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Research article

Soil amendment impact to soil organic matter and physical properties on the three soil types after second corn cultivation

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Abstract: Soil amendment is important for low organic matter soil dominated by sand or clay. Soil amendments using biochar and various types of organic fertilizer have been shown to improve the soil properties. The study aims to evaluate the effectiveness of soil amendment against the second maize plantation season in different soil types. Biochar and organic fertilizer had been applied to the soil amendment 2 years ago (2017) in a polybag during the second plantation season. Polybags were placed in the field and arranged according to nested designs. The experiment used three types of biochar from rice husk, corn cob, by-products of the tobacco industry called jengkok. Two types of organic fertilizer (compost and chicken manure). Soil samples were predominantly sand (entisol) and clay (inceptisol and entisol lithic subgroups). Soil amendment was given at a dose of 300 g per polybags single type, biochar or organic fertilizer without mixing, and each 150 g per polybags for combination type, biochar mixed with an organic fertilizer in 9 kg of soil. Three types of soil (first factor) and soil amendment (second factor nested in the first factor) consisted of 12 treatments: 1. Control, 2. Corn cob biochar (CB), 3. Rice husk biochar (RB), 4. Jengkok biochar (JB), 5. Compost (Cs), 6. Chicken manure (M), 7. Corn cob biochar + compost (CBCs), 8. Corn cob biochar + manure (CBM), 9. Rice husk biochar + compost (RBCs), 10. Rice husk biochar + manure (RBM), 11. Jengkok biochar + compost (JBCs), 12. Jengkok biochar + manure (JBM). Soil physical properties were observed using intact soil samples (rings 5 cm in diameter and 5.5 cm in height), including saturated hydraulic conductivity, texture, soil water retention capacity, soil bulk density, soil particles, soil porosity, macro, meso, and micropores. It was also observed soil organic matter which was taken in a composite from the surface (0–20 cm). Plants are fertilized with 100 kg P_2O_5 ha^{-1}, 110 kg K_2O ha^{-1}, and 135 kg N ha^{-1} at each planting season. Data analysis with SPSS and continued with the Duncan's Multiple Range Test. The results showed each soil amendment had different effectiveness to improve the soil organic matter and its physical properties. Biochar from corn cob mixed with manure is effective to get better corn yields from entisol. While inceptisol soil is suitable with biochar from rice husk mixed with manure. The entisol lithic subgroups are suitable for manure. The soil amendment types affect the soil constituent fraction (sand, dust, clay) composition so that it has an impact on the physical properties of each soil type.

Keywords: biochar; compost; corn; manure; organic fertilizer; soil amendment

1. Introduction

The quality of dry land is generally low due to the low soil organic matter (SOM) which is pivotal to the soil quality [1]. Soil organic matter affects the soil's ability to provide nutrients for plants. In tropical regions, the reduced levels of soil organic matter are unavoidable. Organic materials as soil amendment have been widely used to improve the properties of the soil. A good indicator of the soil quality is soil aggregation as it relates to microbial and the carbon and nitrogen ratio [2,3]. It is also important to increase the soil's carbon and nitrogen, which is an indicator of soil fertility [4]. Busscher et al. [5] showed an increase in organic carbon by the addition of organic soil amendments. Haynes and Naidu [6] stated that the soil organic matter increase can improve soil pore structure. Muyassir et al. [7] explained that the addition of organic materials can degrade the bulk density of 0.16 g cm^{-3}, increasing the aggregate's stability by 21.33%, and increasing the soil porosity of inceptisol by 13.67%.

Improved status of soil cations, such as calcium, can inhibit the dispersion of soil that can affect its aggregate [8]. Gentile et al. [9] reported that the textured soil aggregates will be more responsive to organic material input than the coarse-textured soil. However, Liu et al. [10] declare a higher clay content increases the likelihood of aggregation.

The use of organic fertilizers is intended for the formation of soil humus and nutrient supply in the soil if given in the right amount [11]. The most popular organic fertilizer is compost. According to [12], compost is a substrate rich in organic material. Some researchers reported that the traditional organic fertilizers (such as manure) have the positive effects potential for physical, chemical and biological properties soil [13–15]. However, there is still insufficient information about the effects of manure on soil physical quality indicators. The use of manure as a fertilizer is a common practice, it has been widely used as a natural amendment to improve soil fertility and increase crop yield [16,17]. The addition of manure reduces the bulk density of the soil [18]. Similarly, organic materials, such as green manure, have been used to improve degraded soils [5,19].

However, maintaining long-term soil aggregate stability by applying fresh organic residues is difficult because of the rapid degradation of the traditional amendment. Among the organic soil amendment, biochar is considered to be more stable than others as a nutritional source for soil [20]. Biochar amendment affects different soil properties [21–23]. Biochar can also be used as a soil conditioner to improve yields [24].

Biochar is characterized as a very light material with high porosity and surface area, which changed some of the soil physical properties, such as bulk density, water holding capacity, surface area, and penetration resistance [25]. Other studies have also reported that biochar is more efficient than compost in reducing the bioavailability of Zn and Cd, as biochar can increase the pH above the ground compost [26,27]. Biochar can be a potential agent for carbon sequestration as well as a natural fertilizer to improve the soil properties [28]. Biochar contains calcium, potassium, phosphorus, magnesium, and other elements that can act as an agent for liming of acidic soils. This step could increase the capacity of storing nutrients, water retention, soil pH, and crop's yield found that biochar increases soil pH [29–31], electrical conductivity, cation exchange capacity, organic carbon, organic matter, total nitrogen, cation exchange, and available phosphorus in the soil. The application of biochar has been shown to increase soil fertility by improving the macro and micronutrient status [32]. Inal et al. [33] and Zheng et al. [34] reported that biochar can reduce the acidity of the soil and improve the soil nutrients in field and pot experiments.

