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AGRICULTURE AND NATURAL RESOURCES

Journal homepage: http://anres.kasetsart.org

Research article

# Biochar and organic fertilizer utilization in enhancing corn yield on various types of dryland

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**Article Info**

**Article history:**
Received 29 January 2020
Revised 19 June 2020
Accepted 28 June 2020
Available online 30 December 2020

**Keywords:**
Compost,
Entisol,
Inceptisol,
Soil fertility,
Soil organic matter

**Abstract**

The utilization of organic material on dryland management is generally ineffective in supporting soil productivity. This study evaluated the effectiveness of organic fertilizer and biochar applications on corn yield for various dryland soils. A pot experiment was conducted using three soil types from dryland areas. A nested design was used with three replicates based on biochar and organic fertilizer nested within three different soil types: Inceptisol, Entisol and Entisol lithic subgroup. The biochars were made from corn cobs, rice husks and tobacco industry waste, while the organic fertilizers used were compost and chicken manure. Twelve treatments including a control were planted with the 'Pertiwi' corn variety. The results showed that the highest yields of corn were in the Entisol lithic subgroup (221±2.0 g bag$^{-1}$ with the application of rice husk biochar+chicken manure) and in the Inceptisol (176±0.6 gbag$^{-1}$ with the application of corncob biochar+chicken manure). The application of biochars and organic fertilizers resulted in the same corn yield in the Entisol. Soil fertility improvement, evaluated using chemical properties, produced a better corn yield when the combination of biochar and manure was utilized in all three soil types.

## Introduction

Malang Regency, Indonesia, with an area of 320.3 ha, is ranked as the second-largest area in East Java Province (Department of Agriculture and Food Security, 2013). The Malang Regency area covers 122.6 ha of drylands that have potential to be developed as agricultural land (Central Bureau of Statistics, 2017). Dryland is dominated by several types of soil with various problems (Magray et al., 2014). The low fertility level of soil in the Malang Regency can be prevented by applying organic fertilizer as an agricultural system and is considered sustainable if the soil organic matter is more than 2% (Kullu, 2010; Rosidin, 2013). In the tropical region, organic fertilizer is easily decomposed compared to biochar; however, when they are mixed, the result is more beneficial; for example, adding 10 Mg/ha biochar to compost could increase corn yields by 26%, compared to pure compost (Glaser et al., 2014). The most common organic materials used as soil amendments are manure and compost (Scotti et al., 2015). In this context, compost is a by-product of a recycling process that contains large amounts of humic substances and essential nutrients for plants (Donn et al., 2014).

Compost and Trichoderma spp. have commonly been used to increase corn productivity in drylands (Mahato and Neupane, 2017). However, as compost is easily decomposed in the tropics resulting in the organic material being quickly depleted, biochar has been shown to increase soil fertility and crop yields and to reduce contamination (Ding et al., 2016). The effectiveness of biochar utilization for improvement of soil fertility depends on the source of the biomass used. Widowati et al. (2017) reported that differences in biochar characteristics are related to raw materials and production conditions. The important properties of biochar when it is used

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https://doi.org/10.34044/j.anres.2020.54.6.13

as soil amendments include porosity, pH, water binding capacity, nutrient content and cation exchange capacity (Windeatt et al., 2014). Purakayastha et al. (2013) reported that the highest holding capacity of water (561%) was observed due to the application of wheat biochar followed by corn biochar (456%). According to Uzoma et al. (2011), the cation exchange capacity (CEC) of biochars from different raw materials is the range 4.5–40 $cmol_c$/kg. Production methods did not cause significant variation in the P concentration of biochar, but raw materials produced P variations in the biochar (Ammu and Anitha, 2015). The heterogeneous nature of biochar and organic fertilizers may affect their quality when applied to various types of soil. Hence, the suitability of organic fertilizer and biochar combinations is essential to optimize dryland productivity. This study evaluated the effect of biochar and organic fertilizer application on corn yield in various types of soil of the drylands of the South Malang Regency.

## Materials and Methods

### *Soil, biomass, and organic fertilizer*

A pot experiment was conducted in a field located in Tunggulwulung village Lowokwaru district of Malang. Three soil samples were collected from dryland agroecosystems in southern Malang Regency, which naturally has low fertility. The collected soil samples represented the formation process and development of the soils in the area, namely Entisol (Sumberrejo village, Poncokusumo district), Entisol lithic subgroup (Purwodadi village, Donomulyo district) and Inceptisol (Sukowilangun village, Kalipare district). Composite soil sampling was performed at each sampling location at a depth of 0–30 cm on 15 May 2017. The biomass materials used for producing biochar were corn cobs, rice husks and tobacco industry waste. The rice husk and corn cob biochars were produced using fixed bed pyrolysis equipment at 350–500°C for 4 hr. The tobacco waste biochar was made using an Etia extrusion pyrolysis device at 700°C for 15 min at Gudang Garam, Ltd. The chicken manure and compost were obtained from the PT Java Comfeed Farm and Integrated Waste Processing Site in Mulyoagung village, Dau district of Malang Regency. The characteristics of the soil, biochars, compost and manure are presented in Table 1.

### *Experimental design*

A nested design with two factors was used in the experiment. The first factor consisted of three soil types. Biochars and organic fertilizers were nested in the first factor as the second factor that consisted of 12 (Table 2). Each treatment was repeated 3 times. For each treatment, one seedling of Pertiwi corn variety seeds that had germinated for 7 d was planted in a polybag containing 9 kg of soil. The polybags were randomly placed at a distance of 80 cm ×25 cm based on the soil type for each replicate. The applied rates of biochar (corn cobs, rice husks and tobacco industry waste abbreviated to CcB, RhB andTwB, respectively) and fertilizers (organic compost and chicken manure abbreviated to Cp and CkM, respectively) are presented in Table 2. The biochar, chicken manure and compost were mixed thoroughly with each type of soil according to the respective treatment while water was supplied every 5–10 d to maintain plant growth until harvesting. The soil water content was maintained at 70–80% of field capacity.

