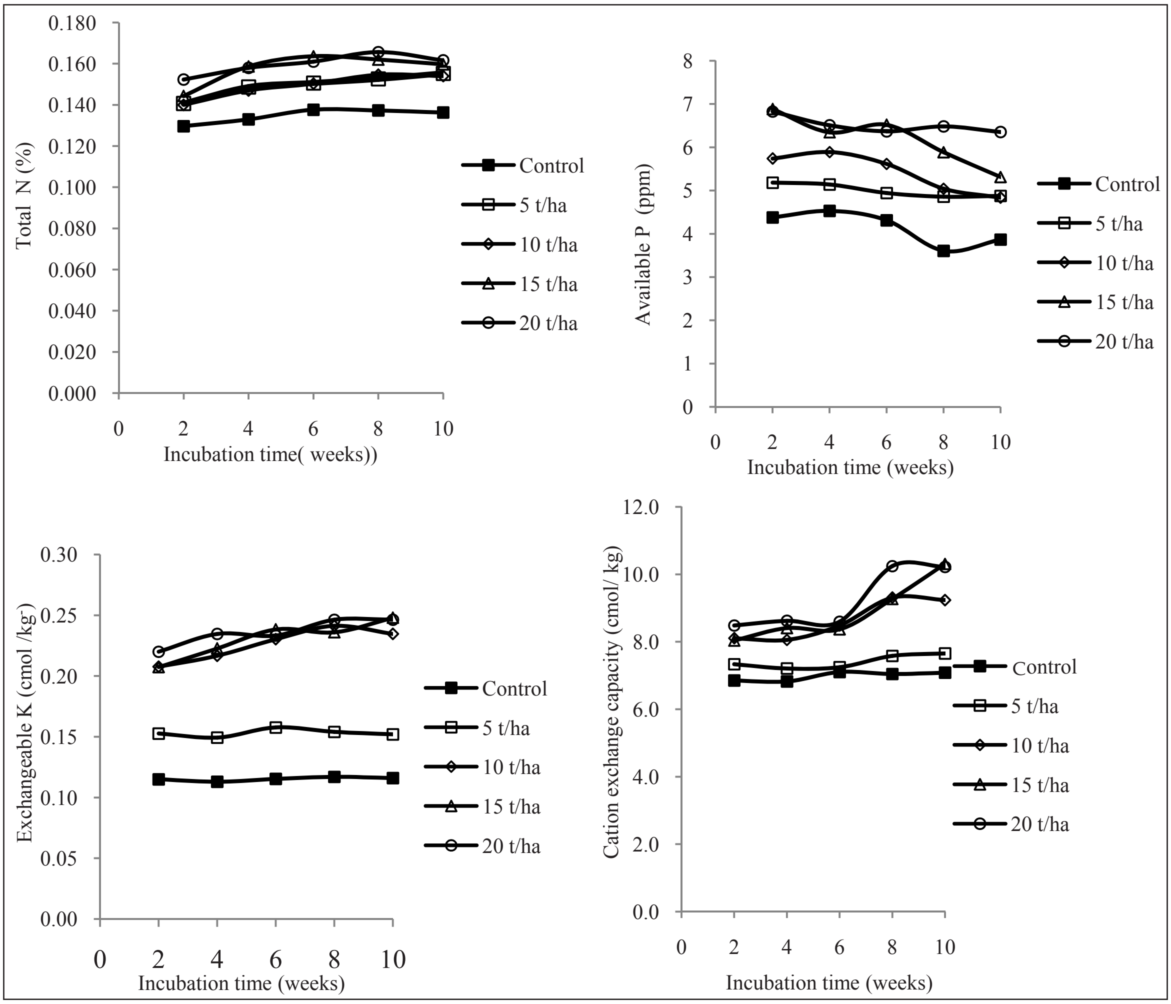

Fig. 3: Dynamics of soil total N, available P, exchangeable K and CEC during incubation with organic waste

