The soil organic dynamics from types biochar-organic fertilizers and soil

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IOP Conference Series: Earth and Environmental Science

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IOP Conf. Series: Earth and Environmental Science **215** (2018) 012008 doi:10.1088/1755-1315/215/1/012008

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Abstract. The study aimed at examining the effect of different types of biochar-organic fertilizer and soil on the dynamics of soil organic matter. The incubation research of three types of infertile and low productivity soils (litosol, mediteran, regosol) was conducted in a greenhouse. There would be twelve applications of different treatments of biochar and organic fertilizer (single or mixed) with controls. The three kinds of biochar were rice husk, corn cob and *jengkok* (by product of cigarette industry) and the organic fertilizer was taken from organic waste compost and chicken manure mixed with rice husks. Biochar-organic fertilizer was mixed with soil 3.85 kg at 150 g pot^{-1} (single) and 75 g pot^{-1} (mixed) and incubated in 70–80% field capacity for 98 days in different pots. Soil organic carbon was observed after the incubations for 7, 14, 28, 56, and 98 days. The results showed that the highest increase in soil organic matter took place after the application of *jengkok* biochar or corncob biochar on clay textured soil, while the *jengkok* biochar or the corncob mix biochar and compost were applied on sandy soil. The highest Regosol soil organic matter of biochar tobacco was applied on the 14th day until the 56th day, and then the corncob mixture biochar and compost were applied on the 98th day. The highest organic soil litosol material of biochar tobacco consisted of tobacco, corncob biochar, and biochar mixture of *jengkok* and compost at certain times. It could also be seen that the highest mediteran soil organic matter consisted of feeding biochar and corncob biochar.

1. Introduction

The condition of land in Southern Malang district was dominated by dry land that naturally had low productivity. Southern Malang consisted of several types of land, such as Litosol, Regosol, and Mediteran. The composition of each type of the soil differed with the locations. Land was composed of minerals and organic materials that played an important role in providing water and nutrients for the sustainability of plant growth. Inferior organic matter caused poor soil parcels, especially nitrogen that also resulted in low soil cation exchange capacity so that the soil ability to store nutrients was low. The soil material would affect the organic matter and/or soil minerals. As a result of low organic matter, the nutrients resulting bothfrom the weathering of the parent material and the fertilizer would be easy to wash.

Efforts to improve soil fertility have been widely made using biochar and organic fertilizers. According to [1], long-term sunk carbon was potentially beneficial for soil improvement and crop growth. [2], [3] reported that biochar could improve soil chemical properties (e.g., pH, CEC, and cation) and physical properties (such as groundwater retention and hydraulic conductivity. According to [4] and [5], biochar at certain temperature during production could show different chemical and physical properties. The characteristics of biochar were influenced by the nature of the raw materials, the pyrolysis temperature, and the process conditions [6]. The positive effects of the biochar on the most prominent tropical soil could be seen in the very rusty and infertile condition of the soil [7]. There was limited number of the researches of the characteristics of the biochar resulting from different feed stocks and the effects of biochar characteristics on several types of land. [8] suggested that biochar amendments might affect soil microbial populations and their activity. However, it was necessary to conduct researches to monitor the soil response to biochar treatment considering biochar levels and soil characteristics. The research hypothesis was that the biochar species would affect the biochar characteristics and had significant effect on different organic carbons of the different types of soil. The study aimed at examining the effect of the characteristics of biochar species and organic fertilizers in some soils types on the dynamics of soil organic matter.

2. Materials and Methods

2.1. Soil

Composite soil sample (depth 0–30 cm) was taken from certain depth of dry land in Southern Malang district, precisely in Purwodadi village, Donomulyo subdistrict, Sukowilangun village, Kalipare subdistrict, and Sumberrejo village, Poncokusumo subdistrict. Donomulyo district was situated at 112° 23'30"– 112°29'64" East longitude and 8°16'75"–8°19'81" South latitude with soil of litosol type of entityorder. Ground material litosol of the type of igneous rock or hard sediment has not undergone a perfect weathering process. The soil was infertile and the productivity was low. Kalipare subdistrict was situated at 21,950–29,610 East longitude and 9,400–16,480 South latitude with red and yellowmediteran land of afisolorder. The land of kalipare was not used for agriculture because almost all types of plants could not grow well. Poncokusumo subdistrict was situated approximately 24 km from the subdistrict capital with regosol land of entisolorder. Unfavorable vegetables were grown on the soil of Poncokusumo.

Air dry ground samples were drawn at ambient temperature with moisture content of 0.34 g g^{-1} (Regosol), 0.5 g g^{-1} (Litosol), and 0.61 g g^{-1} (Mediteran). Soil properties were determined using the soil laboratory survey manual method (2004). Particle size was distributed using pipette. Soil organic carbon was distributed using oxidation of potassium dichromate. Cation exchange capacity was measured using ammonium acetate method, while pH was measured using pH meter in aqueous solution.