Each polybag received equivalent rates of 45 kg N (as urea)/ha, 100 kg $P_2O_5$ (as SP-36)/ha, and 36 kg $K_2O$ (as KCl)/ha at planting. At 28 d after planting (DAP), each polybag received 90 kg N/ha and 72 kg $K_2O$/ha. The corn plant was harvested at 112 d after planting when the moisture content of the corn seed reached 12–15%.

### *Data collection*

The soil organic matter, potassium, calcium, magnesium and sodium contents of the soil were observed at 7 d after mixing (DAM) the soil with biochars and or organic fertilizers, and at the maximum vegetative time of corn growth (56 DAP). The CEC of the soil was observed at harvest (112 DAP) because biochar is relatively resistant to decomposition. Organic C was determined using the Walkley and Black method (Walkley and Black, 1934). Soil organic matter was calculated using the formula: C organic soil × 1.7 (soil organic C was determined based on the results of soil analysis in the laboratory using 1.7 as a constant). The CEC and the exchangeable cations (K, Na, Ca and Mg) were determined by saturation using 1 N ammonium acetate ($NH_4OAc$) at pH 7.0 (Page et al., 1982). K and Na were measured using flame photometry, and Ca and Mg using atomic absorption spectrophotometry.

**Table 1** Characteristics of biochar, compost, chicken manure and soilused in the study

| Parameter | Biochar and organic fertilizer | | | | | Soil | | |
|---|---|---|---|---|---|---|---|---|
| | RhB | CcB | TwB | CkM | Cp | Entisol lithic subgroup | Inceptisol | Entisol |
| pH ($H_2O$ 1:2.5) | 9.4 | 9.5 | 8.9 | 6.0 | 7.3 | 6.4 | 5.3 | 5.6 |
| Total C (%) | 29.8 | 45.6 | 40.0 | | | | | |
| Organic C (%) | | | | 25.0 | 15.6 | 1.4 | 0.7 | 0.5 |
| Ash (%) | 53.4 | 23.6 | 32.8 | | | | | |
| N (%) | 0.6 | 0.5 | 1.8 | 4.1 | 2.6 | 0.2 | 0.1 | 0.1 |
| P (%) | 0.1 | 0.5 | 0.4 | 11.6 | 3.9 | | | |
| P (mg/kg) | | | | | | 45.7 | 45.7 | 10.5 |
| K (%) | 1.7 | 3.9 | 5.2 | 0.3 | 0.1 | | | |
| K (me 100 $g^{-1}$) | | | | | | 0.4 | 0.4 | 0.4 |
| Sand (%) | | | | | | 11 | 9 | 86 |
| Ash (%) | | | | | | 24 | 15 | 3 |
| Clay (%) | | | | | | 65 | 76 | 11 |
| Texture | | | | | | Clay | Clay | Clay sand |

RhB = rice husk biochar; CcB = corn cobs biochar; TwB = tobacco industry waste biochar; CkM = chicken manure; Cp = compost

**Table 2** Treatment for each type of soil

| Symbol | Treatment description | Rate of biochar (g per 9 kg of soil) | Rate of organic fertilizer (g per 9 kg of soil) |
|---|---|---|---|
| Ctr | Control | 0 | 0 |
| CcB | Corncob biochar | 300 | 0 |
| RhB | Rice husk biochar | 300 | 0 |
| TwB | Tobacco waste biochar | 300 | 0 |
| Cp | Compost | 0 | 300 |
| CkM | Chicken manure fertilizer | 0 | 300 |
| CcB+Cp | Corncob biochar + compost | 150 | 150 |
| CcB+CkM | Corncob biochar + chicken manure | 150 | 150 |
| RhB+Cp | Rice husk biochar + compost | 150 | 150 |
| RhB+CkM | Rice husk biochar + chicken manure | 150 | 150 |
| TwB+Cp | Tobacco waste biochar + compost | 150 | 150 |
| TwB+CkM | Tobacco waste biochar + chicken manure | 150 | 150 |

RhB = rice husk biochar; CcB = corn cobs biochar; TwB = tobacco industry waste biochar; CkM = chicken manure; Cp = compost

### *Statistical analysis*

The data obtained were subjected to two-way analysis of variance using the SPSS software (SPSS Inc.; Chicago IL, USA) followed by Duncan's multiple range test at a significance level of 95%.

## Results and discussion

### *Soil organic matter*

The application of biochars and organic fertilizers (single or mixture) increased the organic matter content in the Inceptisol by 2.5±0.0–4.9±0.4% at 7 DAM and by 2.7±0.6–3.7±0.3% at 56 DAP (Table 3). At 7 DAM, the soil organic matter content in the treatment with the mixture of biochar and organic fertilizer was higher than that with a single application of biochar of organic fertilizer. The treatment of tobacco waste biochar mixed with compost and that mixed with manure had similar high organic matter contents at 7 DAM. However, at 56 DAP, the organic matter content of soils was different for the soils treated with tobacco waste biochar, rice husk biochar+compost, tobacco waste biochar+compost and tobacco waste biochar+chicken manure.

The application of biochars and organic fertilizers increased the soil organic matter content in the Entisol lithic subgroup by 2.4±0.0–3.7±0.2% at 7 DAM and by 2.3±0.7–3.7±0.9% at 56 DAP. The highest organic matter content was observed in the treatment of tobacco waste biochar at 7 DAM but the treatment of tobacco waste biochar+compost had the highest organic matter content at 56 DAP (Table 3). The application of biochars and organic fertilizers increased the organic matter content in the Entisol by 1.1±0.1–1.9±0.1% at 7 DAM and by 1.2±0.1–2.0±0.1% at 56 DAP.

At 56 DAP, the application of various organic inputs had no significant effects on the organic matter content in the Entisol (Table 3) probably due to the lower content of soil organic carbon of 0.5% in the Entisol, compared to that of the Entisol lithic subgroup and Inceptisol of 1.4% and 0.7%, respectively. The highest content of organic matter in the Entisol was observed in the treatment of tobacco waste biochar at 7 DAMand 56 DAP (Table 3).

