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Biochar Effects on Soil Properties and Maize Crop in Kavrepalanchok District of Nepal

Roshan M Bajracharya*, Ngamindra R Dahal and Mamta Basnet

Kathmandu University, Nepal

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***Corresponding author:** Roshan M Bajracharya Visiting Professor, Kathmandu University, Nepal.

ABSTRACT

Soil amendments are used on agricultural land to improve soil quality and crop productivity. This preliminary study was conducted to evaluate the effect of biochar application on maize crop yields and soil properties on a hill farm in east-central Nepal. Plots established on a farm field were amended at 2 t/ha, 4 t/ha and 8 t/ha of biochar produced from grasses and weeds. feedstock along with a control that did not receive biochar. Each treatment and the control were assigned randomly to four replicate plots for a total of sixteen 3 m2 plots. The results indicated that biochar amendment significantly increased the SOC and TN contents of the treated soils, with 8 t/ha of applied biochar having the most notable effects. In addition, the soil pH showed a slight increase, which was beneficial for the acidic soil studied. Although growth rates and maize yield differences were not statistically significantly for the biochar treated plots, an increasing trend was seen for mean growth rates and grain yields. Longer-term studies are needed to establish conclusive effects of biochar soil amendment on crop yields.

INTRODUCTION

The addition of soil amendments to improve the overall quality and productivity of soils is a common practice on agricultural soils worldwide. In recent decades, the impacts of climate change and the need for sustainable agricultural practices has led to increased interest in biochar as a potential soil amendment to enhance crop productivity, while also helping to mitigate climate change through carbon sequestration in soils [1,2]. Biochar is a product of the pyrolysis of biomass in an oxygen-limited condition resulting in a black, charcoal-like substance made from plant materials such as grain husks, crop stubble, wood chips or sawdust, leaf litter, grass, weeds, etc. It can be made using special dual-chamber stoves or in conical pits dug into the ground. Numerous studies around the world have shown that application of biochar to soils can have beneficial effects on soil properties, as well as, improved crop productivity[3-6].

As the production of biochar from organic residues involves a thermo-chemical conversion of the material with incomplete combustion under a low oxygen environment, the cellular structure of the organic materials remains intact. Therefore, biochar particles offer a suitable habitat for enhanced microorganism activity while simultaneously improving the soils capacity to hold nutrients and water. This leads to increased nutrient and water retention and availability for crop growth [7,8]. Moreover, other beneficial effects such as reduced soil bulk density, increased soil organic matter content and soil pH (biochar being alkaline in reaction), all help to improve soil quality and crop productivity [9-11].

An additional benefit of biochar amendment of soils is that it can lead to the long-term accumulation and sequestration of carbon in the soil. As biochar is a relatively inert substance, it can remain unaltered within the soil over extended periods of time as evidenced by the discovery of "terra preta" in the Amazon, Andes and in Australia [12,13]. These soils are very dark and rich in organic matter due to the accumulation of applied traditionally produced biochar over thousands of years by ancient civilizations. Hence, once introduced into the soil, the carbon in bochar can become sequestered and remain there for hundreds to thousands of years without being degraded. The use of biochar on a large-scale across agricultural lands would contribute to the mitigation of climate change by trapping carbon from plant residues in the soil, which would otherwise decompose and be released to the atmosphere, thereby, enhancing the greenhouse effect and causing global warming [14-17].

It was, therefore, with the objective of assessing the effects of biochar application on soil properties, as well as, the growth and yield of maize that this preliminary study was conducted during 2015-2016 in a hill farm at Budol, Dhulikhel Municipality in Kavrepalanchok district of Nepal. The location and details of the experimental setup are provided below.

