Study of some chemical properties of ultisol soil applied by biochar and compost from some biomasses and incubation time

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Abstract. Biochar and compost applications are alternative in improving soil chemical properties, such as Ultisol soil and utilizing the current abundance of biomass waste. Biochar has long available properties and takes longer to decompose than compost. This study aims to compare the effect of biochar and compost for several months of incubation on soil chemical properties. This research was conducted with several pot from plastic cup and placed in a greenhouse using a non-factorial randomized block design with control, biochar and compost treatments taken from rice straw biomass, empty palm oil bunches, and cow dung, with 3 replications. The parameters measured were pH H₂O, C-Organic, N-total, and available P. The results indicate that the provision of biochar and compost can increase the pH of H₂O, C-Organic, N-total, and P available in Ultisol soil for 1, 2 and 3 months of incubation. Biochar is better at increasing available pH, C-Organic, N-total, and P than compost with the best treatment found in Biochar from cow dung biomass and oil palm empty bunches. Meanwhile, the treatment of cow manure compost was better at increasing pH H₂O during incubation time and nutrients in Ultisol soil, followed by compost of empty palm oil bunches and straw.

1. Introduction

In recent years, biochar has become a trendsetter as an organic amendment compared to compost. It is believed that compost still leaves several pathogens, methane gas and ammonia which can cause contamination of agricultural land and exacerbate global warming. The large amount of research on biochar around the world is triggered by the fact that biochar can last a long time in the soil. Biochar itself is an ingredient carbon-rich organic amendments from pyrolysis / biomass combustion under limited oxygen conditions at temperatures <700°C [1]. Biochar has advantages over other types of organic matter, where there is about 50% carbon whereas organic matter which is biologically decomposed usually only contains less than 20% carbon after 5-10 years [1,2].

The addition of biochar and compost can solve Ultisol soil problems, because this soil has problems such as acidic pH (<5.5), decreased supply of nutrients such as P, K, Ca, Mg, and high Al saturation, so the soil is not good for plant growth [3]. Biochar and compost are also alternatives for biomass management, especially Indonesia that total biomass around 200 million tons / year obtained from agricultural, forestry, plantation and municipal solid waste [4].

As a soil organic amendment, the availability of nutrients from biochar and compost for some time is the key to maintaining soil fertility. Mulch, compost, manure are said to be effective in increasing soil organic carbon stock and agricultural productivity, but these amendments are often short-lived
especially in the tropics [5]. Until now, data on the ability of biochar and compost to improve soil properties, such as soil chemical properties, have not been known for some time and are still being studied. Application of biochar to tropical acid soils will increase yields over the years, but more long-term studies are needed to assess its stability and degree of decomposition and reactions in the soil [2]. Meanwhile, long-term compost is also reported to increase pH, C-Organic, and agricultural crop yields on acid soils, such as Ultisols [6].

The stability of biochar and compost is also influenced by the quality of both, especially the type of biomass and the manufacturing process. Biomass contains lignocellulose (lignin, hemicellulose, and cellulose). Biochar raw material which has high lignin content will produce biochar of about 65% and has higher carbon content and carbon is difficult to decompose in the soil [7]. Based on research results [8], giving straw compost and P fertilizer as much as 30 g / 300 soil-air dried for 2 months incubation increased pH in Andisol from 4.86 to 5.28. Meanwhile, Oil Palm Empty Fruit Bunches compost can increase soil P-Bray II from 4 ppm to 10 ppm [9]. Organic matter in the soil for some time, such as biochar, changes its properties so that it changes its function of soil properties, such as soil chemical properties. The ability of biochar to overcome soil acidity is also caused by factors such as the length of incubation time and the condition of biochar’s aromatic carbon which undergoes oxidation/weathering, and the nitrification process [1,5].

This research aims to compared the role of biochar and compost from several biomass to several chemical properties of soil at several months of incubation time for Ultisol soil.

2. Materials and methods

2.1. Material preparation

Ultisol soil sample was dried and then aired, sieved with a size of 10 mesh and then placed in a pot of about 340 gr. Biochar and compost used came from biomass of rice straw, oil palm empty bunches, and cow dung at a dose of 10.2 g / pot.

