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Use of Organic Waste as an Alternative Organic Fertilizer and Synthetic Fertilizer to Ameliorate Acid Soil Productivity

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***Abstract*— Liquid waste generated in large quantities in the palm oil mill has low pH, and high organic content and its use as an organic amendment could offer an environmentally friendly management strategy. This pot experiment aimed to evaluate the impact of organic waste of the liquid waste from the palm oil mill and synthetic fertilizer on organic carbon and nutrients of an acid soil and soybean yield. The treatments consisted of no synthetic fertilizers, half recommended dose of synthetic fertilizers (0.5R), synthetic fertilizers as recommended 50 kg ha^{-1} Urea + 200 kg ha^{-1} SP-36 + 150 kg ha^{-1} KCl (R) and organic waste with doses of 0, 5, 10, 15 and 20 t ha^{-1}. The experiment was arranged in a completely randomized design with a factorial pattern and three replications. The results demonstrated that there was no significant interaction on soil chemical characteristics by the addition of organic waste and synthetic fertilizers. However, organic waste addition increased soil pH, total organic C, labile organic C, humic acid C, total N, available P, exchangeable K, and cation exchange capacity (CEC), whereas synthetic fertilizer addition only increased available P and exchangeable K. Exchangeable Al was significantly reduced by organic waste while significant effect didn't occur with synthetic fertilizers. The treatment of organic waste increased total organic C content by 7-24%. A larger sensitivity was indicated by labile organic C compared to total organic C and humid acid C so that labile organic C is a better indicator of alterations of soil organic C owing to organic waste treatment. The treatment of organic waste and synthetic fertilizers showed significant interactions on the dry weight of soybean seed, shoot, and root. The addition of synthetic fertilizers without organic waste increased the dry weight of the soybean seed, shoot and root by 133%, 133% and 140% respectively, while with the addition of 15 t ha^{-1} organic waste combined with synthetic fertilizer, enhancements by 262%, 261%, and 206% in the dry weight of seed, shoot and root were respectively found.**

***Keywords*—organic waste; organic carbon; nutrient; synthetic fertilizer; acid soil; soybean.**

I. INTRODUCTION

The palm oil production process in the mills results in solid waste and liquid waste. The solid waste consists of empty fruit bunch, fiber, and shell. Liquid waste is a waste generated in large quantities, that is about 65% of the fresh fruit bunch processed [1]. Waste derived from the agricultural industry contains high organic matter and can decompose. The palm oil mill liquid waste is brown, thick, and acidic with high solid content, great biological oxygen demand (BOD) and chemical oxygen demand (COD). The properties of liquid waste vary depending on the condition of the palm oil factory and climate. Vijayaraghavan et al., [2] reported that the liquid waste of palm oil factory had pH of 3.5, 25545 mg L^{-1} BOD, 55755 mgL^{-1} COD, 18479 mgL^{-1} suspended solids and 711 mg L^{-1} total nitrogen. Chotwattanasak and Puetpaiboon [3] reported that the palm oil mill liquid waste had pH of 4.72-5.38, 12750-42150 mg L^{-1} BOD, and 15000-66000 mg L^{-1} COD. The high content of BOD in liquid waste shows the high content of degradable organic matter [4]. However, it cannot be directly applied to the soil due to low pH and can lead to nitrogen (N) immobilization and poisoning for plants [5, 6]. The content of organic matter in this liquid waste is difficult to decompose under natural conditions [7].

In the palm oil mill, the liquid waste is treated biologically by using open ponding system before being applied to the field or discharged into the waters, in which it requires a long hydraulic retention time of about 80 days [8]. The liquid waste in open ponds is a major source of pollution because anaerobic ponds release large amounts of methane gas, and liquid waste can also contaminate surface and groundwater [9]. However, it can be used as an alternative organic fertilizer because of its high content of organic matter and plant nutrients.

Acid mineral soils such as Ultisols are soils with low productivity, pH, organic matter, and nutrients. This soil has a pH of 4.6-4.7, 0.90-1.18% organic C, 0.07-0.09% total N, 8.8-9.0 ppm available P and 0.12-0.16 $cmolkg^{-1}$ exchangeable K [10]. Various inputs of organic and synthetic fertilizers have been used to ameliorate soil fertility and raise plant production. Addition of manure such as compost could increase organic soil C [11]. Serramia et al., [12] found an increase in the C fraction of soil humid acid by the addition of organic fertilizer, which indicates a useful indicator for soil C stabilization. Yu et al., [13] reported that the utilization of manure increased the sequestration of C in the soil because of the enhancement in the soil stable organic C while its raise as a result of the treatment of synthetic fertilizers was smaller. In addition to the total organic C increase, giving organic rice straw input to the soil also increases the labile organic C [14]. The use of NPK fertilizers accelerates the breakdown of soil organic matter [15]. A labile organic C fraction is a responsive indicator of alteration of soil organic C owing to different management practices and has a crucial function in the release of nutrients and microbial activity because it is readily decomposed by microorganisms [16].