2) and 3.87 ppm (week 10), while available P in organic waste treatment was 5.18 to 6.83 ppm (week 20) and 4.88 to 6.35 (week 10). Athokpam *et al*. (2016) also found the increase of available P of soil with the addition of organic amendment. This is associated with a decrease in the adsorption capacity of P of the soil due to increased pH and/ or impediment of adsorption sites on soil colloids by organic molecules and /or inorganic P released during decomposition of organic matter (Kasongo *et al*. 2011). The available P content showed a decreasing trend with increasing incubation time (Fig. 3). This indicated that the released P was greater than the P adsorption at the beginning of the incubation. Conversely, at the end of incubation, the P adsorption was greater than that was released. Abbasi *et al*. (2015) also found a decrease in soil available P from 18.8 mg/kg at incubation time of 15 days, which decreased to 9.6 mg/kg in 60 days of incubation with chicken manure treatment. This tendency of decline may be due to the conversion of available P to an insoluble P complex where the phosphate anions (H_2PO4^-, HPO_4^{2-}) are highly reactive and form metal compounds with Fe^{3+} and Al^{3+} in acid soils (Mehta *et al*. 2014).

The addition of organic waste increased exchangeable K and CEC by 25-83%, and 7-24% at week 2 respectively, while at week 10, the increase was 25-108% and 3-45% respectively (Table 5). The K and CEC increases by the incorporation of organic amendment to the soil were also reported by Parewa *et al*. (2004). The exchangeable K and CEC tended to increase with the increasing incubation time (Fig. 3). Organic fertilizers are a source of exchanged cations such as K, Ca and Mg (Soremi *et al*. 2017). The soil exchangeable K derives from soil indigenous K and K from organic amendments (Najafi-Ghiri *et al*., 2017). In addition, organic matter added to the soil also play a role in the process of releasing K from the soil. From the results of research on the K release from the soil treated with organic manure, Najafi-Ghiri *et al*. (2017) found that the highest content of K release from Cambisols were ameliorated with sheep manure and poultry manure. Yilmaz and Alagoz (2010) found that soil CEC increased with increasing dose of organic fertilizer application from 32.17 cmol/kg (control) to 32.38, 34.76 and 38.78 cmol/kg respectively for seven months of incubation with 10, 20 and 40 t/ha organic fertilizer. The increased soil pH and total organic C as a result of organic fertilizer application are the main factors causing the increase of CEC (Kasongo *et al*. 2011). Increasing the content of humic acid also increases CEC. The negative charge of humic acid increases with increasing pH, thus raises CEC (Coles and Yong 2006).

CONCLUSION

Organic waste increased total organic C, labile organic C and humic acid C. The total organic C content and labile organic C exhibited a decreased trend with increasing incubation time. Conversely, humic acid C showed an increasing trend with increasing incubation time. The application of organic waste increased soil pH, total N, available P, exchangeable K and CEC, and reduced exchangeable Al. Increased incubation time caused a decreasing trend in soil pH and available P but caused an increasing trend in soil total N, exchangeable K, exchangeable Al and CEC. The improvement of organic C content and nutrients by adding organic waste from the palm oil mill demonstrates the benefit of effluent as an amendment for an acid soil.

ACKNOWLEDGMENTS

This research was supported by the research fund from the Ministry of Research, Technology and Higher Education, Republic of Indonesia. Authors thank the Dean of the Faculty of Agriculture, Jambi University, Indonesia for providing laboratory facilities and also the supporting staff in laboratory analyses.

REFERENCES

Abbasi, K., Musa, N. and Manzoor, M. 2015. Mineralization of soluble P fertilizers and insoluble rock phosphate in response to phosphate-solubilizing bacteria and poultry manure and their effect on the growth and P utilization efficiency of chilli (*Capsicum annuum* L.). *Biogeosciences*, **12**: 4607–4619.

Athokpam, H., Wani, S. H., Sarangthem, I. and Singh, N. A. 2016. Effects of vermicompost and boron on tomato (*Solanum lycopersicum* cv. Pusa ruby) flowering, fruit ripening, yield and soil fertility in acid soils. *Int. J. of Agri. Environ. and Biotech*., **9**(5): 847-853.

Baldrian, P. 2009. Microbial enzyme-catalyzed processes in soils and their analysis. *Plant Soil Environ.*, **55**(9): 370–378.

Coles, C.A. and Yong, R.N. 2006. Humic acid preparation, properties and interactions with metals lead and cadmium. *Engineering Geology*, **85**: 26–32.

