Oil Palm Empty Fruit Bunches Biochar Potential as Ameliorant for Acid Soil

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Abstract: Research took place in Screenhouse of Agriculture Faculty, Nommensen HKBP University Medan, North Sumatera, Indonesia. The soil used is classified to Inceptisol with loam texture and pH of soil is 4,9 with Al 0,03 m.e/100 g took from Wonosari Tanjung Morawa, Deli Serdang, North Sumatera, Indonesia. The research is intend to know how the hypothesized oil palm emty fruit bunches biochar (OPEFBB) enhanced acid soil. Experiment conduct in Complete Randomized Design with six level and four times repetition, then continued analized with Duncan Multiple Range Test. The application of OPEFBB increasing with highly significat to: pH, sum of basic cations, base saturation and available K. The soil pH increasing is start from 0,2 units in application 5 t/ha up to 1,12 units of pH on application 25 t/ha. The increasing in soil available K reach 1,1 m.e/100 g (high) on application 5 t/ha and up to 2,48 m.e/100 g (very high) on the application 25 t/ha compared to the control with 0,59 m.e/100 g (medium). The levels of Ca, Mg, and P are increased with the application of material but statistically not significant. No significant effect OPEFBB application to the exchangeable Al of soil. The water volume content is increased significantly but simultaneously followed a significantly decrease in air filled pores, but for soil bd and soil total porosity did not effects significantly. The total population of soil microbes differed insignificantly with tendency of decline.

1 INTRODUCTION

In Indonesia the soil conditions tend to react acid with soil pH values ranging from 4,5 to 5,5 so that the soil with a pH of 6,0-6,5 has often been said to be quite neutral when in fact the condition of this pH value of soil is still slightly acid. The world's acid soil covers 40% of the world's land area (Pariasca et al., 2009). In Indonesia the area of acid soil which consists of various order reaches 102.817.113 ha, in Sumatera is an area of 29.344.534 ha, and in North Sumatera is an area of 4.156.283 ha, with the soil classified to Inceptisol in North Sumatera reached 2.414.939 ha (Mulyani et al., 2006). With such a large area of acid soil is very useful to obtain a technology to overcome the obstacles that arise for the plant, so that one day this land can be utilized for optimal even more to become sustainable agriculture.

Acid soil conditions usually coincide with soil infertility, which in many cases becomes unsuitable for agricultural crops (Pattanayak and Khriedunio, 2013), relatively low levels of soil base nutrient, lower availability of macro nutrients both primary and secondary (Cornell, 2010). The nutrient P element in acid soil is often not available to plants due to the fixed by Al (Silveira, 2013). The nutrient K element eventhough pH is considered to have little effect on its availability, but the presence of high Mg and Ca will tend to substitute K in the absorbtion complex, thus K becomes more available to the crop (Alberta Canada Agriculture and Forestry, 2013; McKenzie, 2015).

Low soil pH values on top soil substantially increase the solubility of Al especially if the soil has a pH less than 5.0 (Rout et al., 2001; Gazey and Liam, 2015; Panda et al., 2009). The presence of Al as a source of acid in the soil even under certain concentration level will be toxic to the plant. Aluminum as a toxic in the soil often makes soybean

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plants dwarf at the initial growth (Zulfa, 2015; Wissuwa and Ae, 2001; Wissuwa, 2005). Al is very toxic to plants when the concentration is greater than 2 parts per million (ppm) with a soil pH less than 5.5 (Rout et al., 2001; Gazey and Liam, 2015; Balsberg, 1990) and is a major problem facing by worldwide agriculture on acid soil farming (Vitorello et al., 2005) and its effect is usually highly visible in the final phase of plant growth as a result of the inhibition of water fulfillment by plant roots (Soil quality, 2016). Biological conditions in the soil are also effected by soil pH (Cornell, 2010; Pioneer, 2014) and is also known to inhibit the survival of beneficial microbes such as rhizobia bacteria as a nitrogen-fixing for legumes (Hollier and Michael, 2005). It is necessary to adjust the soil pH from acidic conditions to a level appropriate for plants growth, as it is above 5.5 to 6.5 and grows well on range of soil pH 6-7 (University of Massachusetts, 2016). Soybeans grow well at soil pH ranging from 6.0 to 6.8. On acid soils the presence of Al in the soil may fixed P so that it is less available, P deficiency will greatly affect the growth even to the yield reduction due to fewer pods and smaller seeds (Taufiq, 2014), these adverse effects can already be solved by created a soil pH greater than 5.5.

