

# Quality Improvement of Compost from Empty Oil Palm Fruit Bunch by the Addition of Boiler Ash and its effect on Chemical Properties of Ultisols and the Production of Mustard (*Brassica juncea* L.)

Sri Mulyani, Dyah Tjahyandari Suryaningtyas, Suwardi and Suwarno

*Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University (Institut Pertanian Bogor), Jl. Babakan Tengah No. 114, Dramaga Bogor 16680, e-mail: sri\_mulyani1303@yahoo.com*

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## ABSTRACT

Productions of crude palm oil (CPO) produce waste which include the empty oil palm fruit bunch (EOPFB), palm oil mill effluent, shells, and fiber. The combustions of shell and fiber as boiler feed produce waste in the form of boiler ash. Boiler ash is very potential to use as an additive to improve quality of the EOPFB compost. The objectives of this research were to study : 1) effect of boiler ash on the quality of the EOPFB compost, 2) effect of EOPFB compost on the chemical properties of Ultisol, and the yield of mustard. The first experiment was about quality improvement of compost from EOPFB by the addition of boiler ash. The treatments applied were four dose levels of boiler ash: K1= 0%, K2 = 15%, K3 = 25%, and K4 = 35%. The second experiment was greenhouse pot experiment. This experiment was consisted of thirteen treatments with three replications arranged in completely randomized design (CRD). The treatments applied were: four types of compost from the first experimental results applied to the soil with four dose levels, *i.e.* : 0, 10, 20 and 30 Mg ha<sup>-1</sup>. The results showed that the addition of boiler ash at the beginning of the composting process improved the quality of the EOPFB compost: which increased pH, amount of humic acids, macro and micro nutrients content and decreased content of Pb. The application of all compost –K1, K2, K3, K4– to Ultisol increased pH H<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, organic-C, total-N, exchangeable-Ca, exchangeable-K and yield of mustard and decreased exchangeable-H, exchangeable-Al. Moreover the yield of mustard was increased about 84% (33.9 g plant<sup>-1</sup>) with K4 at doses 20 Mg ha<sup>-1</sup> and 85% (34.1 g plant<sup>-1</sup>) with K3 at doses 10 Mg ha<sup>-1</sup>.

**Keywords:** Boiler ash, empty fruit bunches, humic acid, mustard, Ultisols

## ABSTRAK

Produksi minyak kelapa sawit menghasilkan limbah antara lain tandan kosong kelapa sawit, limbah cair, cangkang, dan serat. Pembakaran cangkang dan serat sebagai umpan boiler menghasilkan limbah dalam bentuk abu boiler. Abu boiler ini berpotensi cukup tinggi sebagai bahan tambahan untuk meningkatkan kualitas kompos tandan kosong kelapa sawit. Tujuan dari penelitian ini adalah untuk mempelajari: 1) pengaruh abu boiler terhadap kualitas kompos tandan kosong kelapa sawit, 2) pengaruh kompos tandan kosong kelapa sawit terhadap sifat kimia Ultisol dan produksi sawi. Percobaan pertama adalah peningkatan kualitas kompos tandan kosong kelapa sawit dengan penambahan abu boiler. Perlakuan pada percobaan pertama terdiri dari empat tingkatan dosis abu boiler yaitu K1 = 0%, K2 = 15%, K3 = 25%, dan K4 = 35%. Percobaan kedua adalah percobaan rumah kaca, terdiri dari tiga belas perlakuan dengan tiga ulangan yang ditempatkan dalam rancangan acak lengkap (RAL). Perlakuan yang diberikan: empat kompos dari hasil percobaan pertama yang diaplikasikan ke tanah dengan empat tingkat dosis, yaitu : 0, 10, 20 dan 30 Mg ha<sup>-1</sup>. Hasil penelitian menunjukkan bahwa pemberian abu boiler pada awal proses pengomposan dapat meningkatkan kualitas kompos tandan kosong kelapa sawit: meningkatkan pH, jumlah asam humat, unsur hara makro dan mikro serta penurunan kandungan Pb. Aplikasi dari semua kompos –K1, K2, K3, K4– pada Ultisol meningkatkan pH H<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, C-organik, N-Total, Ca-dd, K-dd dan produksi sawi serta menurunkan H-dd, Al-dd. Produksi sawi meningkat sebesar 84% (33,9 g tanaman<sup>-1</sup>) pada perlakuan K4 dengan dosis 20 Mg ha<sup>-1</sup> dan 85% (34,1 g tanaman<sup>-1</sup>) pada perlakuan K3 dengan dosis 10 Mg ha<sup>-1</sup>.