The quality of biochar varies according to the raw material resulting in different improvements in soil fertility. In soil, biochar is much more stable than other soil amendments and so it has a long-term impact (Wang et al., 2016). Organic fertilizer varies in influencing soil fertility because of the different labile fractions of the materials that are readily decomposed. The labile fraction maintains soil chemical fertility primarily as a source of plant nutrients because of the chemical composition of the original material and the rapid rate of decomposition (Scotti et al., 2015). Soil microbial biomass plays a vital role in the sustainability of ecosystems and nutrient cycles (Horwath, 2017). Microbial biomass can provide an effective substrate for nutrient mineralization and improve soil fertility (Vivek and Prafulla, 2011). In addition to the labile fraction, there is also a stable fraction that plays a role in the formation of soil aggregates and the binding of cations in the soil (Guo et al., 2019).

Soil texture affects soil organic matter content. A higher amount of clay may result in higher levels of organic matter and soil N. Increased soil organic matter is important for soil aggregation, soil moisture, nutrient supply and fertilizer efficiency (Adugna, 2016). The current results were in line with the finding of Hamzah et al. (2017) that the use of rice husk biochar and tobacco waste biochar had a positive effect on soil properties, such as increasing the pH, CEC, soil organic matter content and cation availability.

### *Number of exchangeable cations*

The treatments affected the number of exchangeable cations in the following order: biochar <biochar+organic fertilizer <organic fertilizer on the Inceptisol at 7 DAM and 56 DAP (Table 3). Likewise, in the Entisol, the application of the biochar alone or a combination of biochar with organic fertilizer produced a lower number than organic fertilizer at 7 DAM (Table 3). Organic fertilizer is a source of nutrients and biochar is expected to reduce the amount of nutrient loss due to leaching (Sanchez and Tom, 2013; Widowati et al., 2014) hence, a mixture of biochar+organic fertilizer was expected to maintain and increase nutrient levels in the Inceptisol and Entisol.

However, in the Entisol Lithic subgroup, the exchangeable bases were higher after the application of biochar compared to that applied with organic and mixed fertilizers at 7 DAM (Table 3). Biochar directly contributed to the nutrient increase in the Entisol Lithic subgroup, specifically Ca and Mg at 7 DAM. The results showed that the soil type determined the ability of biochar to increase Ca and Mg. Radin et al. (2018) reported that soil chemical properties (pH, amount of C and N, C: N ratio, CEC, Mg and Ca) were enhanced by biochar amendments, compost, and biochar+compost. The exchangeable K, Ca, Na and Mg contents were increased with the application of biochar and organic fertilizer in the Inceptisol.

The increase in exchangeable bases was associated with an increase in the soil CEC (Table 6). The increased soil CEC was associated with the efficient use of nutrients, including fertilizers (Singh and Ryan, 2015). According to Liang et al. (2006), the CEC describes the fertility and soil nutrient retention capacity. Here, some of the influencing factors were the soil pH, soil type, and soil organic matter content (Osman, 2012). Biochar can increase the CEC in soils, especially sandy soils that are poor in nutrients; however, this depends on the nature of the biochar applied in the soil (Kookana et al., 2011). The data presented in Tables 4 and 5 show that the exchangeable K, Na and Mg contents in the soil were relatively the same after the use of the type of biochar and organic fertilizer at 7 DAM and 56 DAP but had decreased at 56 DAP. This was different from the exchangeable Ca content, which increased from 12.9±1.3 – 21.0±4.1cmol$_c$/kg at 7 DAM to 19.2±1.2 – 25.2±3.0cmol$_c$/kg at 56 DAP. The number of also relatively the same with the biochar and organic fertilizer application, both in combination and singly to the Inceptisol (Table 3). The biochar and organic fertilizers made minor contributions to increasing the exchangeable K, Na and Mg contents in the Entisol at 7 DAM. The exchange able K and Na contents at 56 DAP were higher than at 7 DAM, but the exchangeable Mg content at 7 DAM was greater than at 56 DAP in the Entisol (Tables 4 and 5). The exchangeable K contentat 56 DAP was higher than at 7 DAM. The exchange able Na contents for the treatments of cob biochar, husk biochar and tobacco waste biochar at 56 DAP were higher than at 7 DAM. In addition, the exchange able Mg content from the application of husk biochar was higher than other treatments at 7 DAM.

### *Cation exchange capacity*

The application of biochars and organic fertilizer increased the negative charge on the soil CEC in all three types of soil (Table 6). The CEC of the Incepticol was higher after the application of a mixture of tobacco waste biochar and chicken manure compared to the application of tobacco waste biochar and chicken manure, respectively. However, it was different in the other two types of soil after using biochar and mixed organic fertilizer combined or individually. This showed that the type of soil influences changes in the CEC after application of biochar or organic fertilizer. In general, the increase in the soil CEC tended to be the same after the types of biochar and organic fertilizers were applied to the Entisol and Entisol Lithic subgroups, either applied as a mixture or individually (Table 6).

**Table 3** Mean soil organic matter and exchangeable base contents (SD in brackets) after mixing soil with biochar and or organic material in three types of soil