Efforts to utilize organic waste such as recycling process provide benefits to ecosystem services and improve soil quality [17]. The usage of recycled organic waste can improve the biological, physical, and chemical soil properties [18]. Bulluck III et al., [19] reported that the use of recycled organic waste as an alternative fertilizer could improve the properties of soil biology, chemistry, physics and crop yields better than synthetic fertilizers. Compost application derived from organic wastes is not only beneficial in terms of waste recycling but can also reduce the number of synthetic fertilizer needs and increase the content of soil organic matter and as a means of reducing atmospheric CO_2 [20]. Rostami et al., [21] found that the treatment of 20 t ha^{-1} compost of municipal waste together with 50% recommended dosages of chemical fertilizers provided the highest soybean production of 4.48 t ha^{-1} where there was a 29% increase compared to the chemical fertilizer treatment of the recommended dosages (40 kg ha^{-1} urea, 60 kg ha^{-1} triple superphosphate and 60 kg ha^{-1} potassium sulfate). Verde et al., [22] obtained the highest soybean yield (2.80 t ha^{-1}) with organic fertilizer treatment, which increased by 146% compared with control. Mucheru-Muna et al. [23] reported that no significant difference was found between the treatment of organic fertilizer alone and the combination of organic fertilizer with half the recommendation of mineral fertilizer on corn yield where the treatment of organic fertilizer alone or organic fertilizer combined with half the recommendation of mineral fertilizer gave higher yields of 5.5 t ha^{-1} and 5.4 t ha^{-1} compared with control (1.5 ton ha^{-1}) and recommended mineral fertilizer application (4.5 ton ha^{-1}). Information on the use of organic waste coming from the liquid waste produced in the palm oil mill as a source of organic matter and nutrients in improving soil quality and crop yields is still limited. The objectives of this study were to (1) evaluate the interaction of organic waste as an alternative organic fertilizer and synthetic fertilizer on organic C and other chemical properties of an acid mineral soil and soybean yield, and (2) determine and compare the sensitivity of organic C fractions as indicators of soil organic C in an acid mineral soil amended with organic and/or synthetic fertilizer.

II. MATERIALS AND METHODS

A. *Liquid Waste, Chicken Manure, and Zeolite*

The study was conducted from March to October 2015. The fresh liquid waste was obtained from the palm oil mill located in Ladang Panjang Village, Muaro Jambi Regency, Jambi Province. Analysis of liquid waste was conducted to determine pH, BOD, COD, total solid, total N, total K, and total P by the American Public Health Association (APHA) method [24]. Characteristics of liquid waste are presented in Table 1. Chicken manure was derived from a local chicken farm. Characteristics of pH, organic C (Walkley and Black), total N (Kjeldahl), total P (25% HCl) and total K (HCl 25%) of chicken manure are presented in Table 2. The characteristics of zeolite are shown in Table 3.

The organic waste used in this study was the fresh liquid waste of palm oil mill mixed with zeolite and chicken manure. The mixture of fresh liquid waste (6 liters) with zeolite (0.6 kg) and chicken manure (2 kg) was put into a plastic bucket (diameter 39 cm, height 41 cm). The bucket was covered with plastic lid and stirring was done daily to provide aeration for four weeks. After four weeks, analysis of the organic waste sample was carried out to determine pH, organic C, total N, total P, total K, CEC, and moisture. The characteristics of organic waste are shown in Table 2.

TABLE I
CHARACTERISTICS OF FRESH LIQUID WASTE

Parameter	Value
pH	4.13
BOD_5 (mg L^{-1})	21720
COD (mg L^{-1})	43490
Total N (mg L^{-1})	560
Total P (mg L^{-1})	96
Total K (mg L^{-1})	819

TABLE II
CHARACTERISTICS OF CHICKEN MANURE AND ORGANIC WASTE

Parameter	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^{-1})	61.66	90.20
Moisture (%)	30.14	80.26

TABLE III.
CHARACTERISTICS OF ZEOLITE

Parameter	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^{-1})	106.48

B. *Experimental Soil*

The soil used in this experiment was taken from Mendalo Darat Village, Muaro Jambi Regency, Jambi Province in which the site was dominated by grassland (*Imperata cylindrica*). The soil was sampled from a depth of 0-20 cm, dried for 3 days, crushed and passed through 2 mm sieve. The sieved dried soil was placed into plastic pots (26.5 cm tall and 31 cm in diameter) wherein each pot contained 10 kg of soil equivalent to oven dry weight. Soil analysis before treatment was performed to determine the texture (pipette method), pH H_2O (1: 2), organic C (Walkley and Black), total N (Kjeldahl), available P (Bray 1), exchangeable K (NH_4OAc 1 M pH 7), exchangeable Al (KCl 1 M) and CEC (NH4OAc 1M pH 7) and the soil characteristics are shown in Table 4.

