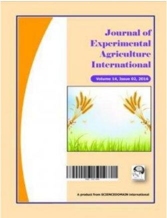

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Biochar Effect on Maize Yield in Selected Farmers Fields in the Northern and Upper East Regions of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author ECT designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AS and EY managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

With the current global concern of high concentration of Green House Gases in the atmosphere and the current struggle to ensure food security for the growing population in Africa within this climate change scenario, biochar amendment to soils is gaining acceptance as an important management option for carbon sequestration, soil productivity and fertility improvement and climate change mitigation. This study was to investigate the effect of biochar on maize yield indices on selected farmers' fields (40 farmers) in the Northern and Upper East Regions of Ghana. The biochar was produced from two feedstock, i.e. rice husk and sorghum. The test crop used was maize where biochar was applied alone and in combination with inorganic fertiliser. The treatments used for this studies were absolute control (No amendment), two tonnes of sorghum biochar, two tonnes of rice husk biochar, full rate of NPK (90:60:60), full rate of NPK with two tonnes of sorghum biochar and full rate of NPK with two tonnes of rice husk biochar. The results showed that biochar in combination

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with inorganic fertiliser had a significant influence on maize grain and biomass yield. The biochar also had a significant impact on soil pH, soil organic carbon and the available N, P and K. All the biochar contained more than 80% stable carbon and more than 0.3% labile carbon. Increase in pH was in the range of 4.5 to 5.6 and that of SOC from 0.7% in control to 1.3% in biochar amended treatment. Biochar in combination with inorganic fertiliser improve percentage Nitrogen from 0.07% to 2.4%, available Phosphorus from 6.8 ppmp to 14.2 ppmp and increased in K content was 60% above the control. Biochar in combination with inorganic fertiliser can significantly increase crop yield.

Decrease medical as well as a financial burden, hence improving the management of cirrhotic patients. These predictors, however, need further work to validate reliability.

Keywords: Biochar; inorganic fertiliser; soil fertility; soil productivity.

1. INTRODUCTION

Soil fertility trials/evaluation and soil use planning provide the framework for predicting the suitability and management of the soil resource for agriculture production and the environment on the basis of their attributes for a specific land utilisation type. Soil fertility trials/evaluation provides the rational basis for the implementation of land-use decisions based on the analysis of soil use and land, giving estimates of required inputs and the projected outputs within socio-economic settings [1].

According to [2], current unsustainable agricultural practices are enhancing the vulnerability of communities and are detrimental to the fragile ecology and the environment. Indeed the biggest challenges in agriculture are to ensure food security through an increase in soil fertility and productivity and mitigate the effect of climate change within the agricultural sector.

Soil conditioning materials, such as organic matter, fertilisers, composting and cover crops [3] has been reported to improve soil fertility and productivity, however, the emission of GHGs such as Methane (CH_4), Carbon dioxide (CO_2) and Nitrogen Oxides (NOx) from these materials are a major concern to climate change watchers according to the Intergovernmental Panel on Climate Change (IPCC) modified in 2001 about the concentration of Green House Gases and other gases in the atmosphere. In the context of UNFCCC, mitigation assessment is a local to the national-level analysis of various technologies and practices that have the capacity to mitigate climate change.

The applications of carbonised biomass (Biochar) to the various types of soils can reduce the emission of the above GHGs from the soils and improve the physicochemical properties of the same. It has been reported that biochar improves the capacity of the soil to retain moisture and nutrients, such as nitrogen and phosphorus. It helps regulate soil temperature and contribute to climate change mitigation. It improves soil life.

Research has shown that the benefits of biochar include improvement in soil productivity, long-term soil carbon sequestration, reduction in greenhouse gas (GHG) emissions, and reduction in loss of nutrients by leaching [4]. Biochar is particularly beneficial in sandy soils and highly weathered clay soils with low native CEC and AEC and low fertility. Biochar also acts as a source of small amounts of P, K, and other nutrients [5,6]. Soil pH is an important factor in determining the bioavailability of nutrients, and biochar is known to raise soil pH [7], thereby improving the availability of nutrients to crop plants.

Biochar is also reported to enhance the microbial population [8,9], and improve moisture holding capacity and soil structure [10,11].

In the wake of rising carbon dioxide concentrations in the atmosphere and global climate change [12], biochar's resistance to decomposition offers another ecological benefit.