Dai, X., Vietor, D.M., Hons, F.M., Provin, T.L., White, R. H., Boutton, T.W. and Munster, C.L. 2009. Effect of composted biosolids on soil organic carbon storage during establishment of transplanted sod. *Hortscience*, **44**(2): 503–507.

Flavel, T.C. and Murphy, D.V. 2006. Carbon and nitrogen mineralization rates after application of organic amendments to soil. *J. Environ. Qual.*, **35**: 183–193.

Follet, R.F., Paul, E.A. and Pruessner, E.G. 2007. Soil carbon dynamics during a long-term incubation study involving 13C and 14C measurements. *Soil Science*, **172**(3): 189-208.

Garcıa-Gill, J.C., Plaza, C., Senesi, N., Brunetti, G. and Polo, A. 2004. Effects of sewage sludge amendment on humic acids and microbiological properties of a semiarid Mediterranean soil, *Biol. Fert. Soils*, **39**: 320–328.

Ghosh, S., Wilson, B., Ghoshal, S., Senapati, N. and Mandal, B. 2012. Organic amendments influence soil quality and carbon sequestration in the Indo-Gangetic plains of India. Agriculture, *Ecosystems and Environment*, **156**: 134– 141.

Gulser, C., Demir, Z. and Ic, S. 2010. Changes in some soil properties at different incubation periods after tobacco waste application. *Journal of Environmental Biology*, **31**(5): 671-674.

Haynes, R.J. and Mokolobate. M.S. 2001. Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: a critical review of the phenomenon and the mechanisms involved. *Nutrient Cycling in Agroecosystems*, **59**: 47–63.

Huang, G.F., Wu, Q.T., Wong, J.W.C. and Nagar, B.B. 2006. Transformation of organic matter during co-composting of pig manure with sawdust. *Bioresource Technology*, **97**: 1834–1842.

Hue, N.V. 2011. Alleviating soil acidity with crop residues. *Soil Sci.*, **176**(10): 543-549.

Kasno, A., and Sutriadi, M.T. 2012. Indonesian rock-phosphate affectivity for maize crop on ultisols soils. *Agrivita*, **34:**(1): 14-22.

Kasongo, R.K., Verdoodt, A., Kanyankagote, P., Baert, G. and Van Ranst, E. 2011. Coffee waste as an alternative fertilizer with soil improving properties for sandy soils in humid tropical environments. *Soil Use and Management*, **27**: 94–102.

Khoi, C.M., Guong, V. T. and Merckx, R. 2006. Predicting the release of mineral nitrogen from hypersaline pond sediments used for brine shrimp *Artemia franciscana* production in the Mekong Delta. *Aquaculture*, **257**: 221–231.

Lal, R. 2004. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science,* **304**: 1623-1627.

Lal, R. 2016. Soil health and carbon management. *Food and Energy Security*, **5**(4): 212–222.

Lucas, S.T. and Weil, R.R. 2012. Can a Labile Carbon Test be Used to Predict Crop Responses to Improve Soil Organic Matter Management?. *Agron. J.,* **104**: 1160–1170.

Masunga, R.H., Uzokwe, V. N., Mlaya, P.D., Odeh, I., Singh, A., Buchan, D. and Neve, S.D. 2016. Nitrogen mineralization dynamics of different valuable organic amendments commonly used in agriculture. *Applied Soil Ecology,* **101**: 185–193.

McCauley, A., Jones, C. and Olson-Rutz, K. 2017. Soil pH and Organic Matter. Nutrient Management Module No. 8. Montana State University Extension Publications. Bozeman Montana.

Mehta, P., Walia, A., Kulshrestha, S., Chauhan, A. and Shirkot, C.K. 2014. Efficiency of plant growth-promoting P-solubilizing *Bacillus circulans* CB7 for enhancement of tomato growth under net house conditions. *J. Basic Microb*., **53**: 1–12.

Murphy, B. 2015. Key soil functional properties affected by soil organic matter– evidence from published literature. *Earth and Environmental Science*, **25**: 1-5.

Najafi-Ghiri, M., Niksirat, S.H., Soleimanpour, L. and Nowzari, S. 2017. Comparison of different organic amendments on potassium release from two fine textured soils. *Organic Agriculture*, 1-12.