TABLE IV
CHARACTERISTICS OF SOIL

Parameter	Value
pH	4.62
Organic C (%)	1.68
Total N (%)	0.124
Available P (ppm)	4.67
Exchangeable K (cmol kg^{-1})	0.102
CEC (cmol kg^{-1})	6.72
Exchangeable Al (cmol kg^{-1})	2.59
Exchangeable H (cmol kg^{-1})	0.78
Sand (%)	41.6
Silt (%)	30.28
Clay (%)	28.12
Texture class	Loam

C. *Experimental Design*

The pot experiment was undertaken in the greenhouse at the Research and Teaching Farm, Faculty of Agriculture, Jambi University, Jambi Indonesia (01^0 37' 03,36" S; 103^0 31' 16,34" E). The treatments consisted of five dosages of organic waste (0, 5, 10, 15 and 20 t ha^{-1}) and three dosages of synthetic fertilizer; no synthetic fertilizer (0 R), half dose of recommendation (0.5 R), recommended dose (R) 50 kg ha^{-1} Urea + 200 kg ha^{-1} SP-36 + 150 kg ha^{-1} KCl [25]. The treatments were located in a completely randomized design with factorial pattern and three replicates (Table 5). The organic waste was added to the soil in pots and stirred evenly, and was then incubated for two weeks. Watering was done every day to 80% field capacity. After two weeks incubation, the synthetic fertilizer was given to the soil according to the treatment and mixed. Then, in each pot, two soybean seeds of Willis variety were planted and after two weeks, thinning was done, where one plant was allowed to grow in each pot.

TABLE V
TREATMENTS OF ORGANIC WASTE AND SYNTHETIC FERTILIZERS

Treatments	Synthetic fertilizers (Urea+SP-36+KCl)		
Organic waste (W) (t ha^{-1})	0	0.5 R	R*
0	0	0.5 R	R
5 W	5 W	5 W + 0.5 R	5 W + R
10 W	10 W	10 W + 0.5 R	10 W + R
15 W	15 W	15 W + 0.5 R	15 W + R
20 W	20 W	20 W + 0.5 R	20 W + R

*R = 50 kg ha^{-1} Urea + 200 kg ha^{-1} SP-36 + 150 kg ha^{-1} KCl

D. *Determination of Crop Yield and Soil Analysis after Harvest*

Soybean was harvested 93 days after planting. Plant roots were separated from the soil and washed. Roots and shoots (leaves and stems) were dried in an oven at 50 ° C to a constant weight and then weighed. The pods were dried in sunlight and the seeds were separated from the pods. The weight of the seeds was weighed with a water content of 13%. The soil in each pot was sampled, dried, crushed and passed by 2 mm sieve. Soil analysis after harvesting was done to determine the pH of H_2O (1:2), total organic C (Walkley and Black), humic acid [26], labile organic C [27], humic acid C (Walkley and Black), total N (Kjeldahl), available P (Bray 1), exchangeable Al (KCl 1M), exchangeable K and CEC (NH_4OAc 1M pH 7).

E. *Statistical Analysis*

The data were analyzed by using variance analysis with F test and Duncan multiple range test (DMRT) at $\alpha = 5\%$. The formula of SI = (C fraction in organic waste or fertilizer treatment - C fraction in control) / C fraction in control determined the sensitivity index (SI) of organic C fraction [28].

III. RESULTS AND DISCUSSION

A. Effect of Organic Waste and Synthetic Fertilizer on Soil Organic C Fractions

The addition of organic waste and synthetic fertilizers did not result in any significant interaction on total organic C, humic acid C, and labile organic C. However, the simple effects of each factor were different. The organic waste addition enhanced the total organic C, humic acid C, and labile organic C significantly, whereas the treatment of synthetic fertilizer could not significantly increase the soil organic C (Table 6).

Total organic C, humic acid C, and labile organic C showed an increasing trend with increasing doses of organic waste added. Total organic C, humic acid C and labile organic C in the treatment of 20W didn’t differ significantly with those in 15W but significantly higher than those in the treatment of 10W, 5W and 0W. The addition of organic waste increased total organic C content by 7-24%. Higher organic C content in organic material treatments can occur due to the direct influence of additional C from organic materials themselves and indirect organic C inputs from increased production of organic matter which includes root and plant residues [29]. Organic C is a major component of soil organic matter in which enhancement in total organic soil C represents an increase in soil organic matter content [27]. Tadesse et al., [30] also reported that an increase in organic C of 2.16% only occurred with the addition of 15 t ha^{-1} chicken manure while the synthetic fertilizer N and P could not increase the soil organic C.

Labile organic carbon is an easily decomposed organic C fraction and exhibited greater sensitivity than the total organic C and humid acid C (Fig. 1). Sensitivity index for total organic C, humid acid C and labile organic C due to the treatment of organic waste were 7.26-23.62%, 5.18-26.94%, and 13.33-35.56%, respectively. The sensitivity index demonstrated that the treatments resulted in greater variation in labile organic C fraction compared with the total organic C and humid acid C [28]. The labile organic C fraction was increased with increasing doses of organic waste while the treatment of synthetic fertilizers showed no significant difference to the labile organic C fraction. Mirsky et al., [31] also reported that organic fertilizer treatment produced higher soil labile organic C contents (0.551 - 0.608 g kg^{-1}) compared with the treatment of synthetic fertilizers (0.467-0.526 g kg^{-1}). The change of the labile organic C fraction could be attributed to an initial hint of soil degradation or improvement as a result of management practice [27]. This fraction probably includes compounds generated by biological metabolization, but this fraction is discovered in the early stages of stabilization with soil components [32]. It consists of more dynamic compounds related to the rapid biological activity and is being an energy source for soil food webs that greatly affects nutrient cycles [27].