| Symbol of treatment | Soil Organic Matter (%) | | | | | | *Number of exchangeable cations* (cmol$_c$ kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inceptisol | | Entisol | | Entisol Lithic Subgroup | | Inceptisol | | Entisol | | Entisol Lithic Subgroup | |
| | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP |
| Ctr | $1.9^{a}$ | $2.2^{a}$ | $0.5^{a}$ | $1.0^{a}$ | $0.9^{a}$ | $2.1^{a}$ | $16.5^{a}$ | $22.1^{a}$ | $10.4^{a}$ | $9.3^{a}$ | $27.5^{a}$ | $35.7^{a}$ |
| | (0.0) | (0.5) | (0.0) | (0.0) | (0.1) | (0.1) | (1.3) | (0.8) | (0.8) | (0.9) | (5.1) | (1.2) |
| CcB | $2.6^{bc}$ | $2.8b^{cd}$ | $1.2^{bcd}$ | $1.3^{ab}$ | $2.5^{b}$ | $3.1^{bcd}$ | $26.4^{bc}$ | $26.2^{a}$ | $12.3^{a}$ | $10.6^{a}$ | $46.4^{d}$ | $37.5^{abc}$ |
| | (0.1) | (0.4) | (0.2) | (0.2) | (0.2) | (0.3) | (3.0) | (1.7) | (0.1) | (0.5) | (8.7) | (0.6) |
| RhB | $2.5^{ad}$ | $1.9^{a}$ | $0.8^{ab}$ | $1.2^{ab}$ | $3.2^{bcd}$ | $2.5^{abc}$ | $24.3^{ab}$ | $24.5^{a}$ | $10.7^{a}$ | $10.5^{a}$ | $46.4^{d}$ | $39.1^{d}$ |
| | (0.0) | (0.2) | (0.1) | (0.1) | (0.3) | (0.2) | (3.7) | (1.6) | (1.2) | (0.5) | (6.6) | (2.6) |
| TwB | $3.9^{b}$ | $3.7^{d}$ | $1.9^{d}$ | $2.0^{b}$ | $3.7^{e}$ | $3.3^{cd}$ | $27.0^{bc}$ | $25.3^{a}$ | $12.2^{a}$ | $11.9^{a}$ | $38.0^{c}$ | $38.8^{bc}$ |
| | (0.1) | (0.3) | (0.1) | (0.0) | (0.2) | (0.9) | (4.1) | (2.9) | (0.3) | (0.5) | (4.3) | (1.9) |
| Cp | $2.8^{bc}$ | $3.2^{cd}$ | $0.7^{ab}$ | $1.2^{a}$ | $2.6^{bc}$ | $3.2^{cd}$ | $30.1^{c}$ | $32.0^{d}$ | $13.2^{a}$ | $11.6^{a}$ | $32.8^{abc}$ | $36.4^{ab}$ |
| | (0.8) | (0.1) | (0.2) | (0.3) | (0.3) | (0.2) | (5.2) | (0.7) | (1.2) | (1.4) | (0.4) | (0.4) |
| CkM | $3.9^{d}$ | $2.7^{bc}$ | $0.9^{ab}$ | $1.0^{a}$ | $2.5^{b}$ | $3.3^{cd}$ | $31.9^{c}$ | $30.2^{cd}$ | $13.6^{a}$ | $11.0^{a}$ | $35.4^{bc}$ | $38.1^{abc}$ |
| | (0.2) | (0.6) | (0.1) | (0.0) | (0.2) | (0.4) | (6.3) | (0.7) | (1.3) | (0.4) | (1.0) | (1.8) |
| CcB+Cp | $3.2^{c}$ | $2.8^{bcd}$ | $1.1^{bc}$ | $1.2^{a}$ | $2.8^{bc}$ | $3.1^{bcd}$ | $30.7^{c}$ | $29.1^{bc}$ | $12.0^{a}$ | $11.0^{a}$ | $30.4^{ab}$ | $37.4^{abc}$ |
| | (0.4) | (0.6) | (0.1) | (0.5) | (0.7) | (0.0) | (3.7) | (0.6) | (0.5) | (0.3) | (2.2) | (2.3) |
| CcB+CkM | $3.1b^{c}$ | $2.7^{bc}$ | $1.3^{bcd}$ | $1.5^{ab}$ | $2.7^{bc}$ | $3.0^{bcd}$ | $26.3^{bc}$ | $26.7^{ab}$ | $11.7^{a}$ | $11.4^{a}$ | $34.6^{bc}$ | $37.8^{abc}$ |
| | (0.2) | (0.0) | (0.1) | (0.2) | (0.2) | (0.3) | (2.8) | (2.1) | (0.2) | (0.3) | (1.0) | (1.1) |
| RhB+Cp | $4.7^{b}$ | $3.6^{d}$ | $1.1^{bc}$ | $1.0^{a}$ | $2.4^{b}$ | $2.3^{ab}$ | $26.0^{bc}$ | $30.7^{cd}$ | $12.2^{a}$ | $11.8^{a}$ | $33.7^{bc}$ | $37.2^{abc}$ |
| | (1.4) | (1.0) | (0.1) | (0.1) | (0.0) | (0.7) | (4.3) | (3.1) | (1.6) | (1.0) | (0.0) | (0.8) |
| RhB+CkM | $3.2^{c}$ | $2.1^{abc}$ | $1.6^{cd}$ | $1.0^{a}$ | $3.6^{de}$ | $2.5^{abc}$ | $28.2^{bc}$ | $25.1^{a}$ | $11.9^{a}$ | $11.9^{a}$ | $33.3^{bc}$ | $37.3^{abc}$ |
| | (0.3) | (0.2) | (0.1) | (0.3) | (0.8) | (0.2) | (0.2) | (0.9) | (0.2) | (0.9) | (2.4) | (0.9) |
| TwB+Cp | $4.9^{e}$ | $3.6^{d}$ | $1.3^{bcd}$ | $1.6^{ab}$ | $3.3^{cde}$ | $3.7^{d}$ | $28.6^{bc}$ | $30.7^{cd}$ | $12.9^{a}$ | $11.4^{a}$ | $35.0^{bc}$ | $38.7^{bc}$ |
| | (0.4) | (1.2) | (0.0) | (0.2) | (0.8) | (0.9) | (0.8) | (3.4) | (0.2) | (1.1) | (1.3) | (0.9) |
| TwB+CkM | $4.8^{e}$ | $3.4^{d}$ | $1.7^{cd}$ | $1.6^{ab}$ | $3.0^{bcd}$ | $2.8^{abc}$ | $30.0^{c}$ | $27.2^{a}$ | $11.7^{a}$ | $10.7^{a}$ | $36.5^{c}$ | $39.8^{c}$ |
| | (0.3) | (0.1) | (0.0) | (0.4) | (0.5) | (0.1) | (0.4) | (2.5) | (0.1) | (0.4) | (2.9) | (2.2) |

Ctr = control; CcB = corncob biochar; RhB = rice husk biochar; TwB = tobacco waste biochar; Cp = compost; CkM =chicken manure fertilizer; CcB+Cp = Corncob biochar+compost; CcB+CkM = corncob biochar + chicken manure; RhB+Cp = rice husk biochar + compost; RhB+CkM = rice husk biochar + chicken manure; TwB+Cp = tobacco waste biochar + compost; TwB+CkM = tobacco waste biochar + chicken manure; DAM = days after mixing; DAP = days after planting;
Means in the same column with different lowercase superscripts are significant different ($p < 0.05$).

