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Response of Biochar to Plant Nutrients and Yield of *Glycine max* In Non-saline Tidal Ecosystem

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Abstract

Biochar is an organic matter produced by gasification used in soil to preserve soil nutrients. Research work was conducted in the field of Patuakhali Science and Technology University from January to May 2018 to observe the effect of biochar on the yield and nutrient conservation ability of soybeans. The research completed four types of soil treatments as Control, 20 t/ha Biochar, Recommended dose of fertilizers, and 20 t ha^{-1} biochar along with recommended doses of fertilizers. Biochar @ 20 t ha^{-1} with a combination of fertilizers showed the maximum yield (2.18 t ha^{-1}). The largest amounts of K, Na, Ca, Mg, S, and P were observed 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 fertilizers could be recommended for higher yield and nutrient conservation in the southern non-saline area of Bangladesh.

Keywords: Biochar, Nutrients, soybean, Yield

Introduction

Soybean (Glycine max L.) grows in tropical, subtropical, and temperate climates. Soybean has many benefits, nutritionally for man and livestock, as well as other industrial and commercial uses. It is classified as an oilseed containing significant amounts of all the essential amino acids, minerals, and vitamins for human nutrition. It is therefore an important source of human dietary protein with an average of 40% content, 30% carbohydrate, and an oil content of 20% (Islam et al., 2019)

Biochar is a porous and highly stable form of charcoal produced by slow pyrolysis of organic wastes such as crop residues. Biochar has the valuable capacity to retain water and nutrients. Moreover, the material offers a conducive habitat for soil microorganisms and, thus can contribute to soil fertility (Kookana et al., 2011). Biochar is used as a soil amendment to increase yields of rice, soybean, corn, and

vegetables (Asai et al., 2009; Vaccari et al., 2011; Yamato et al., 2006). In addition, biochar can also be used to improve topsoil water retention in farmlands, reduce nitrous oxide emissions, balance soil acidity, and increase soil organic carbon (Ginebra et al., 2022). By enhancing soil organic matter, biochar also enhances soil nutrient levels and water availability (Sohi et al., 2010), which in turn contributes to higher crop yields. It reduces the nutrient leaching loss, which in turn can reduce fertilizer needs (Laird et al., 2010; Liang et al., 2006).

The shortage of edible oil has been an acute problem for several years (Khatun et al., 2016). Bangladesh produces 0.358 mt ha-1 of edible while she demands 1.6 million tons (Hossain et al., 2010). 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 oil seed crop production can be maximized by utilizing the fallow land.

Soybeans are highly responsive to fertilizer application and hence, it would require a huge amount of nutrient supply through commercial fertilizers. It involves a lot of investment; therefore it is necessary to study the response of soybeans to a wide range of fertility levels incombinations with organic and inorganic sources. The incorporation of chemical fertilizer with organic manures is completely promising not only keeping higher productivity but also providing greater stability in crop production (Nambiar & Abrol, 1989). For the above circumstances, theresearch was conducted to find the effect of biochar on the yield of soybeans and nutrient conservation in soil.

Methodology

Experimental site

The experiment was conducted at the research field of Patuakhali Science and Technology University. The samples were collected and processed in January 2018 and Laboratory analysis was conducted from May to June 2018 in the Department of Agricultural Chemistry and Central Laboratory of PSTU, Dumki, Patuakhali. Geographically, the experimental area namely Dumki Upazila is 22021¢ N latitude and 90019¢ E longitude, respectively (Figure 1). The study area belongs to the Argo-Ecological Zone of AEZ–13.

