ISSN: 1991-0037 (print), 2710-3285 (online)
SOUTH ASIAN JOURNAL OF AGRICULTURE
www.saja.edu.bd;https://www.banglajol.info/index.php/SAJA
Agrotechnology Discipline, Khulna University
www.ku.ac.bd

OPEN ACCESS

South Asian J. Agric.

Research Article Vol. 9, No. 1 & 2, 2022-’23: 64-71

Title: Impact of Biochar on Yield and Nutrient Conservation in the Sunflower (*Helianthus annuus* L.) Field in Non-Saline Tidal Ecosystem

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Article Info:

Received:
September 5, 2023
Accepted:
November 2, 2023

Keywords: Biochar, Nutrients, Sunflower, Yield

ABSTRACT

Biochar is an organic amendment produced by pyrolysis used in soil to conserve soil nutrients. Research work was conducted to observe the effect of biochar on yield and nutrient conservation ability in non-saline land of southern Bangladesh. The research comprised four different soil treatments as 0, 5, 10, and 20 t/ha biochar along with recommended doses of fertilizers. Biochar @ 20 t/ha with a combination of fertilizers showed the maximum yield (3.37 t/ha). The highest amounts of K, Na, Ca, Mg, S, and P were obtained from biochar-treated plots of 20 t/ha. The control plots showed the lowest yield and the lowest amount of K, Na, Ca, Mg, S and P. Biochar @ 20 t ha^{-1} with a combination of fertilizers could be recommended for higher yield and nutrient conservation in the southern non-saline area of Bangladesh.

DOI: https://doi.org/10.3329/saja.v9i1-2.69750

To cite this article: Lipi, N.J. and Maniruzzaman, M. 2023. Impact of Biochar on Yield and Nutrient Conservation in the Sunflower (*Helianthus annuus* L.) Field in Non-Saline Tidal Ecosystem. South Asian Journal of Agriculture, 9 (1 & 2): 64-71.

INTRODUCTION

Biochar is a carbon-rich organic amendment produced by pyrolysis (Lehmann and Josep, 2009). Biochar improves various soil properties such as water-holding capacity, soil aeration, nutrient-holding capacity, and cation exchange capacity (Downie and Van Zwieten, 2013; Atkinson et al., 2010 Chan et al., 2008). As biochar has large surface area (Liang et al., 2006), application of biochar the net soil surface area is increased which influences the water and nutrient holding capacity (Chan et al., 2008a; Lehmann and Josep, 2009). Biochar is a highly porous organic matter which affects soil moisture content and nutrient dynamics (Glaser et al., 2002; Lehmann et al., 2003). For its larger surface area, greater negative surface charge, and greater charge density than other organic matter (Liang et al., 2006) it can adsorb more nutrients (Sombroek et al., 1993).

Biochar can increase agricultural productivity, especially in low fertile and degraded soil. Though the effect of biochar is dependent on various factors, crop species is a major one (Jeffery et al., 2011). Sunflower (*Helianthus annus* L.) is a major source of oil and it is the fourth largest vegetable oilseed crop in the world (Rodriguez et al. 2002). In Bangladesh, the scarcity of edible oil has been a severe problem for many years (Khatun et al. 2016). The shortage of edible oil has been an acute problem for several years (Khatun *et al*., 2016). Bangladesh produces 0.358 million tons of edible oil while she demands 1.6 million tons annually (Sohel et al., 2023). To fulfill the demand, every year Bangladesh Government has to spend a huge amount of money. As rice is the staple food crop in Bangladesh, the farmers in the southern tidal region follow the rice (transplant *aman*)-fallow- fallow cropping pattern. However, the area of oilseed crop cultivation can be increased by utilizing the fallow land. Cultivation of mustard is limited in this region due to some unavoidable environmental factors. Farmers are not encouraged to grow soybean in their fields as the processing of soybeans is very difficult (need reference). So, sunflower might be the promising oilseed crop that can be cultivated in this region for oil production to help reduction of spend on import.

To keep up the food security of Bangladesh and nutrient availability in the soil, we need soil amendment to increase nutrients status. Biochar may be one of the options to conserve soil nutrients. For the above circumstances, a piece of research work was selected to investigate the ability of biochar to conserve nutrients in combination with fertilizers and sunflower production.

