Australian Journal of Crop Science AJCS

AJCS 12(12):1813-1819 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.12.p944

Growth and yield response of maize to rice husk biochar

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Abstract

Globally, the current important concern is to waste minimization by producing biochar for crop production. The experiment was conducted at the research field from November 2015 to March 2016 to assess the growth and yield of maize (BARI Hybrid Bhutta 9) under variable rice husk biochar levels. The rice husk biochar levels 0, 1.5, 3, 5 and 7 t ha^{-1} constituted the treatment variables. Results revealed that growth and yield of maize were significantly influenced by different doses of rice husk biochar. Highest internodal length, stem diameter, leaf area index (LAI), crop growth rate (CGR), dry matter accumulation, grain yield and lowest net assimilation rate (NAR) were found when soil was treated with rice husk biochar @ 7 t ha^{-1} than in the biochar doses of @ 5, 3, 1.5 t ha^{-1} as well as 0 t ha^{-1} (Control). It was found that biochar increased soil pH from strongly acidic to slightly acidic. Biochar was found efficient in increasing soil organic carbon, nitrogen and sulphur and decreasing soil bulk density to favorable level. We concluded that the application of biochar increased growth and grain yield of maize and improved chemical and physical properties of soil.

Keywords: Maize, rice husk biochar, growth, yield, soil properties.
Abbreviations: CGR_ crop growth rate, DAS_ days after sowing, LAI_ leaf area index, NAR-net assimilation rate.

Introduction

Maize is the third most important cereal crop in Bangladesh, after rice and wheat. It can be cultivated year-round. The crop is high yielding, rich in nutrition, and has diversified uses. The demand for maize in Bangladesh is primarily from the commercial feed processing industry. This industry is the driving force of the maize sector, using 80% of its aggregate maize production (excluding imports) and statistically, the poultry sector (a significant representative of feed industry) is growing at an average rate of 23% per year (WPSA, 2013). Moreover, there is a high demand for maize in cattle, fish and sectors like food processing and medicine in the country. Therefore, production of maize needs to be increased adopting modern soil and crop management practices. Application of biochar is such a technology that can improve soil health, keep the land alive and sustain its productive capacity. Biochar is pyrolysed byproduct of biomass produced at high temperatures (>400 °C) under absence of or limited oxygen. According to international biochar initiatives (IBI), it is purposefully used for agricultural and environmental gains (Sohi et al., 2010). In fact, biochar is a carbon-rich, fine-grained, porous substance which basically consists of nano-structured aromatic compounds systematically arranged like graphite. The decline in soil productivity due to continuous cultivation in Bangladesh has been acknowledged as one of the main causes of food insecurity and poverty. To achieve food adequacy, there is the pressing need to manage the soil infertility problem, improving crop productivity in these soils is essential for socio-economic reasons. Application of inorganic fertilizers provides an alternative to overcome soil infertility. But the solitary application of inorganic fertilizers caused degradation of soil health and decreased its productive capacity. The aim of the research work was to assess the effect of rice husk on growth and yield of maize.

Results and discussion

Inter-nodal length

The effect of rice husk biochar on maize internodal length at different days after sowing was presented in Table 1. The internodal length increased with the increase of number in days after sowing (DAS) irrespective of biochar applied. At 15 DAS, the highest internodal length was recorded in the treatment T5, followed by T4, T1, T2 and the lowest was in the T3 treatment. At 30 DAS the highest internodal length was recorded in the T4 treatment, followed by T5, T3, T2 and the lowest was in the treatment T1. At 45 DAS the highest internodal length was recorded in T4 treatment, followed by T5, T3 , T2 and the lowest was in the T2 treatment. At 60 DAS the highest internodal length was found in treatment T5, followed by T4, T3, T2 and the lowest was in the treatment T1. At 75 DAS, the highest internodal length was recorded in the T5 treatment, followed by T4, T3 , T2 and the lowest was in the treatment T1. Di Lonardo et al. (2013) reported that a greater elongation was also recorded for shoots (intermodal length) grown on a substrate containing biochar than those grown on media without biochar. Zheng et al. (2013) observed that increasing up to 21 %, in shoot biomass of wheat seedling were caused by biochar amendments. Biochar has the potential to reduce accumulation of Cd, Zn, and Pb in wheat shoot and improves its growth.