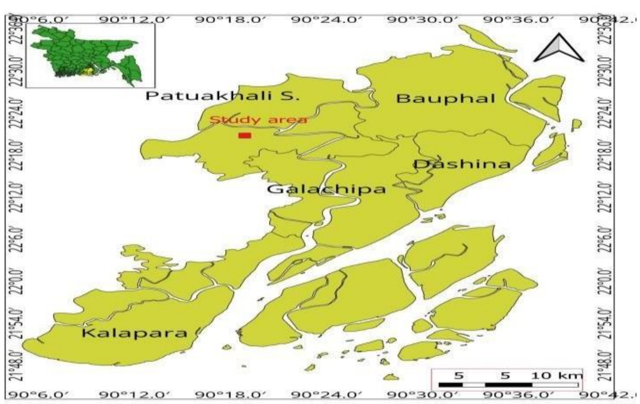

Figure 1. Experimental site

Preparation of biochar

Sawdust was used for feedstock or raw materials. The Sawdust was collected from woodcuts from a local sawmill in Dumki. 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 a biochar stove developed by Shamim et al. (2015) The average residence time was (5 hours) and the highest temperature was >500 0 C. After the pyrolysis process, the biochar will be grounded to pass through a 0.18 mm sieve so that biochar should have the same particle size.

Seed collection

The seeds of soybean (Glycine max) were used as planting materials. The BARI Soybean-6 variety was used.

Soil

The soil of the experiment was silt clay loam having pH > 7.2. It was mildly alkaline and non-saline. The initial soils were collected from each plot after application of treatments before seed sowing and determined the chemical composition of the samples (Table 2).

Experimental treatments and design

In our experiment, we used four (4) treatments. These were: Control, 20 t/ ha biochar, Recommended fertilizers, 20 t/ha biochar, and recommended fertilizers. The BARI recommended fertilizers were Urea-60 kg/ha, TSP-175 kg/ha, MOP-120kg/ha, and Gypsum-115kg/ha. The experiment was laid out in an RCBD (Completely Randomized Block Design) with three replications.

Preparation of soil and plot

From the field, all sorts of stones and bigger particles were moved out manually. A power tiller was used to crumber the soil. The plot with 2.5m x 2m was used for the experiment. Each plot received different rates of biochar and recommended doses of fertilizer. Biochar and all fertilizers were added during the final soil preparation for the plot. A total of twelve (12) plots were filled up by soil or soil with different soil amendments. The moisture content of the soil was maintained at 60% water holding capacity by a manual test. Then plots were kept for 10 days before seed sowing and watered on every alternate day.

Seed sowing of soybean

Seeds were sown on 1 February 2018 in the Rabi season. Seeds were sown in each plot within 1-2 cm depth (approximately) and covered with soil. Necessary shading by rice straw was used to prevent soil moisture until germination.

Irrigation

The plot was moistened to 60% water holding capacity by a manual test. To make the soil 60% moistened, 1000 ml water was used in each plot. All plots were watered evenly and on an "as needed" basis depending on the moisture of the soil.

Intercultural operations

Intercultural operation is mandatory for soybean cultivation. After a week's interval, weeding and irrigation was done in plots during the experiment. During vegetative growth soil born disease and insect infestation were seen in the crops. During reproductive growth, the plot was covered with a net to protect it from birds, especially parrots and doves otherwise it would destroy all the heads of the sunflower and eat all the seeds.

Harvesting and data collection

The crop was harvested in the 2nd week of May. Data were collected on a single plant basis from 10 randomly selected plants of each plot in such a way that the border effect was avoided for high precision. The plot yield was recorded and then the yield was converted to t ha-1.

Collection and processing of soil samples:

The soil samples were collected leveled from 0-15 cm soil depth before seed sowing and after harvesting. Then the collected soil sample was dried and all kinds of dirt, trash, and plant parts. Then it was ground and sieved carefully. After that, the soil samples were dried and kept carefully for further chemical analyses.

Extraction and chemical analysis of nutrients.

For the determination of exchangeable Na, K, Ca, and Mg; the soil was extracted with neutral 1N ammonium acetate (CH_3-COO-NH_4) following the method outlined by the ammonium acetate extraction method (Jackson, 2005). For the determination of available phosphorus, soil was extracted following Olsen's method. 0.15% calcium chloride ($CaCl_2$) extracting solution was used as an extraction agent for the extraction of available sulfur (Tandon, 2005). 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, 2005). The content of sodium and potassium was determined by a flame photometer (Ghosh et al., 1983). Sulfur was analyzed by the turbidimetric method using a spectrophotometer (Page, 1982). Calcium and Magnesium were analyzed by an Atomic absorption spectrophotometer (APHA, 2012).