2.2. Biochar Production

The raw materials of in biochar production were rice husks, corncobs, and tobacco industry waste (*jengkok*). Rice husks biochar and corncobs were produced at 350ºC–500ºC for four hours in the Bioenergy Laboratory of TribhuwanaTunggadewi University Malang. The biochar was produced using fixed bed pyrolysis equipment with a separator system connected to the condenser. The biochar *jengkok*tobacco was produced at 700ºC for 10–15 minutes at PT. Gudang Garam, Tbk. with ethanol pyrolysis tools. The raw material of the raw husk was obtained from rice milling in Malang and dry corn cob from PT. BISI International Branch of Kediri.

2.3. The Characterization of biochar and organic fertilizer

Biochar characterization was conducted by measuring the physical properties following standard procedures. The physical properties such as bulk density (FCO, 1985) and water holding power were measured using AOAC method 19th Ed., 2012, method 969.05. Total C was measured using gravimetric method, while particle size (ASTM) was mechanically measured. Organic fertilizers were analyzed following standard procedures.

2.4. The Incubation od biochar and organic fertilizer in the soil

The experiments were conducted in the TribhuwanaTunggadewi University greenhouse, Malang, Indonesia (7,48'.50" South longitude and 112º.37 '41" East longitude) with daily temperatures were in the range of 16ºC–36ºC, the relative humidity was about 43–86%, and light intensity was 365–1997 lux. Treatment consisted of two factors. The first factor was soil types (regosol, litosol andmediteran). The second factor was biochar and organic fertilizer and consisted of 12 treatments. The use of the biochar and the organic fertilizer in each soil was repeated three times so that there were 108 pots. Each soil sample was placed into a plastic pot (18 cm of diameter and 25 cm of height) and incubated for 98 days. The biochar corncobs were milled for <2 mm, while the biochar *jengkok* tobacco and the biochar rice husk were applied directly.

Three pointseightyfive kilograms of soil was mixed with 150 g of biochar or organic fertilizer following the existing treatment procedure and resulted in the mixture of biochar (75 g) and organic fertilizer (75 g) at the ratio of 1:1 and at 4% dry weight level and 1.2 Mg bulk density M3 (similar to field conditions). The weight of the soil and the biochar and/or the organic fertilizer of each pot was 4 kg. It was equivalent to the biochar amendment and/or organic fertilizer 9.6ton ha^{-1} in a layer of 20 cm. During incubation, groundwater content was maintained at 0.11–0.18 g g^{-1} (equivalent to 70–80% of field capacity) and a liter of water was added every 21 days. The dry condition was reached using 70–80% of field capacity. The effect of the changes in the biochar and/or the organic fertilizer on soil organic matter was measured in the incubations for 7, 14, 28, 56 and 98 days.

2.5. *Statistic Analysis*

This research used nested design. Factor 1 (Nest) was the types of soil, namely regosol, litosol and mediteran. Factor 2 (the nested) was biochar and organic fertilizer.

Controls: Without biochar and organic fertilizer	S: Biochar rice husk	T: Biochar corn cob	J: Biochar jengkok tobacco
SA: Biochar rice husk-chicken manure	SK: Biochar rice husk-compost	TA: Biochar corn cob-chicken manure	TK: Biochar corn cob-compost
JA: Biochar jengkok tobacco-chicken manure	JK: Biochar jengkok tobacco-compost	A: Manure chicken	K: Compost

Note: Once two-way ANOVA analysis has been made, it was followed by DMRT (Duncan Multiple Range Test).

3. Results and Discussion

3.1. *The characteristics of soil*

The characteristics of each soil type were summarized in table 1. The sandy textured regosol soils had very low organic carbon with 86% sand fraction. The litosol soil and mediteran textured clay had 65% and 76% sand fractions, respectively. The organic carbon content in litosol and mediteran soils was low. All of the soils had low C/N ratio, while the pH of the mediterane and regosol soils was acid and the litosol soil was slightly acid.

Table 1. Soil characteristics

Indicators	Litosol	Mediteran	Regosol
pH H_2O	6.40	5.30	5.50
pH KCl 1N	6.10	5.00	5.30
C organic (%)	1.36	0.72	0.48
C/N	8	7	7
Sand (%)	11	9	86
Dust (%)	24	15	3
Clay (%)	65	76	11
Texture	Clay	Clay	Sand Clay

3.2. The physical caharacteristics of biochar and organic fertilizer

The physical characteristics of biochar and organic fertilizer were summarized in table 2. The total carbon of the corncob biochar > biochar *jengkok* tobacco > biochar husk. The organic carbon of chicken manure > compost. The lowest carbon content was found in rice husk biochar, while it had the highest ash content. On the contrary, the highest carbon content was found in corncob biochar, while it had the lowest ash content. It was consistent with [9] suggesting that the ash content of the biochar carbon was relative low. It took place because the high ash content inhibited carbon formation.