In Ghana, research into biochar as soil fertility management option has received a lot of attention to understand the influence of biochar in the soil environment and how it improves crop growth and yield. The experiment which was carried out in the Northern and Upper East region of Ghana was to test the hypothesis that rice husk biochar and sorghum biochar can improve the yield of Maize. Therefore, the broad objective of the studies was to assess the influence of biochar in the soil environment and the specific objective was to assess its impact on the yield on Maize.

2. EXPERIMENTAL DETAILS

2.1 Trial Site

The Northern region is situated between latitude 9.5000˚N and longitude 1.000˚W while the Upper East lies between latitude 10.7500˚N and longitude 0.7500˚W respectively.

Like the Northern region, the people of the Upper East Region are predominantly peasant farmers. Much of the farming is done in the short rainy season with the long dry season as a period of preparation towards farming in the wet season. The vegetation cover is mainly Guinea Savannah with grasses interspersed with short trees. Among the trees is the shea tree, which is the main commercial tree. Mechanised agriculture is possible on this terrain although limited in practice because of the high cost.

2.2 Farmer Characterisation

The age of farmers in the study areas rages from 18 to 65 years old, with an average farm size of 3.7 hectares of land. In general, the education level is low. Around 80.2% of the farmers had some minimal level of education and are well supported by agricultural extension officers. Farming is almost the only productive activity undertaken by the households in the study area and is, therefore, their only source of income. None agricultural activities are almost non-existent due to several factors, such as inaccessible roads, low demand for their products and lack of skills and capital.

2.3 Climate and Soils

The agroclimatic environment in the study areas is generally characterised by short wet seasons and relatively long dry seasons. The study area has an average rainfall of 921 mm. It ranges between 645mm and 1250 mm. Rainfall distribution is unimodal which gives a single 5 to 6 months growing season between June/July and October/November and 6 to 7 long dry seasons from November to May. This is associated with dry harmattan winds with low humidity. Annual average temperatures recorded in the dry season is 15˚ (Dec. to Feb.) at minimum limits and highest at 45˚ (March to April). The relative Humidity ranges between 30% and 80% in the dry and wet seasons respectively.

The soils are mainly, savannah ochrosols and groundwater lateritic soils. The soils have predominantly light textured surface horizons in which sandy loams and loams with very poor organic matter content and usually low in phosphorus and potassium. Lower soil horizons have slightly heavier textures varying from coarse sandy loams to clays. Heavier textured soils occur in many valley bottoms which are suitable for rice cultivation. Many soils contain abundant coarse material either gravel and stone, or concretionary materials which affect their physical properties, particularly their water holding capacity. Table 1 indicates some soil parameters in the study area which was analysed in the laboratory of CSIR-Soil Research Institute Kumasi, Ghana.

2.4 Biochar

The biochar used for the studies were obtained from two different feedstock which was rice husk and sorghum straw. The most important waste materials from rice production are the straw and husk. The amount of rice crop residue is substantial about 15 million tons annually. [13], reported that the global amount of residues from rice crops is 0.9 Gt i.e., 25% of the amount of global agricultural residues. In Ghana, almost all the residues from rice production are burnt which has a negative impact on the environment. Unlike rice straw and husk, sorghum straw had other competing uses in the study area but was selected for the trials because of the high content phosphorus Table 2. These feedstocks were carbonised at a temperature of 650˚-700°C as measured with a thermocouple. Pyrolysis time was two days using a home built reactor. Figure 1 shows the home built reactor which was design and built by the chemical engineering department of the Kwame Nkrumah University of Science and Technology Kumasi, Ghana. A summary of some selected chemical properties of the rice husk biochar and that of sorghum biochar are shown in Table 2. The biochar was applied fresh from the rector.

2.5 Field Experiment

The studies were carried out in the Northern and Upper East regions of Ghana. Two districts were selected from each region. The studies were on the farm, with ten farmers from each district and their agricultural extension officers.