Statistical analysis:

The mean values of all the characters were calculated and an analysis of variance was performed by using the 'Analysis of variance technique' with the help of the JMP 8 computer program the mean differences were compared by Duncan's Multiple Range Test at a 5% level of significance.

RESULTS AND DISCUSSION

Effect of biochar on seed yield of soybean:

A significant difference was found in the seed yield of soybeans applying different treatments. The biochar with a recommended dose of fertilizer-treated plots produced a higher yield than other treatments. The highest yield (2.18 t/ha) was observed in 20 t/ha biochar and recommended dose of fertilizers. The control plots produced the lowest (1.6 t ha-1) yield (Table 1). Biochar has a positive effect on the yield of Soybeans (Major et al., 2010; Sanvong & Nathewet, 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 & Rondon, 2006) which affect on yield of Soybeans.

Table 1: Effect of biochar on yield of soybean

Treatments	Average yield (t/ha)
Control	1.6±0.10c
20(t/ha) Biochar	1.8±0.10bc
Recommended fertilizers	1.96±0.12ab
20(t/ha) Biochar and Recommended fertilizers	2.18±0.02a

Effect of biochar on Nitrogen (N) content in Soybean field :

The content of nitrogen was significantly difference with different treatments before seed sowing and after harvesting of soybean (Table 2 and Figure 2)

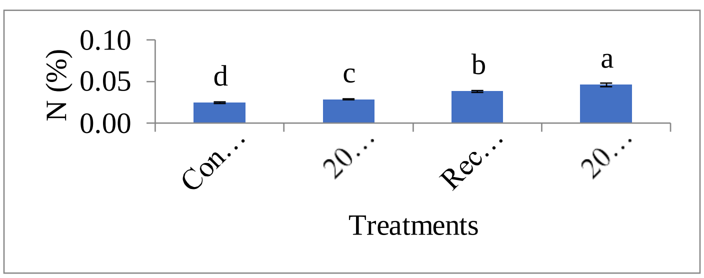

Figure 2. Effect of biochar on nitrogen (N) content in the soil

The highest amount of nitrogen (0.08%) was found in 20 (t/ha) Biochar and Recommended fertilizers treated initial soil (Table 2). Soil nutrients were also determined after harvesting soybeans. In this case, the highest N content (0.046%) was observed in 20 t ha-1 biochar treated plots with a recommended dose of fertilizer, and the lowest N content (0.024%) was observed in control plots.

Table 2: Nutrient status of initial soil (application of treatments before seed sowing)

Nutrients			Treatments	
	Control	20 (t/ha) Biochar	Recommended fertilizers	20 (t/ha) Biochar and Recommended fertilizers
Nitrogen (%)	0.07	0.071	0.0712	0.08
Phosphorus (ppm)	10.2	12.14	24.31	25.2
Potassium (meq/100g)	0.25	0.3	0.31	0.61
Calcium (meq/100g)	6.8	7.4	6.86	13.2
Magnesium (meq/100g)	4.6	4.73	4.6	8.56
Sulphur (ppm)	2.5	2.51	12.9	15.3

From the experiment, it was observed that biochar increased the nitrogen content in the soil. As biochar reduces nutrient leaching (Sika, 2012), the addition of biochar and fertilizer in the soil increases the N content more than needed by plants (Chan et al., 2007; Major et al., 2010; Nelson et al., 2011; Van Zwieten et al., 2010).

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

Soil samples showed significant variation in phosphorus (P) content under various treatments (Table 2). Soil phosphorus was also determined after harvesting Soybeans. In that case, the highest phosphorus (P) content (15.714 ppm) was observed in 20 t ha-1 biochar-treated plots with a recommended dose of fertilizer (Figure 3).

