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Corn Cob Biochar Improves Aggregate Characteristics of a Tropical Sandy Loam

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Introduction

Biochar, as a soil amendment, has received global attention. However, little is known about its effect on aggregate characteristics of weathered tropical soils.

Objective

To evaluate the effect of corn cob biochar on the aggregate characteristics, soil tensile strength, friability, soil aggregate stability, clay dispersibility and soil workability of a highly weathered tropical sandy loam soil.

Materials and methods

Figure 1. Location map of study area

Field layout and experimental design

- Randomized Complete Block Design
- 4 treatments with 4 replications
- 16 plots (3 m × 6 m)

Figure 2. Field Layout

Biochar preparation

- Feed stock: Corn cob
- Pyrolytic temperature: 550°C

Biochar dose

- 10 t ha^{-1} (0.17% (w/w)) and 20 t ha^{-1} (0.34% (w/w)) and 20 t ha^{-1} with P (P-enriched biochar).

Treatments

- The treatments are denoted by CT, BC-10, BC-20, and BC-20+P for the 0, 10 t ha^{-1} and 20 t ha^{-1}, and 20 t ha^{-1} with P respectively.

Soil sampling

- 197 days after biochar application at a depth of 0-20 cm.
- Bulk samples were taken from the middle of each plot, avoiding visibly compacted areas of the field due to human traffic.

Acknowledgments

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Abstract

Most tropical soils are highly weathered and are vulnerable to soil erosion due to their poor aggregate characteristics. Soil aggregate characteristics are critical indicators of soil structural stability, and they have the propensity to influence soil physical behavior and functioning. In this study, we investigated the effect of corn cob biochar on the aggregate characteristics of a highly weathered tropical sandy loam. Biochar significantly increased soil organic carbon by 22-40% relative to the untreated soil with a surprising trend of increasing water dispersible clay as biochar rate increased. Amount of water stable aggregates was significantly improved by 15 – 34% in biochar treatments compared to control. Incorporation of biochar decreased the tensile strength of the large aggregates (4–8 mm and 8–16 mm), but increased same in the smaller aggregates (1–2 mm). Soil friability and workability were significantly improved in the BC-20 and BC-20+P treatments.

Aggregate tensile strength (Y, (kPa))

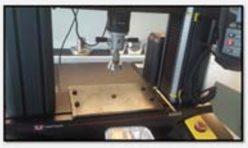

Figure 3. Instron for Y measurement

- Aggregates in the size classes of 1–2, 2–4, 4–8, and 8–16 mm for the tensile strength test were obtained from air-dried soil.
- In brief, the aggregates were crushed individually between two parallel plates in an indirect tension test. Fifteen (15) individual randomly selected aggregates for each combination of treatment, replicate, aggregate size, were tested (4 treatments × 4 replicates each × 4 aggregate size fractions × 15 aggregates = 960 tests).
- A constant displacement rate of 0.03 mm s^{-1} and a load cell of 0–100 N was used for all the tests. The point of failure for each aggregate failure was detected when a continuous crack or a sudden drop in the force reading was observed (Dexter and Kroesbergen, 1985).
- Y (kPa) was calculated from Eq. [1]

$$Y = \frac{0.576 \times F}{d^2} \quad [1]$$

where F (N), and d (m)denote the polar force required to fracture the aggregate and the mean aggregate diameter, respectively.

- For each aggregate, the effective diameter used for was estimated from Eq. [4] following (Dexter and Kroesbergen, 1985).

$$d = d_i \left(\frac{m_o}{m_i}\right)^{\frac{1}{3}} \quad [2]$$

where, d_i is the mean diameter of the aggregates calculated from the respective aggregate size classes, m_o is the dry mass of individual aggregates and m_i is the mean dry mass for batches of 15 aggregates of each treatment.

Soil friability

- Soil friability index was taken as the slope of the plot of the natural logarithm of the tensile strength (kPa) of the aggregates against the natural logarithm of the aggregate volume (m^3).

Rupture energy

- The energy at rupture (E) for each aggregate was obtained by computing the area under the stress-strain curve according to eq. 3..

$$E \approx \sum_i F(s_i)\Delta s_i \quad [3]$$

- The specific rupture energy was computed from eq. [4]:

$$E_{sp} = \frac{E}{m} \quad [4]$$

where $F(s_i)$ is the mean force at the i^{th} subinterval and Δs_i is the displacement length of the i^{th} subinterval.