**Kata Kunci :** Abu boiler, asam humat, sawi, tandan kosong, Ultisols

## INTRODUCTION

The growth of oil palm plantations in Indonesia has shown a marked acceleration, as manifested by continuing extensive plantation development. To illustrate, in 2013, the total area of oil palm plantations in the country reached 10.01 million hectares producing an average of up to 20.08 Mg of fresh fruit bunches per hectare, as more oil palm plantations have been developed in various parts of Indonesia, the national output of crude palm oil (CPO) also increased significantly, in the same year (2013), the country's CPO production amounted to 27.74 million Mg (Sekjen Pertanian 2014). Of course, this CPO turnout came with some negative impacts, particularly in the resulting production wastes, consisting of empty palm oil fruit bunches 21.5% (43.21 million Mg), liquid waste 18.3% (45.97 million Mg), fruit shells 5.4% (10.85 million Mg), and fiber residues 11.5% (23.11 million Mg) (Departemen Pertanian 2006).

The utilization of empty oil palm fruit bunch (EOPFB) waste has not yet been optimally realized. For example, among oil palm plantations with own palm oil processing plants, these empty fruit bunch are simply spread out over the plantation ground to serve as mulch, and left to rot and become a useful organic fertilizer for the growing crop. However, this natural process of decomposition of strewn

EOPFB occurs at a very slow rate thereby rendering the polluted plantation area, in a way, due to the foul odor from rotting, and making the area vulnerable to the reproduction of, and infestation by, horned beetles (*Oryctes rhinoceros*). Aside from this, its utilization as mulch material is rather uneconomical because of transport constraints and prohibitive cost. For over 17 years now, there are piles of EOPFB that could be burned in the oil palm processing plants, and the resulting ashes could be utilized as organic fertilizer. However, in 1997, the Indonesian Government issued Agriculture Minister Decree No. KB 550/286 MENTAN VII 1997 prohibiting any burning activity in oil palm plantation development, as well as associated industrial operations, such that unprocessed wastes kept on piling up. In this regard, one option with high potential beneficial effects is by composting the EOPFB.

While, by themselves, the EOPFB possess complete nutrient elements (Table 1). Their nutrient content level is quite low hence, there is a need to supplement them with material with high nutrient content, like boiler ash. Boiler ash is generated from shells and fibers combustion process at high temperatures. Boiler ash contains macro and micro nutrients (Table 1). Up to  $\pm 5\%$  boiler ash can be recovered out of the total waste materials burned (Borhan *et al.* 2010). This means that burning 33.96 million Mg of oil palm wastes, composed of 10.85

Table 1. Characteristics of compost materials.

| Parameter           | Unit                | EOPFB | Boiler ash | Palm oil mill effluent |
|---------------------|---------------------|-------|------------|------------------------|
| Water content       | %                   | 5.80  | 2.22       | -                      |
| pH H <sub>2</sub> O | -                   | 5.61  | 7.33       | 7.51                   |
| Organik-C           | %                   | 58.04 | 6.61       | 0.10                   |
| Total -N            | %                   | 0.79  | 0.30       | 0.02                   |
| Total -P            | %                   | 0.76  | 1.01       | 0.17                   |
| Ca                  | %                   | 0.22  | 2.16       | 0.01                   |
| Mg                  | %                   | 0.21  | 0.55       | 0.005                  |
| Na                  | %                   | 0.16  | 0.36       | 0.03                   |
| K                   | %                   | 0.46  | 1.14       | 0.10                   |
| S                   | %                   | 0.03  | 0.05       | 0.08                   |
| Fe                  | mg kg <sup>-1</sup> | 25.00 | 22 100     | 1.29                   |
| Mn                  | mg kg <sup>-1</sup> | 99.14 | 0.69       | 0.67                   |
| Cu                  | mg kg <sup>-1</sup> | 6.81  | 462.79     | nd                     |
| Zn                  | mg kg <sup>-1</sup> | 20.15 | 36.28      | 17.23                  |
| As                  | mg kg <sup>-1</sup> | 2.28  | 4.45       | <0.0001                |
| Hg                  | mg kg <sup>-1</sup> | 0.16  | 0.21       | <0.0001                |
| Cd                  | mg kg <sup>-1</sup> | 3.13  | 3.33       | <0.002                 |
| Pb                  | mg kg <sup>-1</sup> | 22.83 | 29.25      | 0.27                   |
| Cr                  | mg kg <sup>-1</sup> | 1.37  | 4.61       | 0.05                   |
| Silicate            | %                   | -     | 80.09      | -                      |

note: nd = no detected.

million Mg fruit shells, and 23.11 million Mg fibers, can yield an estimated  $\pm 1.70$  million Mg boiler ash. Based on the analysis of nutrients and heavy metals as well as its potential, boiler ash can be used as an additive to improve the quality of the EOPFB compost. However, boiler ash has been utilized, generally, only as a surfacing material for hardening access roads in oil palm plantations. Until now, little research information to inform the quality of the compost produced by the addition of boiler ash at the beginning of the composting process, so the research needs with the addition of ash boiler with the objectives were to study the effect of boiler ash on quality of the EOPFB compost.