The positive responses of biochar applications not only related to plant nutrients including toxin neutralization [10], but also improved soil physical properties (e.g., the increase in water holding capacity) [11] or reduced soil strength [12]. The capacity to retain water of the biochar and the organic fertilizer depended on biomass feedstock. The water holding capacity of the biochar rice husk > biochar corn cob > chicken manure > biochar*jengkok* tobacco > compost. [13] suggested that the surface area and porosity of biochar at different pyrolysis temperatures had significant potential to affect the water holding capacity, the adsorption capacity (the particle ability to stick to the biochar surface) and the nutrient retention capability.

The bulk density of the biochar rice husk, the corncob, and the tobacco *jengkok* were 0.65, 0.27, and 0.31 g cm^{-3}, respectively. According to [14], biochar had a much lower bulk density than that of the mineral soils in tropics (~ 0.3 Mg m^{-3} forbiochar as compared to the weight of soil volume of 1.3 Mg m^{-3}) so that biochar applications could reduce the bulk density of soil that was generally desirable for plant growth. Several different sizes of biochar pores were bigger than the pore size of organic fertilizers (Table 2). Mesh grain sizes30 and 18 of the *jengkok* biochar were greater than the tuna biochar, but the size of the *jengkok*biochar particles was smaller than the tuna biochar on mesh 325 and above 60. The particle size of the biochar resulted from pyrolysis of organic material, which depended on the nature of the original material. [4] reported increased porosity (and then surface area) combined with total carbon reduction and fly substances. Volatile matter of the corncob biochar > biochar *jengkok* tobacco> biochar rice husk.

3.3. Theeffects of the use of biochar andorganicfertilizer onorganicmaterials ofsomesoil types

After the addition of biochar and organic fertilizer to the soil, variations in the characteristics of the biochar and the organic fertilizer could have various effects on the soil organic matter and the soil type. The organic matters of the regosol, litosol, and mediteran soils after treatment were summarized in Table 3–4. The treatment significantly affected soil organic matter on the 7^{th} day until the 98^{th} day. The soil type had significant effect on soil organic matters. The use of the biochar and the organic fertilizer in the soil of various types had a significant effect on soil organic matters. The use of the biochar and the organic fertilizer in each type of the soil significantly affected the soil organic matters (significance value < α (= 0.05).

Table 2. The characteristics of the biochar and the organic fertilizer

Indicator	Biochar and organic fertilizer				
	Biochar rice husk	Biochar corn cobs	Biochar *jengkok* tobacco	Chicken manure	Compost
Water Holding Capacity (%)	326.04	249,6	143.7	213.38	111.68
Volatile matter (%)	42	75	66		
Ash (%)	53.4	23.6	32.8		
Bulk Density (g cm^{-3})	0.65	0.7	0.31		
Particle Size (%)					
- Mesh 325 (0,044 mm)	2.7	0.8	0.55	0.15	0.2
- Mesh >60 (0.250 mm)	16.75	14.25	4.9	3.05	7.6
- Mesh Grain Size 30 (0.595 mm)	42.6	54.2	79.9	10.55	22
- Mesh 18 (1,00 mm)	68.15	70.8	94.9	20.95	36.2
Total C (%)	29.8	45.6	40		
Organic C (%)				25.02	15.58

Changes in organic carbon would affect soil fertility. The use of the biochar and the organic fertilizer increased the soil organic matters of the three soil types from the 7th day to the 98th day 98. The soil organic matter content varied greatly up and down on every observation day. The soil organic matter resulting from the biochar treatment was higher than that resulting from the organic fertilizer. The biochar*jengkok* tobacco mixed with compost increased the organic matter of the litosol soil 7–14 days after incubation, but the compost mixed with the corn biochar increased the organic matter of the regosol soil on the 98th day. The biochar was a charcoal for the application in the soil. It was often claimed to have several potential benefits, including carbon sequestration [15].

Each soil type showed different levels of soil organic matter although it got the same treatment. The organic matter of the litosolis soil was higher than that of the mediterane soil in all of the observations although both soils had the same texture (clay). It related to the initial organic matter of the litosol soil (1.36%) that was greater than that of the mediterane soil (0.72%). The highest organic matter of the Litosol soil took place in the treatment of the biochar *jengkok* tobacco that was not different from the biochar jengkok tobacco mixed with compost and chicken manure. The highest soil organic matter was 3.56–3.98% (litosol), 1.3–2.1% (mediterane), and 0.97–1.85%(regosol) (table 3). The use of different types of the biochar and the organic fertilizer has not shown any significant difference in the organic matter of the regosol soil on the 7th day, but not on the 14th day. It indicated that the soil organic matter drastically increased on the 14th day (0.94–2.5%). However, the organic matter of the mediteran soil resulting from the mixed treatment of the biochar and the organic fertilizers tended to be better than the treatment of biochar only on the 7th day (table 3).