METHODOLOGY

Site Description

The experiment was conducted in the field of Patuakhali Science and Technology University located at 22°37'N latitude and 90°10' longitude (Figure 1). The experimental field belongs to the Agroecological zone of AEZ-13 namely the Ganges Tidal Flood Plains.

Preparation of biochar

Rice husk was used for feedstock or raw materials. Previously produced biochar (from rice husk) was used for this experiment.

Seed collection

The seeds of sunflower Kiron (*Helianthus annuus* L.) were used as planting materials which was released from BARI (Bangladesh Agriculture Research Institute).

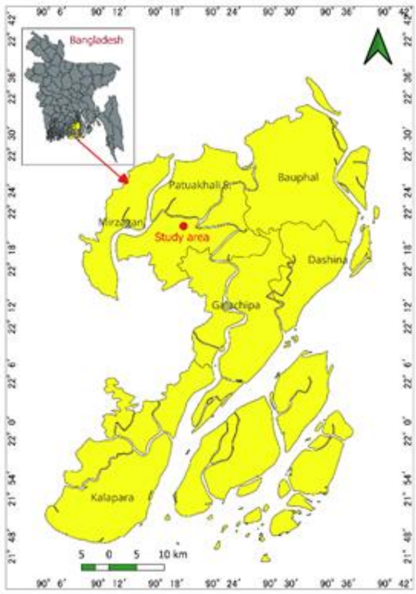

Figure 1. Location of the study area in the map

Characteristics of soil

The soil of the experimental field was silt clay textured with pH ranged from 7.2-7.73. It was mildly alkaline and non-saline. The initial soils were collected from each plot before biochar application to determine the chemical composition of the samples.

Experimental treatments

In our experiment, we used four (4) treatments. They were: T_1- Control (no biochar), T_2 - 5 t/ha biochar, T_3 – 10 t/ha biochar, and T_4 - 20 t/ha biochar. The same amount of fertilizers @ 90:35:80:30:3.6 and 1.8 kg/ha of N, P, K, S, Zn and B, respectively were used in every plot as recommended by BARI. After the application of fertilizer biochar was applied in each plot as per treatment. Biochar and fertilizers were applied in the field manually.

Experimental design and layout
The experiment was laid out in a randomized completely block design (RCBD) with four soil treatments and three replications.

Preparation of soil and plot
The experimental plot was harrowed, ploughed, and cross-ploughed three times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained the desired tilth of soil. The plot size was (2.5 x 2) m^2 for the experiment. Biochar and all fertilizers were added during the final land preparation. A total of twelve (12) plots were prepared for this experiment.

Seed sowing of sunflower
Seeds of sunflower (kiron) were sown on 1 February 2018 in rabi season. Before sowing, seeds were soaked for 24 hours. Then seeds were sown manually in each plot within 1-2 cm depth (approximately) and 50 cm × 25 cm spacing and covered with soil.

Intercultural operations
Intercultural operation is mandatory for sunflower cultivation. After a week's interval, weeding and irrigation were done in plots during the experimentation. During vegetative leaf blast disease was seen in the crops. To control this disease, a recommended dose of fungicide (Amistar Top) was used. During reproductive growth, the plot was covered with a net to protect the seed from birds, especially parrots and doves otherwise it would destroy all the heads of the sunflower and eat all the seeds.

Harvesting
The fully mature (the back of the head turned yellow from green) the sunflowers were harvested.

Chemical analysis of soils
After harvesting sunflowers from the field, soil was collected from each plot. Then soil nutrients were analyzed in the laboratory which was described below-

Phosphorus was extracted from soil by Olsen method Olsen's method. The content of phosphorus was measured by spectrophotometer (Model T60 U) at the wavelength of 660nm after 15 minutes after the addition of ascorbic acid (Jackson, 1973). For potassium and sodium determination, 1 N $NH_4C_2H_3O_2$ (pH 7.0) was used as an extraction reagent. The content of sodium and potassium was determined by a flame photometer (Gosh et al., 1983). Calcium chloride solution was used as an extraction reagent for sulfur determination. Sulfur was analyzed by the turbidimetric method using a spectrophotometer (Page et al., 1982). To extract the sample for Ca and Mg determination, ammonium acetate ($NH_4C_2H_3O_2$) was used. Calcium and Magnesium were analyzed by a complexometric method of titration (Page et al., 1982).