While much attention has been given to the effect of biochar on soil chemical properties, the data is scarce on the impact of biochar on soil's physical quality indicators [35]. The information about biochar and organic fertilizer types in influencing the soil properties would be beneficial to maximize the profits in a soil application. The soil type is one of the important factors to see the impact of biochar usage, but the raw materials of biochar cannot be ignored either. Several studies confirmed that the raw material's nature is a key factor to understand the differences in the composition and function of biochar elements which in turn have an impact on the performance of the biochar as a soil amendment. The aims of the study are (1) to evaluate the effectiveness of soil amendment to second maize plantation season to soil organic matter and physical properties in different soil types and (2) determine the best soil amendments treatment for each soil type.

2. Materials and Methods

2.1. Biochar and organic fertilizer production

Two types of biochar from corn cob and rice husk were made by a fixed bed pyrolysis system with separator and condenser for 4 hours at the temperature of 350–500 °C. The process was done at Tribhuwana Tunggadewi University. Biochar from jengkok tobacco industry waste was produced by pyrolysis extrusion Etia for 15 minutes at a temperature of 700 °C. The process was done at PT. Gudang Garam Tbk. Dried and sieved biochar is more than 2 mm with biochar characteristics was reported by Widowati et al. [36]. Biochar with these characteristics was also used in this study. The inceptisol soil after air drying, as much as 9 kg the were moved into polybags. Biochar or organic fertilizer were applied singly, respectively 300 g pot^{-1}, but the treatment of biochar mixed with organic fertilizer, respectively as 150 g pot^{-1}. Soil and biochar and organic fertilizer were mixed thoroughly and incubated for 7 days after that the corn is planted. Measurement of soil physical properties after maize harvested at 112 days. Crushed corn cob (size < 2 mm), jengkok, and rice husk biochars were directly applied to the soil in the pot. Two manure organic fertilizers were produced from chicken manure and compost from municipal waste. Chicken manure was taken from the Java Comfeed, Ltd. Organic waste compost was taken from an integrated waste treatment plant in Mulyoagung Village, Dau District, Malang Regency.

2.2. Soil treatment

The soil sample was taken from the Southern region of Malang as the soil characteristics in this area varied greatly. Geographically, the sampling sites were: (1) District Donomulyo (112°23'30''–112°29'64'' E and 8°16'75''–8°19'81'' S) is located in the high lands, with little or no soil profile of development in soil minerals, yet undergo further development so that it has a layer of the shallow horizon (soil depth < 30 cm), and relatively young with poor soil nutrients and high clay fraction (entisol lithic subgroups); (2) Subdistrict Kalipare (21.95°–29.61° E and 9.40°–16.48° S) is located on the slopes of Mount Kendeng, which is an agricultural area without an irrigation system, resulting in dryland/rainfed agricultural soil. The clay fractions are high and hard so not many plants that can grow (inceptisol); and (3) District Poncokusumo (8°0'23'' S, 112°46'40'' E) which has young soil without soil profile development of the. The soil is dominated by sand (entisol) with low water-holding ability, poor soil organic matter, and low cation exchange capacity that causes the high-nutrient leaching.

Three different types of agricultural land, two types of clay (inceptisol and entisol lithic subgroups) and one type of sandy soil (entisol) soil samples were taken from the soil surface (0–30 cm) in the composite. The pots were randomly placed in the field by the soil type with a distance of 80 × 25 cm.

2.3. Experimental design

The trial was set in a nested design with three repetitions. There were eight varieties of corn in each treatment so there were 864 polybags in total. Three types of soil (the first factor) and soil amendment (the second factor that was nested in the first factor) made up 12 treatments, namely: 1. Control, 2. Corn cob biochar (CB), 3. Rice husk biochar (RB), 4. Jengkok biochar (JB), 5. Compost (Cs), 6. Chicken manure (M), 7. Corn cob biochar + compost (CBCs), 8. Corn cob biochar + manure (CBM), 9. Rice husk biochar + compost (RBCs), 10. Rice husk biochar + manure (RBM), 11. Jengkok biochar + compost (JBCs), 12. Jengkok biochar + manure (JBM). Biochar and organic fertilizers were applied according to treatment on May 7, 2017. The corn was planted in the first planting season (PS-I) on May 19, 2017, and harvested on September 4, 2017. The roots of the plants and stems were not harvested. For PS-II, the corn was grown and harvested on August 7, 2018, and December 20, 2018. The observations of soil organic matter and the physical properties of the soil were conducted on January 18, 2019. During PS I and II, a plant cultivated 100 kg of P_2O_5 ha^{-1} (simultaneously planting) and 110 kg of K_2O ha^{-1} and 135 kg of N ha^{-1} (1/3 dose at age 7 and 2/3 dose days after planting/ DAP when 28 DAP).

2.4. Measurements and statistical analysis

Intact soil samples (a ring with 5 cm diameter of and 5.5 cm height) from a 15 cm depth from the surface were taken for soil physical properties measurement. The soil samples to measure the soil organic matter levels were the composite taken from the surface (0–20 cm). Both samples were taken from the PS-II soil. The corn yields were measured on the dry corn (moisture content 10–15%) of 3 plant samples.