Biochar was produced by dried all the biomass material for about 1 week, then chopping it into ± 5 cm sizes, then pyrolysis by means of a retort [10]. Pyrolysis is carried out in about 1,5-3 hours. Furthermore, biochar was analyzed for moisture content, pH, C-Organic, N-total, total P. Composting was also produced by chopping ± 5 cm of biomass, then adding EM4 to speed up the composting process. Composting lasts for ± 4 weeks until C / N <20. Furthermore, biochar was analyzed for moisture content, pH H2O (H2O extract), C-Organic, N-total, C/N and total P.

2.2. Research methods

This study used a randomized block design with 7 treatments and 3 replications so that there were 21 treatments. The linear model used is:

\[ Y_{ij} = \mu + \pi_i + \beta_j + \epsilon_{ij} \]  

(1)

The parameters observed were soil pH, C-Organic (%), total N, and P of available soil for 1,2, and 3 months. The data obtained will be tested statistically based on analysis of variance at the 5% and 1% levels and then the Orthogonal Polynomial difference test (contrast) is carried out at the 5% level.

3. Results and discussion

3.1. pH H2O

Application of biochar and compost for 1,2, and 3 months of incubation affected the pH of soil H2O as presented in table 1 below.
### Table 1. The pH value of Ultisol for 1, 2, and 3 months incubation of biochar and compost.

| Treatment                       | 1 Month | 2 Month | 3 Month |
|---------------------------------|---------|---------|---------|
| C Control                       | 4.01<sup>va</sup> | 4.06<sup>va</sup> | 4.12<sup>va</sup> |
| BS Straw Biochar                | 4.70<sup>a</sup> | 4.72<sup>a</sup> | 4.59<sup>a</sup> |
| BB Oil Palm Empty Bunches Biochar | 5.15<sup>a</sup> | 5.18<sup>a</sup> | 5.21<sup>a</sup> |
| BC Cow Manure Biochar           | 5.13<sup>a</sup> | 5.23<sup>a</sup> | 5.27<sup>a</sup> |
| CS Straw Compost                | 4.66<sup>a</sup> | 4.63<sup>a</sup> | 4.49<sup>a</sup> |
| CB Oil Palm Empty Bunches Compost | 4.67<sup>a</sup> | 4.52<sup>a</sup> | 4.44<sup>a</sup> |
| CC Cow Manure Compost           | 5.92<sup>la</sup> | 5.69<sup>la</sup> | 5.63<sup>la</sup> |

**Contrast Test**

| Test                        | C vs BS, BB, BC, CS, CB, CC | BS, BB, BC vs CS, CB, CC | BJ vs BB, BC | BB vs BC | KS vs KB, KC | KB vs KC |
|-----------------------------|-----------------------------|--------------------------|--------------|----------|--------------|----------|
|                             | **                          | ns                       | **           | ns       | **           | **       |

Note: (*) significant; (**) very significant; (tn) not significant
(va) very acidic; (a) acidic; (la) a little acidic

### Table 2. C-Organic Ultisol for 1, 2, and 3 months of incubation of biochar and compost.

| Treatment                       | 1 Month | 2 Month | 3 Month |
|---------------------------------|---------|---------|---------|
| C Control                       | 0.76<sup>vl</sup> | 0.80<sup>vl</sup> | 0.77<sup>vl</sup> |
| BS Straw Biochar                | 1.07<sup>i</sup> | 1.36<sup>i</sup> | 1.32<sup>i</sup> |
| BB Oil Palm Empty Bunches Biochar | 1.25<sup>i</sup> | 1.77<sup>i</sup> | 1.82<sup>i</sup> |
| BC Cow Manure Biochar           | 1.12<sup>i</sup> | 1.47<sup>i</sup> | 1.52<sup>i</sup> |
| CS Straw Compost                | 1.22<sup>i</sup> | 1.19<sup>i</sup> | 1.04<sup>i</sup> |
| CB Oil Palm Empty Bunches Compost | 1.27<sup>i</sup> | 1.31<sup>i</sup> | 1.19<sup>i</sup> |
| CC Cow Manure Compost           | 1.16<sup>i</sup> | 1.10<sup>i</sup> | 1.02<sup>i</sup> |