MATERIALS AND METHODS

The study was conducted on a farm field located in Dhulikheld Municipality of Kavrepalanchok district, 30 km east of Kathmandu, Nepal. The location of the study site is indicated in the map shown in Figure 1. The rectangular field plots of 1.5 by 2 m size were laid out in a randomized complete block design across the farm as shown in Figure 2. The treatments consisted of four replications each of a control (C) which did not receive any biochar, and three biochar amendment treatments incorporated into the topsoil during tillage at rates of 2 t/ha, 4 t/ha and 8 t/ha (i.e., T2, T4 and T8, respectively). The plots were planted in mid-April and harvested in August of 2015.

Figure 1: Map of the study area showing approximate location of the site (indicated by red circle).

Biochar for application to the soil was produced using grasses and a weedy shrub, namely, *Eupatorium* sp. The mixed biomass was subjected to pyrolysis using a concentric double-chamber steel stove (kiln) designed for the purpose. The air-dried grass and *Eupatorium* twigs and leaves were heated at 350 to 400 C for about four hours in order to produce the biochar. The process yielded approximately 43% by weight of the biochar from the organic material for each batch made.

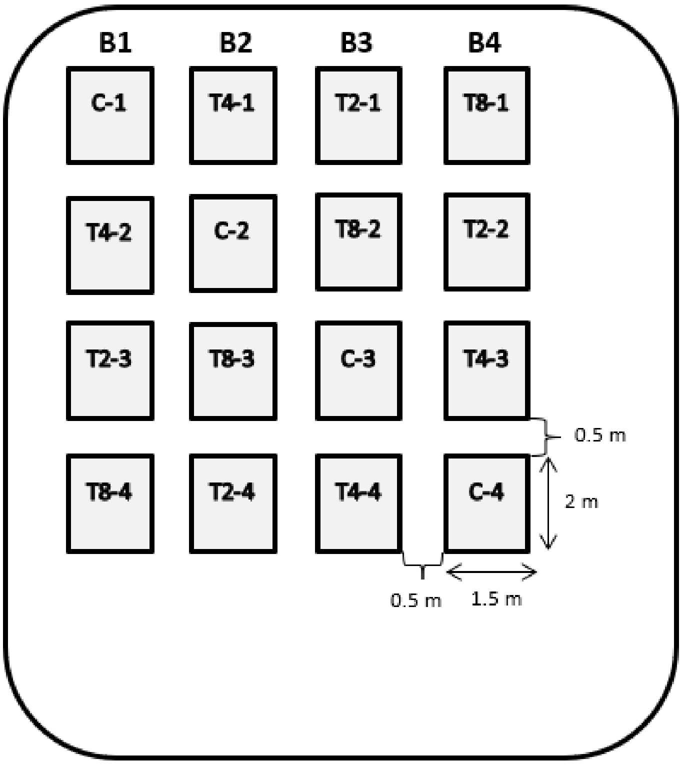

Figure 2: Diagram showing the plot layout and allotted treatments.

The soil was sampled prior to the application of the biochar amendment to establish a baseline and subsequently at the time of harvest of the maize crop for evaluating the effects of biochar on soil properties. The sampled soil was analyzed for soil organic carbon content (SOC), soil pH, total nitrogen (TN), available phosphorus (AP), exchangeable potassium (EK) and cation exchange capacity (CEC). Standard methods were used for soil analyses, i.e., loss-on-ignition method for SOC [18], 1:1 soil:water mixture for pH using a digital pH meter [19], Kjeldahl method for TN [20], 0.5M NaHCO3 extraction for AP [21], and ammonium acetate extraction for EK [22] and CEC [23].

The growth of maize crop was monitored by measuring the plant height (cm) on a fortnightly basis after seedling emergence. In August 2015, the maize crop was harvested and the grain yield (t/ha) as well as, biomass yields (t/ha) were determined for each plot. The data obtained was analyzed statistically using analysis of variance for treatment (biochar amendment) effects and for correlation among the soil and crop parameters.