Soil pH is measured for H_2O (1:1); the organic carbon content was measured using Walkey and Black methods; Saturated Hydraulic Conductivity (SHC) was measured by the constant head method, and; the soil texture was assessed by hydrometer method. To measure the water retention capacity of the soil, the ground was saturated with water (pF = 0), and then allow the water to flow. After that, the pressure was applied from below. Good available water for plants if the water retention is between pF = 2.5 and pF = 4.2. Soil dry weight, which was corrected for the number of roots and gravel and dried at 105 °C was used to determine the soil bulk density (BD) and the weight of the soil particles (SP). Soil porosity was the result from the following formula Eq (1):

$$(1 - (BD/SP)) \times 100 \quad (1)$$

Soil macropores were obtained from the difference in water levels between pF = 0 and pF = 2.5 and then multiplied by 100. The micropores were calculated from water content at pF = 4.2 multiplied by 100. The mesopore water content was obtained from the difference between pF = 2.5 and pF = 4.2. The data were analyzed with SPSS software version 23.0 (IBM, USA) according to the study design and analysis of variance (ANOVA) followed by Duncan Multiple Test post-hoc test with α = 5%.

3. Results and discussion

3.1. Soil amendment influence on the soil organic matter after two years of application

Organic fertilizers are very popular because they can overcome the lack of nutrients in plants and organic materials in the soil. Organic fertilizer acts as a buffer and maintains soil moisture. There are some traditional ways to improve soil organic matter, such as ground cover, leaving crop residues after harvest, and applying manure. However, it is often difficult to do because of water availability and salinity problem [37]. The application of the soil amendment plays an important role in improving the physical quality of the soil. Novak et al. [38] stated that the increased porosity of biochar can increase the soil's water retention. Soil water-holding capacity and water availability to the plants in clay and sandy loam soil can be enhanced with biochar [39–41]. Biochar increases the soil pH between 0.34 to 1.51 points, the soil organic carbon by 2.20% to 2.34%, and the microbial activity by 496–1615 mg kg^{-1} compared to controls after 140 days [42].

Biochar is one of the soil amendment products that has been known for many years, but it is now being rediscovered. Several studies conducted worldwide have shown a positive role in environmental protection, agriculture, and waste management of the biochar [43]. The positive effects of biochar on soil properties are realized through increased soil fertility. Scislowska et al. [44] explain that biochar, regardless of origin, significantly increasing the pH of all types of soil (0.1–0.9 units), improving the carbon content of the soil, and soil's water holding capacity by a certain degree based on the type of soil. Fryda and Visser [45] reported that one size-fit all biochar production may not be suitable for all soil type characteristics.

This study aimed to increase the levels of soil organic matter on dry land. Soil organic matter can contribute to soil aggregation and eventually increase the soil aggregate stability, which is one of the important indicators of soil quality. Arthur et al. [46] observed no correlation between soil organic carbon and soil aggregation when fixed with 7.5 t ha^{-1} of manure. Biochar in the soil can increase soil aggregate stability [47]. According to Fungo et al. [48], biochar application alone does not affect the stability of aggregates in ultisol within two years. However, when applied together with *T. diversifolia*, the proportion of soil aggregates increase and eventually increase the micro soil organic matter aggregate.

All the soil amendment applications significantly affect soil organic matter in entisol lithic subgroups and inceptisol soil. Jengkok biochar increased the highest soil organic matter while manure was the lowest with no difference from controls on entisol type of soil, Table 1. Both single and combined with organic fertilizer showed a distinct improvement of soil organic matter in entisol and entisol lithic subgroups. In entisol, the soil organic matter improvement was the highest after jengkok biochar, followed corn cob biochar, and then lastly corn cob biochar. The combined use of all biochar with manure or compost resulted in a relatively similar soil organic matter with control after two years of application. Soil organic matter of entisol was different from entisol lithic subgroups. Corn cob biochar treatment increased the soil organic matter significantly in entisol lithic. The increase was followed by the combination of corn cob biochar + compost and jengkok biochar + manure, Table 1. Soil moisture, oxygen supply, and clay content will affect the decomposition of soil organic matter. Therefore, it highlights the importance of biochar application as a potential organic amendment to improve the soil quality in the long term. Three types of biochar used in this study show the various effect based on the types of soil, Table 1. Organic matter content was increased when compared to control in three types of soil. The biochar that affects the soil organic matter in the entisol lithic subgroup was a corn cob, while tobacco affects the entisol. The increase in soil organic matter was not followed by the improvement in the physical properties of soil in any kind of soil and the crop yield. Best crop yields are not produced from the highest levels of organic matter in each type of soil. Increasing soil organic matter provided by biochar can improve or degrade some physical properties of soil in each soil type [49]. Some soil properties, such as the organic matter percentage, phosphorus, sulfur, and zinc content was significantly increased when biochar is applied with or without the recommended dosage of NPK compared to controls. Understanding the effect of each type of biochar and organic fertilizer would be beneficial to maximize the benefit in a particular type of soil.

The quality of organic fertilizer is influenced by the composition of the base material and the level of decomposition. In this study, manure or compost provides a relatively equal influence on soil organic matter after 2 years in each soil type. The soil organic matter content is rapidly declined with sole manure application in the entisol and entisol lithic subgroup. Changes in soil organic matter and soil physical properties also have the effect of fresh organic matter from the roots of corn during the first growing season. Pandit et al. [50] state that biochar increases soil moisture, available potassium, and phosphorus. Biochar is much more effective if the groundwater is plentiful (+311% biomass) than in the water shortage condition (+67% biomass). Other than that, biochar has a stronger effect on nutrient depressed conditions (+363%) than nutrient-rich ones (+132%). Each corn planting season (I and II), the urea, SP_{36} and KCl fertilizers certainly improves the growth and yield so that the fresh organic matter was added through the crop's roots.