The soil type used in this study is Ultisol. Ultisol is very potential as agricultural land with an area of 48.3 million hectares which is about 29.7% of the land area of Indonesia (Hakim *et al.* 1986). However, constraints as agricultural land are high level of acidity, high Al saturation, low nutrient content and low organic matter (Hardjowigeno 2003).

Thus, it is important to study whether there is any difference in chemical properties Ultisol improvement after application of the EOPFB compost without and with addition of boiler ash as well as it is necessary to study the effect of the EOPFB compost application on Ultisol. The objectives of the research were to investigate: 1) effect of boiler ash on the quality of the EOPFB compost, 2) effect of EOPFB compost on the chemical properties of Ultisol and yield of mustard.

## MATERIALS AND METHODS

### Research Location

The field experiment was conducted in the greenhouse at Cikabayan Trial Plantation, IPB, while the analysis of the quality of compost from EOPFB residue, chemical properties of the soil, and nutrient content of the experimental plants were undertaken at the Laboratory of the Soil Science and Land Resources Department, IPB, and at the Soil Research Station Laboratory, Agricultural Land Resource Research and Development Center (BBSDLP), Ministry of Agriculture. This Study was conducted from March 2015 to January 2016.

### Research Methods

This Study was done in 3 stages, namely: composting, compost quality observation, and greenhouse pot trials.

The EOPFB residue was first beaten using a pounding machine to yield fibers with  $\pm 5$  cm measurement. Before using, boiler ash was milled and sifted through a 100 mesh sieve. Liquid waste used for composting came from the ANP-3 (Anaerobic Primer 3) pool. Prior to the composting process, the properties of the compost material were characterized (Table 2). The results of the analysis of the characteristics of compost materials are presented in Table 1.

Composting was carried out in a composting vat made of wood with dimensions 1 m  $\times$  1 m  $\times$  1 m

Table 2. Parameter and methods of analysis for compost material, soil, and quality of compost and plants.

| Parameter   | Method of Analysis/Measurement Instrument                 |
|---|---|
| pH H <sub>2</sub> O   | Elektrode (pH meter)                                      |
| K   | Wet ash ( <i>Flamephotometer</i> )                        |
| Ca and Mg   | Wet ash (AAS)   |
| Fe, Mn, Cu, dan Zn  | Wet ash (AAS)   |
| Organic-C   | Walkley and Black (Titration)<br>*Dry ash                 |
| Total-N   | Kjeldahl (Titration)                                      |
| NH <sub>4</sub> <sup>+</sup> dan NO <sub>3</sub> <sup>-</sup> | Extraction KCl 1 N (Titration)                            |
| S   | Wet ash ( <i>Spectrophotometer</i> )                      |
| P available   | Bray I ( <i>Spectrophotometer</i> )                       |
| Exchangeable-K  | NH <sub>4</sub> OAc 1 N pH 7.0 ( <i>Flamephotometer</i> ) |
| Exchangeable-Ca   | NH <sub>4</sub> OAc 1 N pH 7.0 (AAS)                      |
| Exchangeable-Mg   | NH <sub>4</sub> OAc 1 N pH 7.0 (AAS)                      |
| Exchangeable-Al and exchangeable-H                            | KCl 1 N (Titration)                                       |
| Humic acid determination                                      | Extraction – acid base                                    |
| Heavy metal Hg, Pb, Cd, As, Cr                                | Wet ash (AAS)   |
| Silicate  | Gravimetric   |

Note: \* = Analysis of C-organic content of palm oil fruit bunch waste and compost using ash test

(1 m<sup>3</sup>), and equipped with a 4-inch diameter, 1-m long PVC pipe which had been perforated (with small holes) around the side. Towards obtaining the best compost, different composting material combinations, viz: 150 kg oven-dry EOPFB residue mixed with 4 dosages of boiler ash: 0% (K1), 15% (K2), 25% (K3), and 30% (K4). Each combination was added with liquid waste at 50% of the combined weight of the EOPFB and boiler ash. Each combination of compost material was applied with urea and brown sugar, at 1% and SP-36 0.5% respectively, of the weight of organic waste. Compost turning over was carried out once weekly. The humidity of the compost was also maintained by means of water sprinkling, and was controlled through indicative kneading of the compost material. The composting process was lasted for 45 successive days.

The greenhouse pot experiment was consisted of thirteen treatments and three replications arranged in a completely randomized design (CRD). The treatments applied were: four of compost from the first experimental results applied to the soil with four dose levels, i.e : 0, 10, 20 and 30 Mg ha<sup>-1</sup>. For planting medium, soil was prepared with 2.9 kg oven-dry weight (ODW), or corresponding to 3.5 kg air-dry weight (ADW). The treated soil was then incubated for 14 days, after which it was re-incubated using dolomite lime over 7 days, and mixed with 1× soil exchangeable-Al. The application of urea fertilizer, SP-36, and KCl was done at 50% of the recommended standard fertilizer dosage for mustard, which is 100 kg ha<sup>-1</sup> urea, 100 kg ha<sup>-1</sup> SP-36, and 75 kg ha<sup>-1</sup> KCl (Manulu 2008). Each pot was sown with 4 mustard seeds and grewed until harvest time. Plant maintenance involved watering once every day, and kept at field capacity level. The experimental mustard plants were harvested when they were 45 days old.