RESULTS AND DISCUSSION

The effect of biochar application on selected soil properties of the farm plots are shown in Table 1. Of the properties examined only SOC percent and total nitrogen content showed statistically significant differences among the treatments. The SOC content of the soils showed the highest levels for plots treated with 8 t/ha of biochar although plots receiving 2 and 4 t/ha of biochar were also significantly higher than that of the control plots as seen from Fisher's LSD value of 0.143 for comparing means. This is as expected since biochar is derived from organic materials, in our study from *Eupatorium* sp., a type of weedy vegetation. The findings of this study are consistent with those of other studies [4,17,24,25]. An increase in the SOC content of agricultural soils could eventually represent enhanced carbon sequestration in the soil if the increase can be maintained over long periods and to greater depths within the soil profile.

Treatment	**Soil pH**	**SOC**	**TN**	**AP**	**EK**	**CEC**
		(%)	**(g/kg)**	**(mg/kg)**		**(cmolc/kg)**
Control	5.18 0.09	1.145 0.171	1.55 0.28	548.5 64.8	197.0 39.1	36.45 6.17
Biochar-2	5.44 0.10	1.365 0.130	2.37 0.69	538.3 21.8	280.5 75.2	37.60 12.45
Biochar-4	5.42 0.20	1.370 0.135	2.20 0.81	619.8 161.9	21.3 70.9	42.35 6.08
Biochar-8	5.64 0.32	1.528 0.138	3.38 1.03	652.0 162.0	283.0 130.1	35.80 5.90
F-test/Signif.	2.75	12.42**	5.14*	0.68ns	1.34ns	0.57ns

Table 1: Selected soil properties as affected by biochar treatments at Budol, Kavrepalanchok, Nepal.

Likewise, TN for plots treated with biochar were also significantly higher for plots receiving 8 t/ha of biochar compared to the control, however, plots receiving 2 and 4 t/ha were not significantly different from the control (LSD = 1.073). The nitrogen content in soil also tends to follow the levels of organic matter, thus in the absence of nitrogen fertilizers, the levels of TN in the soil reflects the SOC contents. The pH values for the biochar treated plots were also somewhat higher than those for the control plots, however, they were only weakly significantly different ($P<0.10$). The increase in pH could be due to the alkaline nature of the biochar, which had a pH of about 10. The other soil properties, namely, available phosphorus, exchangeable potassium and cation exchange capacity did not differ significantly among the treatments, hence the application of biochar did not have a notable effect on these parameters.

Treatment	**Growth Rate**	**Biomass Yield**	**Grain Yield**
	(cm/day)	**(t.ha)**	
Control	2.59 0.03	3.23 0.76	1.28 0.19
Biochar-2	2.65 0.06	2.78 0.27	1.30 0.09
Biochar-4	2.73 0.03	3.13 0.68	1.33 0.28
Biochar-8	2.68 0.07	2.99 0.65	1.39 0.44
F-test/Signif.	1.25ns	0.31ns	0.09ns

Table 2: Maize growth, biomass yields and grain yields at Budol, Kavrepalanchok, Nepal.

As can be seen from the results in Table 2, the growth and yields of maize did not differ significantly among the treatments, although the average growth rate in centimeters per day and grain yields of biochar treated plots both did show a slightly increasing trend compared to the control. The differences in growth rate at various days after planting (DAP) shown in Figure 3 also show slightly higher rates for the biochar amended plots. It is possible that the effects of biochar application on growth and yield of crops may require a longer time frame than a single season to become evident. Other studies have reported improved growth and yields of pumpking, wheat and maize crops as a result of biochar soil amendment [4,26,27,29]. Therefore, it is recommended that long-term field trials over several growing seasons be conducted to confirm this.

Significant correlations among some of the crop and soil parameters were observed as shown in Table 3. Expectantly, the soil pH was correlated with AP and EK in the soil as these properties are highly influenced by the pH level of the soil. Moreover, AP and EK were also correlated with each other reflecting their relative availability on exchange sites within the soil. Also highly correlated was the maize biomass with maize grain yield indicating that increased growth of the crop led to better yields. Finally, the SOC percent of the soil was weakly correlated with soil pH, suggesting that high SOC levels in the soil could contribute to ameliorating soil pH for acidic soils such as the one studied. The results of this study are in agreement with numerous other studies, such as, Butnan et al. [30], Gautam et al. [24] and Karim et al. [11].