Table 1. Results DMRT soil organic matter, soil bulk density, soil particle and porosity on the type of soil.

Treatment	Soil organic matter (%)			Bulk density (g cm^{-3})			Soil particles (g cm^{-3})			Porosity (%)		
	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol
Control	1.36 a	1.19 a	1.21 abc	1.2 c	1.3 e	1.3 ns	2.1 a	2.2 a	2.3 ns	43.8 a	41.2 a	45.1 a
CB	3.76 g	2.07 b	1.63 de	1.0 a	0.9 a	1.1 ns	2.5 cd	2.4 cd	2.5 ns	60.6 c	61.5 d	54.2 b
RB	2.52 cde	2.05 b	1.19 abc	1.0 a	0.9 a	1.2 ns	2.4 bcd	2.5 e	2.5 ns	60.2 c	60.8 d	52.6 b
JB	2.71 de	2.36 b	1.72 e	1.0 a	0.9 a	1.1 ns	2.3 abc	2.3 bc	2.4 ns	54.2 b	61.4 d	52.1 b
Cs	2.54 cde	2.09 b	1.26 abcd	1.1 ab	0.9 a	1.1 ns	2.4 bcd	2.3 ab	2.5 ns	53.6 b	61.0 d	53.4 b
M	2.39 c	2.13 b	0.96 a	1.1 ab	0.9 a	1.1 ns	2.4 bcd	2.6 e	2.5 ns	57.0 bc	61.5 d	54.7 b
CBCs	3.03 f	1.98 b	1.54 cde	1.1 ab	1.1 cd	1.1 ns	2.4 bcd	2.5 de	2.4 ns	56.1 bc	54.0 b	52.9 b
CBM	1.99 b	2.18 b	1.41 bcde	1.1 ab	1.2 d	1.1 ns	2.4 bcd	2.5 de	2.4 ns	55.9 bc	53.3 b	52.7 b
RBCs	2.36 c	2.01 b	1.06 ab	1.0 a	1.0 ab	1.1 ns	2.3 ab	2.4 bc	2.3 ns	56.3 bc	57.4 bcd	51.9 b
RBM	2.76 e	2.08 b	1.27 abcd	1.0 a	1.0 ab	1.1 ns	2.3 ab	2.4 bc	2.4 ns	57.0 bc	60.0 cd	55.7 b
JBCs	2.44 cd	2.26 b	1.20 abc	1.1 b	1.0 ab	1.1 ns	2.6 d	2.3 bc	2.4 ns	53.9 b	55.4 bc	51.8 b
JBM	3.09 f	2.40 b	1.36 bcde	1.1 b	1.0 ab	1.1 ns	2.4 bcd	2.4 bc	2.3 ns	54.0 b	57.7 bcd	53.3 b

Note: Different notations show the difference between fertilizer and biochar types in each soil but the same notation shows no difference; DMRT test with $\alpha = 5$.

3.2. Soil amendment influence the physical properties of the soil

Soil texture determines the potential soil fertility because it can affect the water-holding capacity and the water movement in the soil. Gwenzi et al. [51] said that biochar potentially improves soil and crop productivity through the increased nutrients content, soil water availability, acid soil improvement, and the stimulation of microbial diversity and activity. Although two types of soil in this study have the same clay texture, any type of soil amendment gave a different effect on the sand content. Sand content was increased by 68% after corn cob biochar application but the other treatments showed a relatively similar effect with an average rise of 15.4% in entisol lithic subgroups. In contrast, an increase of 83.7% in sand content was observed after corn cob biochar, manure mixed with rice husk biochar or jengkok biochar application in inceptisol. The joint use of corn cob or jengkok biochar with manure contributes better to the increased sand content level than single-use, except for corn cob biochar, Table 2. In line with Zhang et al. [52], rice straw mixed with biochar could be the key to restoring degraded land. Similarly, combining biochar and compost to soil also improves soil fertility. The effect of compost has been well-known to improve soil characteristics, including soil structure and water retention [53–56]. In contrast, sand content after manure application was decreased by 12.9% in entisol. The use of three types of biochar and compost, when given by its own or mixed, showed a relatively equal decrease in sand levels a 5.2% decrease in average.

The dust percentage in various types of soil tends to be similar to the control in entisol lithic subgroups, except jengkok biochar combined with manure, and in entisol, except corn cob biochar. But, it is observed that the increase of dust percentage was very prominent in inceptisol soil type after jengkok biochar or corn cob biochar + compost application, followed by organic fertilizer treatment. In entisol, the increase was observed after corn cob biochar and manure treatment. Texture and soil pore space will affect the soil water retention ability. The coarse sand fraction is dominated by the space between the particles, which causes rapid drainage, fewer nutrients, and is sensitive to drought. Dust held more water but slow in drainage. Compared to clay, which has very small pore spaces and interconnected, water movement becomes very slow, but clay soil is highly capable of absorbing water even though not all of the water is available to plants to absorb [57].