### The Variables of Observation

Observed variables on the quality of the compost from EOPBF was undertaken based on the result of the analysis of humic acid, pH, C/N ratio, macro and micro-nutrient (N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn) elements, as well as heavy metal Pb.

Observed variables on the Ultisol land included ...<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, exchangeable-H, exchangeable-Al, organic-C, total-N, exchangeable-Ca, exchangeable-K, exchangeable-Mg. Observed variables on the mustard plants were green weight which was measured at harvest time.

### Data Analysis

Statistical analysis of observed data was done using *Analysis of Variance* (ANOVA) with F-test

at 5% level of significance using SAS 9.0. When the treatment showed significant difference in effect, further statistical test was carried out using *Duncan's Multiple Range Test* (DMRT) at 5% probability level.

## RESULTS AND DISCUSSION

### Quality of Compost from EOPFB

The addition of boiler ash at composting start-up increased the compost pH as the boiler ash dosage was raised (Figure 1a). This was attributed

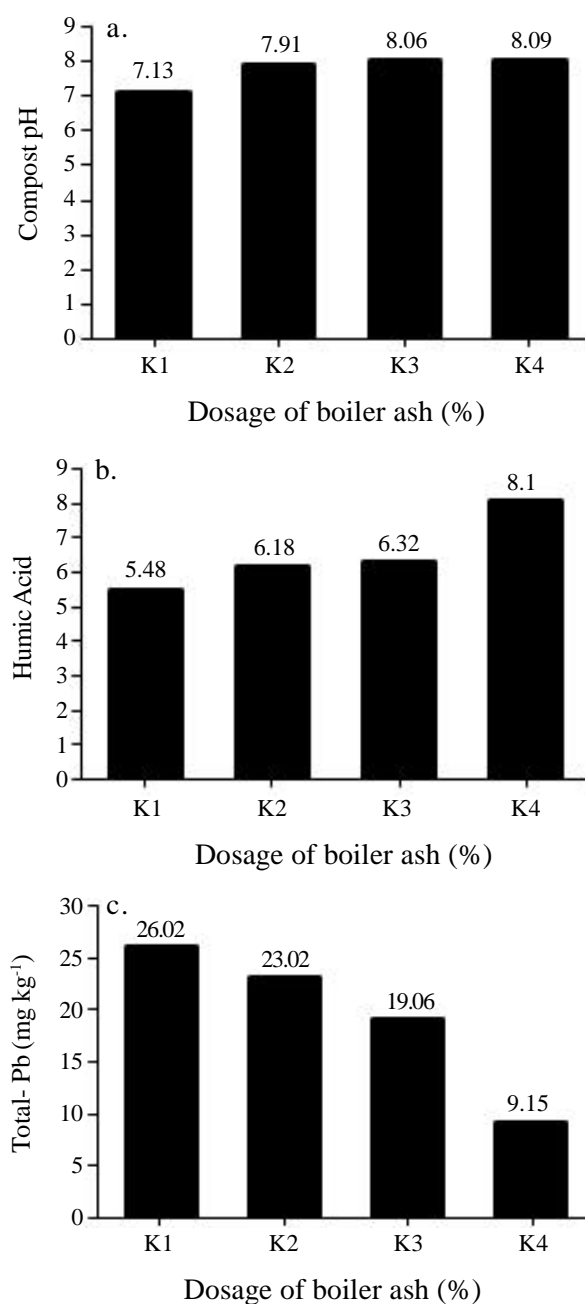


Figure 1. Effects of application of varying dosages of boiler ash on (a) pH value, (b) total humic acid, and (3) the level of heavy metal Pb of EOPFB residue compost.

to the fact that boiler ash has higher pH (7.33) compared to that of EOPFB residue pH (5.61). Increasing the pH of the compost caused an increasing levels of humic acid (Figure 1b). This was mainly due to the fact that mixing boiler ash during composting process start-up encouraged microorganism activity resulting into accelerated compost maturity, as exemplified by the successively decreasing C/N ratio (Table 2). Levels of humic acid increased by 47.81 % compared to the compost without the addition of boiler ash. This result was supported by the findings of Agustian *et al.* (2004) in a study on composting of rice straw, which showed lowering of C/N ratio from 48.20 into 37.50, and which raised total humic acid by as much as 136.47%.