**Contrast Test**

| Test                        | C vs BS, BB, BC, CS, CB, CC | BS, BB, BC vs CS, CB, CC | BJ vs BB, BC | BB vs BC | KS vs KB, KC | KB vs KC |
|-----------------------------|-----------------------------|--------------------------|--------------|----------|--------------|----------|
|                             | **                          | ns                       | **           | ns       | **           | **       |

Note: (*) significant; (**) very significant; (tn) not significant
(l) very low; (i) low
3.3. Total N

**Table 3.** Total N Ultisols after 1, 2, and 3 months of incubation of biochar and compost.

| Treatment                     | 1 Month | 2 Month | 3 Month |
|-------------------------------|---------|---------|---------|
| C Control                     | 0.13\( ^{\text{I}} \) | 0.12\( ^{\text{I}} \) | 0.10\( ^{\text{I}} \) |
| BS Straw Biochar              | 0.18\( ^{\text{I}} \) | 0.17\( ^{\text{I}} \) | 0.16\( ^{\text{I}} \) |
| BB Oil Palm Empty Bunches Biochar | 0.16\( ^{\text{I}} \) | 0.17\( ^{\text{I}} \) | 0.15\( ^{\text{I}} \) |
| BC Cow Manure Biochar         | 0.20\( ^{\text{I}} \) | 0.21\( ^{\text{I}} \) | 0.19\( ^{\text{I}} \) |
| CS Straw Compost              | 0.16\( ^{\text{I}} \) | 0.14\( ^{\text{I}} \) | 0.12\( ^{\text{I}} \) |
| CB Oil Palm Empty Bunches Compost | 0.17\( ^{\text{I}} \) | 0.15\( ^{\text{I}} \) | 0.13\( ^{\text{I}} \) |
| CC Cow Manure Compost         | 1.15\( ^{\text{I}} \) | 0.13\( ^{\text{I}} \) | 0.12\( ^{\text{I}} \) |

Contrast Test

- C vs BS, BB, BC, CS, CB, CC ** ** **
- BS, BB, BC vs CS, CB, CC ** ** **
- BJ vs BB, BC ns * **
- BB vs BC ** ** **
- KS vs KB, KC ns ns ns
- KB vs KC ** ** ns

Note: (*) significant; (**) very significant; (tn) not significant; (l) low

3.4. P available

**Table 4.** P Available Ultisols after 1, 2, and 3 months of incubation of biochar and compost.

| Treatment                     | 1 Month | 2 Month | 3 Month |
|-------------------------------|---------|---------|---------|
| C Control                     | 4.14\( ^{\text{I}} \) | 2.10\( ^{\text{I}} \) | 2.03\( ^{\text{I}} \) |
| BS Straw Biochar              | 11.95\( ^{\text{I}} \) | 12.21\( ^{\text{I}} \) | 13.31\( ^{\text{I}} \) |
| BB Oil Palm Empty Bunches Biochar | 11.52\( ^{\text{I}} \) | 11.25\( ^{\text{I}} \) | 11.17\( ^{\text{I}} \) |
| BC Cow Manure Biochar         | 38.54\( ^{\text{h}} \) | 40.18\( ^{\text{h}} \) | 58.62\( ^{\text{vh}} \) |
| CS Straw Compost              | 24.62\( ^{\text{m}} \) | 30.02\( ^{\text{m}} \) | 38.52\( ^{\text{vh}} \) |
| CB Oil Palm Empty Bunches Compost | 14.25\( ^{\text{m}} \) | 12.61\( ^{\text{m}} \) | 12.37\( ^{\text{m}} \) |
| CC Cow Manure Compost         | 32.18\( ^{\text{h}} \) | 38.59\( ^{\text{vh}} \) | 47.34\( ^{\text{vh}} \) |

