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Utilizing Palm Oil Mill Effluent Compost for Improvement of Acid Mineral Soil Chemical Properties and Soybean Yield

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***Abstract*— Effluent from a palm oil mill contains organic matters and nutrients. It can result in water pollution when it is discharged into river without treatment. One way to manage this effluent is through composting that has potential to allow the recycling of effluent nutrients in a sustainable and environmentally friendly manner so that it can be used as organic fertilizer. This study was intended to evaluate the benefit of effluent compost application to improve soil chemical properties and soybean yield. Effluent was composted with chicken manure and lime for eight weeks. A pot experiment of which each pot was filled with 10 kg of soil (Ultisol) was conducted in a screen house from April to November 2012 at the Experimental Farm, University of Jambi, Muaro Jambi Regency. The treatments were without compost (adding 0.25 g Urea, 0.75 g SP-36 and 0.50 g KCl) and compost application with amounts of 12.5 ml, 25 ml, 37.5 ml, 50 ml, 62.5 ml, and 75 ml. The indicator plant was soybean. The treatments were arranged in a completely randomized design and replicated four times. Results of study showed a significant improvement of soil chemical properties with compost application in which application of 75 ml compost resulted in the highest increase of pH, organic C, cation exchange capacity, total N, available P, exchangeable cations (K, Ca, Mg). Furthermore, the dry weight of shoot, pod number and dry weight of seed increased significantly with compost application. The highest dry weight of seed was 28 g (equivalent to 2.82 t ha^{-1}) obtained by compost application of 75 ml (equivalent to 15 t ha^{-1}).**

***Keywords*— Effluent; Compost; Ultisol; Soybean**

I. INTRODUCTION

Processing fresh fruit bunches of oil palm into crude palm oil (CPO) in a palm oil mill produces huge liquid waste or effluent which is very dangerous when it is discharged into river without treatment. Fresh effluent contains high organic matters, total dissolved solid (TDS) (40500 mg L-1), oil and fat (4000 mg L-1), chemical oxygen demand (COD) (50000 mg L-1) and biological oxygen demand (BOD) (25000 mg L-1) [1]. In addition, this effluent contains nutrients in a significant amount such as N (450-590 mg L-1), P (92-104 mg L-1), K (1246-1262 mg L-1) and Mg (249-271 mg L-1) [2]. One way to manage this effluent is through composting that has potential to allow the recycling of effluent nutrients in a sustainable and environmentally friendly manner so that it can be used as organic fertilizer.

Composting constitutes a biotechnology that can change organic matters into organic fertilizer or compost. It can stabilize organic wastes in which during composting process, most of organic wastes will be degraded and it can be partially changed into humic substances and finally can results in chemically stabile compost substances [3]. Furthermore, composting effluent reduces pathogens and toxic organic compounds [4].

Several studies indicated the benefit of palm oil mill effluent as a nutrient source for plant. Application of effluent on oil palm plantation could increase fresh fruit bunch of oil palm by 35.3% and improve soil chemical properties of which soil pH, total N, available P, exchangeable cations were increased [5]. In addition, application of effluent at a rate of 150000 L ha-1 + 150 kg ha-1 SP-36 at first planting could produce 2.15 t ha-1 dry weight of soybean seed and application of 75000 L ha-1 effluent at second planting produced 2.03 t ha-1 [6]. The lower rate of effluent application at second planting indicated the residual effect of effluent application. The result of this study also showed that improvement in soil chemical properties such as increasing in soil pH, organic C, total P, available P and exchangeable K occurred with effluent application [6]. The studies stated above used effluent that has undergone retention time of 60-75 days at liquid waste ponds so that BOD and TDS values have decreased to 4000 mg L-1 and 4120 mg L-1 respectively.

The usage of fresh effluent of palm oil mill as nutrient source is still rarely studied. With its higher content of organic matters and nutrients, the rate applied could be less than that of treated effluent. Application of fresh effluent with high BOD (16300 mg L-1) and TDS (12000 mg L-1) fermented for 20 days at a rate of 4.7 m3 ha-1 increases soil total N, organic C and P, and corn yield to 3.4 t ha-1 [7].

In Indonesia, soybean is generally planted in an acid mineral soil such as Ultisol. This soil is characterized by low soil chemical fertility. Naturally this soil has low pH, organic C, nutrients and exchangeable cations (Ca, K, Mg and Na) as a result of intensive leaching [8]. The low nutrient content of Ultisols become a big hindrance for plant production [9]. Furthermore, a high content of Al in Ultisol toxic to plant inhibits root growth and nutrient uptake of plant [10]. This study aimed to evaluate the benefit of effluent compost to improve soil chemical properties and soybean yield.