Table 1. Some selected analytical soil parameters in the study area before the trails

Soil parameter	Bongo	Karaga	Kasena	Tamale
pH (1:1 H_20)	4.5	4.8	4.6	4.5
Organic C	0.6	0.8	0.3	0.7
O/M	0.9	1.3	0.6	0.8
% N	0.05	0.05	0.03	0.06
Available P (ppm)	12,1	11.1	4.42	4.14
Available K (ppm)	51.1	66.2	37.5	47.8
% Sand	30.92	35.44	51.16	63.24
% Silt	56.08	56.4	44.84	32.76
% Clay	4	8.16	4	4
Textural class	Silty loam	Silty loam	Sandy loam	Sandy loam

** The results are the average of 10 sites in each District*

Fig. 1. The first homebuilt biochar rector

Table 2. Analytical properties of some selected parameter of the two different biochar

Biochar parameters	Rice biochar	Sorghum biochar
pH (1:1 H_20)	8.9	10.9
Org C (%)	2	2
Total N	0.2	0.2
Available K (ppm)	107.4	266.8
Available P (ppm)	4.1	14.9
Ca (c mol (+) / kg	19.8	22.9
Mg (c mol (+) / kg	6.8	7.4
Na (c mol (+) / kg	1.8	1.5
Exchangeable K (c mol (+) / kg	2.6	3.1
Stable C (%)	81.61	86.87
Liable C (%)	0.34	0.48
Carbon (%)	44.45	45.96

Field studies were conducted during the rainy seasons using six treatments. The treatments used for this purpose were absolute control (No amendment), two tonnes of sorghum biochar, two tonnes of rice husk biochar, full rate of NPK (90:60:60), full rate of NPK with two tonnes of sorghum biochar and full rate of NPK with two tonnes of rice husk biochar in a randomised complete block design with plot size of 6.4 m×6.4 m. The source of N was urea; P was triple superphosphate while K was muriate of potash. A maize variety called "Obatanpa" (i.e., Good Mother) improved quality protein maize was the test crop.

2.6 Crop Management

The planting distance was 80 cm×40 cm at two plants per hill. The biochar was applied by ring incorporated one week after planting together with the full rate of NPK. N alone was applied as split i.e. one third was applied one week after planting and two third was applied six weeks after planting. In all the trials sowing and plot maintenance were done by the farmers and their technical team. Only biochar amendment, fertilizer application and harvesting were done by the research team.

2.7 Statistical Analysis

The data collected were subjected to statistical analyses. One-way analysis of variance (ANOVA) was performed to compare variations in soil properties and plant growth characteristics for each biochar and NPK application. For all the analyses, treatment means were separated using the least significant difference (LSD), and treatments effects were declared significant at the 5% level of probability (P<0.05). All the analyses were performed using the 12th edition of Gen stats statistical package.

3. RESULTS AND DISCUSSION

3.1 Effect of Soil Treatments on Biomass Yield in the Districts

Figs. 2 and 3 show the impact of soil treatments on biomass yields at Bongo, Karaga, Kasena and Tamale. The result showed that there were no significant differences in biomass yield among the districts of Bongo, Karaga and Kasena (P> 0.05). Meanwhile, there was a significant difference between the district of Tamale and Bongo, Karaga and Kasena (P <0.05). The district of Tamale recorded the highest biomass yield of 4022.894 kg/ha, followed by Kasena with 2275.1kg/ha and Bongo with 2054.4 kg/ha. Karaga district recorded the lowest biomass yield of 1971.2 kg/ha. The differences in the biomass yields can be attributed to the two-month delay in rainfall in the districts. However, in Tamale and Kasena districts some of the fields can be classified as compound farms where household refuse and wastewater are deposited as was cited in the work of [5]. Concerning the control, all the treatments applied were able to increase the biomass yield significantly. There was no difference in the type of biochar used in this experiment with respect to the biomass yield. However, there is a significant difference between 2 tons sorghum biochar with a full rate of NPK (90-60-60) and 2 tons of rice husk biochar (p<0.05). The combined effect of high P value in the sorghum biochar with the 60% P in the inorganic fertiliser may have accounted for the difference this was evident in the work of [4]. Meanwhile, there is no significant difference between the 2 tons of rice husk biochar and 2 tons sorghum biochar (p>0.05) (Fig. 3).