After 14 days, the highest soil organic matter resulting from the biochar treatment was found in tobacco (regosol), corncob biochar that was not different from the mixture of tobacco and compost (litosol) [illegible] biochar, and the tobacco juvenile biochar that was not different from corncob (Mediterane) biochar. It has been reported that biochar increased the percentage of organic carbon in various soils, but the exact nature of this component has not been well-understood [5]. The total carbon of the corn and the tobacco cobs were respectively 46% and 40% higher than other treatments. The high levels of the soil organic carbon accumulation related to biochar amendments could increase N efficiency and also crop productivity [16].

The highest soil organic matter resulted from the treatment of the tobacco biochar *jengkok* (regosol and mediterane) and the corncob biochar (litosol) on the 28th day and the 56th day (table 4). It was possible that the C/N ratio and the pH had significant effect on the decomposition of the organic matter. The C/N ratio of both soils was the same (7), while the regosol soil at the pH of 5.5 and the mediteranean at the pH of 5.3 tended to be acidic so that the highest increase in the organic matter was found in the treatment of*jengkok* of both of the soil types (regosol andmediterane). The clay content of the litosol soil was lower than that of the Mediterranean. The ability of the soil to hold water depended on the clay content. The water holding capacity of the corncob biochar (249.6%) was higher than that of *jengkok* biochar (143.7%). Increasing the water-holding capacity of the biochar could increase the capacity of the soil to retain water so that the biochar could retain water in the litosol soil so that its reactivity increased and it stimulated microbes to multiply depending on various elements and other compounds and soil moisture for decomposition rate.

Table 4 showed that the highest soil organic matter took place in the corn and the compost biochar mixture (regosol), tobacco juvenile biochar (litosol), and corncob biochar that was not significantly different from the mediterranean tobacco biochar at the end of the observation (on the 98th day). The organic matter of the litosol soil resulting from the rice husk biochar treatment increased from 2.5% to 2.8–2.9% if the biochar husk was mixed with organic fertilizer (chicken manure and compost manure).

The results of the observation on the 98th day showed that the organic matter of the regosol soil increased 2–2.4 times if the corncob biochar was mixed with organic fertilizers (compost or chicken manure). On the contrary, the organic matter of the litosol and Mediterranean soils decreased 1.3 to 1.5 times if the biochar cob was mixed with organic fertilizer. Also, the organic matter of the litosol and mediterane soils decreased 1.1–1.4 times if the biochar *jengkok* tobacco was used along with organic fertilizer.

The biochar *jengkok* tobacco applied to regosol showed the highest organic material until the 28th day and would increase if it was mixed with chicken manure on the 56th day, and then decreased until the 98th day. The organic matter of the litosol soil tended to continuously increase drastically until the 28th day of the corncob biochar treatment, and then further decreased until the 98th day. However, it was not the case if the biochar*jengkok*tobacco was used. The organic matter of the litosol soil did not drastically increase and decrease during the biochar treatment of the tobacco *jengkok*. On the contrary, if the biochar of the *jengkok* tobacco was mixed with compost, the organic matter of litosol soil increased and decreased on the 14th day until the 28th day, and then it was relatively stable until the 98th day. The biochar could change the physical properties of the soils such as structure, pore size and density distribution, with implications for soil aeration, water holding capacity, plant growth, and soil treatment [13]. Evidence showed that the application of the biochar in the soil might increase the overall surface area of the soil [12] and consequently could increase ground water and nutrient retention [13] and the aeration of the soil especially in fine textured soils [17].

The organic matter of the mediterane soil was higher in the biochar treatment of the tobacco *jengkok* as compared to other treatments until the 98th day. The organic matter of the litosol soil increased until the 14th day, and then decreased steadily until the 98th day.

4. Conclusion

The highest increase in soil organic matter for clay textured soil took place after the application of the biochar *jengkok* or the corn cob biochar, while the biochar *jengkok* or the corn cob biochar mixture and the compost were best applied for the sandy soil.The highest organic matter of the regosol soil resulted from the tobacco *jengkok* biochar on the 14th day to the 56th day, and then from the corncob mixed with biochar and the compost on the 98th day while the highest organic matter of the litosolic soil resulted from the biochar application in the tobacco, the corncob biochar, and the biochar mixture of *jengkok* and compost at certain times.The highest organic matter of the litosolic soil resulted from the application of the biochar in the tobacco and the corncob biochar in a period of time.

Acknowledgement

Thanks to the Ministry of Higher Education, Technology and Research that has funded the Superior Research of Higher Education in 2017.

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