International Journal of Life Science and Agriculture Research

ISSN (Print): 2833-2091, ISSN (Online): 2833-2105

Volume 03 Issue 01 January 2024

DOI: https://doi.org/10.55677/ijlsar/V03I1Y2024-04

Page No : 22-27

Effect of Biochar on Tomato Productivity and Soil chemical Properties under Acidic Soil Condition

Tania Sultana[1*], kabil Hossain[2], Md. Forhad Hossain[3], Alok Kumar Paul[4], Nazmun Naher[5]

[1,2,3,5] Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

[4] Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

ABSTRACT: Biochar is being evaluated globally as a means to improve soil fertility, ecosystem services and sequester carbon. This study presents an attempt to analysing the influence of biochar application on the soil properties, growth, yield of tomato plant under acid soil. The study was conducted at Sher-e-Bangla Agricultural University during Robi season 2022 with 2 factor Randomized Completely Block Design. Factor A was the different acid soils with pH 6.5, 5.5, 5.0 and 4.5 and Factor B was the control, biocar and biochar+compost. The results showed that soil pH, bulk density, water content and soil organic matter were improved significantly as biochar and biochar + compost application. Biochar application also enhanced plant height, leaf number and yield components of tomato plant. It also revealed that combined application of biochar and compost increased the uptake and available of N, P, K than biochar alone and control in different level of acid soils. It was found that biochar + compost treatment in the whole growing period was best to improve tomato plant growth and yield, providing a biochar amendment recommendation for tomato production in field. Moreover, biochar application improved the soil physical and chemical properties. Therefore, biochar amendment could be an effective option to improve acidity affected croplands.

Published Online: January 12, 2024

Corresponding Author: Tania Sultana

KEYWORDS: Biochar, Acidic soil, Compost, Soil pH, Tomato

INTRODUCTION

Acidic soils are characteristics of semi arid climates. Out of 8.77mha of cultivable land in Bangladesh 0.25mha lands across the country are very strongly acidic (pH<4.5). 3.70mha lands are strongly acidic (pH4.5-5.5) and 2.74mha lands are slightly acidic (pH5.6-6.5). Acid soils may constraints crop production in more than 30% lands of Bangladesh. Acid soils possess toxic concentration of $Al3+$, $Fe3+$, $Mn2+$ lower concentration p and low availability of base together cause reduction of crop yield. To overcome the problem of soil acidity, farmers adopt a variety of soil amendments like manures, lime, compost, and bio-sorbents to make soil nutrients available to crops as well as to protect them from toxic elements. Biochar is an alternative, good and cheap organic source to overcome the soil acidity problem (Chan et al., 2008).

However tomato is an important vegetable crop in our country and a source of vitamin C. Among all vegetables tomato counts more than 7% vitamin C in Bangladesh. Biochar used in soils improves alkalinity and it's capacity to increase the pH. Not all biochars are alkaline. The pH of biochar has been reported to vary from 4 to 12 depending on the pyrolysis conditions and feedstock used (Bagreev *et al.,* 2001). Additionally, it has been found that raising the pyrolysis temperature can increase the pH of some biochars. For instance raising the pyrolysis temperature from 310 to 850o C, increased the pH of biochar produced from bagasse from 7.6 to 9.7 (Sohi *et al.,* 2010). Though high pH biochar can be produced, they might not have a big impact on the pH of soils when they are added and this effect is connected to biochar's acid neutralising capacity. Biochar indirectly influence nutrient availability by changing soil pH. In view of the fact that biochar normally has higher pH than soil it acts as a liming agent generally increasing soil pH (Glaser *et al.,* 200l; Rondon *et al.,* 2007). Soil with higher pH increases nutrient availability and decreases the quantity of Al+3 and H+ ions residing in cation exchange sites, which can efficiently increase base saturation (Sohi *et al.,* 2010). Biochar in combination with inorganic fertilizers had shown significant increase in yield different crops (Hammond *et al*., 2013). This study aim to access the morphological and yield characteristics of tomato, to determine the nutrient uptake by the different parts of the tomato plant and to examine the change of soil chemical properties after biochar and compost application.

MATERIALS AND METHODS

Location

The experiment was conducted at the research field of Agroforestry and Environmental Science department, at Sher-e-Bangla Agricutural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh.