Biochar behave alkaline can even function to increase acid soil pH (Ogawa and Okimori, 2010; Diacarbon energy, 2016; Hugill, 2011; Chan et al., 2007). The basic nutrient elements contained in the biochar material will serve to increase the base cations into the soil and can be used by soil microbes as well as plant roots. Biochar is porous thus able to hold water or air in considerable amounts so improvement of crop yields is not only in terms of nutritional but also by an increase in water holding capacity (USBI, 2016; Toll et al., 2011). Micro pore on biochar function in holding water in the soil. Biochar application on textured sandy soil can increase water availability for plants up to 11% (Karhu et al., 2011). Biochar effected on enzymatic activity occurring in soil also proved to maintain the fertility of the soil for a long time despite the high rainfall in a region that is very potential for washing (Hunt et al., 2011). The use of biochar into the soil is not something universally but rather needs consideration of local circumstances and it sources (Abiven et al., 2014; Jenkins et al., 2016). Biochar can improve the conditions of plant growth very well (Nature, 2009). The application of one kilogram per square meter gives better results and other crops and thoroughly influence the soil ecosystems (Girardin, 2016; Wen-fu et al., 2013). As we knew that the source of oil palm empty fruit bunches is a reneweable natural resource so it will be very worthwhile to invent the way how to manage it to support a sustainable agriculture.

2 MATERIALS AND METHODS

2.1 Time and Place

The screenhouse experiment had done in October-November 2016 held at Faculty of Agriculture University of HKBP Nommensen Screenhouse in Simalingkar. The soil used in this study is inceptisol with loam texture class that was taken from Wonosari Village, Tanjung Morawa Deli Serdang Regency, Indonesia.

2.2 Materials and Tools

The materials use in this study consist of: inceptisol soil material, oil palm empty fruit bunches biochar, and rainfall data. The tools use in this study consist of: plastic, label paper, markers, stationery, meter, scales weights 15 kg, black buckets as pot, and camera.

2.3 Experimental Design

The experimental design use Completely Randomized Design with a six-stages biochar: without biochar 0,0 (w/w); biochar 0,25% (w/w) equivalent to 5 t/ha; biochar 0,5% (w/w) equivalent to 10 tons / ha; biochar 0,75% (w/w) equivalent to 15 t/ha; biochar 1,0% (w/w) equivalent to 20 t/ha; biochar 1, 25% (w/w) is equivalent to 25 t/ha, treatment was repeated four times so the sum of experiment is 24. The effect of treatment on observation parameters was done by Variance Analysis Test and when showing significant followed by Duncan Multiple Range Test.

2.4 Soil Properties Parameters

The main parameters of soil properties observed in this study including: pH, K, Ca, Mg, Na, sum of basic cations, base saturation, Al, P, soil bulk density, total porosity of soil, volumetric water content, percent of air filled pores, and total population of soil microbes.

3 RESULTS AND DISCUSSION

3.1 Effect of Oil Palm Empty Fruit Bunches Biochar Application on Several Soil Chemical Properties of Tanjung Morawa Inceptisol

Oil palm empty fruit bunches biochar application as a renewable resource increased the: soil pH, the sum of basic cations (SBC), base saturation (BS) and K available of soil with very highly significant as seen in laboratory analysis results presented in Table 1. The increase of soil pH occurring starting from 0,2 units in application equivalent to 5 t/ha up to 1,12 units of pH (logarithm value) on OPEFBB application equivalent to 25 t/ha. The increase in soil pH, is an indication of the decrease in the number of H^+ ions and accompanied by an increase in OH^- ions.