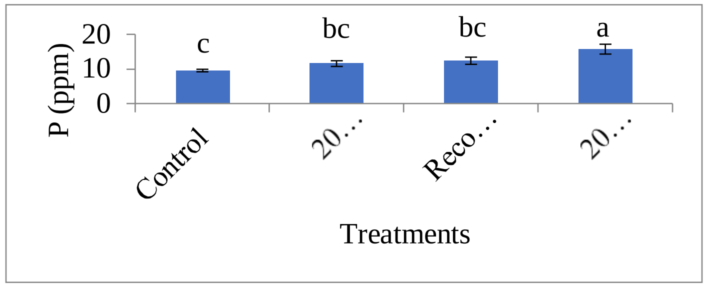

Figure 3. Effect of biochar on phosphorus (P) content in the soil

The lowest phosphorus (P) content (9.506 ppm) was observed in control plots. From the current study, it was found that the addition of biochar increased phosphorus availability in soil and reduced nutrient leaching from soil. Biochar releases phosphorus into the soil (Tryon, 1948). Biochar, when produced at high temperatures (typically above 700°C), retains phosphorus rather than volatilizing it, unlike organic carbon which volatilizes at lower temperatures (around 100°C). This retention of phosphorus in biochar can be beneficial when applied to soil, as it can contribute to increasing phosphorus levels and improving soil fertility over time. This property of biochar makes it a valuable amendment for soil management and agriculture (Ghodszad et al., 2021; Glaser & Lehr, 2019; Li et al., 2020; Nelson et al., 2011).

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

The content of potassium was significantly difference with different treatments in initial soil (Table 2).

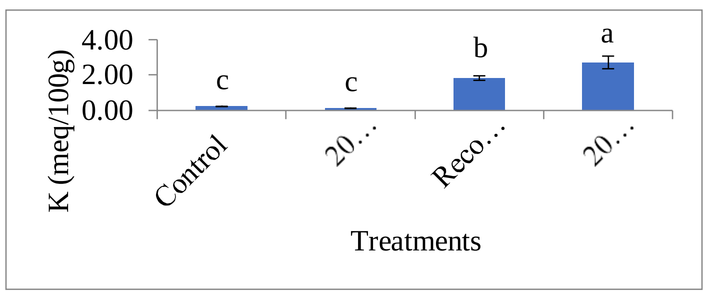

Figure 4. Effect of biochar on potassium (K) content in the soil

Soil potassium was also determined after harvesting Soybean significant difference ($p<0.001$) was observed. In this case, the highest K content (2.718 meq/100 gm soil) was observed in 20 t ha-1 biochar treated plots with a recommended dose of fertilizer, and the lowest K content (0.23 meq/100 gm soil) was observed in control plots (Figure 4). From the experiment, it was observed that biochar increased the potassium content in soil. As biochar reduces nutrient leaching (Sika, 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 calcium (Ca) content is Soybean field :

Calcium (Ca) levels in the initial soil were found significantly different when varying soil treatments (Table 2). Soil Ca was also determined after harvesting Soybeans and found a significant difference ($p<0.001$). In that case, the highest Ca content (17.812 meq/100 gm soil) was noticed in 20 t ha-1 biochar with a recommended dose of fertilizer, and the lowest Ca content (9.572 meq/100 gm soil) was observed in control (Figure 5) . Calcium became available in soil with the application of biochar and fertilizers. Biochar typically has a high cation exchange capacity (CEC) due to its porous structure and negative surface charge. This negative charge attracts positively charged ions (cations) like calcium (Ca^{2+}), holding them on its surface (Lehmann & Joseph, 2015). The addition of biochar increased the calcium content in soil made by biochar itself. Biochar can reduce calcium leaching from soil (Major et al., 2012).