Soil Sample

Acid soil was collected from different sites of Mirzapur upazila of Gazipur. Soil was collected by systematic random sampling technique from 30 sites at 0-30 cm depth from four upazillas of Gazipur district which was in different acidity level.

Experimental Design

The pot experiment used a two-factor Factorial Randomized Block Design with the following treatments:
Factor A (Levels of soil acidity)
1. Control 6.5,
2. pH 5.5,
3. pH 5.0 and
4. pH 4.5

Factor B (Fertilizer doses)
1. Control (Recommend fertilizer dose),
2. Biochar (5t/ha),
3 Biochar (5t/ha) + Compost (5t/ ha).

The treatment was replicated three times, resulting in a total of 36 experimental pots.

Parameters and Statistical Analysis

The pH was determined by a glass-electrode pH. The electrical conductivity (EC) was measured by an EC meter, the total nitrogen content was estimated by the micro-Kjeldhal digestion method. A simpler method for a rapid measurement of potassium in soil measured by *the LAQUAtwin potassium ion meter B-731.* The available phosphorous was measured by Olsen *et al.* method. Soil moisture was determined by portable soil moisture meter. All these properties were estimated at the end of the crop growing season.

Fruits were harvested in several pickings according to their physiological maturity. Data was collected on soil parameters such as bulk density, pH, EC, moisture, N, P and K and plant morphological, physiological and yield parameters were collected at the final harvesting stage. The data obtained for different parameters were statistically analyzed by using R-Sat program to find out the significance of variation resulting from the experimental treatments.

RESULTS

Plant height (cm)

Based on Table 1 plant height per plant displayed obvious differences in biochar, biochar + compost treatments (Table 1). Plant height in S_3T_2 and S_2T_2 were largest at 110 and 108 cm respectively, which significant higher than that in control treatment at maturity stage.

Table 1. Effects of biochar and biochar-compost mixture on the plant morphological and yield parameters of Tomato plant

Treatments	Plant height (cm)	No. of fruit	Single fruit wt. (g)	Yield (kg/plant)
T_1S_1	93	13.00	57.20	1.03
T_1S_2	96	8.00	49.70	0.67
T_1S_3	100	4.67	38.45	0.26
T_1S_4	92	2.67	33.93	0.23
T_2S_1	108	26.67	71.98	2.14
T_2S_2	105	21.67	64.30	1.58
T_2S_3	100	17.00	51.92	1.08
T_2S_4	110	13.00	41.33	0.80
T_3S_1	103	34.67	85.76	2.97
T_3S_2	85	28.33	75.76	2.14
T_3S_3	87	25.00	63.38	1.58
T_3S_4	86	20.00	63.38	1.93
CV%	**5.59**	**11.25**	**15.93**	**14.22**
LSD $_{(0.05)}$ **SE±**	**2.25** **2.18**	**6.18** **1.69**	**NS** **7.49**	**0.54** **0.15**

Note: S1 = Control (pH 6.5); S2 = pH (5.5); S3 = pH (5.0); S4 = pH 4.5;
T1= Control (Recommend fertilizer dose); T2 = Biochar (5t/ha); T3 = Biochar (5t/ha) + Compost(5t/ha)

Fruits Plant^{-1}

Fruit Plant^{-1} increased significantly in biochar and biochar-compost mixture treatments compared to control. Highest number of fruits per plants was recorded in T_3S_1 (biochar + compost with soil pH 6.5) treatment. Biochar amendment increased fruit yield in all soil pH treatments.

Single fruit weight

Single fruit weight was not significantly influenced by biochar and biochar + compost treatment under different pH levels. The fruit weight was recorded after harvest of fruits. The highest single fruit weight (85.76 gm) was recorded from T_3S_1 (biochar + compost with soil containing pH 6.5) treatment, while the lowest single fruit weight (33.93 gm) was observed from T_1S_4 (without soil amendment and soil containing pH 4.5) (Table 1).

Yield per plant (kg/plant)

Effects of different biochar application and biochar-compost mixture application on tomato yield per plant under different pH levels was significantly affected during the growing period are shown in Table 1. Highest yield per plant (2.97kg) was recorded in T_3S_1 (biochar + compost with soil containing pH 6.5) treatment, while the lowest yield per plant (0.23 kg)) was observed from T_1S_4 (without soil amendment and soil containing pH 4.5).