The increase of unit soil pH value with application 5 t/ha has not given significant change compared to soil pH without application of OPEFBB and also no change to soil pH level in soil acidity classification, this is evidence of soil bufferability has been occured. So the OPEFBB functions to neutralize the available supply of soil acids of available buffer capacity in the soil exchange system. In the application of OPEFBB equal to 10 t/ha soil pH is 5,75 (an increase 0.5 units in soil pH value) compare to soil pH on the control treatment with a soil pH 5,25. An increase in soil pH of 0,5 pH unit statistically has given a significant effect on the soil pH rise compared to the untreated soil pH and also rise up classification of the soil pH state from acid to slightly acidic on the basis of soil acidity classification (CFSAR, 1994).

Table 1. Effect of Oil Palm Empty Fruit Bunches Biochar Application to Some Soil Chemical Properties

Application of Oil Palm Empty Fruit Bunches Biochar (t/ha)					
0	**5**	**10**	**15**	**20**	**25**
Soil pH					
5,25D	5,45D	5,75C	6,15B	6,15B	6,37A*
Sum of Basic Cations (m.e/100 g)					
4,95C	5,85B	5,78B	6,36B	6,48B	7,36A
Soil Base Saturation (%)					
41,5C	49,09B	48,44B	53,36B	54,37B	61,68A
Available Soil K (m.e/100 g)					
0,59C	1,1CB	1,24B	1,63B	1,61B	2,48A
Available Soil Ca (m.e/100 g)					
3,28	3,33	3,08	3,17	3,39	3,34**
Available Soil Mg (m.e/100 g)					
1,12	1,24	1,28	1,26	1,29	1,34
Available Soil Na (m.e/100 g)					
0,13	0,16	0,17	0,17	0,18	0,19
Available Soil P (ppm)					
60,92	65,49	64	59,8	63,95	77,66
Available Al (m.e/100 g)					
0,03	0,03	0,03	0,03	0,03	0,17
Description: *) Numbers followed by unequal letters differ significantly according to Duncan highly significant 0.01 (uppercase). **) Numbers not followed by letters are not followed by Duncan's multiple range test.					

It is known that the basic cations can react with water and produce hydroxyl (OH^-) in the soil, so the increasing of basic cations in the soil will increased amount of hydroxyl as well. The hydroxyl ions that formed will react with the H^+ cations from the soil solution and produce water molecules. The reaction resulted in the binding of the cation of H^+ of the soil solution by each of the formed hydroxyl anions, in this way resulting in an increasing pH of the soil.

As indicated from the results of this study, the application of OPEFBB increased the sum of basic cations (SBC) of soil is significantly different as shown in Table 1. The number of soil basic cations in the treatment of OPEFBB application equivalent to 5 t/ha is 5,85 m.e/100 g, an increase in SBC ranging from 0,9 m.e/100 g (compared to controls increased by about 18.18% with SBC of soil 4,95 m.e/100 g). The SBC in the treatment of OPEFBB application equivalent to 25 t/ha was 7,36 m.e/100 g, there was an increasing of SBC of soil of 2,41 m.e/100 g (an increase of about 48,68% compared to SBC control value with SBC soil 4,95 m.e/100. So on the basis of the above data after the calculation is known there is an increase in SBC of soil ranging from 0,9 to 2,41 m.e/100 g if expressed in percent then the magnitude of this increase ranges from 18,18% to 48,68%). The increase in SBC accompanied with increase of soil BS with highly significant as presented in Table 1 due to an increasing of OPEFBB applied to the soil. The soil BS increased from 41,5% (control) to 49,09 % in the application of OPEFBB equivalent to 5 t/ha up to 61,68% at application 25 t / ha. Application of OPEFBB into Tanjung Morawa inceptisol increased soil BS from 7,59% to 20,18%. This is evidence that the OPEFBB potentially as amelioration material for acid soil.