The reduction in the heavy metal Pb level was consistent with the higher pH and total humic acid in the EOPFB residue compost. The lowest heavy metal Pb was observed at Treatment K4 which went down by as much as 184.81% (Figure 1c). This occurred because, at solution pH of 3.5 – 9, humic acid forms a linear polyelectrolyte colloid system which is characteristically flexible, whereas at lower pH, humic acid becomes rigid and tends to aggregate and form a macromolecule solid through hydrogen bonding. As pH goes up, the hydrogen bond becomes weaker so that disaggregation among molecules occurs. Such condition is influenced by the functional group association which is characteristically acidic in the humic acid like –COOH. Generally, the –COOH group becomes dissociated at pH range of 4 – 5, whereas the –OH phenolyte group, or the –OH alcoholyte group disaggregates at pH range 8 – 10 (Swift 1989). In other words, it can be stated that at relatively high pH (low H<sup>+</sup> concentration), the –COOH concentration increases and serves as an organic ligand on the humic acid. Tan (1991) reported that in one type of transitional metal, Pb<sup>2+</sup>, most bonding that occurred was due to the coordinated bonding with organic ligand such that the bond became very strong and difficult to replace by exchangeable K, Na, Ca and Mg cations.

The addition of boiler ash at composting start-up decreased the C/N ratio (Table 3). The lowering of the C/N ratio was brought about by the carbon element in the compost material that was being used up as a source of energy by decomposition (Surya dan Suryono 2013), and released into the atmosphere in the form of CO<sub>2</sub> (Triatmojo 2003). As a result, the organic carbon in the compost material continued to decline from 58.04% to 49.43 – 32.44%.

Mixing boiler ash raised the level of nitrate (Table 4), with the highest level reached at Treatment

Table 3. C, N, and C/N Ratio of compost.

| Compost | C      | N     | C/N   |
|---------|--------|-------|-------|
|         | -----% | ----- |       |
| K1      | 49.43  | 4.15  | 11.94 |
| K2      | 41.97  | 4.17  | 9.95  |
| K3      | 35.42  | 3.97  | 9.01  |
| K4      | 32.44  | 3.41  | 9.54  |

K3, and a drop in value was exhibited at Treatment K4. This rise in the nitrate level also demonstrated that during the process of composting, most of the ammonium went through nitrification and became nitrate. This ammonium-nitrate conversion during composting was carried out by the microorganisms, mainly *Nitrosomonas* and *Nitrobacter* groups of bacteria (Basuki 1994). The amonium that was subjected to nitrification came from the process of ammonification and ammonification of organic-N forms from the mixture of EOPFB residue, boiler ash, and liquid waste. Apart from this, there was an increase specifically, in the P levels due to the addition of P from SP-36 fertilizer. The added P are essential elements in the synthesis of cell components, and in the energy transfer within the cells of microorganisms.

Overall, the levels of macro- and micronutrient elements in the compost from EOPFB (Table 4) went up when compared to the initial state of the compost material. The rise in the nutrient levels was due to the humic acid which played a key role in boosting the solubility of both macro- and micronutrient elements present in the boiler ash. Boiler ash typically contains high levels of macro- and micronutrient elements. Nevertheless, many elements form into crystalline silicates resulting from high temperatures during burning thereby rendering the macro- and micronutrient elements difficult to dissolve. Besides, the levels of the macro- and micronutrients went up as a consequence of the decomposition process, as well as the release of some nutrient elements by way of the mineralization process bringing about higher concentrations of nutrient elements in the compost material.

Referring to the minimum technical specifications for solid organic condensation, based on existing Indonesian Government regulations (Peraturan Menteri Pertanian No.70/Permentan/SR.140/10/2011) issued by the Minister of Agriculture in 2011, which stipulate organic-C, pH, Pb, Mn and Zn the compost in this Study clearly met the set conditions. C/N ratio throughout the compost is already under the C/N quality

Table 4. Levels of macro- and micronutrient elements in the EOPFB compost mixed with varying dosages of boiler ash (at composting start-up).

| Parameter                     | Unit                | Compost 1 | Compost 2 | Compost 3 | Compost 4 |
|-------------------------------|---------------------|-----------|-----------|-----------|-----------|
| NH <sub>4</sub> <sup>+</sup>  | mg kg <sup>-1</sup> | 309.75    | 448.80    | 246.60    | 216.98    |
| NO <sub>3</sub> <sup>-</sup>  | mg kg <sup>-1</sup> | 762.08    | 1616.13   | 2548.20   | 2310.02   |
| P <sub>2</sub> O <sub>5</sub> | %                   | 1.82      | 2.82      | 4.87      | 4.75      |
| K <sub>2</sub> O              | %                   | 4.48      | 5.59      | 4.85      | 4.05      |
| CaO                           | %                   | 2.57      | 4.03      | 4.50      | 4.42      |
| MgO                           | %                   | 1.65      | 2.56      | 2.51      | 2.57      |
| S                             | %                   | 1.94      | 2.24      | 2.83      | 1.72      |
| Fe                            | mg kg <sup>-1</sup> | 15 800    | 16 300    | 18 800    | 23 500    |
| Mn                            | mg kg <sup>-1</sup> | 604.27    | 967.65    | 1090.62   | 1131.05   |
| Cu                            | mg kg <sup>-1</sup> | 106.46    | 166.09    | 229.69    | 217.98    |
| Zn                            | mg kg <sup>-1</sup> | 174.29    | 400.42    | 317.24    | 414.99    |