TABLE VI
EFFECT OF ORGANIC WASTE AND SYNTHETIC FERTILIZERS ON TOTAL ORGANIC C, HUMID ACID C, AND LABILE ORGANIC C

Treatment	Total organic C	Humid acid C	Labile organic C
	g kg^{-1}		
Organic waste			
0 W	17.36 c	3.86 c	0.451 d
5 W	18.62 c	4.06 bc	0.512 c
10 W	19.88 b	4.32 b	0.556 b
15 W	20.79 a	4.82 a	0.581 ab
20 W	21.46 a	4.90 a	0.605 a
Synthetic fertilizer			
0	19.79 a	4.33 a	0.538 a
0.5 R	19.10 a	4.39 a	0.543 a
R	19.98 a	4.46 a	0.542 a

The values followed by the same letter of vertical direction do not differ significantly using DMRT at $\alpha = 0.05$

Increased humid acid C with organic waste treatment showed an increase in sequestration of C in the soil. Increased humid acid C also represents an increase in one of the stable soil C fractions and an important indicator for soil C stabilization [12]. Rivero et al. [33] reported that the enhancement in soil organic C was related to a raise in humid acid C fraction and the compost quality applied. This is in agreement with the results of the Hueso et al., [34] and Angelova et al. [35] which found that humid acid in soil treated with organic fertilizers such as compost was higher than that of non-composted soils where the increase in humid acid in the soil was derived from the given compost. The humification process of organic C can only occur when essential nutrient elements (N, P, S) are available [36].

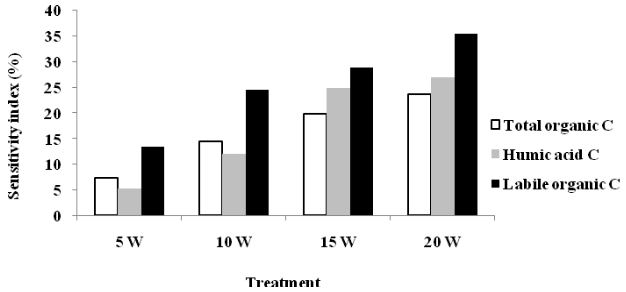

Fig. 1. The sensitivity indexes of total organic C, humid acid C and labile organic C due to the organic waste treatment

B. *Effect of Organic Waste and Synthetic Fertilizers on Soil pH, N, P, K, Al and CEC*

No significant interaction between organic waste and synthetic fertilizer treatment on soil pH, total N, available P, exchangeable K, exchangeable Al and CEC. The simple effects of each factor showed that the significant increases in pH, total N, available P, exchangeable K, and CEC occurred with the organic waste addition, whereas the use of synthetic fertilizers could only increase the available P and exchangeable K significantly (Table 7). The values of pH, total N, available P, exchangeable K, and CEC showed an increasing trend with increasing dosage of organic waste addition. The significant decrease of exchangeable Al occurred with the addition of organic waste while the synthetic fertilizers did not decrease exchangeable Al significantly.

Increased soil pH with organic waste treatment corresponds to the results of other studies, where soil pH increases occur with organic fertilizer application [37]–[39]. Some mechanisms that can increase soil pH due to organic matter are oxidation of organic acid anions from decomposed organic matter, ammonification of organic N and specific adsorption of organic molecules generated during decomposition [38]. An increase in pH by adding manure to acid soils may occur due to proton exchange between soil and manure added wherein functional groups on organic materials such as carboxyl can bind and discharge protons that depend on soil pH [39].

Exchangeable Al content was decreased with the organic waste addition. This could be related to the role of humic acid from organic matter of the organic waste. The mechanism of decreasing Al in solution by humic acid is through the formation of a complex compound of humic acid-Al and precipitation of the complex compound [40].

Increasing content of soil N, P, and K due to the addition of organic waste is due to the process of decomposition of organic waste, which contributes nutrients to the soil. In addition, the application of organic fertilizer to the soil also increases the content of macro and micronutrients [41].

Tadesse et al., [30] also reported that a rise in soil N and P after the addition of chicken manure was due to decomposition of chicken manure added to the soil. The treatment of synthetic fertilizer increased available P and exchangeable K significantly but could not increase the pH, total N and CEC. Increased P and K were derived from SP-36 and KCl fertilizers added to the soil and residues of nutrients used after crop harvesting. However, urea as a source of N fertilizer is easily lost because it easily dissolves and undergoes leaching and volatilization.