The available potassium (K^+) of soil has increased with highly significant with the application of OPEFBB into the soil. Laboratory analysis carried out that this OPEFBB contains potassium element in the form of K_2O of 10,10% (dry weight). Giving this material into the soil is enhance in soil available K when compared to the control 0,59 m.e/100 g (medium), whereas with OPEFBB equivalent to 5 t/ha K level available soil reach to 1,1 m.e/100 g (high) and this value reaches 1,864 times of control (increase 86,44%). The highest increase reaches soil available K value of up to 2,48 m.e/100 g (very high) or to 4,20 times (up 320%) on application equivalent to 25 t/ha. How the three of pH, sum of basic cations and available K increased with the increasing of OPEFBB shown in Figure 1.

Other basic cations such as Ca and Mg, although statistically not significant but increased. For the soil Mg level on this test scale looks different from the effect on the soil Ca, that every addition of OPEFBB always gives consistent tendency to increase to the available Mg level of soil. The increased availability of these plant nutrients in the soil with biochar treatment is directly from biochar (Chan et al., 2008; Lehmann et al., 2003; Lehmann et al., 2006; Sohi et al., 2009).

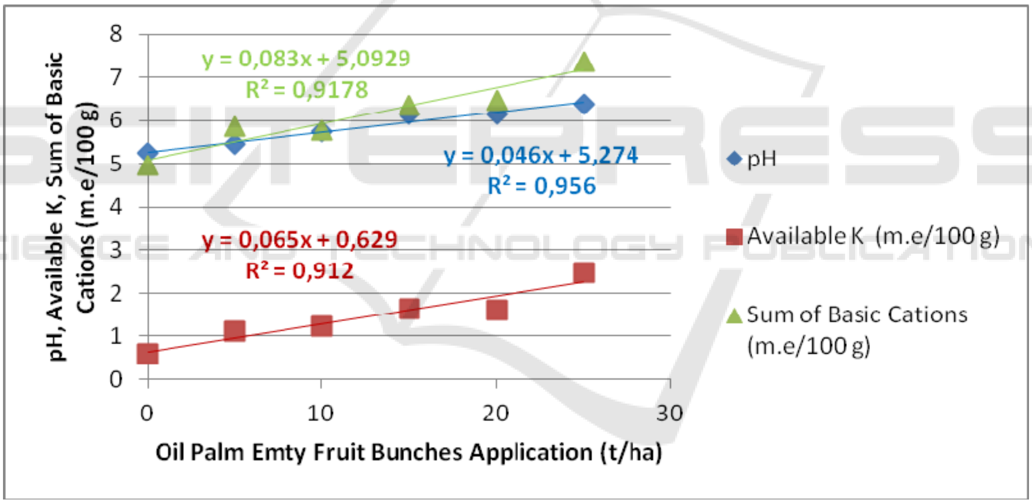

Figure 1. Effect of Oil Palm Empty Fruit Bunches Biochar Application to pH, K Available and Sum of Soil Base Cations.

Soil available P showed an increasing trend, although in this study the increase was statistically not significant. Increase in available P of soil ranges from 4,57 ppm in application of 5 t/ha with P available soil is 65,49 ppm compared to P content of control with P content of soil 60,92 ppm. The highest increase in soil available P is 16,74 ppm which occurs in the application of 25 t/ha OPEFBB with available soil P 77,66 ppm. The result data also shows that there is no significant effect OPEFBB application to the exchangeable Al of soil.

3.2 Effect of Oil Palm Empty Fruit Bunches Biochar Application to Some Soil Physical Properties of Tanjung Morawa Inceptisol

The water holding capacity of OPEFBB is capable of holding water equivalent to up to 231% water content (g/g). Application into the soil gives a significant effect on the increase in soil water volume (v/v) Table 2, along with the significant decrease of air filled pores, this relationship shown in Figure 2. But for soil density and total porosity the application did not have a significantly different effect.