standards requirements as organic condensation. However, the Fe content ranged from 15 800 to 23 500, this value exceeds the maximum allowed which is 9000 mg kg<sup>-1</sup>. Determination of total iron content of a maximum of 9000 mg kg<sup>-1</sup> to be seen again, given the oxidative iron is not active when pH > 4.0 (Dewi et al. 2012).

#### Effects of Compost Dosage on the Chemical Properties of Ultisol Soil

The results of the various analyses showed that the application of varying dosages of EOPFB residue compost mixed with boiler ash (at the start of the composting process) yielded significant effects on raising soil pH H<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, organic-C, Total-N, exchangeable-Ca, exchangeable-K while reducing

soil exchangeable-H and exchangeable-Al and had non significant effects on raising soil exchangeable-Mg.

The soil pH H<sub>2</sub>O in the Control was 4.05; after treatment this went up to 4.24, which still falls under the category of Highly Acidic per set Indonesian standard (Balai Penelitian Tanah 2009). It can be seen clearly in this study that the highest pH H<sub>2</sub>O (8.09) was obtained in Treatment K4 with dosage of 30 Mg ha<sup>-1</sup> (K43). This was also because Treatment K4 had a higher pH H<sub>2</sub>O than treatments K1, K2, and K3 (Figure 1a). The soil exchangeable-H in the control was 3.60, after treatment this decreased into 2.53. The decline in exchangeable-H ground in line with the increase in soil pH (Table

Table 5. Soil pH H<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, exchangeable-H and exchangeable-Al after application of varying dosages of EOPFB compost.

| Treatments | pH H <sub>2</sub> O | Exch-H<br>(me 100g <sup>-1</sup> ) | Exch-Al<br>(me 100g <sup>-1</sup> ) | P <sub>2</sub> O <sub>5</sub> Bray I<br>(mg kg <sup>-1</sup> ) |
|------------|---------------------|------------------------------------|-------------------------------------|--|
| K00        | 4.05 g              | 3.60 d                             | 28.98 e                             | 10.64 c  |
| K11        | 4.07 f              | 3.47 d                             | 28.34 de                            | 12.25 bc   |
| K21        | 4.11 ef             | 3.33 cd                            | 28.19 d                             | 13.19 bc   |
| K31        | 4.11 ef             | 3.27 bcd                           | 27.80 bcd                           | 13.41 bc   |
| K41        | 4.13 de             | 2.93 abc                           | 27.88 cd                            | 13.72 bc   |
| K12        | 4.13 de             | 2.87 abc                           | 27.61 bcd                           | 14.13 bc   |
| K22        | 4.14 cd             | 2.80 ab                            | 27.60 bcd                           | 14.41 bc   |
| K32        | 4.15 cd             | 2.73 a                             | 27.53 bcd                           | 14.72 bc   |
| K42        | 4.16 bc             | 2.67 a                             | 27.52 bcd                           | 16.55 abc  |
| K13        | 4.16 bc             | 2.67 a                             | 27.15 abc                           | 19.05 ab   |
| K23        | 4.18 b              | 2.67 a                             | 27.01 ab                            | 19.04 ab   |
| K33        | 4.18 b              | 2.60 a                             | 26.59 a                             | 22.22 a  |
| K43        | 4.24 a              | 2.53 a                             | 26.59 a                             | 21.98 a  |

Note: Numerical values in the same column which are followed by same letters indicate no significant difference at 5% level of significance, based on *Duncan Multiple Range Test* (DMRT).

5). Tan (1991) suggested that the soil exchangeable-H as acidity potential currently on sorption and pH as acidity active are in the soil solution so that the H in sorption continuous with H solution, if H solution is reduced, then the exchangeable-H will be out of the sorption and into the soil solution. The lowest exchangeable-H was obtained in Treatment K4 with dosage of 30 Mg ha<sup>-1</sup> (K43).

The level of soil Al-exchangeable at initial analysis was 28.98 me 100g<sup>-1</sup>, which decreased after treatment into 26.59 me 100g<sup>-1</sup> (Table 4), or a 8.99% reduction. This decline in the soil exchangeable-Al could be attributed to the role played by humic acid from the EOPFB compost. The higher the amount of humic acid in the compost, the faster would be the lowering in soil exchangeable-Al. Tan (1991) stated that the reduction in soil exchangeable-Al was due to the chelate formation mechanism producing chelate elements through mono-, bi-, or multidentate chelation.