TABLE VII
EFFECT OF ORGANIC WASTE AND SYNTHETIC FERTILIZERS ON SOIL PH, TOTAL N, AVAILABLE P, EXCHANGEABLE K, EXCHANGEABLE AL, AND CEC

Treatment	pH	Total N	Av. P	Exc. K	Exc. Al	CEC
		%	ppm	cmol kg^{-1}	cmol kg^{-1}	cmol kg^{-1}
Organic waste						
0 W	4.86d	0.135c	3.98d	0.11c	1.94a	8.20d
5 W	5.04cd	0.134c	4.57cd	0.12c	1.66b	9.99c
10 W	5.10b	0.142b	5.16bc	0.12c	1.64b	10.03bc
15 W	5.09bc	0.144b	5.57b	0.18b	1.55c	12.03b
20 W	5.17a	0.153a	7.73a	0.21a	1.41c	13.56a
Synthetic fertilizer						
0 R	5.07a	0.13a	4.42b	0.12b	1.68a	10.44a
0.5 R	5.05a	0.144a	5.80a	0.15ab	1.61a	10.48a
R	5.03a	0.143a	5.99a	0.18a	1.63a	11.36a

The values followed by the same letter of vertical direction do not differ significantly using DMRT at $\alpha = 0.05$

The increase of CEC by the organic waste is attributed to the increase of organic C and humid acid C. The results of this study were in accordance with the results of Soares and Alleoni [42] reporting that soil C was increased as the soil C content increased where the increase in CEC caused by an increase per soil organic C unit is more than 60 times higher than the increase caused by the clay fraction raise in Oxisols and Ultisols. Bulluck III et al., [19] reported that the soil organic C content and CEC following organic fertilizer addition were 1.90% and 7.97 cmol kg^{-1} higher than those of synthetic fertilizer i.e. 1.17% organic C and 6.05 cmol kg^{-1} CEC. Yilmaz and Alagöz [43] also found an enhancement in soil organic matter and CEC by the addition of chicken manure. Most of the charges that contribute to CEC are derived from the humus fraction [44].

The treatment of 0.5R and R increased available P significantly compared with 0 R. However, the 0.5 R treatment was not significantly different from the R. The soil K content in R was significantly higher than 0 R but not significantly different from the treatment of 0.5 R. Increased soil available P and K were derived from P (SP-36) and K (KCl) fertilizers added to the soil.

C. *Effect of Organic Waste and Synthetic Fertilizers on Soybean Yield*

The addition of organic waste and synthetic fertilizers showed significant interactions in increasing dry weight of soybean seed, shoot, and root (Tables 8, 9 and 10). Increased doses of organic waste and synthetic fertilizer showed an increasing trend of soybean yield.

The synthetic fertilizer treatment of 0.5R and R increased the dry weight of seed and shoot significantly compared to 0R. Nevertheless, the 0.5R treatment didn't differ significantly from the R treatment. Compared with 0R, the 0.5R and R treatment produced the same increase of the dry weight of seed and shoot by 113 and 133% respectively. The dry weight of root increased by 52 and 140% with 0.5R and R treatments compared with 0R.

The organic waste combined with synthetic fertilizers 15W + R was significantly different from 15W but did not differ significantly from 15W + 0.5R and 20W + R on the dry weight of seed and shoot. The dry weight of seed and shoot in the 20W+ R treatment were not significantly different from the 20W + 0.5 R, 20W and 15W + R but significantly higher than the 10W + R, 10W + 0.5R, 10W and 5W. The 10W+R treatment showed significant differences in root dry weight compared with 10W + 0.5R and 10W treatments. However, at higher doses of organic waste, 20W with or without synthetic fertilizers, the treatment of organic waste alone and with synthetic fertilizers showed no significant difference. The dry weight of root in the 20W+ R treatment was not significantly different from the 20W + 0.5R, 20W and 15W + R but was significantly different from 10W + R. In general, no significant difference was found between the addition of organic waste alone and organic waste combined with synthetic fertilizers at the same dosages of organic waste on the dry weight of the seed, shoot and root.

Organic waste combined with synthetic fertilizers provided a greater increase in soybean yield compared to synthetic fertilizers without organic waste, which increased the dry weight of soybean seeds by 185% (5W + R) to 262% (15W + R) compared with control. The dry weight of shoot and root in organic waste treatment with synthetic fertilizer increased by 185-261% and 154-206% compared with control.