**Table 4** Mean soil potassium and sodium contents (SD in brackets) after mixing soil with biochar and or organic material in three types of soil

| Symbol of treatment | K ($NH_4OAC$ 1M pH: 7) $cmol_c$ $kg^{-1}$ | | | | | | Na ($NH_4OAC$ 1M pH: 7) $cmol_c$ $kg^{-1}$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inceptisol | | Entisol | | Entisol Lithic Subgroup | | Inceptisol | | Entisol | | Entisol Lithic Subgroup | |
| | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP |
| Ctr | 1.6$^{a}$ | 1.4$^{a}$ | 0.5$^{a}$ | 0.2$^{a}$ | 0.1$^{a}$ | 0.9$^{a}$ | 0.8$^{a}$ | 0.8$^{a}$ | 0.5$^{a}$ | 1.0$^{a}$ | 1.5$^{a}$ | 1.1$^{a}$ |
| | (0.4) | (0.2) | (0.1) | (0.1) | (0.0) | (0.1) | (0.1) | (0.1) | (0.0) | (0.2) | (0.1) | (0.0) |
| CcB | 4.6$^{b}$ | 2.3$^{ab}$ | 2.0$^{c}$ | 2.0$^{ab}$ | 1.5$^{c}$ | 1.4$^{ab}$ | 2.0$^{bc}$ | 1.9$^{bc}$ | 0.9$^{a}$ | 1.4$^{a}$ | 1.9$^{a}$ | 4.5$^{d}$ |
| | (1.2) | (0.9) | (0.1) | (0.2) | (0.3) | (1.1) | (0.8) | (0.1) | (0.0) | (0.4) | (0.5) | (0.3) |
| RhB | 4.1$^{bc}$ | 2.0$^{ab}$ | 0.9$^{ab}$ | 1.9$^{ab}$ | 1.4$^{b}$ | 1.4$^{ab}$ | 2.9$^{ab}$ | 1.4$^{abc}$ | 0.7$^{a}$ | 1.2$^{a}$ | 1.7$^{a}$ | 2.2$^{bc}$ |
| | (1.6) | (0.8) | (0.0) | (0.4) | (0.3) | [illegible] | (1.8) | (0.3) | (0.1) | (0.2) | (0.1) | (1.0) |
| TwB | 4.0$^{bc}$ | 2.5$^{ab}$ | 1.6$^{abc}$ | 2.5$^{b}$ | 1.0$^{ab}$ | 1.6$^{ab}$ | 1.6$^{ab}$ | 1.4$^{abc}$ | 0.9$^{a}$ | 1.3$^{a}$ | 1.5$^{a}$ | 3.0$^{c}$ |
| | (0.7) | (0.4) | (0.3) | (0.4) | (0.2) | (0.9) | (0.3) | (0.5) | (0.1) | (0.4) | (0.1) | (1.6) |
| Cp | 4.1$^{bc}$ | 2.7$^{b}$ | 1.2$^{ab}$ | 1.6$^{ab}$ | 0.7$^{ab}$ | 1.7$^{ab}$ | 1.7$^{d}$ | 1.6$^{abc}$ | 0.7$^{a}$ | 1.1$^{a}$ | 1.5$^{a}$ | 1.4$^{ab}$ |
| | (0.8) | (0.7) | (0.1) | (0.5) | (0.1) | (0.6) | (0.3) | (0.3) | (0.1) | (0.5) | (0.2) | (0.0) |
| CkM | 4.4$^{bc}$ | 2.4$^{ab}$ | 1.9$^{bc}$ | 2.1$^{ab}$ | 0.9$^{ab}$ | 2.4$^{b}$ | 4.4$^{bc}$ | 1.3$^{ab}$ | 0.9$^{a}$ | 1.2$^{a}$ | 1.5$^{a}$ | 1.5$^{ab}$ |
| | (0.8) | (1.1) | (0.1) | (0.1) | (0.3) | (0.9) | (2.4) | (0.3) | (0.0) | (0.3) | (0.1) | (0.0) |
| CcB+Cp | 4.3$^{bc}$ | 3.2$^{b}$ | 1.4$^{ab}$ | 2.0$^{ab}$ | 0.6$^{ab}$ | 1.8$^{ab}$ | 2.2$^{bc}$ | 1.9$^{bc}$ | 0.8$^{a}$ | 1.2$^{a}$ | 1.4$^{a}$ | 1.6$^{ab}$ |
| | (1.5) | (1.8) | (0.1) | (0.5) | (0.4) | (0.5) | (0.4) | (0.9) | (0.1) | (0.5) | (0.1) | (0.3) |
| CcB+CkM | 4.7$^{bc}$ | 3.3$^{b}$ | 1.9$^{bc}$ | 2.5$^{b}$ | 0.4$^{ab}$ | 2.2$^{b}$ | 2.4$^{bc}$ | 2.0$^{c}$ | 1.0$^{a}$ | 1.0$^{a}$ | 1.4$^{a}$ | 1.5$^{ab}$ |
| | (1.5) | (0.8) | (0.3) | [illegible] | (0.2) | (0.0) | (0.4) | (0.5) | (0.0) | (0.1) | (0.1) | (0.5) |
| RhB+Cp | 3.3$^{c}$ | 3.1$^{b}$ | 1.0$^{ab}$ | 1.9$^{ab}$ | 0.5$^{ab}$ | 1.5$^{ab}$ | 2.0$^{bc}$ | 1.1$^{ab}$ | 0.8$^{a}$ | 0.9$^{a}$ | 1.5$^{a}$ | 1.3$^{ab}$ |
| | (1.3) | (0.3) | (0.1) | (0.0) | (0.1) | (1.0) | (0.2) | (0.1) | (0.1) | (0.2) | (0.1) | (0.1) |
| RhB+CkM | 4.5$^{c}$ | 2.3$^{ab}$ | 0.9$^{ab}$ | 2.7$^{b}$ | 0.7$^{ab}$ | 1.3$^{ab}$ | 2.4$^{bc}$ | 1.0$^{a}$ | 0.9$^{a}$ | 1.6$^{a}$ | 1.6$^{a}$ | 1.3$^{ab}$ |
| | (1.3) | (0.1) | (0.0) | (0.2) | (0.3) | (0.6) | (0.3) | (0.2) | (0.0) | (0.3) | (0.1) | (0.3) |
| TwB+Cp | 3.9$^{c}$ | 2.9$^{b}$ | 1.6$^{abc}$ | 2.1$^{ab}$ | 1.1$^{ab}$ | 1.7$^{ab}$ | 2.3$^{c}$ | 1.8$^{bc}$ | 1.0$^{a}$ | 1.0$^{a}$ | 1.7$^{a}$ | 1.4$^{ab}$ |
| | (0.1) | (0.5) | (0.2) | (0.1) | (0.3) | (0.4) | (0.0) | (1.0) | (0.0) | (0.2) | (0.1) | (0.2) |
| TwB+CkM | 4.9$^{c}$ | 2.3$^{ab}$ | 1.3$^{ab}$ | 2.0$^{ab}$ | 0.8$^{ab}$ | 2.2$^{b}$ | 2.5$^{bc}$ | 0.9$^{a}$ | 1.0$^{a}$ | 1.0$^{a}$ | 1.7$^{a}$ | 1.7$^{ab}$ |
| | (0.1) | (0.2) | (0.2) | (0.1) | (0.1) | (0.3) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.3) |