As observed in this Study, the lowest level of soil Al-exchangeable was obtained in Treatment K4 with compost dosage of 30 Mg ha<sup>-1</sup> (K43). This was consistent with the higher amount of humic acid in K4 (Figure 1a) compared to K1, K2, and K3. At initial analysis, the level of soil P<sub>2</sub>O<sub>5</sub> (10.64 mg kg<sup>-1</sup>) was still under Moderate category; after treatment soil P<sub>2</sub>O<sub>5</sub> level became 22.22 mg kg<sup>-1</sup> which is classified as Very High (Table 5). The results of this Study illustrated that the highest level of soil P<sub>2</sub>O<sub>5</sub> was obtained at Treatment K3 with a dosage of 30 Mg ha<sup>-1</sup> (K33). This was consistent with

higher level of soil P<sub>2</sub>O<sub>5</sub> in treatment K3 (Table 4) as against those of Treatments K1, K2 and K4, respectively. The results of this study are supported by several studies including the provision of compost can improve soil pH, lowering the Al saturation, and increase P<sub>2</sub>O<sub>5</sub> (Tufaila *et al.* 2014; Wahyudi 2009).

Soil organic-C at the Control was 0.90% which is categorized as Very Low Level; after treatment it rose to 1.22% (Low Level) based on existing Indonesian standards (Balai Penelitian Tanah, 2009). Soil organic-C level went up due to the presence of carbon (C) which served as the principal composer of organic matter thus, the application of compost could raise the level of soil organic-C (Barus *et al.* 2013). The highest level of soil organic-C was obtained at Treatment K4 with compost dosage of 30 Mg ha<sup>-1</sup> (K43) (Table 6). Initial soil total-N (0.10%) at Control went up to 0.16% after treatment, which falls under category Low Level. This increase in the level of soil total-N was due to the contribution of total-N coming from the EOPFB residue compost (Table 4).

According to Hardjowigeno (2003), nitrogen in the soil may originate from organic matter in the soil, N bonding by microorganism, fertilizer, and rain water. The highest level of soil total-N was obtained at Treatment K3 with compost dosage of 30 Mg ha<sup>-1</sup> (K33) as shown in Table 6.

Initial soil exchangeable-Ca at Control (1.72 me 100g<sup>-1</sup>) which is category as Very Low Level and it became 2.43 me 100g<sup>-1</sup> (Low Level) after treatment. At the same time, Control exchangeable-

Table 6. Levels of soil organic-C, total-N, Exch-Ca and Exch-K after the application of varying dosages of EOPFB residue compost.

| Treatment | Soil Organic-C (%) | Soil Total-N (%) | Exch-Ca (me 100g <sup>-1</sup> ) | Exch-K (me 100g <sup>-1</sup> ) | Exch-Mg (me 100g <sup>-1</sup> ) |
|-----------|--------------------|------------------|----------------------------------|---------------------------------|----------------------------------|
| K00       | 0.90 c             | 0.10 c           | 1.72 e                           | 0.53 g                          | 1.22                             |
| K11       | 0.93 c             | 0.11 bc          | 1.79 de                          | 0.56 fg                         | 1.24                             |
| K21       | 0.93 c             | 0.11 bc          | 1.80 de                          | 0.61 fg                         | 1.25                             |
| K31       | 0.95 c             | 0.11 bc          | 1.86 de                          | 0.62 fg                         | 1.25                             |
| K41       | 0.95 c             | 0.11 bc          | 1.89 cde                         | 0.62 fg                         | 1.26                             |
| K12       | 1.01 bc            | 0.11 bc          | 2.00 bcde                        | 0.65 efg                        | 1.26                             |
| K22       | 1.04 abc           | 0.12 abc         | 2.06 bcd                         | 0.68 def                        | 1.27                             |
| K32       | 1.04 abc           | 0.12 abc         | 2.16 abc                         | 0.79 bcd                        | 1.28                             |
| K42       | 1.07 abc           | 0.13 ab          | 2.18 abc                         | 0.76 cde                        | 1.28                             |
| K13       | 1.09 abc           | 0.15 a           | 2.24 ab                          | 0.79 bcd                        | 1.30                             |
| K23       | 1.18 ab            | 0.16 a           | 2.25 a                           | 0.86 abc                        | 1.31                             |
| K33       | 1.21 a             | 0.16 a           | 2.35 a                           | 0.94 a                          | 1.32                             |
| K43       | 1.22 a             | 0.15 a           | 2.43 a                           | 0.90 ab                         | 1.42                             |

Note: Numerical values in the same column which are followed by same letters indicate no significant difference at 5% level of significance, based on *Duncan Multiple Range Test*(DMRT).