Statistical analysis
The mean values of all the characters were calculated and analysis of variance was performed by using the 'Analysis of variance technique' with the help of the SPSS computer program. The mean differences were compared by Duncan's Multiple Range Test at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of biochar on seed yield of sunflower
A significant difference ($p<0.01$) was found in the seed yield of sunflowers applying different treatments. The biochar with a recommended dose of fertilizer-treated plots produced a higher yield than other treatments. The highest yield (3.37 t/ha) was observed in biochar-treated plots with 20 t ha^{-1} biochar containing a recommended dose of fertilizers. The control plots that contained only fertilizers produced the lowest (2.45 t/ha) yield (Table 1). Biochar has a positive effect on the yield of sunflowers (Major et al., 2009; Sanvong et al., 2014; Suppadit et al., 2012). It improves soil properties such as increasing soil micro and macronutrients, reducing nutrient leaching loss, and

increasing water-holding capacity (Glaser et al., 2002; Lehmann and Randon, 2006) which increase yield of sunflowers.

Table 1: Effect of biochar on yield of sunflower grown in non-saline coastal soil in southern Bangladesh

Treatments	Average yield (t/ha)
Control	2.45±0.11
5 tha^{-1} biochar	3.00±0.23
10 tha^{-1} biochar	3.23±0.16
5 tha^{-1} biochar	3.37±0.25

Table 2: Nutrient status of initial soil

Name of nutrients	Nutrient status
Potassium (K)	0.173 (meq/ 100 g soil)
Sodium (Na)	0.319 (meq/ 100 g soil)
Calcium (Ca)	6.5 (meq/ 100 g soil)
Magnesium (Mg)	1.497 (meq/ 100 g soil)
Sulphur (S)	21.305 (µg/g)
Phosphorus (P)	2.373 (µg/g)

Effect of biochar on nutrient conservation

Effect of biochar on potassium (K) content in sunflower field

The content of K was significantly different ($p<0.01$) due to the application of biochar (Figure 2).

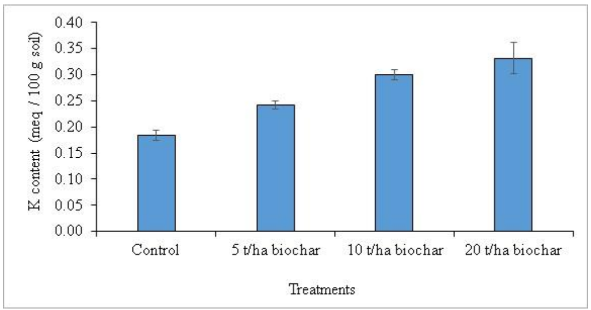

Figure 2. Effect of biochar on potassium (K) content in the soil of a non-saline field of southern Bangladesh

K content was found 0.173 meq/100 g soil in the initial soil (Table 2). Soil nutrients were also determined after harvesting sunflowers. After harvest, the highest K content (0.330 meq/100 g soil) was observed in 20 t ha^{-1} biochar treated plots with a recommended dose of fertilizer, and the lowest K content (0.182 meq/100 gm soil) was observed in control plots that contained no biochar.

From the experiment, it was observed that biochar increased the potassium content in soil. As biochar reduces nutrient leaching (Sika and Hardie, 2012), the addition of biochar and fertilizer in the soil increases the content more than needed by plants (Chan et al., 2007; Major et al., 2010; Van-zwieten et al., 2010).

Effect of biochar on sodium (Na) content in sunflower field

The content of Na in soil significantly differed ($p<0.01$) in different treatments (Figure 3). Na content was found in 0.319 meq/100 g soil in the initial soil (Table 2). Soil Na was also determined after harvesting sunflowers. In this case, the highest sodium (Na) content (0.808 meq/100 g soil) was observed in biochar-treated soil containing 20 t ha^{-1} biochar with a recommended dose of fertilizer, and the lowest Na content (0.378 meq/100 g soil) was observed in control plots that contained no biochar.