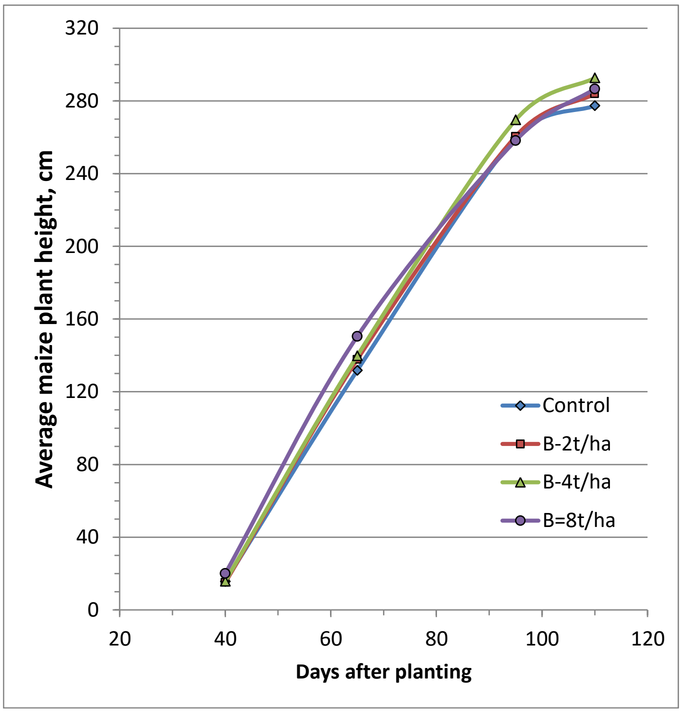

Figure 3: Maize growth rates at different days after planting during the growing season.

Parameter	Soil pH	TN	AP	EK	CEC	Growth rate	Biomass yield	Grain yield
SOC	0.468† 0.068	0.332 0.209	0.306 0.249	0.221 0.410	-0.088 0.747	0.262 0.420	0.002 0.995	-0.033 0.903

Soil pH		0.401 0.124	0.624** 0.010	0.534* 0.033	-0.141 0.602	0.217 0.420	-0.307 0.248	-0.030 0.911
TN			0.073 0.789	0.209 0.437	0.394 0.131	0.230 0.327	-0.169 0.531	-0.070 0.798
AP				0.566* 0.022	0.010 0.970	0.285 0.286	-0.341 0.196	-0.235 0.381
EK					0.277 0.298	0.177 0.513	-0.246 0.358	-0.030 0.911
CEC						0.118 0.662	0.110 0.684	-0.230 0.392
Growth rate							-0.190 0.481	-0.139 0.607
Biomass yield								0.671** 0.004

Table 3: Pearson's correlation for the soil and crop paramenters at Budol, Kavrepalanchok, Nepal.

CONCLUSIONS

The preliminary study on the effects of biochar on several soil properties and the growth and yield of maize crop indicated that biochar application to the soil had some beneficial effects on soil properties and growth parameters. Specifically, the biochar amendment significantly increased the SOC and TN contents of the treated soils, with 8 t/ha of applied biochar having the most notable effects. Also, marginally increased was the soil pH, which is a positive effect for acidic soil such as the one studied. Although growth rates and maize yields were not statistically significantly different for the biochar treated plots, an increasing trend was seen for mean growth rates and grain yields. Biochar application to soils clearly holds potential for carbon sequestration, as well as, enhancing agricultural production [2,31,32,33]. Hence, further, long-term studies are recommended to establish the beneficial effects of biochar on crop performance as well as on enhancing carbon sequestration in soils to mitigate climate change.

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