Abbreviations are shown in Table 3.

Means in the same column with different lowercase superscripts are significant different ($p < 0.05$).

**Table 5** Mean soil calcium and magnesium contents (SD in brackets) after mixing soil with biochar and or organic material in three types of soil

| Symbol of treatment | Ca ($NH_4OAC$ 1M pH: 7) $cmol_c$ $kg^{-1}$ | | | | | | Mg ($NH_4OAC$ 1M pH: 7) $cmol_c$ $kg^{-1}$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inceptisol | | Entisol | | Entisol Lithic Subgroup | | Inceptisol | | Entisol | | Entisol Lithic Subgroup | |
| | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP | 7 DAM | 56 DAP |
| Ctr | 15.3$^{a}$ | 12.5$^{a}$ | 9.0$^{a}$ | 6.7$^{a}$ | 25.7$^{ab}$ | 28.3$^{a}$ | 1.7$^{a}$ | 1.3$^{ab}$ | 0.4$^{a}$ | 0.4$^{a}$ | 0.4$^{ab}$ | 0.3$^{a}$ |
| | (0.8) | (1.0) | (1.0) | (0.9) | (4.9) | (1.3) | (0.0) | (0.2) | (0.1) | (0.2) | (0.1) | (0.1) |
| CcB | 13.3$^{bc}$ | 19.6$^{ab}$ | 7.4$^{a}$ | 6.3$^{a}$ | 37.8$^{d}$ | 33.5$^{b}$ | 6.5$^{e}$ | 2.4$^{bcde}$ | 1.2$^{a}$ | 0.8$^{ab}$ | 2.4$^{d}$ | 3.1$^{d}$ |
| | (0.3) | (1.4) | (0.1) | (0.2) | (6.9) | (2.8) | (0.7) | (1.3) | (0.1) | (0.0) | (1.0) | (1.5) |
| RhB | 12.9$^{b}$ | 19.2$^{ab}$ | 8.2$^{a}$ | 7.4$^{a}$ | 38.8$^{d}$ | 34.2$^{b}$ | 4.4$^{cd}$ | 2.0$^{abcde}$ | 0.9$^{a}$ | 0.5$^{ab}$ | 4.5$^{e}$ | 1.3$^{abc}$ |
| | (1.3) | (1.2) | (1.0) | (0.2) | (9.3) | (1.8) | (1.0) | (0.2) | (0.1) | (0.0) | (2.5) | (1.1) |
| TwB | 16.3$^{bc}$ | 20.2$^{ab}$ | 8.2$^{b}$ | 7.4$^{a}$ | 24.2$^{a}$ | 33.3$^{b}$ | 5.1$^{d}$ | 2.1$^{abc}$ | 1.5$^{b}$ | 0.7$^{ab}$ | 1.4$^{abcd}$ | 0.9$^{ab}$ |
| | (3.3) | (2.5) | (0.5) | (0.8) | (4.5) | (0.6) | (0.1) | (0.5) | (0.0) | (0.5) | (0.0) | (0.1) |
| Cp | 21.0$^{b}$ | 24.8$^{c}$ | 9.9$^{bc}$ | 8.1$^{a}$ | 28.4$^{abc}$ | 32.7$^{b}$ | 3.3$^{bc}$ | 2.9$^{e}$ | 1.3$^{bc}$ | 0.9$^{ab}$ | 2.3$^{d}$ | 0.6$^{a}$ |
| | (4.1) | (1.5) | (1.2) | (0.1) | (1.1) | (1.4) | (0.1) | (1.4) | (0.1) | (0.4) | (0.9) | (0.5) |
| CkM | 20.3$^{c}$ | 25.0$^{c}$ | 9.2$^{e}$ | 6.8$^{a}$ | 31.3$^{c}$ | 32.9$^{b}$ | 2.8$^{b}$ | 1.5$^{abc}$ | 1.5$^{e}$ | 0.9$^{ab}$ | 1.8$^{d}$ | 1.3$^{abc}$ |
| | (2.8) | (1.8) | (1.0) | (0.4) | (0.8) | (0.9) | (0.3) | (0.8) | (0.4) | (0.6) | (0.0) | (0.1) |
| CcB+Cp | 20.6$^{b}$ | 19.4$^{ab}$ | 8.1$^{cd}$ | 7.5$^{a}$ | 28.0$^{abc}$ | 31.9$^{b}$ | 3.6$^{bc}$ | 2.6$^{cde}$ | 1.6$^{cd}$ | 0.4$^{a}$ | 0.5$^{abc}$ | 2.1$^{bcd}$ |
| | (5.4) | (3.4) | (0.3) | (0.8) | (2.2) | (2.5) | (0.1) | (0.9) | (0.2) | (0.2) | (0.4) | (0.5) |
| CcB+CkM | 14.8$^{c}$ | 21.6$^{ab}$ | 8.0$^{de}$ | 7.1$^{a}$ | 31.5$^{c}$ | 32.9$^{b}$ | 4.4$^{cd}$ | 2.7$^{de}$ | 0.9$^{de}$ | 0.9$^{ab}$ | 1.3$^{abcd}$ | 1.2$^{abc}$ |
| | (0.7) | (2.3) | (0.0) | (0.1) | (1.0) | (1.3) | (0.2) | (0.5) | (0.0) | (0.5) | (0.1) | (0.2) |
| RhB+Cp | 16.3$^{b}$ | 25.0$^{c}$ | 9.3$^{c}$ | 7.4$^{a}$ | 30.1$^{bc}$ | 33.3$^{b}$ | 4.5$^{cd}$ | 1.6$^{abcd}$ | 1.0$^{c}$ | 1.5$^{b}$ | 1.7$^{cd}$ | 1.1$^{abc}$ |
| | (1.8) | (2.5) | (1.6) | (0.2) | (0.4) | (1.2) | (1.0) | (0.8) | (0.0) | (1.0) | (0.4) | (0.7) |
| RhB+CkM | 14.9$^{c}$ | 19.2$^{ab}$ | 6.7$^{de}$ | 6.9$^{a}$ | 29.6$^{bc}$ | 33.1$^{b}$ | 6.3$^{e}$ | 2.6$^{cde}$ | 1.4$^{de}$ | 0.7$^{ab}$ | 1.5$^{bcd}$ | 1.6$^{ab}$ |
| | (2.4) | (1.8) | (0.4) | (0.3) | (2.1) | (0.0) | (1.0) | (2.0) | (0.3) | (0.5) | (0.1) | (0.2) |
| TwB+Cp | 18.0$^{b}$ | 22.1$^{b}$ | 9.1$^{bc}$ | 7.3$^{a}$ | 32.0$^{c}$ | 34.1$^{b}$ | 4.4$^{cd}$ | 0.8$^{a}$ | 1.3$^{bc}$ | 0.9$^{ab}$ | 0.3$^{a}$ | 1.4$^{ab}$ |
| | (0.2) | (2.3) | (0.5) | (0.7) | (1.6) | (0.5) | (0.6) | (0.3) | (0.1) | (0.3) | (0.1) | (0.4) |
| TwB+CkM | 18.3$^{b}$ | 25.2$^{c}$ | 8.6$^{de}$ | 7.0$^{a}$ | 32.4$^{c}$ | 33.6$^{b}$ | 4.3$^{cd}$ | 1.9$^{abcde}$ | 0.8$^{de}$ | 0.7$^{ab}$ | 1.8$^{d}$ | 2.2$^{cd}$ |
| | (0.9) | (3.0) | (0.0) | (0.1) | (3.4) | (1.7) | (1.6) | (0.6) | (0.1) | (0.2) | (0.5) | (0.5) |