II. Materials And Method

A pot experiment was carried out from April to November 2012 in a screen house, at the Experimental Farm, University of Jambi, Mendalo Darat Village, Muaro Jambi Residency. Materials used included fresh effluent of palm oil mill from Bahari Gembira Ria Ltd located in Ladang Panjang Village, Sungai Gelam Sub District, Muaro Jambi Regency, soybean seeds (variety Anjasmoro), Rhizobium inoculant, Urea (45% N), SP-36 (36% P2O5), KCl (50% K2O), chicken manure and lime.

Fresh effluent was put in into a 37 dm3 plastic container. Lime and chicken manure were then added to fresh effluent at about 1:10 and 1:3 (weight/vol) respectively. Mixture was manually mixed every day and composted for 8 weeks. Soil was taken from the 0 -20 cm depth layer and air dried for three days and then sieved to ≤ 2 mm for separating gravels. Each pot was filled with 10 kg soil Treatments were without compost but adding 0.25 g Urea, 0.75 g SP-36 and 0.50 g KCl and compost with amounts of 12.5 ml, 25 ml, 37.5 ml, 50 ml, 62.5 ml and 75 ml. Treatments were arranged in a completely randomized design with four replications. Compost was added to the pots in accordance with treatment and incubated for one week. Urea, SP-36 and KCl were added to pots without compost at planting time. Two soybean seeds were planted on each pot and after two weeks, one was discarded and leaving one plant to grow. Watering was done at 85% field capacity. To control plant pest and disease Decis and Dithane were used.

Analysis of effluent was done to determine pH, COD, BOD5, N, P, K, Ca, Mg, Cu, Zn, Pb and Cd. Chicken manure was analyzed to determine pH, organic C, total N, C/N ratio, total P2O5, total K2O. Lime analysis was done to determine total CaO and total MgO. Analysis of effluent compost was conducted for pH, organic C, total N, total P2O5, total K2O, total Ca, and total Mg.

To determine the characteristics of soil before experiment, a composite soil was taken for soil analysis to determine soil texture, pH (H2O, 1:2), total N (Kjeldahl), organic C (Walkley and Black), available P (Bray 1), exchangeable cations (Na, K, Ca and Mg) (NH4OAC 1 N pH 7), exchangeable Al (KCl 1 M) and cation exchange capacity (CEC) (NH4OAC 1 N pH 7). Except for texture the same analysis were performed after harvesting. Plant parameters consisted of dry weight of shoot, number of pod and dry weight of seed. Soil and plant data were analyzed statistically by using analysis of variance and Duncan's Multiple Range Test at the 0.05 level.

III. Results And Discussion

A. *Characteristics of Soil*

The characteristics of soil used in this experiment were sandy clay loam, acid, very low to low nutrient content, very low CEC, low base saturation and moderate Al saturation (Table I). The low content of exchangeable cations (Ca, Mg, Na and K) of this soil demonstrated that Ultisol constitutes a highly weathered soil undergoing high leaching so that its content of exchangeable base cations was low, while its Al cation was relatively dominant in exchangeable acidity.

TABLE I
Characteristics Of Soil

Parameter	Amount
pH (H_2O)	4.9
Organic C (%)	1.79
Total N (%)	0.15
C/N Ratio	11.93
Available P (ppm)	7.34
Ca ($cmolkg^{-1}$)	1.37
Mg ($cmolkg^{-1}$)	0.33
K ($cmolkg^{-1}$)	0.18
Na ($cmolkg^{-1}$)	0.19
Al-dd ($cmolkg^{-1}$)	0.95
H-dd ($cmolkg^{-1}$)	0.39
CEC ($cmolkg^{-1}$)	2.07
Base Saturation (%)	30
Al Saturation (%)	27.86
Sand (%)	55.9
Silt (%)	8.9
Clay (%)	35.2

B. *Effluent, Chicken Manure and Lime*

Effluent from palm oil mill had a low pH (acid), high value of BOD5, COD and TDS (Table II). In addition, effluent contained macro nutrients such as N, P, Ca and Mg, while heavy metals such as Cd and Pb were very low. Heavy metals probably came from equipments used in processing activities and soil of lagoon in which the effluent was collected, because processing fresh fruit bunches into CPO was done mechanically and without using any chemicals. High value of BOD and COD of fresh effluent demonstrated high content of organic matter in effluent that has not been decomposed. Chicken manure used had a relatively high pH (7.2) and a low C/N ratio (8.43), and contained P (3.57%) and K (2.13%) (Table III.). Lime was characterized with 54.69 % CaO and 0.54 % MgO (Table IV).

