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RESEARCH PAPER

Response of Biochar to Plant Nutrients and Yield of *Amaranthus tricolor*

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ABSTRACT

Biochar, a by-product of biomass pyrolysis, has been suggested as a mean to combat nutrient deficiency by reducing nutrient loss, and at the same time to increase crop yields. A field experiment was carried out at the Research field of Patuakhali Science and Technology University, from March to April, 2015 to examine the effect of biochar application with the combination of N, P, and K fertilizers on amaranth biomass production and soil nutrient status. The research comprised with different soil treatment which includes control, biochar, recommended rate of N, P and K fertilizers, biochar with combination of recommended rate of N, P and K fertilizers. Sawdust biochar at the rate of 15 t ha^{-1} was used. Inorganic fertilizers were applied as Urea-TSP-MOP at the rate of 95-75-100 kg ha^{-1} as per BARI recommendation. Biochar with combination of N, P, and K fertilizers showed the highest fresh (5.5kg/m^2) and dry biomass (1.5 kg/m^2). The lowest fresh (1.93 kg/m^2) and dry biomass (0.57 Kg/m^2) was harvested from the control treatment. The highest amounts of OM (6.67 %), N(3.13%), P (3.02 µg/g), K (0.95 meq/100g) were obtained from biochar in combination with nitrogen, phosphorus and potash bearing fertilizers. The control showed the lowest OM (1.39%), N (0.29%), P (2.22 µg/g) and K (0.37 meq/100g). Biochar with combination of N, P and K fertilizers might be effective for getting higher yield of amaranth and have positive effect on soil nutrient status.

Key words: Amaranth, Biochar, nutrients.

Introduction

Biochar is a carbon rich, porous substance produced under oxygen-limiting conditions (Liu *et al.*, 2014). It can be defined as the solid residue obtained from the thermo chemical decomposition or pyrolysis of plant and waste feed stocks, and can be specifically used for application to soil as part of an agronomic or environmental management plan (Lehmann and Joseph, 2009).

It has higher soil organic carbon, nitrogen and phosphorus, relatively high basic cations like calcium, magnesium and potassium leading to higher cation exchange capacity (CEC) compared to surrounding oxisols (Glaser, 2007; Sombroek, 1966). The slow release of plant macronutrients contained in the Biochar is considered as possibility to reduce the need for adding the different chemical fertilizers in agriculture (Lehmann, 2007; Laird, 2010; Zhang *et al.*, 2012). Further, Biochar can also lead to increase water and nutrients holding capacity (Uzoma *et al.*, 2011; Kloss *et al.*, 2012).

When biochar is used as a soil amendment, it can alter the surface area, pore distribution, bulk density, and penetration resistance of the soil (Mukherjee *et al.*, 2014). According to numerous studies, biochar has an agronomic value through improvement of composition, water retention, and increased nutrient uptake and crop yield of the soil (Novak et al. 2009; Zhang *et al.* 2010).

Population of Bangladesh depend on a number of vegetable crops of which *Amaranthus spp.* is the most important since it is the only crop available in the hot summer months when no other foliage crop grows in the field. The species used as vegetable types have short plants with large smooth leaves, small auxiliary inflorescences, and succulent stems. The leaves of amaranth constitute an inexpensive and rich source of protein, carotenoid, vitamin C, and dietary fiber (Prakash and Pal, 1991; Shukla *et al.*, 2003). Besides this, the plant can also grow successfully under varied

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soil and agro climatic conditions (Shukla and Singh, 2000).

There is absolutely no information about the effect of biochar on the yield of amaranth and the nutrients availability in soil. Therefore, to fill this knowledge gap, the present investigation was undertaken to examine the effect of biochar on amaranth.

Materials and Methods

Site Description

The experiment was carried out in the research farm of Patuakhali Science and Technology University (PSTU), during March to April, 2015. The soil samples were analyzed in the Laboratory of the Department of Agricultural Chemistry and Central Laboratory of Patuakhali Science and Technology University (PSTU), Patuakhali.

Biochar production

Sawdust was used for feedstock or raw materials. The sawdust was collected from woodcuts from a local sawmill. The raw materials were spread on a polythene sheet for sun drying to decrease the water content for two days. The biochar was produced in biochar stove (Mia 2012). Biochar used for the field experiment was produced from sawdust by pyrolysis. The average residence time was (5 hours) and the highest temperature was >350 ^{0}C. Fifteen (15) kg dry sawdust were pyrolysed each time by 5 kg fuel (dry wooden stem) and produced biochar was 3.3 kg on an average.