Okolo, C., Nweke, C.O., Nwabueze, R.N., Dike, C.U. and Nwanyanwu, C.E. 2007. Toxicity of phenolic compounds to oxidoreductases of *Acinetobacter* species isolated from a tropical soil. *Scientific Research and Essay*, **2**(7): 244-250.

Oyonarte, J.C., Mingorance, M.D., Durante, P., Piñeiro, G. and Barahona, E. 2007. Indicators of change in the organic matter in arid soils. *Science of the Total Environment*, **378**: 133–137.

Parewa, H.P., Yadav, J. and Rakshit, A. 2014. Effect of Fertilizer Levels, FYM and Bioinoculants on Soil Properties in Inceptisol of Varanasi, Uttar Pradesh, India. *Int. J. of Agri. Environ. and Biotech*.**,** **7**(3): 517-525.

Rousk, J., Brookes, P.C. and Baath, E. 2009. Contrasting soil pH effects on fungal and bacterial growth suggest functional redundancy in carbon mineralization. *Applied and Environmental Microbiology*, **75**(6): 1589–1596.

Roy, S. and Kashem, M.A. 2014. Effects of organic manures in changes of some soil properties at different incubation periods. *Open Journal of Soil Science*, **4**: 81-86.

Ryals, R., Kaiser, M., Torn, M.S., Berhe, A.A. and Silver, W.L. 2014. Impacts of organic matter amendments on carbon and nitrogen dynamics in grassland soils. *Soil Biology & Biochemistry*, **68**: 52-61.

Said, M., Ahmad, A. and Mohammad, A.W. 2013. Removal of phenol during ultrafiltration of Palm oil mill effluent (POME): Effect of pH, ionic strength, pressure and temperature. *Der Pharma Chemica,* **5**(3): 190-196.

Saifuddin, N. Saltanat, A. and Refal, H. 2014. Enhancing the Removal of Phenolic Compounds from Palm Oil Mill Effluent by Enzymatic Pre-treatment and Microwave-Assisted Extraction. *Chemical Science Transactions*, **3**(3): 1083-1093.

Serramia, N., Sanchez-Monedero, M.A., Roig, A., Contin, M. and De Nobili, M. 2013. Changes in soil humic pools after soil application of two-phase olive mill waste compost. *Geoderma*, **192**: 21-30.

Shen, Q.R. and Shen, Z.G. 2001. Effects of pig manure and wheat straw on growth of mung bean seedlings grown in aluminium toxicity soil. *Bioresource Technology,* **76**: 235-240.

Shoba V.N. and Chudnenko, K.V. 2014. Ion exchange properties of humus acids. *Eurasian Soil Science*, 47(8): 761–771.

Soares, M.P. and Alleoni, L.R.F. 2008. Contribution of Soil Organic Carbon to the Ion Exchange Capacity of Tropical Soils. *Journal of Sustainable Agriculture*, **32**(3): 439-462.

Soelaeman, Y. and Haryati, U. 2012. Soil physical properties and production of upland ultisol soil as influenced by manure application and fertilization. *Agrivita*, **34**(2): 137-144.

Soremi, A.O., Adetunji, M.T., Adejuyigbe, C.O., Bodunde, J.G. and Azeez, J.O. 2017. Effects of poultry manure on some soil chemical properties and nutrient bioavailability to soybean. *Journal of Agriculture and Ecology Research International,* **11**(3): 1-10.

Stevenson, B.A., Sarmah, A.K., Smernik, R., Hunter, D.W.F. and Fraser, S. 2016. Soil carbon characterization and nutrient ratios across land uses on two contrasting soils: Their relationships to microbial biomass and function. *Soil Biology & Biochemistry*, **97**: 50-62.

Subagyo, H., Suharta, N. and Siswanto. A.B. 2004. Agricultural soils in Indonesia. p. 21–66. In A. Adimihardja, L.I. Amien, F. Agus and D. Djaenudin (Ed.). Indonesian land resource and management. Soil and Agroclimate Research Centre. Bogor. (In Indonesian).