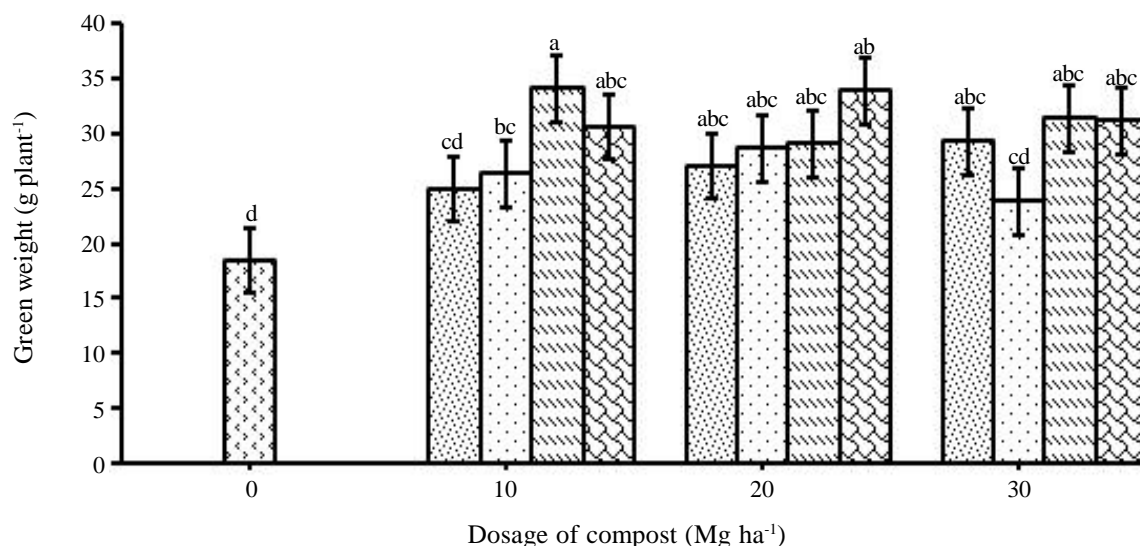


Figure 2. Relationship between dosage of EOPFB residu mixed with ash at composting start-up and green weight of mustard plant. The vertical lines above each data block is a standard error and the letters on top indicate statistical test results based on *Duncan's Multiple Range Test* (DMRT) at 5% probability level. □: K0, ▨: K1, ▩: K2, ▪: K3, ▫: K4.

K level of 0.53 me 100g<sup>-1</sup> (Moderate Level) rose to 0.90 me/100 g (High Level) based on set Indonesian standards (Balai Penelitian Tanah 2009). The rise in exchangeable-Ca and exchangeable-K levels was caused by the contribution of Ca and K which came from the EOPFB residue compost (Table 4). Peak exchangeable-Ca level was yielded by Treatment K4 with compost dosage of 30 Mg ha<sup>-1</sup> (K43), while highest exchangeable-K level was observed at Treatment K3 with compost dosage of 30 Mg ha<sup>-1</sup> (K33), as shown in Table 6.

### Effects of Compost Dosage on Green Weight of Mustard Plants

Based on the results of the treatment analyses in this Study, the application of compost from EOPFB residue, mixed with boiler ash (at composting start-up) demonstrated significant positive effect on the green weight of harvested mustard plants.

Figure 2 illustrates that adding varying dosages of compost mixed with boiler ash (Treatment K3) at compost dosage of 10 Mg ha<sup>-1</sup> (K31) and K4 at compost dosage of 20 Mg ha<sup>-1</sup> (K42) with dosing urea 50% of recommended doses produced the highest green weight value of the mustard plants. Compared to Control, the green weight of mustard plant at Treatment K3 with compost dosage of 10 Mg ha<sup>-1</sup> (K31) increased by 85% (34.1 g plant<sup>-1</sup>) and K4 with compost dosage of 20 Mg ha<sup>-1</sup> (K42) increased by 84% (33.9 g plant<sup>-1</sup>) by production produced was 8.4 up to 8.5 Mg ha<sup>-1</sup>. Erawan *et al.* (2013) conducted a study in Southeast Sulawesi in

Ultisol without the addition of compost, therefore to achieve a production of 10 Mg ha<sup>-1</sup> it required fertilizer with high dose up to 125 kg ha<sup>-1</sup>.

### CONCLUSIONS

The addition of boiler ash at the beginning of the composting process improved the quality of the EOPFB compost which were increased of pH, amount of humic acids, macro and micro nutrients content and decreased Pb content.

The application of all compost–K1, K2, K3, K4–to Ultisol increased pH H<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, organic-C, total-N, exchangeable-Ca, exchangeable-K and yield of mustard and decreased exchangeable-H, exchangeable-Al. Moreover the yield of mustard increased about 84% (33.9 g plant<sup>-1</sup>) with K4 at doses 20 Mg ha<sup>-1</sup> and 85% (34.1 g plant<sup>-1</sup>) with K3 at doses 10 Mg ha<sup>-1</sup>.

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