Increment in the dry weight of seed, shoot and root due to the addition of sole organic waste or synthetic fertilizer or organic waste combined with synthetic fertilizer was caused by nutrients derived from organic waste and/or synthetic fertilizer such as Urea (45 % N), SP-36 (36% P_2O_5) and KCl (60% K_2O). The treatment of organic waste alone or together with synthetic fertilizer gave the higher yields of soybean compared with the treatment of synthetic fertilizer. These results were in line with other studies. In their study Majumder et al., [45] found higher wheat straw biomass, root, and grain in the treatment of synthetic fertilizers NPK + organic fertilizer compared with synthetic fertilizer NPK without organic fertilizer and without treatment. Duong et al., [46] found two to four-fold increase in dry weight of wheat shoot with compost while the increase in the root dry weight was obtained by 5 to 78%. Increased yield of crops with organic manure was followed by an increase in soil C and N content, while the increase in crop yields by synthetic fertilizer was not followed by an increment in organic C and N soil [47]. From the result of their research, Zhang et al. [48] discovered that NPK + organic manure significantly increased rice production by 24% higher than the yield in the NPK fertilizer treatment without organic fertilizer. The main benefit of organic fertilizer to increase crop production is the capability of organic fertilizers to ameliorate the soil physical, biological, and chemical properties through enhancing organic substance and nutrient availability [49]. Organic materials can hold cations for crop needs and protect them from leaching [50].

TABLE VIII
EFFECT OF INTERACTION OF ORGANIC WASTE AND SYNTHETIC FERTILIZERS ON THE DRY WEIGHT OF SEED

Treatment	0 R	0.5 R	R
		g pot^{-1}	
0W	3.12 Bd	6.64 Ac	7.26 Ac
5W	7.31 Ac	9.39 Ab	8.90 Ab
10W	9.25 Ab	9.60 Ab	9.65 Ab
15W	10.00 Bab	10.22 ABab	11.28 Aa
20W	11.06 Aa	10.93 Aa	11.23 Aa

The values followed by the same lowercase letter of the vertical direction or the same capital letter of the horizontal direction do not differ significantly using DMRT at α = 0.05

TABLE IX
EFFECT OF INTERACTION OF ORGANIC WASTE AND SYNTHETIC FERTILIZERS ON THE DRY WEIGHT OF SHOOT

Treatment	0 R	0.5 R	R
	g pot^{-1}		
0W	3.31 B d	7.04 Ac	7.70 Ac
5W	7.75 Bc	9.96 A b	9.44 A b
10W	9.81 Ab	10.18 Ab	10.23 A b
15W	10.60 B ab	10.84 ABab	11.96 A a
20W	11.73 Aa	11.58 A a	11.90 Aa

The values followed by the same lowercase letter of the vertical direction or the same capital letter of the horizontal direction do not differ significantly using DMRT at α = 0.05

TABLE X
EFFECT OF INTERACTION OF ORGANIC WASTE AND SYNTHETIC FERTILIZERS ON THE DRY WEIGHT OF ROOT

Treatment	0 R	0.5 R	R
	g pot^{-1}		
0W	1.34 Bc	2.03 Bd	3.21 Ab
5W	3.24 Ab	3.45 Ac	3.40 Ab
10W	3.46 Bb	3.66 Bbc	3.88 Aa
15W	4.02 Aa	3.94 Aab	4.06 Aa
20W	4.01 Aa	4.04 Aa	4.10 Aa

The values followed by the same lowercase letter of the vertical direction or the same capital letter of the horizontal direction do not differ significantly using DMRT at α = 0.05.

The study results indicated a rise in soil organic C and nutrients (N, P K) because of the addition of organic waste alone or combined with synthetic fertilizer, while the addition of synthetic fertilizers can only increase available P and K. In addition, the addition of organic waste also increased soil CEC and reduced exchangeable Al, which is toxic to the soybean crop. Improvement of crop yield owing to the addition of organic waste that exceeds synthetic fertilizer shows an important role of organic waste as an alternative organic fertilizer.

IV. CONCLUSIONS

The addition of organic waste and synthetic fertilizers showed no significant interaction on soil chemical properties. However, the addition of organic waste increased total organic C, humid acid C, labile organic C, pH, total N, available P, exchangeable K and CEC, and decreased exchangeable Al, while synthetic fertilizer addition only increased P availability and exchangeable K, but could not reduce exchangeable Al. The sensitivity of labile organic C was greater than total organic C, humid acid C so that labile organic C showed a better indicator of the change from the accumulation of soil C owing to the treatment of organic fertilizer. The treatment of organic waste and synthetic fertilizers showed significant interactions on the dry weight of shoot, root, and seed, where the addition of organic waste (15-20 t ha^{-1}) plus synthetic fertilizers provided the largest increases in the dry weight of seed, shoot, and root, which reached 262%, 261% and 206% respectively. Increased soybean yield with the organic waste addition followed by improved soil quality indicates the important role of organic waste as an organic fertilizer in enhancing the productivity of the soil.