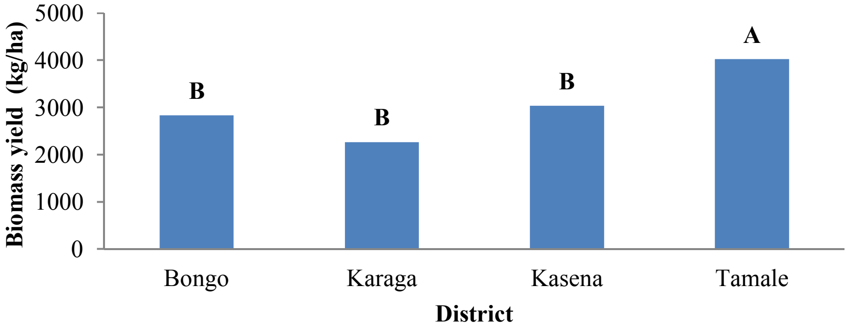

Fig. 2. Influence of soil treatment on biomass yields in the districts. Means with the same letters are not a significant difference

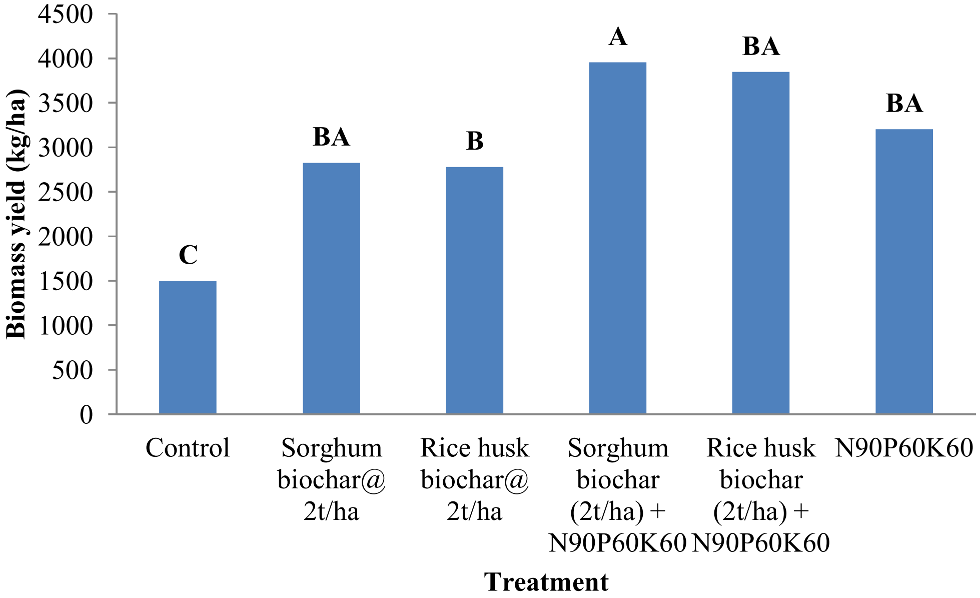

Fig. 3. Biomass yield as affected by the soil amendments. Means with the same letters are not a significant difference

3.2 Effect of Soil Treatments on Grain Yields

Grain yield was significantly increased with respect to the control ($p<0.05$). However, sorghum biochar at 2 ton/ha alone was significantly different from the two different biochar amended with the full rate $N_{90}P_{60}K_{60}$, and the Full rate N90P60K60 alone ($p<0.05$), this can be attributed to the high P value in the sorghum biochar (Lehmann, 2007). Meanwhile, the difference between rice husk and sorghum biochar were not significantly different ($p>0.05$). Full rate $N_{90}P_{60}K_{60}$, rice husk and sorghum biochar with the amended full rate of $N_{90}P_{60}K_{60}$ did not show any significant difference ($p>0.05$). Figs. 4 and 5 show the influence of the treatments on grain yield and the impact in the districts. Sorghum and rice husk biochar with a full rate of $N_{90}P_{60}K_{60}$ recorded the highest grain yield of 3446.5 kg/ha and 3342 kg/ha respectively. Full rate of $N_{90}P_{60}K_{60}$ alone and rice husk biochar alone recorded 2729.6 kg/ha and 2065 kg/ha respectively. The control (no amendment) recorded the lowest grain yield of 1105.4 kg/ha while sorghum biochar alone recorded 1953.5 kg/ha. The yields within the Bongo, Karaga and Kasena districts did not show any significant difference ($p>0.05$). The yield differences in Tamale district was however significant from the rest of the districts ($p<0.05$).

3.3 Effect of Biochar Amendment on Some Selected Soil Chemical Properties

Tables 3 and 4 show the influence of biochar amendment on some selected soil chemical properties after the harvest and how the treatments impacted on the four selected districts which have different soil texture. The district of Tamale and Kasena which have sandy loam soil texture responded favourably to the biochar amendments than Karaga and Bongo which have silty loam soil texture [5,6]. There were significant differences between the two different soils types in the districts with Tamale and Kasena recording the highest in all the soil chemical parameters measured (Table 3). However, with respect to the soil organic carbon, there was a significant difference between Tamale and Kasena with Tamale recording 1.16% as compare to Kasena 1.09%. Table 1 also showed that the soil parameters measured in Karaga and Bongo did not show any significant difference, however, there was a significant difference with respect to N. Bongo recorded the higher of 1.42% and 1.34 respectively.