TABLE II
CHARACTERISTICS OF FRESH EFFLUENT

Parameter	Amount
pH	4.56
BOD_5 (mg L^{-1})	22540
COD (mg L^{-1})	49997
Total solid (mg L^{-1})	83810
Oil and grease (mg L^{-1})	362
Total N (mg L^{-1})	246
Total P (mg L^{-1})	2
Total K (mg L^{-1})	105
Ca (mg L^{-1})	386
Mg (mg L^{-1})	385
Cd (mg L^{-1})	<0.005
Cu (mg L^{-1})	1
Pb (mg L^{-1})	<0.02
Zn (mg L^{-1})	1

TABLE III
CHARACTERISTICS OF CHICKEN MANURE

Parameter	Amount
pH (H_2O)	7.2
Organic C (%)	12.14
Total N (%)	1.44
C/N Ratio	8.43
Total P_2O_5 (%)	3.57
Total K_2O (%)	2.13

TABLE IV
CHARACTERISTICS OF LIME

Parameter	Amount
Total CaO (%)	54.69
Total MgO (%)	0.54

C. Effluent Compost

Effluent compost was characterized with nutrients and pH value higher than those of fresh effluent (Table V). Increased pH of effluent compost could be caused by neutralization of lime added to fresh effluent. Lime increases pH of compost effectively at the initial period and this effect became less obvious with increasing composting time [11]. The usage of alkaline materials for composting is beneficial in reducing the soluble and exchangeable fractions of heavy metals through formation of insoluble carbonates, adsorption of metals into particles of alkaline material or formation of organo-metals with organic matter in soluble fractions during composting process so that the bioavailability of heavy metals was decreased [12]. A low C/N ratio of compost (18,11) indicated that decomposition process during composting produced a mature compost. Composting causes a reduction of total C and weight by producing CO2, whereas percentage of total N was increased [4]. The content of N, P, K, Ca and Mg of effluent compost was also higher than fresh effluent. The increased quality of effluent compost as a result of composting fresh effluent showed the importance of composting process in managing fresh effluent, in which chicken manure had an important role in this process. Adding chicken manure in composting produces better compost with a higher N content and resulted in degradation process faster than that without chicken manure [13].

TABLE V
CHARACTERISTICS OF EFFLUENT COMPOST

Parameter	Amount
pH (H_2O)	8.3
Water content (%)	63.8
Organic C (%)	18.29
Total N (%)	1.01
C/N Ratio	18.11
Total P_2O_5 (%)	1.85
Total K_2O (%)	1.59
Total Ca (%)	19.34
Total Mg (%)	0.64

D. Soil Chemical Properties

1) pH, Organic C, Exchangeable Al and CEC

Soil pH, organic C and CEC significantly increased with effluent compost application, while exchangeable Al showed a significant decrease (Table VI). The increasing amount of compost input increased soil pH, organic C and CEC, and decreased exchangeable Al. The addition of 75 ml compost resulted in the highest increases of soil pH, organic C and CEC and the lowest concentration of exchangeable Al .

Enhancement of soil pH and decrease in exchangeable Al occurred due to the content of Ca and organic matters in effluent compost. Organic addition can cause organic C accumulation on top soil [14]. Enhancement of soil organic C also increases soil humus or soil organic colloid which increases soil CEC [15]. Soil exchangeable Al decreased because organic compound reacts with Al cations to form Al-organic complexes [16].

TABLE VI
SOIL PH, ORGANIC C, EXCHANGEABLE AL AND CEC AS A RESULT OF EFFLUENT COMPOST APPLICATION

Effluent compost (ml)	pH	Organic C	Exch. Al	CEC
		%	cmolkg^{-1}	
0	4.57 f	1.29 a	0.86 a	6.18 a
12.5	4.94 e	1.44 a	0.61 b	6.13 b
25.0	5.52 d	1.67 a	0.27 c	6.29 c
37.5	5.96 c	1.83 b	0.15 d	7.19 cd
50.0	6.25 b	2.00 c	0.11 de	8.23 d
62.5	6.55 a	2.08 d	0.09 de	9.19 e
75.0	6.73 a	2.13 e	0.05 e	10.87 e

Value with the same letters within a same coulum are not significantly different at the 0.05 level

2) Soil N, P, K, Ca and Mg

Application of effluent compost did not affect significantly soil N but affected significantly soil P, K, Ca and Mg (Table VII). Increases in amount of effluent compost application caused enhancement of soil P, Ca and Mg, while significant increase in soil K occurred only by application of 75 ml effluent compost. The highest soil P, K, Ca and Mg were founded with application of 75 ml effluent compost.