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REFERENCES

[1] Schuchardt F., K. Wulfert, D. Darnoko and T. Herawan. 2008. Effect of new palm oil mill processes on the EFB and POME utilization. Journal of Oil Palm Research (Special Issue): 115-126.
[2] Vijayaraghavan, K., D. Ahmad and M. E. Abdul Aziz. 2007. Aerobic treatment of palm oil mill effluent. J. Environ. Manage. 82 (1): 24–31a.
[3] Chotwattanasak, J. and Puetpaiboon, U., 2011. Full scale anaerobic digester for treating palm oil mill wastewater. Journal of Sustainable Energy & Environment. 133-136.
[4] Penn, M.R., J.R. Pauer and J.R. Mihelcic. 2003. Biochemical Oxygen Demand. In Environmental and Ecological Chemistry; Sabljic, A., Ed.; EOLSS Publishers Company: Oxford, UK.
[5] Darby, H.M., A.G. Stone and R.P. Dick. 2006. Compost and manure mediated impacts on soilborne pathogens and soil quality. Soil Sci Soc Am J 70:347–358.
[6] De Araujo, A.S.F., W.J. De Melo and R.P. Singh. 2009. Municipal solid waste compost amendment in agricultural soil: changes in soil microbial biomass. Rev Environ Sci Biotechnol 9:1–9.
[7] Rupani, P.F., R. P. Singh, M. H. Ibrahim and N. Esa. 2010. Review of Current Palm Oil Mill Effluent (POME) Treatment Methods: Vermicomposting as a Sustainable Practice. World Applied Sciences Journal 10(10): 1190-1201.
[8] Rahardjo, P.N. 2006. The ideal effluent management technology for palm oil mills. J. Agr. Ind., 3:66-72. (In Indonesian).
[9] Wu T.Y., A. W. Mohammad, J. Md. Jahim and N. Anuar. 2010. Pollution control technologies for the treatment of palm oil mill effluent (POME) through end-of-pipe processes. J. Environ. Manage 91: 1467-1490.
[10] Kasno, A., and M.T. Sutriadi. 2012. Indonesian rock-phosphate effectivity for maize crop on ultisols soils. Agrivita 34 (1):14-22.
[11] Lim, S.S., K.S. Lee, S.I. Lee, D. S. Lee, J. H. Kwak, X. Hao, H. M. Ro and W.J. Choi.2012. Carbon mineralization and retention of livestock manure composts with different substrate qualities in three soils. J. Soils Sediments 12:312–322.
[12] Serramiá, N., M.A. Sánchez-Monedero, A. Roig, M. Contin and M. De Nobili. 2013. Changes in soil humic pools after soil application of two-phase olive mill waste compost. Geoderma 192:21-32.
[13] Yu, H., W. Ding, J. Luo, R. Geng, A. Ghani, and Z. Cai. 2012. Effects of long-term compost and fertilizer application on stability of aggregate-associated organic carbon in an intensively cultivated sandy loam soil. Biol. Fertil. Soils, 48:325–336.