Table 2. Effect of Oil Palm Empty Fruit Bunches Biochar Application to Some Soil Physical Properties.

Application of Oil Palm Empty Fruit Bunches Biochar (t/ha)					
0	**5**	**10**	**15**	**20**	**25**
Soil BD (g/cm^3)					
1,02	1,02	1,02	1,02	1,06	1,04**
Soil Porosity (%)					
61,65	61,17	61,24	61,20	59,47	60,47
Soil Volumetric Water Content (%)					
48,44c	49,41cb	52,95a	53,25a	52,46ab	51,05abc*
Soil Air Filled Pores (%)					
13,1a	11,75ab	8,28bc	7,95d	6,99c	9,41abc
Description: *) Numbers followed by unequal letters differ significantly according to Duncan 0.05 multiple test (lowercase) **) Numbers not followed by letters are not followed by Duncan's multiple range test.					

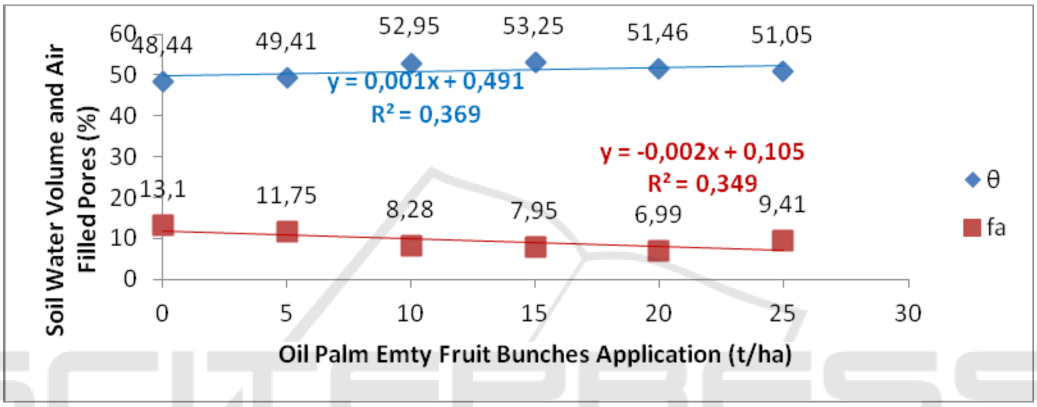

Figure 2. Effect of Oil Palm Empty Fruit Bunches Biochar Application to Porosity, Water Volume and Pore Filled Air Soil

The increasing of the soil volumes moisture content is ranging from 0,97% in the application equivalent to 5 t/ha to 4,81% occurring in the application of materials equivalent to 15 t/ha. The increased of soil water content is certainly very meaningful for the cultivated crops, even it will be reduce the movement of water as percolation water in the soil, which means to prevention of soil nutrient leaching occurs in the soil treatment, so increased the available nutrients for crops, such an effect will further improve the efficiency of fertilizer.

3.3 Effect of Oil Palm Empty Fruit Bunches Biochar Application to Total Population of Soil Microbes on Tanjung Morawa Inceptisol

The data shown in Table 3 informs that there is a decrease in the soil microbes population with the increasing of the OPEFBB, with the pattern of population decline shown in Figure 3. It is known that the number of bacteria as the largest number of microbes in the soil only ranges between 10^6 to 10^9 per gram of soil [39], so with the lowest population occurring on the soil experiments that the microbial function of the soil can still run normally.

Table 3. Effect of Oil Palm Empty Fruit Bunches Biochar Application to Total Population of Soil Microbes

Application of Oil Palm Empty Fruit Bunches Biochar (t/ha)					
0	**5**	**10**	**15**	**20**	**25**
Total Population of Soil Microbes					
10,74	10,25	10,08	10,31	10	10,05*
Description: *) Numbers not followed by letters are not followed by Duncan's multiple range test. Note: The population value used is the logarithm value of the TP at dilution 10^{-9}.					