Pravin et al. [58] reported the levels of soil organic matter determines the weight of the soil contents. The results of this study indicate that increased soil organic matter content can both reduce bulk density and increase the soil particles. The application of biochar lowers the soil density from 1.4 to 1.1 Mg m^{-3} in highly weathered soils in Asia with low soil fertility and high soil erosion potential [8]. The results are consistent with the value of soil bulk density was much lower after treated by organic amendments rather than without amendment and NPK fertilizer [59]. Compared with NPK only application, NPK with biochar is more effective in improving soil organic carbon content. The application of biochar to improve soil bulk density [60].

The provision of soil amendment can increase the porosity of the three types of soil. Soil porosity was higher on a single type (biochar or organic fertilizers) than the combined use in inceptisol. The corn cob and rice husk biochar application showed similar results and were better than other treatments on entisol lithic subgroups, Table 2. Soil porosity of entisol showed the same results on all types of soil amendment.

Table 2. Results DMRT sand, silt, clay and soil texture on soil type.

Treatment	Sand (%)			Dust (%)			Clay (%)			The soil texture		
	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol
Control	12.2 a	9.2 a	80.6 d	12.4 a	24.9 abc	17.7 ab	75.4 b	65.9 e	1.7 ns	loamy	loamy	sandy sand
CB	20.5 c	18.0 d	72.3 ab	17.0 ab	22.7 ab	26.3 d	62.5 a	59.3 dac	1.4 ns	loamy	loamy	sandy sand
RB	13.7 ab	12.0 bc	76.5 dac	16.2 ab	27.6 cdef	20.2 ab	70.1 ab	60.4 bcd	3.3 ns	loamy	loamy	sandy sand
JB	13.9 ab	11.6 abc	77.5 bcd	20.1 ab	30.0 f	17.3 ab	66.0 a	58.4 abc	5.2 ns	loamy	loamy	sandy sand
Cs	15.3 abc	13.5 c	74.4 abc	20.0 ab	29.6 def	22.2 bcd	64.7 a	56.9 a	3.4 ns	loamy	loamy	sandy sand
M	15.3 abc	12.7 bc	71.4 a	18.3 ab	29.7 ef	25.9 cd	66.4 a	57.6 ab	2.7 ns	loamy	loamy	sandy sand
CBCs	16.7 abc	10.6 ab	76.7 dac	15.0 a	29.6 f	21.7 bcd	68.3 a	59.8 dac	1.6 ns	loamy	loamy	sandy sand
CBM	17.3 bc	13.5 bc	78.2 cd	19.7 ab	25.3 bc	20.2 ab	63.0 a	61.2 cd	1.6 ns	loamy	loamy	sandy sand
RBCs	15.7 abc	11.3 abc	77.4 bcd	18.3 ab	26.5 cde	18.0 ab	66.0 ab	62.2 d	4.6 ns	loamy	loamy	sandy sand
RBM	16.7 abc	16.7 d	79.3 cd	13.7 a	21.7 a	16.0 a	69.6 a	61.6 cd	4.7 ns	loamy	loamy	sandy sand
JBCs	15.5 abc	13.1 bc	76.8 bcd	17.0 ab	26.3 cd	20.0 ab	67.5 a	60.6 bcd	3.2 ns	loamy	loamy	sandy sand
JBM	13.7 ab	16.1 d	74.6 abc	24.1 b	23.0 ab	21.3 bc	62.2 a	60.9 bcd	4.1 ns	loamy	loamy	sandy sand

Note: Different notations show the difference between fertilizer and biochar types in each soil but the same notation shows no difference; DMRT test with $\alpha = 5\%$.

Corn cob biochar increased the sand percentage on entisol lithic subgroups and inceptisol. Inceptisol, in particular, the increase was the same for manure combined corn cob biochar and jengkok biochar. In contrast, a decline in sand percentage was observed after manure application. Dust was increased after jengkok biochar combined with manure application (JBM) on entisol lithic subgroups. On the other hand, jengkok biochar with compost and corn cob biochar combination showed a better increase in the dust percentage than other treatments. Corn cob biochar showed the highest contribution to dust percentage increase on entisol.

The soil amendment lowered the clay content in entisol lithic subgroups but no real effect on entisol was observed. Compost was the best in reducing the clay percentage in inceptisol, Table 3.

The hydraulic saturated conductivity was increased in entisol lithic subgroups and decreased in entisol, but no real effect on inceptisol was observed after the soil amendment application. The highest observed increase in entisol lithic subgroups came from manure combined with corn cob or rice husk biochar, Table 4. While the lowest decline was observed after corn cob biochar application on entisol.

Table 3. Results DMRT saturated hydraulic conductivity and water content on soil type.