Nutrient concentration of Tomato fruits

The statistics have-to-do with nitrogen concentration (%) and uptake (kg/ha) in fruit as affected by biochar and compost as a component of integrated nutrient management are presented in Table 2. The highest nitrogen concentration in fruit was noticed in the treatment receiving T_3S_1 (biochar and compost application with control soil containing pH 6.8-7) with 0.98%. Similar trend was also obtained in the case of nitrogen uptake (kg/ha) in fruit and the highest nitrogen uptake (kg /ha) in fruit was recorded 51.26 kg/ha, whereas the lowest N uptake in fruit was recorded as 5.74 kg/ha in T_1S_4 treatments (Table 2).

The highest Phosphorus concentration in fruit was noticed in the treatment receiving T_3S_1 (biochar and compost application with control soil containing pH 6.8-7) with 0.40%. Similar trend was also obtained in the case of nitrogen uptake (kg/ha) in fruit and the highest phosphorus uptake (kg /ha) in fruit was recorded 20.07 kg/ha, whereas the lowest P uptake in fruit was recorded as 1.29 kg/ha in T_1S_4 treatments (Table 2).

The highest Potassium concentration in fruit was noticed in the treatment receiving T_3S_1 (biochar and compost application with control soil containing pH (6.8-7) with 0.70%. Similar trend was also obtained in the case of Potassium uptake (kg/ha) in fruit. The highest Potassium uptake (kg /ha) in fruit was recorded 35.36 kg/ha, whereas the lowest K uptake in fruit was recorded as 3.76 kg/ha in T_1S_4 treatments (Table 2). The application of biochar has showed a slight increase in K concentration with increasing the soil pH. Addition compost with biochar showed a significant increase over sole application of biochar in fruit. Yadev *et al.* (2020) revealed that combined application of biochar, fertilizers and vermicompost increased the uptake and available of N, P, K, Fe, Zn, Mn and Cu over graded doses of biochar + fertilizers, biochar alone and control. Electrical conductivity, bulk density, exchangeable acidity, exchangeable aluminium and acid saturation followed the same trend.

Table 2. Impact of biochar and compost as a component of integrated nutrient management on N, P and K concentration (%) and uptake (kg/ha) in tomato fruit

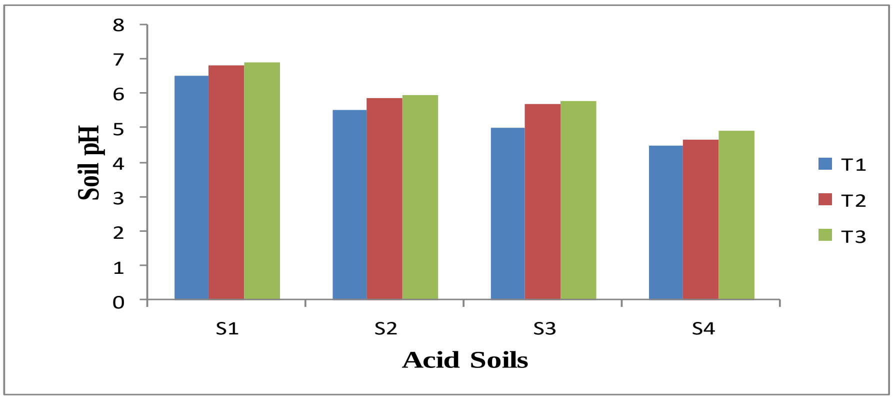
Treatments	N concentration	N Uptake	P Concentration	P Uptake	K Concentration	K Uptake
T_1S_1	0.73	11.51	0.28	3.66	0.55	7.67
T_1S_2	0.71	9.53	0.27	3.03	0.51	5.14
T_1S_3	0.69	7.68	0.22	2.25	0.48	4.14
T_1S_4	0.65	5.74	0.19	1.29	0.46	3.76
T_2S_1	0.90	26.6	0.36	12.71	0.64	19.07
T_2S_2	0.88	38.15	0.34	10.36	0.62	26.36
T_2S_3	0.86	32.57	0.34	7.31	0.61	11.36
T_2S_4	0.84	14.87	0.33	5.87	0.60	10.35
T_3S_1	0.98	51.26	0.40	20.7	0.70	35.36
T_3S_2	0.94	40.35	0.38	16.22	0.67	28.77
T_3S_3	0.86	32.57	0.34	7.34	0.62	11.38
T_3S_4	0.82	12.17	0.32	4.94	0.59	10.13