Experimental design and layout

The experiment consisted of four soil treatments and was laid out in a RCBD (Completely Randomized Block Design) with three replications.

Seed collection:

The seeds of Amaranth (*Amaranthus tricolor)* were used as planting materials.

Experimental treatments:

There were four (4) treatments: T_1 (Treatment-1): Control (no fertilization), T_2 (Treatment-2): 15 t/ha saw dust biochar, T_3 (Treatment-3): Recommended dose of NPK fertilizers (Urea-TSP-MOP at the rate of 95-75-100 kg ha^{-1}), and T_4 (Treatment-4): 15 t/ha saw dust biochar with combination of Urea-TSP-MOP at the rate of 95-75-100 kg ha^{-1}).

Preparation of soil and plot

The top soil from research field of Patuakhali Science and Technology University was used for the experiment. The land was filled with sand soil in the previous from unknown source. The soil samples were air-dried and moved out all sort of stones and bigger particles manually. One m^2 plot was used for the experiment. Each plot received a uniform weight of 1.5 kg biochar mixture. Inorganic fertilizers were applied as Urea-TSP-MOP at the rate of 95-75-100 kg ha^{-1} as per BARI recommendation (BARI, 2005). Biochar and all fertilizers were added during final soil preparation for plot. Then plots were kept for 10 days before seed sowing and watered on every alternate day.

Chemical Analysis of soils

Soil samples were collected by the auger at a depth of 0-15 cm i.e. surface soil. The soil samples were collected and stored following the instructions reported by Allen *et al.* (1990). The soil samples were then dried at room temperature, ground to pass through twenty mesh sieve and kept separately for chemical analysis. Organic matter was determined titrimetrically following Walkley and Black (1934) method and modified by Ghosh *et al.* (1983). Total nitrogen content was determined by macro Kjeldhal method (Jackson, 1973). Available soil phosphorus was determined by Olsen's method calorimetrically using $SnCl_2$ as reductant. The soil samples were analyzed in the Laboratory of the Department of Agricultural Chemistry and Central Laboratory, PSTU, Dumki, Patuakhali. Exchangeable potassium was determined with the help of flame emission spectrophotometer using potassium filter in the Laboratory of Agricultural Chemistry, PSTU (Ghosh *et al.*, 1983 and APHA, 2005).

Statistical analysis

All data were presented as mean with Standard deviation (SD). Differences among the means were analyzed using one-way analysis of variance (ANOVA) following Duncan's multiple range test (DMRT) at the level of $P < 0.05$. For this purpose SPSS for windows (release 13, SPSS INC., Chicago, IL) statistical software package were used.

Results and Discussion

Effect of biochar on yield

The effect of the additions of biochar to soil on plant productivity is the most important outcome for its useful uses. There was a significant difference (P<0.01) of fresh biomass obtained from different treatments. Biochar and recommended N, P, K fertilizer treatment (T_4) produced a higher biomass than other treatments. The biochar amended treatment (T_2) and recommended NPK fertilizer treatment (T_3) shows a statistically similar result in their biomass production. The fresh biomass of amaranth in the biochar and recommended rate of N, P, & K fertilizers (T_4) treatment was the highest which produced 5.5 kg/m^2 and the control showed the lowest fresh biomass of 1.93 kg/m^2 (Table 1). The recommended N, P, K fertilizer treatment (T_3) produced lower fresh yield than biochar with combination of N, P, & K fertilizer treated (T_4) plots. Similarly in the context of dry biomass, there was a significant difference (P<0.01) of dry biomass production in different treatments (Table 1). The dry biomass production was observed at 1.5 kg/m^2 in biochar and NPK treated plot which was greater than other treatment. The control treatment produced the lowest dry biomass of 0.57 kg/m^2. Biochar with combination of N, P & K fertilizer enhanced total biomass production of plant. The results show that biochar significantly increased rice yields The results show that biochar significantly increased rice yields (Zhang *et al.* 2010).This was happened due to biochar act as soil conditioners to enhance plant growth by increasing availability of macro and micro-nutrient elements, retention of nutrients, reduce nutrients leaching and improve soil physical and biological properties (Glaser *et al.,* 2002; Lehmann and Randon, 2006).