[14] Ibrahim, M., C.G. Cao, M. Zhan, C.F. Li and J. Iqbal. 2015. Changes of CO2 emission and labile organic carbon as influenced by rice straw and different water regimes. Int. J. Environ. Sci. Technol. 12:263–274.
[15] Ding, W.X., H.Y. Yu, Z.C. Cai, F.X. Han and Z.H. Xu. 2010. Responses of soil respiration to N fertilization in a loamy soil under maize cultivation. Geoderma 155:381–389.
[16] Lucas, S.T., and R. R. Weil. 2012. Can a Labile Carbon Test be used to Predict Crop Responses to Improve Soil Organic Matter Management. Agron. J. 104:1160–1170.
[17] Schroder, J. 2005. Revisiting the agronomic benefits of manure: A correct assessment and exploitation of its fertilizer value spares the environment. Bioresour. Technol. 96:253–261.
[18] Diacono, M. and F. Montemurro. 2015. Effectiveness of organic wastes as fertilizers and amendments in salt-affected soils. Agriculture, 5: 221-230.
[19] Bulluck III, L.R., M. Brosius, G.K. Evanylo and J.B. Ristaino. 2002. Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. Applied Soil Ecology 19: 147–160.
[20] Ros, M., , S. Klammer, B. Knapp, K. Aichberger and H. Insam. 2006. Long-term effects of compost amendment of soil on functional and structural diversity and microbial activity. Soil Use and Management. 22, 209–218.
[21] Rostami, S.V., H. Pirdashti, M. A. Bahmanyar and A. Motaghian. 2012. Response of soybean (Glycine max L.) yield and nutrient uptake to three consecutive year’s application of municipal solid waste compost. International Journal of Agriculture and Crop Sciences, 4(8):468-473.
[22] Verde, B.S., B. O. Danga and J. N. Mugwe. 2013. The Effects of Manure, Lime and P Fertilizer on N Uptake and Yields of Soybean (Glycine max (L.) Merrill) in the Central Highlands of Kenya. Journal of Environmental Science and Engineering, 2:111-116.
[23] Mucheru-Muna, M., D. Mugendi, J. Kung’u, J. Mugwe and A. Bationo. 2007. Effects of organic and mineral fertilizer inputs on maize yield and soil chemical properties in a maize cropping system in Meru South District, Kenya. Agroforest Syst 69:189–197.
[24] APHA. 2012. AWWA, WEF. Standard Methods for examination of water and wastewater. 22nd ed. Washington: American Public Health Association. Washington. DC.
[25] Nursyamsi D. 2006. The need of potassium for soybean in ultisols. J. Ilmu Tanah dan Lingkungan, 6 (2): 71-81. (In Indonesian).
[26] Tan K.H. 1996. Soil Sampling, Preparation, and Analysis. Marcel Dekker Inc. New York.
[27] Weil R.W., K.R. Islam, M.Stine, J.B. Gruver and S.E. Samson-Liebig. 2003. Estimating active carbon for soil quality assessment: a simplified method for laboratory and field use. Am. J. Altern. Agric. 18:3–17.
[28] Banger, K., G.S. Toor, A. Biswas, S.S. Sidhu and K. Sudhir. 2010. Soil organic carbon fractions after 16-years of applications of fertilizers and organic manure in a Typic Rhodalfs in semi-arid tropics. Nutr. Cycl. Agroecosyst. 86:391–399.
[29] Bhattacharyya, R.., V. Prakash, S. Kundu, A. K. Srivastva, H. S. Gupta and S. Mitra. 2010. Long term effects of fertilization on carbon and nitrogen sequestration and aggregate associated carbon and nitrogen in the Indian sub-Himalayas. Nutr Cycl Agroecosyst 86:1–16.
[30] Tadesse T., N. Dechassa, W. Bayu and S. Gebeyehu. 2013. Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem. American Journal of Plant Sciences, 4: 309-316.
[31] Mirsky, S.B., L.E. Lanyon and B.A. Needelman. 2008. Evaluating soil management using particulate and chemically labile soil organic matter fractions. Soil Sci. Soc. Am. J., 72:180-185.
[32] Oyonarte, C., M. D. Mingorance, P. Durante, G. Piñeiro and E. Barahona. 2007. Indicators of change in the organic matter in arid soils. Science of the Total Environment 378: 133–137.
[33] Rivero, C., T. Chirenje, L.Q. Mac, and G. Martinez. 2004. Influence of compost on soil organic matter quality under tropical conditions. Geoderma 123, 355–361.
[34] Hueso, S., G. Brunetti, N. Senesi, K. Farrag, T. Hernández and C. García. 2012. Semiarid soils submitted to severe drought stress: influence on humic acid characteristics in organic-amended soils. J. Soils Sediments 12:503–512.
[35] Angelova, V.R., V. I. Akova, N. S. Artinova and K. I. Ivanov. 2013. The effect of organic amendments on soil chemical characteristics. Bulgarian Journal of Agricultural Science, 19 (5): 958-971.
[36] Lal, R. 2007. Carbon management in agricultural soils. Mitigation and Adaptation Strategies for Global Change 12: 303–322.
[37] Tang, Y. , H. Zhang, J. L. Schroder, M. E. Payton and D. Zhou. . 2007. Animal Manure Reduces Aluminum Toxicity in an Acid Soil. Soil Sci. Soc. Am. J. 71:1699–1707.
[38] Haynes, R.J. and M.S. Mokolobate. 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.
[39] Wong, M.T.F., and R.S. Swift. 2003 Role of organic matter in alleviating soil toxicity. p. 337–358. In Z. Renger (ed.) Handout of soil acidity. Marcel Dekker, New York.
[40] Yamaguchi, N., S. Hiradate, M. Mizoguchi and T. Miyazaki. 2004. Disappearance of aluminium tridecamer from hydroxyaluminum solution in the presence of huic acid. Soil Sci. Soc. Am. J. 68:1838-1843.
[41] Brown, S. and M. Cotton. 2011. Changes in soil properties and carbon content following compost application: Results of on-farm sampling. Compost Science and Application, 19:88-97.
[42] Soares, M.R., and L. R. F. Alleoni. 2008. Contribution of soil organic carbon to the ion exchange capacity of tropical soils. Journal of Sustainable Agriculture, 32(3):439-462.
[43] Yilmaz, E., and Z. Alagöz. 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.
[44] Murphy, B., 2015. Key soil functional properties affected by soil organic matter– evidence from published literature. Earth and Environmental Science 25:1-5.
[45] Majumder B., B. Mandal and P.K. Bandyopadhyay. 2008. Soil organic carbon pools and productivity in relation to nutrient management in a 20-year-old rice-berseem agroecosystem. Biol. Fertil. Soils, 44: 451–461.
[46] Duong, T.T.T., C. Penfold and P. Marschner. 2012. Differential effects of compost on properties of soils with different textures. Biol Fertil Soils, 48:699-707.
[47] Hepperly, P., D. Lotter, C. Z. Ulsh, R. Seidel and C. Reider. 2009. Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. Compost Science & Utilization. 17(2), 117-126.
[48] Zhang, Q., W. Zhou1, G. Liang, X. Wang, J. Sun, P. He1 and L. Li. 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.
[49] Bowden, C.L., G.K. Evanylo, X. Zhang, E.H. Ervin and J.R. Seiler. 2010. Soil carbon physiological responses of corn and soybean to organic amendments. Compost Science & Utilization 18(3): 162-173.
[50] Bot, A. and J. Benites. 2005. The importance of soil organic matter: Key to drought-resistant soil and sustained food and production. Food and Agriculture Organization of the United Nations. Rome.