Contrast Test

- C vs BS, BB, BC, CS, CB, CC ** ** **
- BS, BB, BC vs CS, CB, CC ns ** *
- BJ vs BB, BC ** ** **
- BB vs BC ** ** **
- KS vs KB, KC ns ns ns
- KB vs KC ** ** **

Note: (*) significant; (**) very significant; (tn) not significant; (vl) very low; (l) low; (m) moderate; (h) high; (vh) very high

Based on table 1, the application of organic amendments in the form of biochar or compost from several biomass was not significantly different. However, the provision of biochar from raw materials increased the pH of H\(_2\)O to an average of 0.91-0.98 points and tended to be stable. This is because biochar has a high pH and alkaline material when it is hydrolyzed at a temperature (± 300°C). According literature [11], stated that biochar is alkaline, and has alkaline components that form carbonates and oxides, as well as functional groups (COO- and -O) which play a role in biochar...
alkalinity when it is pyrolyzed at low temperatures (300-500°C). Meanwhile, when giving compost, the pH of soil H2O decreased with the incubation time. This happens because over time, the decomposition process by microorganisms will contribute H⁺ in the soil, organic acids, CO₂, and water. According to literature [12], when the compost time is longer in the soil, the results of microorganism decomposition will release NH₄⁺ so that more nitrate (NO₃⁻) produces CO₂ which reacts quickly with H₂O to produce H⁺ and HCO₃⁻, and organic acids are slightly acidic because it releases H⁺. The decomposition reaction of organic matter can cause soil acidity over the incubation period, written as follows:

\[
\text{NH}_4^+ + 2\text{O}_2 \rightleftharpoons \text{NO}_3^- + \text{H}_2\text{O} + 2\text{H}^+ \\
\text{C}_{-\text{Organic}} \rightarrow \text{R-}\text{COOH} \rightarrow \text{R-}\text{COO}^- + \text{H}^+
\]

Soil C-Organic content was better for 2 and 3 months of incubation due to the provision of biochar compared to compost with the highest percentage of soil C-Organic content found in oil palm empty bunches of biochar by 1.82%. This is because biochar has a relatively high carbon content and a carbon structure that is resistant to the decomposition process so that it can last for some time in the soil compared to compost. That shows biochar has carbon in the form of aromatic compounds which form a solid poliaromatic sheet consisting of a crystalline phase so that it is resistant to microbial degradation in the soil [13].

The total N content in the soil was better and more stable due to biochar application of up to 1,2, and 3 months of incubation than the addition of compost in the soil with the highest N-total value of 0.21% due to cow manure biochar. The N function can be maintained by biochar in the soil, because biochar, especially cow dung biochar, has a large surface area with many pores, thus preventing the washing of N. Biochar pores are oxidative, which effectively absorbs NH₄⁺ and NO₃⁻ so that a nitrification process occurs which will reduce N leaching [1].

Other nutrient elements, such as P in the soil, generally increase better due to the provision of compost for 2 and 3 months of incubation due to the provision of biochar with the highest average P content, namely compost from cow dung (47,34), followed by straw (38,52), and oil palm empty bunches (12,37). This is because the mineralization of compost based mainly on animal manure is a slow release nutrient which during the incubation period mineralizes which can provide a number of organic acids chelating Al in the soil so that P is available. Compost organic acids form stable complex compounds that bind Al³⁺ and Fe²⁺ so that they can reduce the levels of soil Al and P that are bound by metals which can be separated from bonds and become available.

4. Conclusions

The application of biochar and compost can increase the pH H₂O, C-Organic, N-total, and P available soil up to 3 months of incubation. Biochar better than compost to increasing pH H₂O, C-Organic, N-total, and P available according to the incubation time. Biochar that has high lignin is better at increasing carbon organic, while biochar from cow dung is better at increasing pH and nutrients. Compost is able to provide higher nutrients within an incubation period of 1-2 months but decreases with incubation. Biochar is more stable in soil for up to 3 months of incubation than compost.

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