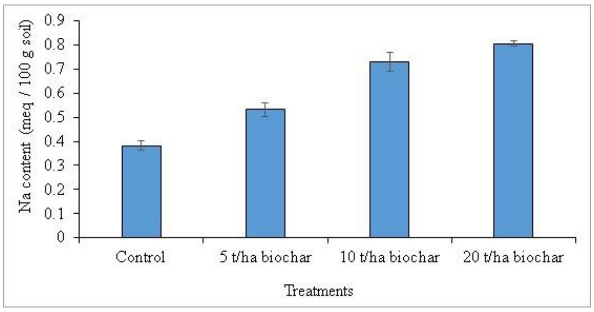

Figure 3. Effect of biochar on Sodium content in the soil of a non-saline field of southern Bangladesh

It was observed that sodium content was increased when biochar was applied (Figure 3). The increased amount of Na in soil might be the reflection of the biochar property itself (Chan et al., 2008). The application of biochar increased the exchangeable Na in soil (Chan et al., 2007; Major et al., 2010; Van Zwieten et al., 2010).

Effect of biochar on calcium (Ca) content is Sunflower field

Calcium levels in the soil were found significantly different ($p<0.01$) when varying soil treatments (Figure 4). Calcium content was found 6.5 meq/100 g soil in the initial soil (Table 2). After harvest, the highest Ca content (9.6 meq/100 g soil) was noticed in biochar-treated plots containing 20 t ha^{-1} biochar with a recommended dose of fertilizer, and the lowest Ca content (6.4 meq/100 g soil) was observed in control plots that contained no biochar. Calcium became available in soil with the application of biochar and fertilizers. The negative charge of biochar attracted more positive charges to its surface and kept ions available to plants (Lehman et al., 2009). The addition of biochar increased the calcium content in soil made by biochar itself. Biochar can reduce calcium leaching from soil (Sika and Hardie, 2012).

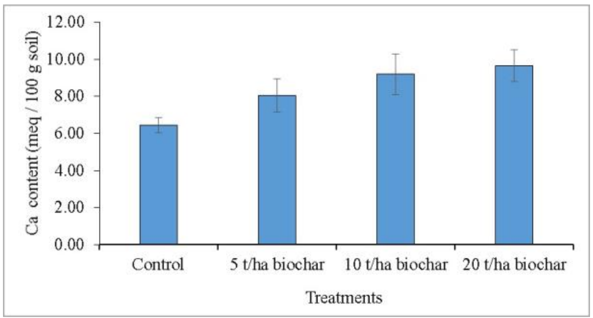

Figure 4. Effect of biochar on sodium (Na) content in the soil of a non-saline field of southern Bangladesh

Effect of biochar on magnesium (Mg) content in the soil

The Mg availability was significantly different (p<0.01) in each treatment (Figure 5). The initial soil contained 1.497 meq Mg/100 g (Table 2). Soil Mg was also determined after harvesting sunflowers. After harvest, the highest Mg content (3.489 meq/100 g soil) was observed in biochar-treated plots containing 20 t ha^{-1} biochar with a recommended dose of fertilizer, and the lowest Mg content (1.461 meq/100 g soil) was observed in control plots that contained no biochar.

From the experiment, it appeared that the application of biochar in soil increased Mg availability and reduced nutrient leaching. The Mg is a highly mobile nutrient element and very susceptible to leaching from soil. Biochar could solve the problem as it makes complex with Mg (Havlin et al., 2005). Besides this, a lesser quantity of Mg could be leached out from soil as biochar increases the exchangeable Mg in soil (Chan et al., 2007; Major et al., 2010; Van Zwieten et al., 2010).