Average	**0.82**	**23.58**	**0.31**	**7.97**	**0.58**	**14.45**
SD	**0.10**	**15.22**	**0.06**	**5.98**	**0.07**	**10.50**

Note: S1 = Control (pH 6.5); S2 = pH (5.5); S3 = pH (5.0); S4 = pH 4.5;
T1= Control (Recommend fertilizer dose); T2 = Biochar (5t/ha); T3 = Biochar (5t/ha) + Compost(5t/ha)

Soil pH

Despite the long term potential impacts are to be seen, application of biochar and compost combination treatment raised the soil pH substantially in one season. From the Figure 1, it was found that the highest pH values (6.9) were obtained on application of biochar and compost combination treatment, whereas the lowest pH (4.5) was found on the T_1 S_4 treatment combination.

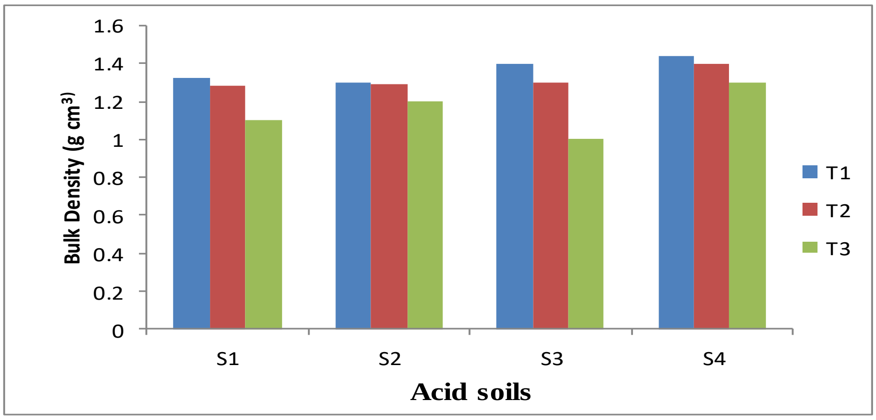


S1 = Control (pH 6.5); S2 = pH (5.5); S3 = pH (5.0); S4 = pH 4.5; and
T1= Control (Recommend fertilizer dose); T2 = Biochar (5t/ha); T3 = Biochar (5t/ha) + Compost(5t/ha)

Figure 1. Effect of Biochar and compost on soil pH in different acid soils at at LSD $_{0.05}$

Soil bulk density

Figure 2 shows that soil bulk density (BD) decreased insignificantly as the biochar quantity went up in each during the growing period. The biggest reduction was presented in treatment T_3, with the most reduction of 1.1 g cm^3 in the BD, followed by treatments T_1, compared to the least in control treatment (T_1).

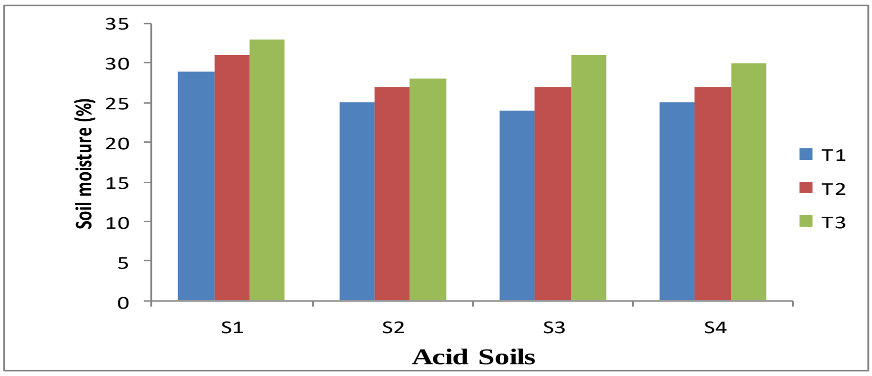


S1 = Control (pH 6.5); S2 = pH (5.5); S3 = pH (5.0); S4 = pH 4.5; and
T1= Control (Recommend fertilizer dose); T2 = Biochar (5t/ha); T3 = Biochar (5t/ha) + Compost(5t/ha)

Figure 2. Effect of Biochar and compost on soil bulk density (g/m^3) in different acid soils

Soil moisture

The change of soil water content in the pots during the experiment under biochar, biochar-compost and without biochar treatments are shown in Figure 3. It was found that biochar compost (T_3) treatments had comparatively higher soil water content (33%) with respect to biochar (T_2) non-biochar (T_1) treatment. Biochar-compost treatment T_3 showed the highest value of water content followed by T_2 and T_1 respectively.