Soil workability (W) obtained from eq. [5]:

$$W = F \times \left(\frac{1}{Y}\right) \quad [5]$$

A greater value of W implies a more easily workable soil and vice-versa

Aggregate stability

Figure 4. Wet sieving machine

- 51g of air-dried aggregates were placed on a stack of sieves ranging from 5mm (top), 2mm, 1mm, 0.5mm, 0.25mm, 0.125mm and 0.053mm (bottom), and subjected to 48 oscillations/minute.
- The stability index (SI) was used to classify the aggregate stability of treatments based on Eq.[6], [7] and [8].

$$MWD = \frac{\sum m_{i \times d_i}}{\sum m_i} \quad [6]$$

IS$= MWD_{dry} - MWD_{wet}$ [7]

$$SI = \frac{1}{IS} \quad [8]$$

Clay dispersibility

Figure 5. End-over-end shaking method

- 10 g of air-dried aggregates used.
- In brief, cylindrical plastic bottles with the aggregates and 80 mL artificial rainwater (0.012 mM $CaCl_2$, 0.15 mM $MgCl_2$ and 0.121 mM NaCl; pH 7.82; EC 2.24×10^{-3} S m^{-1}) were rotated end-over-end (33 rpm, 23-cm diam. rotation) for 2 min.

Results and discussion

Table 2. Particle size distribution and chemical properties of top soil (0-20 cm) prior to start of experiment.

Clay	Silt	Sand	OC	Total N	Total P	K	Mg	pH	EC
% by weight					mg 100 g^{-1}				µS cm^{-1}
18	9	73	0.93	0.073	<0.4	11.9	9.3	6.1	200

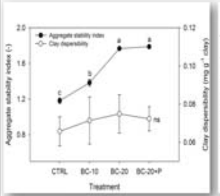

Figure 5. Corn cob biochar effects on aggregate stability index and dispersible clay content

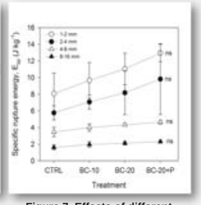

Figure 7. Effects of different application rates of corn cob biochar on specific rupture energy of various air-dried aggregate classes.

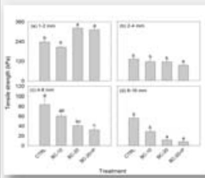

Figure 6. Effects of different application rates of corn cob biochar on tensile strength of various air-dried aggregate classes.

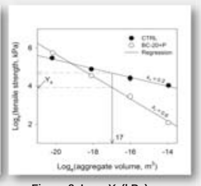

Figure 8. Log$_e$ Y, (kPa) as a function of log$_e$ aggregate volume, V (m^3) for air-dry aggregates.

Soil friability index, k_Y, determined as the slope of the regression equation is shown for each soil. Estimation of the median size soil aggregate class (4-mm = 17 m^3) of air-dry aggregates is also shown.

Table 3. Aggregate friability (k_Y and k_E), characteristic aggregate strength (Y_4) and workability (W) for control and biochar treatments.

Treatment	k_Y	k_E	Y_4 (kPa)	W (×10^3)
CTRL	0.23^c	1.04^c	107	2.16
BC-10	0.32^b	1.26^b	77.3	4.08
BC-20	0.53^a	1.56^{ab}	61.8	8.63
BC-20+P	0.58^a	1.83^a	50.4	11.5

- k_Y, friability derived from tensile strength; k_E, friability derived from specific rupture energy
- Different letters indicate that slopes (friability) are significantly different ($p<0.05$) between biochar treatments.

Conclusions

- Increasing the rate of corn cob biochar improved the water stability of the aggregates compared to the CT, despite the absence of a significant effect on the dispersible clay content.
- For smaller aggregates (1–2mm), tensile strength for BC-20 and BC-20+P treatments was significantly higher than the CT and BC-10, with an opposite trend observed for larger aggregates (4–8 mm and 8–16 mm).
- Corn cob biochar significantly improved soil friability and the ease of tillage quantified with a workability index.

Reference

Dexter, A.R., and B. Kroesbergen. 1985. Methodology for determination of tensile strength of soil aggregates. Journal of Agric. Engineering Research 31:139-147.