Treatment	Saturated hydraulic conductivity ($cm\ h^{-1}$)			Water content (pF) 0 ($cm^3\ cm^3$)			Water content (pF) 2.5 ($cm^3\ cm^3$) (Field capacity)			Water content (pF) 4.2 ($cm^3\ cm^3$) (Wilting point)		
	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol
Control	1.7 a	5.4 ns	32.2 d	0.52 a	0.44 a	0.57 c	0.41 ns	0.30 a	0.26 ns	0.33 f	0.17 a	0.13 ab
CB	9.7 b	11.8 ns	10.5 a	0.60 b	0.61 de	0.48 ab	0.42 ns	0.37 cde	0.29 ns	0.19 cd	0.32 f	0.09 a
RB	9.0 b	10.7 ns	11.3 ab	0.60 b	0.62 e	0.48 ab	0.39 ns	0.39 de	0.31 ns	0.19 cd	0.25 cde	0.13 ab
JB	13.2 b	9.3 ns	14.5 abc	0.60 b	0.61 de	0.49 b	0.38 ns	0.39 de	0.30 ns	0.17 abc	0.28 def	0.13 ab
Cs	8.4 b	9.8 ns	13.8 abc	0.57 ab	0.60 de	0.49 b	0.36 ns	0.39 de	0.27 ns	0.20 de	0.23 bc	0.16 b
M	12.8 b	12.0 ns	21.3 c	0.58 ab	0.61 de	0.49 b	0.39 ns	0.39 de	0.32 ns	0.18 bcd	0.24 cd	0.13 ab
CBCs	9.8 b	9.5 ns	17.9 abc	0.62 b	0.53 c	0.50 b	0.42 ns	0.34 abc	0.31 ns	0.19 bcd	0.28 def	0.15 b
CBM	19.8 d	11.4 ns	13.1 abc	0.58 ab	0.58 d	0.46 ab	0.39 ns	0.38 de	0.28 ns	0.16 ab	0.29 ef	0.14 b
RBCs	18.8 cd	9.2 ns	19.8 bc	0.60 b	0.59 d	0.45 ab	0.42 ns	0.39 de	0.29 ns	0.22 e	0.29 ef	0.15 b
RBM	23.0 d	11.5 ns	14.9 abc	0.63 b	0.61 de	0.45 ab	0.42 ns	0.42 e	0.28 ns	0.14 a	0.27 cdef	0.15 b
JBCs	9.5 b	10.1 ns	14.7 abc	0.61 b	0.51 b	0.41 a	0.42 ns	0.32 ab	0.24 ns	0.18 bcd	0.19 ab	0.12 ab
JBM	14.2 bc	10.9 ^{TN}	18.1 abc	0.61 b	0.55 c	0.44 ab	0.42 ^{TN}	0.35 bcd	0.27 ^{TN}	0.18 bcd	0.25 cde	0.12 ab

Note: Different notations show the difference between fertilizer and biochar types in each soil but the same notation shows no difference; DMRT test with $\alpha = 5\%$.

The soil water content (pF 0) was increased in entisol lithic subgroups and inceptisol but declined in entisol. The soil amendment application resulted in the same water content volume in entisol lithic subgroups and entisol. In contrast, husks biochar provide the highest water content volume in inceptisol. The water content of the soil (pF 2.5) was not significantly different among all treatments in entisol lithic subgroups and entisol soil types, but significantly different in inceptisol. Corn cob biochar combined with manure showed the highest water levels. Soil amendment application showed a significant effect on the soil water content (pF 4.2), especially in entisol lithic subgroups and inceptisol. The decline in groundwater levels was observed in the control treatment. The highest water capacity of wheat biochar followed by corn biochar [60].

Corn cob biochar combined with manure was the best to increase the percentage of mesopores on entisol lithic subgroups. But corn cob and rice husk biochar showed the same increase in mesopore yet still better than other treatments on entisol. Compost showed the highest increase of meso pore in Inceptisol, while the application of single corn cob biochar or in combination with compost showed a decline of meso pore in inceptisol. Each type of soil amendment can increase the macropores in clay soils and lowering the macropores in sandy soils. Jengkok biochar was the best to increase in the percentage of macropores on entisol lithic subgroups while corn cob biochar was the best on inceptisol soil.

Table 4. Results DMRT pores and weight of corn on soil type.

Treatment	Macro pores (%)			Meso pore (%) (Water available)			Micropore (%)			Weight of corn (t ha^{-1})		
	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol	Entisol lithic subgroups	Inceptisol	Entisol
Control	11.1 a	13.7 a	30.8 c	7.5 a	12.9 bcd	12.9 abc	33.2 e	16.9 a	8,8 a	4.39 a	3.48 a	2.80 a
CB	17.8 b	23.7 d	19.0 ab	23.1 bcd	15.5 de	20.1 e	19.0 bc	31.8 f	13,3 b	5.07 ab	6.54 b	5.42 b
RB	21.0 cd	22.7 cd	16.8 a	20.7 bcd	14.7 cde	18.5 e	18.6 bc	24.7 cde	12.5 ab	5.90 bc	6.93 b	6.15 cde
JB	21.5 d	21.3 bcd	18.7 ab	21.7 bcd	11.3 bcd	17.2 cde	16.6 ab	28.0 def	12.6 ab	5.40 abc	6.43 b	5.81 bc
Cs	21.0 cd	18.7 b	21.7 b	16.0 b	18.8 e	11.6 a	20.0 cd	22.8 bc	15.5 b	5.75 bc	6.76 b	6.09 cd
M	19.6 bcd	21.7 bcd	17.3 a	20.1 bc	15.3 de	18.3 de	18.4 bc	24.1 cd	13.4 b	6.59 c	6.65 b	6.62 def
CBCs	19.7 bcd	19.8 bc	19.2 ab	23.4 bcd	5.3 a	16.6 bcde	18.6 bc	28.2 def	14.8 b	5.83 bc	6.51 b	6.79 ef
CBM	19.3 bcd	20.0 bc	18.4 ab	23.5 bcd	8.9 ab	13.4 abc	15.6 ab	29.5 ef	14.1 b	5.93 bc	6.96 b	6.90 f
RBCs	18.1 b	19.5 bc	15.9 a	20.1 bc	10.3 bcd	13.7 abc	22.3 d	29.0 def	15.1 b	6.07 bc	6.68 b	6.36 cdef
RBM	20.8 cd	19.2 b	17.2 a	28.2 d	14.5 cde	12.2 ab	14.1 a	27.2 cdef	15.3 b	5.84 bc	7.68 b	6.48 cdef
JBCs	18.9 bc	18.5 b	17.2 a	24.1 cd	13.0 bcd	11.8 a	18.3 bc	19.3 ab	12.3 ab	5.66 bc	6.70 b	6.31 cdef
JBM	18.7 bc	19.9 bc	17.8 a	24.0 cd	9.7 abc	14.2 abcd	18.3 bc	25.3 cde	12.5 ab	6.20 bc	6.35 b	6.50 def

Note: Different notations show the difference between fertilizer and biochar types in each soil; DMRT test with α = 5%.