Tang, Y., Zhang, H., Schroder, J.L., Payton, M.E. and Zhou, D. 2007. Animal manure reduces aluminum toxicity in an acid soil. *Soil Sci. Soc. Am. J.,* **71**: 1699-1707.

Tan K.H. 1996. Soil Sampling, Preparation, and Analysis. Marcel Dekker Inc. New York.

Teng, T.T., Wong, Y.S., Ong, S.A., Norhashimah, M. and Rafatullah, M. 2013. Start up operation of anaerobic degradation process of palm oil mill effluent in anaerobic bench scale reactor (ABSR). *Procedia Environmental Sciences,* **18**: 442-450.

Usman, A.R.A, Kuzyakov, Y. and Stahr, K. 2004. Dynamics of organic c mineralization and the mobile fraction of heavy metals in a calcareous soil incubated with organic wastes. *Water, Air, and Soil Pollution*, **158**: 401–418.

Vel Murugan, A. and Swarnam, T.P. 2013. Nitrogen release pattern from organic manures applied to an acid soil. *Journal of Agricultural Science*, **5**(6): 174-184.

Wang, N., Xu, R.K. and Li, J.Y. 2011. Amelioration of an acid ultisol by agricultural by-products. *Land Degrad. Develop.*, **22**: 513–518.

Wang, X., Jia, Z., Liang, L.,Yang, B., Ding, R., Nie, J. and Wang, J. 2016. Impacts of manure application on soil environment, rainfall use efficiency and crop biomass under dryland farming. *Sci. Rep.*, **6**: 20994.

Weil, R.W., Islam, K.R., Stine, M., Gruver, J.B. and Samson-Liebig, S.E. 2003. Estimating active carbon for soil quality assessment: a simplified method for laboratory and field use. *American Journal of Alternative Agriculture*, **18**: 3–17.

Whalen, J.K., Benslim, H., Jiao, Y. and Sey, B.K. 2008. Soil organic carbon and nitrogen pools as affected by compost applications to a sandy-loam soil in Quebec. *Can. J. Soil Sci.*, **88**: 443_450.

Wong, Y.S., Kadir, M.O.A.B. and Teng, T.T. 2009. Biological kinetics evaluation of anaerobic stabilization pond treatment of palm oil mill effluent. *Bioresour. Technol.*, **100**: 4969-4975.

Xiao, K., Yu, L., Xu, J. and Brookes, P. C. 2014. pH, nitrogen mineralization, and KCl-extractable aluminum as affected by initial soil pH and rate of vetch residue application: results from a laboratory study. *J. Soils Sediments*, **14**: 1513–1525.

Yamaguchi, N., Hiradate, S., Mizoguchi, M. and Miyazaki, T. 2004. Disappearance of aluminium tridecamer from hydroxyaluminum solution in the presence of huic acid. *Soil Sci. Soc. Am. J.*, **68**: 1838-1843.

Ye, R., Jin, Q., Bohannan, B., Keller, J. K., McAllister, S. A. and Bridgham, S.D. 2012. pH controls over anaerobic carbon mineralization, the efficiency of methane production, and methanogenic pathways in peatlands across an ombrotrophiceminerotrophic gradient. *Soil Biology & Biochemistry*, **54**: 36-47.

Yilmaz, E. and Alagoz, Z. 2010. Effects of short-term amendments of farmyard manure on some soil properties in the Mediterranean region – Turkey. *Journal of Food, Agriculture & Environment*, **8**(2): 859 -862 .

Yuan, J.H., Xu, R.K. Qian, W. and Wang, R.H. 2011. Comparison of the ameliorating effects on an acidic Ultisol between four crop straws and their biochars. *J. Soils Sediments*, **11**: 741–750.

Zhang, Q., Zhou, W., Liang, G., Wang, X., Sun, J., He, P. and Li, L. 2015. Effects of different organic manures on the biochemical and microbial characteristics of albic paddy soil in a short-term experiment. *PLoS One*, **10**(4): 1-19.

Zołotajkin, M., Ciba, J., Kluczka, J., Skwira, M. and Smoliński, A. 2011 Exchangeable and bioavailable aluminium in the mountain forest soil of Barania Góra Range (Silesian Beskids, Poland). *Water Air Soil Pollut.*, **216**: 571–580.