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Table 1. Effect of biochar on crop biomass (mean±SD)

Variable	Fresh biomass weight (kg/m^2)	Dry biomass weight (kg/m^2)
Control (T_1)	1.93±0.27 c	0.57±.07 c
Biochar (T_2)	2.35±0.14 c	0.65±.04 c
NPK (T_3)	3.87±0.23 b	1.04±0.06 b
Biochar +NPK (T_4)	5.50±0.11 a	1.50±0.05 a
EMS	0.14	0.02
LSD	0.74	0.28
Sx-	0.21	0.08
CV	10.83%	10.85%
P-value	<0.01	<0.01

Effect of biochar on organic matter content in soil

The effect of biochar on organic matter content in soil is presented in figure 1. Biochar and N, P, & K amended soil was contained highest amount of organic matter, one the other hand control soil contained lowest amount of organic matter. The organic matter content of biocharred soil (T_2) was also considerably higher than that of NPK treated soil. The control and NPK treated soil was found statistically similar result (Figure 3). The control (T_1) and N, P, K treated (T_3) soil contained 1.39% and 1.720% OM respectively, which is lower than the initial soil (3.24%) but in the biochar and N, P, K amended soil (T_4) and only biochar amended soil (T_2) gave higher amount of organic matter content 6.67% and 4.51% respectively (Figure 1).

According to the results, biochar played a positive role on promoting the formation of soil humus. Contents of humic acids (HAs), fulvic acids (FAs), and humins (HMs) in treatment with biochar increased obviously, which was benefit to the stability of soil organic carbon pool. Biochar promoted the accumulation of nutrient elements thereby improved the soil quality. In addition, biochar accelerated the formation of carbohydrate, esters, aromatics and other organic macromolecules, which is difficult to decompose by soil microbial, resulting in the stability increase of organic carbon (Li *et al*, 2015)

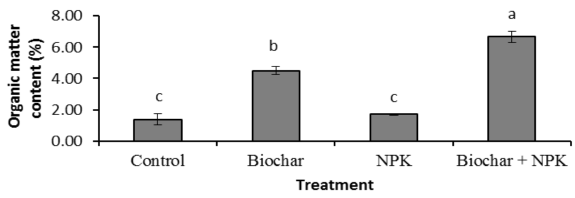

Figure 1. Effect of biochar on organic matter content in soil

Effect of biochar on total nitrogen content in soil

The amount of nitrogen content in soil as a function of treatment is presented in the Figure 2. Different treatment showed significant ($P<0.01$) differences in the effect on total N in soil (figure 2). In biochar and recommended dose of N, P, & K fertilizers (T_4) amended soil, the amount of nitrogen was increased due to the effect of biochar and fertilizer combination and the nitrogen percentage was higher than the other treatment. The lowest amount of nitrogen content was recorded in control (T_1) plot. Only recommended dose of N, P, & K fertilizers treated (T_3) plot showed higher amount of nitrogen than the control and biochar treated plot. The N, P, & K treated plots showed lower amount of nitrogen than the combination of biochar and recommended dose of N, P, & K fertilizers treated plots. The biochar and recommended dose of N, P, & K fertilizers treated soil (T_4) contained 3.13% nitrogen. The recommended dose of N, P, & K fertilizers treated soil and the control plots contained 2.35% and 0.29% nitrogen respectively (Figure 4). This difference might be due to the effect of the interaction of biochar and fertilizer combination. A pot study of maize showed higher biological nitrogen fixation with biochar addition due to nutrient effects (Rondon et al., 2007); higher yield and N uptake reported in pot trials using radish (Chan et al., 2007, 2008). A key consideration highlighted in several studies is the potential for biochar to immobilize previously plant available N. This could be from the mineralization of labile, high C–to–N fractions of biochar drawing N into microbial biomass, sorption of ammonium, or sequestration of soil solution into fine pores.

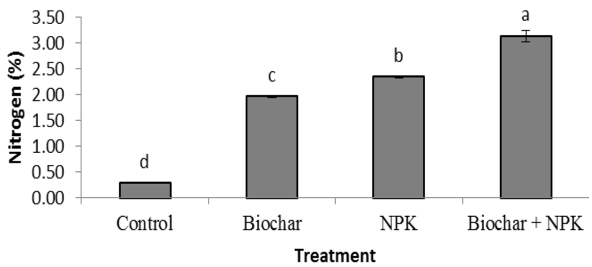

Figure 2. Effect of biochar on nitrogen content in soil

They found that biochar application lead to improve the response to N fertilizer treatments and concluded that biochar application is highly dependent on soil fertility and fertilizer management.