Abbreviations are shown in Table 3.

Means in the same column with different lowercase superscripts are significant different ($p < 0.05$).

**Table 6** Mean corn grain weight (12–15% moisture content) and soil cation exchange capacity (SD in brackets) after mixing mixed with biochar and or organic material

| Symbol of treatment | Corn grain (g bag$^{-1}$) | | | Soil Cation Exchange Capacity (cmol$_c$ kg$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Inceptisol | Entisol | Entisol Lithic Subgroup | Inseptisol | Entisol | Entisol Lithic Subgroup |
| Ctr | $68^{a}$ | $91^{a}$ | $89^{a}$ | $31.6^{a}$ | $10.5^{a}$ | $35.5^{a}$ |
| | (0.7) | (0.5) | (0.8) | (0.5) | (0.5) | (0.5) |
| CcB | $121^{bc}$ | $132^{b}$ | $163^{b}$ | $37.6^{cd}$ | $12.9^{b}$ | $38.6^{ab}$ |
| | (1.1) | (1.2) | (1.1) | (0.2) | (2.9) | (1.2) |
| RhB | $120^{bc}$ | $146^{b}$ | $190^{bc}$ | $34.7^{b}$ | $12.5^{b}$ | $39.7^{bc}$ |
| | (1.1) | (2.2) | (0.5) | (1.0) | (1.2) | (1.5) |
| TwB | $104^{ab}$ | $136^{b}$ | $165^{b}$ | $33.9^{b}$ | $11.8^{ab}$ | $40.1^{ab}$ |
| | (1.0) | (1.9) | (1.2) | (0.9) | (0.7) | (0.3) |
| Cp | $148^{bcd}$ | $141^{b}$ | $186^{bc}$ | $33.3^{ab}$ | $12.6^{b}$ | $37.4^{c}$ |
| | (0.8) | (1.0) | (1.2) | (0.8) | (0.3) | (2.0) |
| CkM | $163^{cd}$ | $166^{b}$ | $209^{bc}$ | $37.4^{bc}$ | $12.1^{ab}$ | $40.6^{bc}$ |
| | (1.5) | (1.4) | (1.6) | (2.4) | (0.5) | (2.0) |
| CcB + Cp | $151^{bcd}$ | $141^{b}$ | $168^{b}$ | $33.6^{ab}$ | $11.9^{ab}$ | $39.4^{bc}$ |
| | (1.5) | (0.7) | (0.4) | (1.3) | (0.3) | (2.2) |
| CcB + CkM | $176^{d}$ | $143^{b}$ | $204^{bc}$ | $34.9^{bc}$ | $12.0^{ab}$ | $38.5^{bc}$ |
| | (0.6) | (1.1) | (0.6) | (0.9) | (0.2) | (0.7) |
| RhB + Cp | $128^{bcd}$ | $139^{b}$ | $190^{bc}$ | $38.4^{c}$ | $13.0^{b}$ | $38.3^{bc}$ |
| | (0.6) | (2.5) | (0.6) | (0.8) | (1.2) | (0.1) |
| RhB + CkM | $113^{bc}$ | $167^{b}$ | $221^{c}$ | $37.8^{cd}$ | $11.3^{ab}$ | $39.9^{ab}$ |
| | (0.7) | (1.4) | (2.0) | (3.2) | (0.5) | (1.9) |
| TwB + Cp | $138^{bcd}$ | $124^{b}$ | $166^{b}$ | $34.7^{b}$ | $11.1^{ab}$ | $36.3^{ab}$ |
| | (0.5) | (1.4) | (0.7) | (0.1) | (0.5) | (0.5) |
| TwB + CkM | $132^{bcd}$ | $165^{b}$ | $201^{bc}$ | $42.1^{d}$ | $12.0^{ab}$ | $36.2^{ab}$ |
| | (1.1) | (1.6) | (1.1) | (1.7) | (0.2) | (0.9) |

Abbreviations are shown in Table 3.
Means in the same column with different lowercase superscripts are significant different ($p < 0.05$).