The increase of soil P, K, Ca and Mg by effluent compost application was likely caused by P, K, Ca and Mg content of effluent compost. According to [17] increases in soil P, K, Ca and Mg occurs due to soil organic accumulation as a result of organic addition to soil and enhancement of microorganism activity which produces enzymes for degradation of organic matters. Mineralization of organic matters releases inorganic N and P and other nutrients contained in organic matters [18]. The amount of K in soil increased with organic decomposition [19]. Furthermore, compost application increased soil P content to 198 % and soil K to 55 % compared to without compost application on planting of maize, soybean and wheat [20].

TABLE VII
SOIL N, P, K, CA, AND MG AS A RESULT OF EFFLUENT COMPOST APLICATION

Effluent compost (ml)	N	P	K	Ca	Mg
	%	ppm	cmolkg^{-1}		
0	0.121 a	0.19 e	0.14 b	1.65 a	0.47 c
12.5	0.121 a	0.41 de	0.14 b	3.52 b	0.47 c
25.0	0.124 a	0.74 d	0.14 b	6.38 c	0.47 c
37.5	0.133 a	0.96 cd	0.15 b	7.80 d	0.49 c
50.0	0.136 a	1.38 c	0.15 b	8.23 e	0.49 c
62.5	0.143 a	5.54 b	0.16 b	11.30 f	0.99 b
75.0	0.168 a	11.96 a	0.34 a	15.03 g	1.47 a

Value with the same letters within a same column are not significantly different at the 0.05 level

E. Plant Yield

1) Dry weight of shoot, pod number and dry weight of seed

Applying effluent compost significantly affected the dry weight of shoots, pod number and the dry weight of seed (Table VIII). These increases of shoot dry weight, pod number and seed dry weight occurred with increasing amount of effluent compost application. The highest shoot dry weight, pod number and seed dry weight were found with application of 75 ml effluent compost of which shoot dry weight, pod number and seed dry weight were 26.25 g, 98.13 pods and 28 g respectively.

Enhancement of plant yield may be caused by the increase of plant nutrients coming from effluent compost application. Organic matters undergo degradation that release nutrients such as N, P, K Ca and Mg to the soil and available for plant uptake [17]. Application of compost to the soil also could increase the availability of micro nutrients [21]. Al cation that is relatively high in a highly weather soil and toxic for plant could be decreased by forming Al-organic compound with organic application [16]. Adding organic matters to soil could improve soil physical properties and increase water retention of soil [22]. Compost application also could improve soil biological properties so that efficiency of nutrient uptake and plant yield were increased [20]. According to [23] enhancement in plant growth and yield as a result of compost application could be caused by the content of plant hormone in compost that functions as stimulants. Improvement of soil quality resulting from compost application occurs owing to increasing quality and quantity of organic matters and subsequently improves soil productivity [24].

TABLE VII
DRY WEIGHT OF SHOOT, POD NUMBERS AND DRY WEIGHT OF SEED AS RESULT OF EFFLUENT COMPOST APLICATION

Effluent compost (ml)	Dry weight of shoot	Pod number	Dry weight of seed
	g plant^{-1}	pod plant^{-1}	g plant^{-1}
0	7.91 e	10.75 e	2.93 e
12.5	9.72 de	22.00 d	5.80 d
25.0	12.44 cd	37.63 c	10.06 c
37.5	13.39 cd	43.00 c	11.79 c
50.0	13.65 cd	46.13 c	12.56 c
62.5	18.98 b	71.63 b	20.11 b
75.0	26.25 a	98.13 a	28.00 a

Value with the same letters within a same column are not significantly different at the 0.05 level

IV. CONCLUSIONS

Composting fresh effluent with lime and chicken manure produced compost with a higher pH and nutrients than that of fresh effluent. Compost application improved soil fertility and soybean yield. Improved soil fertility was demonstrated with a decrease in exchangeable Al and increases in soil pH, organic C, P, K, Ca, Mg and CEC, while improved crop yield was showed with increases in dry weight of shoot, pod number and dry weight of seed. Compost application at amount of 75 ml (equivalent to 15 t ha-1) produced the best improvement in soil chemical properties and the highest dry weight of soybean seed of 28 g (equivalent to 2.8 t ha-1).

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