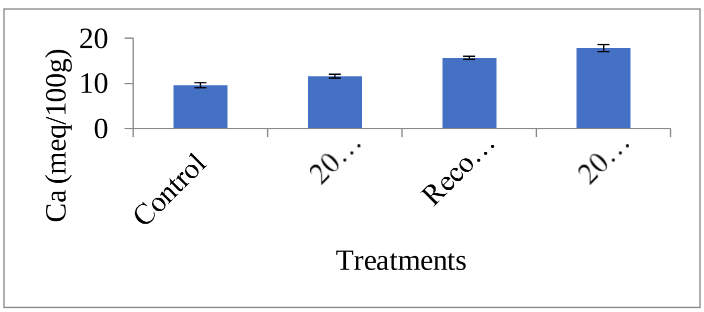

Figure 5. Impact of biochar on sodium (Na) keep in the soil

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

The magnesium (Mg) availability was significantly different in each treatment in the initial soil (Table 2). A significant difference ($p<0.001$) was also found in the soil after harvesting the soybean (Figure 6). Soil magnesium was also determined after harvesting Soybeans. In this case, the highest magnesium content (7.836 meq/100 gm soil) was observed in biochar-treated plots containing 20 t ha-1 biochar with a recommended dose of fertilizer, and the lowest magnesium content (4.384 meq/100 gm soil) was observed in control plots.

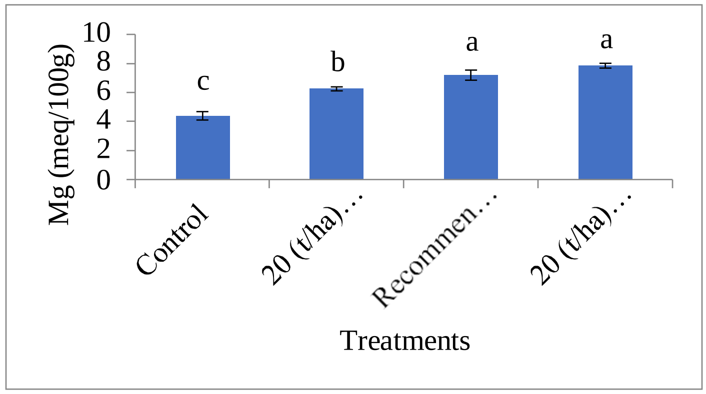

Figure 6. Effect of biochar on magnesium (Mg) content in the soil

From the experiment, it appeared that the application of biochar in soil increased magnesium availability and reduced nutrient leaching. Magnesium is a highly mobile nutrient element and very susceptible to leaching from soil. Biochar typically has a high cation exchange capacity (CEC) due to its porous structure and negative surface charge. This negative charge attracts positively charged ions (cations) like magnesium (Mg^{2+}), holding them on its surface (Chan et al., 2007; Major et al., 2012; Van Zwieten et al., 2010).

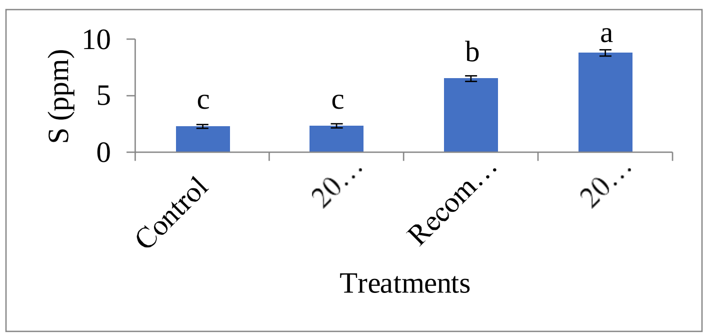

Figure 7. Effect of biochar on sulfur (S) content in the soil

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

Soil samples collected before seed sowing showed significant variation in sulfur content under various soil treatments (Table 2). Soil sulfur was also determined after harvesting Soybeans and found a significant difference. In that case, the highest sulfur content (49.566 µg gm-1 soil) was observed in biochar-treated plots containing 20 t ha-1 of biochar with a recommended dose of fertilizer, and the lowest sulfur (S) content (19.827 microgram/gm soil) was observed in control plots (Figure 7). 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 & Cole, 1999). The addition of biochar reduces the extent of SO42- 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 & Dighton, 2006)..

CONCLUSIONS

The maximum yield (2.18 t ha-1) was found in 20 t ha-1 biochar-treated plots with recommended fertilizers. The largest 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 fertilizers could be recommended for a higher yield of soybeans and nutrient conservation in the southern non-saline area of Bangladesh .

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