The current results were different from those of Schulz and Glaser (2012) who concluded that the CEC was not increased by the addition of biochar, but base saturation increased significantly. On the other hand, the CEC significantly increased with the addition of compost. Granatstein et al. (2009) who studied the effect of biochar on different soil textures reported that the CEC of sand and silt loam increased with increasing rates of biochar application. Peng et al. (2011) reported that the use of soil amendments with 1% biochar increased the CEC by 3.9–17.3%. Cheng et al. (2006) explained that the CEC increase after biochar application was due to the formation of abiotic oxidation carboxylic groups that occurred on the outer surface of biochar particles. Phares et al. (2017) reported that application of biochar or a combination of biochar with poultry manure increased the CEC and organic carbon and the increased surface area of biochar increased the ability to adsorb base cations (Ca, Mg, Na, and K). Asai et al. (2009) reported that biochar had a high total porosity and could store water in the pores so that the availability of nutrients is improved. The current results showed that corn grain increased with the application of biochar and organic fertilizers (Table 6). Gokila and Baskar (2015) reported that the combined application of biochar with 100% of the recommended dose of fertilizer and biofertilizer increased the nutrient use efficiency and soil fertility status of the soil. In short-term incubation studies, even without long-term microbial activity, an increase in the CEC was mainly due to the large surface area of biochar and the abiotic oxidation of functional groups (Cheng et al., 2006; Liang et al., 2006).

*Weight of corn grain*

The weight of corn grain increased after the application of biochars and organic fertilizers (Table 6). The weight of corn grain in the Entisol lithic subgroup was higher than for the Inceptisol because the soil pH and the total N and organic C contents of the Entisol lithic subgroups were higher than those of the Inceptisol (Table 1).

The highest corn grain weights were obtained from the application of cob biochar+chicken manure to the Inceptisol, and the application of husk biochar+chicken manure to the Entisol lithic subgroup. The results of the application of biochar and organic fertilizer to the Entisol showed that is similar to the results for the Entisol lithic subgroup, although there was no significant difference among the treatments with the two types of soil amendment. Corn grain weight of the treatments was in the following order: corncob biochar+manure > manure > corncob biochar in the Inceptisol. The highest corn grain weight in the Entisol lithic subgroup was obtained from rice husk biochar+chicken manure treatment and this was not significantly different from the chicken manure, corncob biochar+chicken manure or tobacco waste biochar+chicken manure treatments (Table 6).

A mutual synergy of corncob biochar and chicken manure for crop yields was caused by the mutual roles of each organic material. Manure functions as a source of nutrients, while biochar increases the available nutrients, given that the activity of soil enzymes increases with biochar (Lei et al., 2014). Additionally, the P content of the soil increased with the addition of manure. Manure contained higher levels of P and N than compost (Table 1) and this resulted in increased corn grain weight (Table 6).

Biochars and organic fertilizers applied to the same soil texture (clay) had different influences on the corn grain weight. The amount of soil organic carbon might have affected the clay fraction, resulting in differences in corn grain weight. The improvements in the chemical properties of the soil due to the application of biochar and organic fertilizers (Table 1) had a positive impact on the corn grain weight (Table 6). The addition of soil organic carbon has a direct effect on microbes, biomass activity, and soil enzymes (Ouni et al., 2013; Blanchet et al., 2016) that increase plant growth and yield (D'Hose et al., 2014; Ninh et al., 2015). Biochar increases the soil moisture content and pH so that it stimulates N mineralization, which causes an increase in plant uptake (Saarnio et al., 2013). Biochar mineralization is accelerated when biochar is combined with ryegrass (Luo et al., 2011) but manure significantly increases mineralization of C (Van Zwieten et al., 2013). Both biochars with N fertilizer and biochar amendment increased the soil moisture in the range 1–5% (Horák et al., 2019).

Glaser et al. (2014) concluded that the application of 10 Mg biochar/ha in combination with organic fertilizer increased the corn yield compared to the application of organic fertilizer in sandy soil. However, they reported that the efficiency of mineral fertilizers increased significantly with the application of 1 Mg biochar/ha. Composting processes by adding biochar could increase the corn yield. Further studies to understand the interaction of biochar and-organic fertilizers need to be done to optimize the application of organic biochar-fertilizer in the field. The study conducted by Glaser et al. (2014) showed positive results in corn plants by applying a combination of biochar and organic fertilizer. However, Schulz and Glaser, (2012) who conducted a study on sandy soil in a greenhouse reported that the growth of wheat plants and soil fertility were in a decreasing in the order:compost > biochar + compost > biochar + mineral fertilizer > mineral fertilizer > control.

As discussed above, the treatment of biochar and organic fertilizer on the Entisol had the same effects in increasing corn yield, while the use of husk biochar+manure produced the best corn yield in the Entisol lithic subgroup. The corn yield was higher with the application of cob biochar+manure, which was not significantly different from the manure-only treatment in the Inceptisol. Soil fertility improvement (based on chemical properties) produced a better corn yield when the combinations of biochar and manure were utilized in all three types of soil.

## Conflict of Interest

The authors declare that there are no conflicts of interest.

## Acknowledgements

The authors thank Kemenristek Dikti for funding the University's Applied Superior Research in 2018 (Number: DIPA-042.06.1.401516/2018). PT Gudang Garam, Tbk provided the biochar of jengkok tobacco waste.

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