The decline of the total microbes population of this soil is occur due to lack of food, as seen in the initial soil data that the C concentration of soil is only 0,93% thus by multiply 1,724 it is obtained the percentage of organic matter only 1,60 %. Meanwhile, if only expect of OPEFBB given as source of carbon will be difficult for microbes to immediately to decayed or to decompose it in a short time, because the ratio of C and N of the OPEFBB is still very high that 37,90:1 is rounded to 38:1. This fact should be something to consider soil organic matter in the use of biochar into the soil as it is known on the basis of existing theory that while microbes soil consumes C at the very time requires enough nitrogen, if not will create the immobilization of N [40]. Material with nitrogen content of less than 4% while the carbon content is very high then this material can not be considered as fertilizer, but merely just a matter of soil amendment (Lawn Care Academy, 2016).

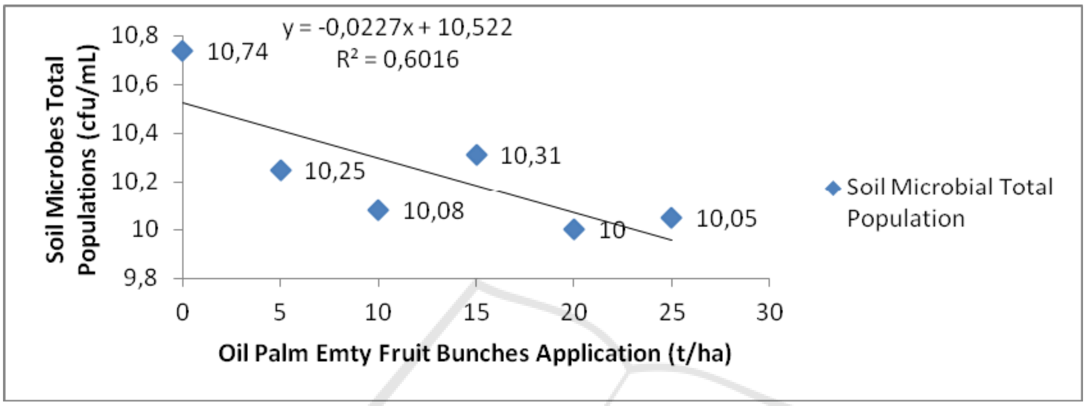

Figure 3. Effect of Oil Palm Empty Fruit Bunches Biochar Application to to Total Population of Soil Microbes.

4 CONCLUSIONS

Based on screenhouse test result obtained can be drawn some conclusions such as: The application of OPEFBB as a renewable resource to acid soil is highly significant to increased pH. The increase in soil pH occurring from 0,2 units in the application of OPEFBB equivalent to 5 t/ha up to 1,12 units of pH in equivalent to 25 t/ha. The application of 10 t/ha has been able to secure the Al in the soil with a soil pH of 5,75, as it was previously known that the soil pH of 5,5 was safe enough to prevent the dissolution of Al in the soil, but to makes acid soil become an optimal for soybeans growth with pH 6,15 is needed to 15 t/ha. The OPEFBB is highly significant increase soil available K, the application 5 t/ha reach 1.1 m.e/100 g (high) and the highest up to 2,48 m.e/100 g (very high) on equivalent to 25 t/ha compared to control with 0,59 m.e/100 g (medium). The application of OPEFBB as a renewable resource to acid soil is highly significant to increased sum of basic cations as well as base saturation. For the levels of Ca, Mg, and P of acid soil are increased with the of OPEFBB but statistikically not significant. No significant effect OPEFBB application to the exchangeable Al of soil. The water volume of soil increased significantly but simultaneously resulted in a significantly decrease in percentage of air filled pores but not for bd and porosity. The effect of OPEFBB application to total population of soil microbes is not significantly and has tendency to decline.

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