Each type of soil showed different changes in micropores after the application of the soil amendment. Micro pores have declined on entisol lithic subgroups but increased in entisol and inceptisol after applications. The highest decline in micropores was observed after corn cob biochar combined with manure (CS + Pk) application. Almost all types of soil amendments showed similar micro pores percentage compared to controls on entisol lithic subgroups. The biggest increase in micropores was observed after corn cob biochar application in inceptisol. However, the increased micropores in entisol were relatively similar to other soil amendment types, Table 4. The results showed that each type of soil amendment changes in the percentage of micropores depends on the soil type and interestingly, similar soil texture could have a different effect. It was increased the micropores in inceptisol but decreased in entisol lithic subgroups, and relatively equal in entisol. Husk biochar combined with manure application is more effective than corn cob biochar cob combined with compost on entisol lithic subgroups. As with the inceptisol, corn cob biochar is superior to improve the micropores. In contrast, all kinds of soil amendments contribute the same as control except corn cob biochar on entisol.

The soil amendment application increased soil porosity. Increased soil porosity resulting in a three-fold increase in surface area which leads to the increased water-holding capacity of biochar [61]. Biochar contributed to the increase in soil porosity of entisol and inceptisol. The use of different types of biochar and organic fertilizers in a single application was better than combined in inceptisol type. While in the entisol lithic subgroup, the use of both single or combined showed similar results.

Saturated Hydraulic Conductivity determines the water volume that goes into the ground. The biochar influence on the establishment of a macro aggregate was deeper in sandy loam soil than in clay dust [62]. The addition of biochar significantly increases the formation of macro aggregate and slightly increases the Saturated Hydraulic Conductivity of the soil. The changes in soil structure increase saturated water content while residual moisture content was decreased by the biochar amendment. The results showed that the application of soil amendment contributes to Saturated Hydraulic Conductivity differently on clay soil, one is increased in the entisol lithic subgroup while another was similar to control. Each type of biochar and organic fertilizer contributed equally to the Saturated Hydraulic Conductivity increase in the entisol lithic subgroup. The use of biochar mixed with manure produced a higher Saturated Hydraulic Conductivity than mixed with compost on the entisol lithic subgroup. Each type of soil amendment influences relatively similar to the decline of Saturated Hydraulic Conductivity on entisol soil type. Poultry biochar application was significantly lower ($p < 0.05$) compared to other organic amendments. Compost, biochar fertilizer, and non-compostable produce better corn growth and the yield that were significantly higher compared to the control treatment.

Macro pores are increased in clay soils but decreased in sandy soil. In general, the soil amendment application relatively increases the macropores on entisol lithic subgroups and Inceptisol, except for jengkok and corn cob biochar. The decrease in macropores will have an impact on increasing the ability of the soil to hold water will have an impact on improving the ability of the soil to hold water and aeration. Soil aeration for oxygen in the soil which is crucial for plant root respiration [63]. Soil aeration is highly dependent on the groundwater, soil texture, and porosity. Soil with higher clay content will decrease soil porosity.

Micro pores (slow drainage) is the determinant for soil's water-holding capacity. The research result of Hseu et al. [64] showed that the porosity and size of aggregates increased after being given biochar, by 16% to 22% and 0.59 mm to 0.94 mm. Water availability was observed to increase significantly in the biochar-treated soil due to an increase in micropores.

The retained groundwater from field capacity (pF 2.5) until the permanent wilting point (pF 4.2) is called the soil water availability, which indicates the water volume that can be absorbed directly by plants. According to Karhu et al. [65], water-holding capacity has a very important effect on drought-prone land. Increasing available water on soil would be beneficial to plants. According to Ma et al. [59], increasing water retention in the soil can be attributed to an increase in soil organic carbon and aggregate stability. The significant correlation between organic carbon content and water and the average diameter of the aggregates confirmed the relationship between the improvement of soil structure and its ability to supply water. Research result by de Melo Carvalho et al. [60] showed the biochar effects on soil water retention capacity was associated with the effect of the porosity of sandy loam soil. It was further reported that the use of biochar as a soil amendment could be a viable strategy to ensure the stability of the results under short-term limited water conditions.

Retention of soil moisture at field capacity (pF 2.5) of the clay soil showed different results: it was not significant on the entisol lithic subgroup but significant on inceptisol and entisol. Soil amendment increases water-holding capacity or field capacity of inceptisol soil. Field capacity indicates the maximum amount of water that can be retained by the soil against the gravity. In this situation, most of the soil micropores are still filled with water which also available for plants. The use of biochar and organic fertilizer alone or blended showed the same soil moisture retention, except for compost mixed with jengkok or corn cob. Wang et al. [66] stated that soil moisture was increased but not on plant growth after biochar application.