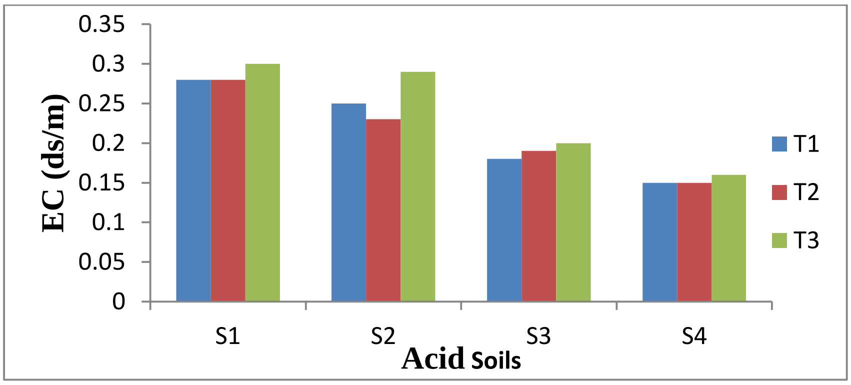


S1 = Control (pH 6.5); S2 = pH (5.5); S3 = pH (5.0); S4 = pH 4.5; and
T1= Control (Recommend fertilizer dose); T2 = Biochar (5t/ha); T3 = Biochar (5t/ha) + Compost(5t/ha)

Figure 3. Effect of Biochar and compost on soil moisture(%) in different acid soils

Soil Electrical conductivity

The application of biochar did not have any significant effect on electrical conductivity (EC) of the soil. Meanwhile, the addition of biochar and compost combination treatment showed the highest values (0.33 dS m^{-1}) and lowest soil Electrical conductivity was observed in T_1S_4 treatment combination that is (0.15 dS m^{-1}) (Figure 4).



S1 = Control (pH 6.5); S2 = pH (5.5); S3 = pH (5.0); S4 = pH 4.5; and
T1= Control (Recommend fertilizer dose); T2 = Biochar (5t/ha); T3 = Biochar (5t/ha) + Compost(5t/ha)

Figure 4. Effect of Biochar and compost on soil EC (ds/m) in different acid soils

DISCUSSION

The improvements of tomato growth parameters under biochar application could attribute to the improvements in bulk density, soil water content and soil organic matter. This result was in agreement with the result obtained by Hansen *et al*., (2016) who stated that biochar addition enhanced plant growth. Saqib *et al*. (2014) showed that addition of biochar-compost mixture increased the fruit weight due to increase in plant growth and consequently improved physiology, yield, and quality of tomato as compared with the non-biochar control. The application of biochar increase in nitrogen concentration with increasing the soil pH. The application of compost in combination with biochar increasesoil pH. Yamato *et al*. (2006) reported that biochar in combination with compost fertilizers had shown significant increase in yield of tomato and other vegetables.

Biochar application indeed made lower soil BD during the growing period. This due to porosity of biochar is very high and when it used in soil it significantly decrease bulk density by increasing the pore volume (Lehmann *et al*., 2011). Moreover, decrease in soil bulk density following the application of biochar can positively influence root development and growth (Atkinson *et al*., 2010; Laird *et al*., 2010). The application of biochar increase in P concentration with increasing the soil pH. Addition compost with biochar significantly increase over sole application of biochar in fruit. This due to application of biochar and compost increase the proportion of the soil pore size, and thus enhance soil moisture content and other soil hydrological properties. Our result also agrees with Novak *et al*. (2009), who stated that additions of biochar to soils can improve soil water storage capability.

CONCLUSION

The use of biochar for soil fertility improvement is due to its potential to improve soil quality and increase crop yield in Tomato. From the results it may be concluded that biochar improves the soil pH, bulk density, moisture% and uptake of nutrients in plants. Morphological and yield parameters also increased due to biochar and compost application. The biochar 5 t/ha + compost 5 t/ha is the most appropriate combination for increasing tomato productivity and improving soil health of acidic soil in Gazipur district of Bangladesh.

ACKNOWLEDGEMENT

This research was funded by Ministry of science and Technology, Bangladesh.

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