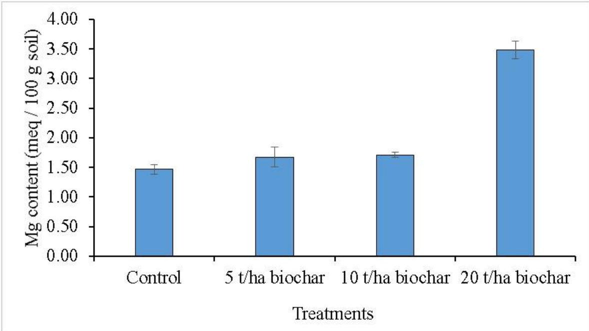

Figure 5. Effect of biochar on magnesium content in the soil of a non-saline field of southern Bangladesh

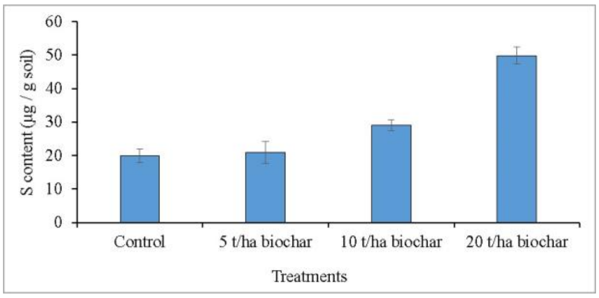

Figure 6. Effect of biochar on sulfur content in the soil of a non-saline field of southern Bangladesh

Effect of biochar on sulfur (S) content in the soil

Soil samples collected before seed sowing showed significant variation ($p<0.01$) in sulfur content under various soil treatments (Figure 6). The initial soil content was 21.305 µg S/g soil (Table 2). Soil sulfur was also determined after harvesting of sunflowers. After harvest, the highest sulfur content (49.566 µg g^{-1} soil) was observed in biochar-treated plots containing 20 t $ha^{-1}$of biochar with a recommended dose of fertilizer, and the lowest S content (19.827 µg/g soil) was observed in control plots that contained no biochar. From this research, it was noticed that soil sulfur was increased with the application of biochar. The sulfur oxidation or mineralization was increased in the springtime due to the faster warming of soil with the addition of biochar (Stevenson and Cole, 1999). The addition of biochar reduces the extent of SO_4^{2-} sorption in soil (Johnson, 1984), therefore, the application of biochar and fertilizer in soil might increase the concentration of sulfur in soil. Though it is very difficult to separate the effect of biochar and fertilizers on sulfur content in the soil, it was most likely due to the release of soluble S from both biochar and fertilizers (Gray and Dighton, 2006).

Effect of biochar on phosphorus (P) content in the soil

Soil samples collected before seed sowing showed significant variation ($p<0.05$) in P content under various treatments (Figure 7). Phosphorus content was found in 2.373 µg/g soil in the initial soil (Table 2). After harvest, the highest P content (3.271 µg/ g soil) was observed in biochar-treated soil containing 20 t ha^{-1} biochar with a recommended dose of fertilizer, and the lowest P content (2.327 µg/g soil) was observed in control plots that contained no biochar. From the current study, it was found that the addition of biochar increased P availability in soil and reduced nutrient leaching from soil.

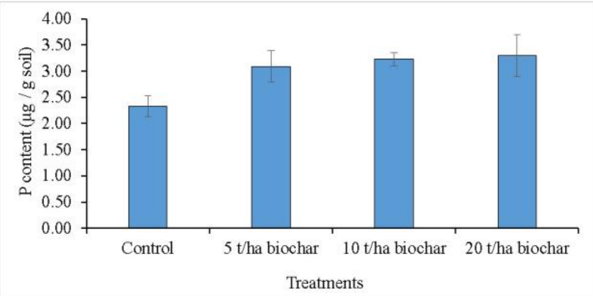

Figure 7. Effect of biochar on phosphorus (P) content in the soil of a non-saline field of southern Bangladesh

Biochar releases P into the soil (Tyron, 1948). When biochar is produced the P does not volatilize at 700 °C whereas the organic carbon is volatilized at approximately 100 °C (Knoepp et al., 2005) resulting increase of P in the soil after the application of biochar in the soil (Gudale and Deluca, 2006).

CONCLUSION

The highest seed yield and highest amounts of K, Na, Ca, Mg, S, and P were obtained from biochar-treated plots of 20 t ha^{-1}. The control plots showed the lowest yield and the lowest amount of K, Na, Ca, Mg, S and P. Biochar @ 20 t ha^{-1} with a combination of recommended fertilizers could be suggested for a higher yield of sunflowers and nutrient conservation in the southern non-saline area of Bangladesh.

DISCLOSURE STATEMENT

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

DATA AVAILABILITY STATEMENT

Anonymized Data can be made available on reasonable request.

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