Permanent wilting point (pF 4.2) indicates the soil moisture availability is lower than the plant requirement thus plants will wilt permanently. Almost any type of soil amendment gives the same contribution to decrease the wilting point, except for corn cob biochar combined with compost or manure.

3.3. Soil amendment affect the maize yield of on three types of soil

The soil amendment showed a significantly different effect on the outcome of dried corn in every soil type. The best corn yield was observed on entisol lithic subgroups after manure treatment (6.6 ± 1.4 t ha^{-1}) while the other soil amendment tends to have a similar increase (5.2 ± 1.5 t ha^{-1}). In inceptisol, various types of soil amendments produced a relatively the same average (6.7 ± 1.2 t ha^{-1}). In contrast to the entisol, the best yield was observed to be the corn cob biochar combined with manure application (6.9 ± 0.98 t ha^{-1}), whereas the other soil amendments were 6.3 ± 1.1 t ha^{-1}.

Biochar application increases wheat grain and straw yield by 15.7% and 16.5% respectively, and the root biomass by 20% [67]. This suggests that biochar retains nutrients and water to increase grain productivity. The fresh and dry weight of tomatoes, pepper, and lettuce were recorded to increase after biochar treatment than other treatments. Similarly, according to Akca and Namli [68], soil amendment with biochar increases the plant yield, enzyme activity, soil organic matter content, and improve soil properties.

Manure increased the crop yield by 50.1%, while other types of soil amendment only 18.5% in the entisol lithic subgroups. Different types of soil amendments increased crop yields by 92.5% in inceptisol. It seems that the best crop yield at entisol lithic subgroups was the result of the variations of the soil physical properties due to manure application even though it showed the lowest levels of organic matter at the end of the observation. Although the use of jengkok biochar gave the highest in the improvement of soil organic matter, the physical properties of the soil also affect the outcome of the crop yield. According to Schnell et al. [69], the level of nutrients in biochar amendments was significantly lower than inorganic fertilizers. Three types of biochar improve the soil properties and increase crop yield and nutrient accumulation in grains of pea plants [70]. Biochar increases the availability of nutrients for plants and improves the quality of the soil for plant growth. According to Chan et al. [20], the addition of biochar promotes positive changes in soil quality, such as acidity improvements, increased cation exchange capacity, and improve the environment for root growth. This increases the efficiency of nutrient absorption by plants.

The corn crop is planted on sandy soil with low soil organic matter, available nutrients, and water-holding capacity. For this reason, adding biochar could lead to an increase in water and nutrient retention. Biochar cane and *eucalyptus* waste can improve soil aeration and water infiltration [71]. The use of soil amendment on clay soil will give a different effect on increasing crop yields. The availability of resources, such as water and nutrients, is a major determinant of biomass production and its partitioning between roots and shoots [72]. This implies that any kind of soil requires specific amendment material input to get the most effective crop yields. Soil organic matter is not the only determinant of crop yield but there are still physical soil properties that also affect the yield. The results of this study, especially on clay soil, were in line with Yeboah et al. [73], which showed the benefits of the combined application of manure and biochar for better maize production. Surprisingly, the results of this study were not in line with the Jeffery et al. [74], who conducted a meta-analysis to investigate the constraints report that land and crop yield increases by 25% in tropical soils with the addition of biochar was largely through the influence of liming and nutrient (nitrogen and retention of potassium, phosphor, and potassium availability). Conservation agriculture is precision farming, which combines minimum tillage, crop rotation, and residue retention. Biochar amendment could be a part of that combination which could improve crop's yield on sandy acid soils, but no significant effect on yields of corn on neutral clay soil [27]. Biochar composition can affect crop yields and soil biota, in some cases increasing soil microbial and in other cases causing toxic effects [75]. Likewise organo-mineral fertilizers [2:10:1 (w/w/w) mixture of sulfur, compost and potassium humic] as much as 5 and 10 t ha^{-1} significantly increased the cucumber and reduce the effects of water stress [76]. But organo-mineral fertilizers [5:2:1 (w/w/w) mixture of green waste compost, elemental sulfur (S) and humic acid, respectively] can reduce soil salinity and bulk density and increasing the total porosity [77] and increase field capacity and water available in the newly reclaimed saline soils [78]. The use of organic compost and mulch can reduce the negative effects of water stress and increase grain yield and forage sorghum in the newly reclaimed land [79].

4. Conclusion

In entisol, corn cob biochar mixed with manure decreases saturated hydraulic conductivity (59.3%) and macropores (67.4%), and increased soil organic matter (16.5%), porosity (16.9)%, micropores (60.2%), and maize yield (146.4%) compared to controls. In inceptisol, rice husk biochar mixed with manure decreases the soil bulk density (23.1%), clay fraction (6.4%), water content at the permanent wilting point (41.2%), and increased soil organic matter (135. 3%), soil particle (9.1%), porosity (45.6%), a sand fraction (81.5%), macropores (40.1%), micropores (60.9%), water available (12.4%), the moisture content in the field capacity (30%), and maize yield (120.7%) compared to controls. In entisol lithic subgroups, manure decreases soil bulk density (9%), clay fraction (12.2%), micropores (44.6%), water content at permanent wilting points (45.5%), and improving soil organic matter (75.7%), soil particle (14.3%), porosity (30.1%), a sand fraction (25.4%), dust fraction (47.6), saturated hydraulic conductivity (652%), water available (168%), macropores (76.6%), and corn yield (50.1%) compared to controls.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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