Effect of biochar on phosphorus (P) content in soil

Microbial turnover and organic matter decomposition regulate phosphorus (P) mineralization and hence its availability to crops. In our experiment, we observed that the biochar with recommended N, P, K fertilizer dose (T_4) showed significant ($P<0.01$) increase in phosphorus (P) content than control.

Biochar-induced inhibition of P sorption may improve the availability of added P and it has the potential to improve aggregate stability in clay soils, which may be beneficial for reducing particulate P load soils (Soinne *et al.* 2014). For this reason, the biochar treated (T_2) plot also increased Phosphorus (P) availability. The N, P, K treated (T_3) plot and the biochar treated (T_2) plot were statistically similar. The mean value of phosphorus (P) content was observed 3.02 microgram/g in the biochar and N, P, K amended soil which was greater than the control (2.22 microgram/g). The biochar treated soils and N, P, K treated soil recorded at 2.80 microgram/g and 2.75 microgram/g (Figure 3). The biochar treatment (T_2), recommended dose of N, P, K

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treatment (T_3) and the combination of biochar and NPK fertilizers treated (T_4) soil showed greater p content than the control (T_1).

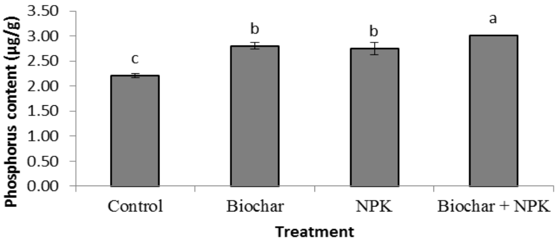

Figure 3. Effect of biochar on phosphorus content in soil

The biochar were able to bring available P into soils, but the amount and form of available P was dependent on biochar types (Zhang *et al*, 2016). Chintala *et al*. (2014) also found that P adsorption on biochar was significantly affected by initial P concentration and biochar type. P availability might be greatly affected by application of biochar with N, P, & K fertilizers that influence the ratio of soluble-to-insoluble P pools in the soil. Griffin and Brandon (1983) reported that Phosphorus (P) increased in soil with increasing of P fertilizer supply.

Effect of biochar on potassium (K) content in soil

Soil K content was significantly ($P < 0.01$) greater in the plot of biochar application with recommended rateof N, P, & K fertilizer treated soil (T_4) (figure 4). This treatment indicated highest potassium (K) content when the control (T_1) showed lowest potassium (K) content. There were no statistical significant difference of potassium (K) content between biochar treated (T_2) and recommended dose of N, P, & K fertilizer treated plots (T_3). The control (T_1) plot was found about 0.37 meq/100g potassium (K) which was less than the only biochar, only NPK and biochar with NPK treated soil. It was due to the absence of biochar in control soil. In biochar with recommended dose of N, P, & K fertilizer treatment and biochar treatment, potassium (K) was added from the biochar itself. The highest mean of potassium (K) content was observed at the combination of biochar and recommended dose of N, P, & K fertilizer treated soil of 0.95 meq/100g. The biochar treatment and the recommended dose of N, P, and K fertilizer treated plot had 0.65meq/100g and 0.69meq/100g of potassium (K) respectively (Figure 4).

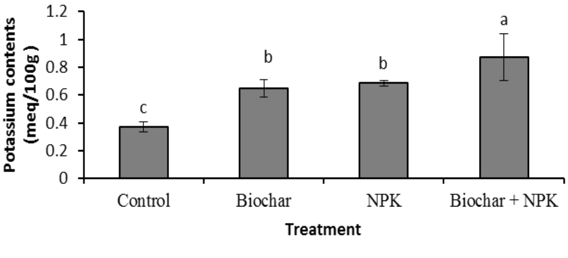

Figure 4. Effect of Biochar on Potassium content in meq/100g of soil

Sika (2012) showed the empirical evidence for the ability of biochar to reduce nutrient leaching. Therefore, fertilization and the addition of biochar increased and improved the K availability of the soil.

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