The application of biochar significantly improved soil chemical properties with reference to the control (Table 4). The combined effect of rice husk biochar and sorghum biochar with the inorganic fertiliser significantly improved soil chemical parameters which were measured. However, there was a significant difference between the pH, and P. Sorghum biochar recorded pH of 5.48 and Phosphorus was 13.59ppm while rice husk biochar was 5.28 and 12.82ppm respectively. The chemical analysis of both biochars suggests that sorghum biochar is high in phosphorus and pH content (Table 2) hence the significant difference between the values. N in the inorganic fertiliser recorded high value than rice husk and sorghum biochar alone. Meanwhile, the values of pH, P, K and SOC were high in rice husk and sorghum biochar alone than the inorganic fertiliser (Table 4).

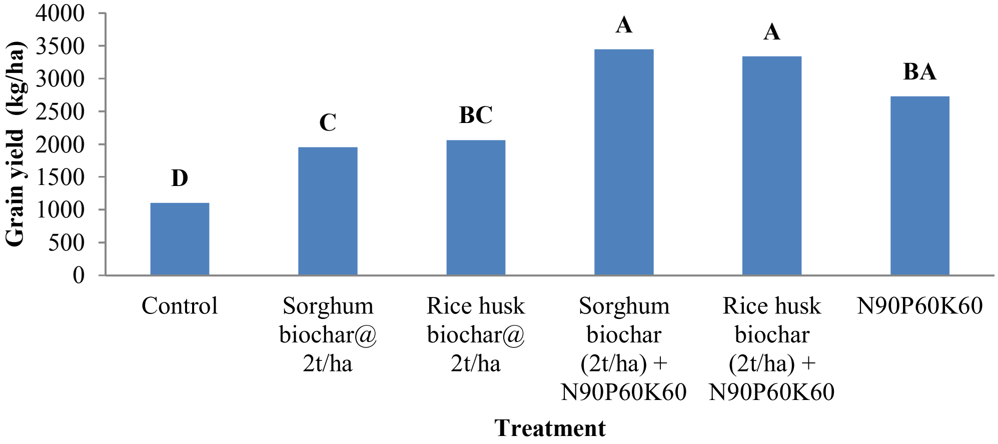

Fig. 4. Grain yield as affected by the soil amendments. Means with the same letters are not significant difference

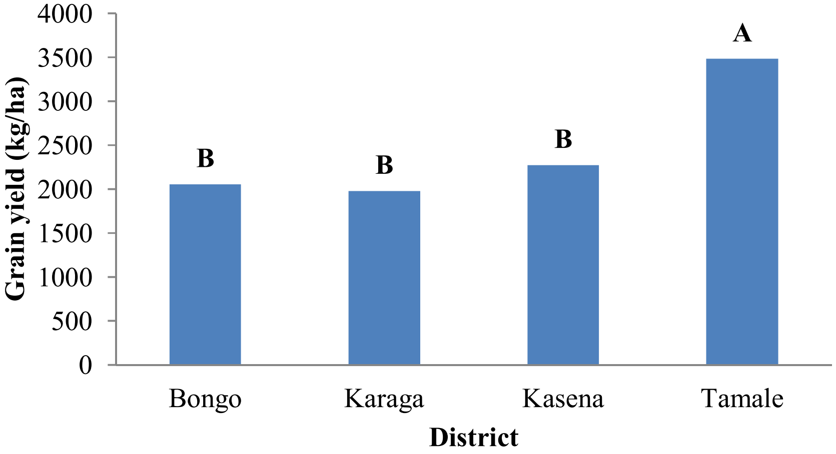

Fig. 5. Influence of soil treatment on grain yields in the districts. Means with the same letters are not significant difference

Table 3. Influence of biochar on some soil chemical parameters after harvest in the districts

District	pH	N	ppmP	ppmK	OC
Karaga	4.87^b	1.34^c	10.21^b	51.55^b	0.97^c
Bongo	4.89^b	1.42^b	10.03^b	51.63^b	1.01^c
Kasena	5.17^a	1.55^a	11.13^a	54.83^a	1.09^b
Tamale	5.24^a	1.60a	10.97^a	55.72^a	1.16^a

Values with the same letters for a parameter are not statistically different at p< 0.05 lsd

Table 4. Influence of biochar amendment on some selected soil chemical properties after the harvest

Treatment	pH	N	ppmP	ppmK	OC
Control	4.34^{e}	0.23^{e}	6.54^{f}	36.51^{e}	0.62^{d}
NPK	4.77^{d}	1.88^{b}	9.31^{e}	47.30^{d}	0.89^{c}
Rice husk biochar	5.14^{c}	1.03^{d}	9.81^{d}	55.43^{b}	1.09^{b}
Sorghum biochar	5.23^{b}	1.15^{c}	11.35^{c}	53.05^{c}	1.14^{b}
Rice husk biochar + NPK	5.28^{b}	2.29^{a}	12.82^{b}	64.30^{a}	1.28^{a}
Sorghum biochar + NPK	5.48^{a}	2.28^{a}	13.59^{a}	63.84^{a}	1.33^{a}

Values with the same letters for a parameter are not statistically different at p< 0.05 lsd

4. CONCLUSION

The results of the experiment revealed that the application of biochar in combination with inorganic fertiliser improved maize growth and increased grain yield. Application of both sorghum and rice husk biochar alone and the combined effect with the full rate inorganic fertiliser N_{90} P_{60} K_{60} improved soil pH that also impacted positively in nutrient availability for maize that resulted in the increased in both biomass and grain yield. Tamale and Karaga districts revealed a favourable effect of biochar in combination with inorganic fertiliser on biomass and grain yield in sandy loam soil as compared to the silt loam soils which are in the districts of Bongo and Kasena. The observation in the farmer field led trials revealed that the farmers are highly motivated in adopting the biochar technology and producing their own biochar. It is recommended that further research into the use of biochar from different feedstock as a soil amendment for sustainable crop production in the tropics.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Cools N, De Pauw E, Deckers J. Towards an integration of conventional land evaluation methods and farmers' soil suitability assessment: A case study in North-Western Syria. Agriculture, Ecosystems & Environment. 2003;95(1): 327-342.
2. Bhaskar N. Biochar for environment and development 1st Ed. publisher: Meta paardskerkhofweg 14 5223 aj's-hertogenbosch, the Netherlands. 2014;25-26.
3. Yeboah E, Ofori P, Quansah GW, Dugan SE, Sohi B. Improving soil productivity through biochar amendments to soils. Afric. J. Envir. Sci. & technol. 2009;3(2): 34-41.
4. Lehmann J, Gaunt J, Rondon M. Bio-char sequestration in terrestrial ecosystems and review. Mitigation and adaptation strategies for global change. 2006;11:395-419.
5. Lehmann J, Da Silva Jr JP, Steiner C, Nehls T, Zech W, Glaser B. Nutrient availability and leaching in an archaeological anthrosol and a ferralsol of the central amazon basin: Fertilizer, manure and charcoal amendments. Plant and soil. 2003;249:343-357.
6. Glaser B, Jehmann J, Zech W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal-a review. Biological and Fertility of Soils. 2002;35:219-230.
7. Chan K, Van Zwieten I, Meszaros I, Downie A, Joseph S. Agronomic values of green waste bio-char as a soil amendment. Soil Research. 2008;45:629-634.
8. Wardle DA, Zackrisson O, Nilsson MC. The charcoal effect in boreal forests: Mechanisms and ecological consequences. Oecologia. 1998;115:419-426.
9. Zackrisson O, Nilsson MC, Wardle DA. Key ecological function of charcoal from wildfire in the boreal forest. Oikos. 1996; 10-19.
10. Piccolo A, Mbagwu J. Effects of different organic waste amendments on soil microaggregates stability and molecular sizes of humic substances. Plant and Soil. 1990;123:27-37.
11. Basso AS, Miguez FE, Laird DA, Horton R, Westgate M. Assessing potential of biochar for increasing water-holding

capacity of sandy soils. GCB Bioenergy. 2013;5:132-143.

12. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K. Tignor M, Miller H. Summary for policymakers. Climate Change. 2007;93-129. IPCC.

13. Knoblauch C, Maarifat AA, Pfeiffer EM, Haefele S. Degradability of black carbon and its impact on trace gas fluxes and carbon turnover in paddy soils. Soil Biol. Biochem. 2011;43:1768-177.

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