Stem diameter

Effect of rice husk biochar on stem diameter of maize at different days after sowing is described in Figure 1. In the figure it was clear that rice husk biochar had significant effect on the stem diameter of maize plants. At 15 DAS the highest stem diameter was recorded in the treatment T4, followed by T5, T3, and T2 and the lowest was in the treatment T1. At 30 DAS the highest stem diameter was found in the treatment T4, followed by T5, T3, and T2 and the lowest was in the treatment T1. At 45 DAS the highest stem diameter was recorded in the treatment T5, followed by T4, T3, and T2 and the lowest was in the treatment T1. At 60 DAS the highest stem diameter was recorded in the treatment T5, followed by T4, T3 and T2 and the lowest was in the treatment T1. At 75 DAS the highest stem diameter was recorded in the treatment T5, followed by T4, T3 and T2 and the lowest was in the treatment T1. It is clear that there is noticeable difference in stem diameter in highest doses of rice husk biochar treatments compared to 0 t ha^{-1} biochar treatments. Similar result was found by Varela et al. (2013) that the stem size of water spinach increased due to application of both wood biochar and rice husk biochar. They also proposed that the working mechanism of wood biochar and rice husk biochar in soil would be such, that the decomposition of organic carbon in biochar-added soil to organic matter resulted in increased water holding capacity and decreased silt in biochar-added soil which ultimately enhanced the stem diameter. Fagbenro et al. (2013) reported that rates of application of saw dust biochar were significantly and positively correlated with stem diameter (r=0.99**). Maize girth as influenced by biochar during growth stages reported by Abukari (2014). Fagbenro et al. (2015) mentioned that there was a positive but comparable effect of applying biochar and inorganic fertilizer in stem diameter.

Leaf area index

Effect of rice husk biochar on leaf area index of maize at different days after sowing is described in Fig 2. Leaf area index was significantly influenced by different doses of applied rice husk biochar. The change was progressively increasing up to 100 days after sowing. At 50 days after sowing the highest leaf area index was recorded in treatment T5, followed by T4 T3 T2 and the lowest was in the T1 treatment. At 100 days after sowing highest leaf area index was recorded in treatment T5, followed by T4, T3 , T2 and the lowest was in the treatment T1. The significant increase in leaf area index with the application of rice husk biochar indicated the effectiveness of applied rice husk biochar in improving the growth of maize crop. Using the model plant Arabidopsis and the crop plant lettuce (*Lactuca sativa* L.) Viger et al. (2015) found increased plant growth in both species due to biochar application. They found significant increases in leaf area in Arabidopsis (130%), where biochar application also increased leaf cell expansion. The result was in consistence the findings of Burke et al. (2012) who also found increased leaf area due to biochar application. Njoku et al. (2015) showed that biochar amended plots had significantly ($P < 0.05$) higher leaf area index than control. Lashari et al. (2015) reported that there were great increases in leaf area index of maize when grown in biochar amendments. Ahmad et al. (2015) found that application of biochar significantly improved soil fertility, leaf area $plant^{-1}$ (171.99 cm^2) and leaf area index (6.48).

Crop growth rate

Crop growth rate were significantly influenced by different doses of rice husk biochar application in maize Fig. 3. The highest crop growth rate was recorded in treatment T5, followed by T4, T3, T2 and the lowest was in treatment T1. Biochar amendment may improve crop growth through its nutrients and indirect fertility. However, this improvement varies in a wide range of biochars, crops, and soils. The results are similar with the findings of Agegnehu et al. (2016) who observed that biochar amendment increased the crop growth and maize biomass production. Van Zwieten et al. (2010) found in wheat in the ferrosol soils, there was no significant difference in the absence of fertilizer, however with fertilizer, significant increases in biomass production were recorded, indicating a strong fertilizer by biochar interaction. Rondon et al. (2007) mentioned that the biomass production increased by 39% over the control at 60 g kg^{-1} and 90 g kg^{-1} biochar application in a pot experiment. Edmunds (2012) reported that biochar application increased above-ground biomass yield in both switchgrass and sorghum by up to 25 %. Schulz et al. (2013) showed that biomass production was increased with rising biochar and compost amounts. Plant growth characteristics, such as shoot to root biomass, improved with increasing biochar level reported by Brennan et al. (2014).

Net assimilation rate

A useful measure of the photosynthetic efficiency of plants is net assimilation rate which is significantly influenced by the level of rice husk biochar treatments Fig. 4. Regardless of treatments, net assimilation rate of maize was decreased. The highest net assimilation rate was obtained from T1 treatment then decreased, followed by T2, T3, T4 and T5. This result is in agreement with the findings of Bali et al. (1991). The decline in net assimilation rate in the later part of growth was mainly because of progressive mutual shading by the increase of leaf area. The net assimilation rate was not improved with increasing rice husk biochar levels.

Dry matter partitioning

The pattern of dry matter distribution into components of maize at harvest time is illustrated in Figure 5. The highest leaf blade dry weight was recorded in T2 treatment, followed by T5, T4, T3 and the lowest was in T1 treatment. The highest leaf sheath weight was recorded in T3

Table 1. Effect of rice husk biochar on internodal length of maize at different days after sowing (DAS).

Treatments	Internodal length of maize (cm)				
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
T 1	2.63	3.59	5.78	6.40	8.74
T 2	2.52	3.70	5.75	7.45	9.18
T 3	2.37	4.17	6.31	8.08	10.06
T 4	2.64	4.51	7.34	8.52	10.23
T 5	3.09	4.50	7.06	8.81	10.49
$LSD_{(0.05)}$	0.35	0.47	0.13	0.29	0.18
CV %	8.8	7.5	4.1	2.5	1.2

T1= 0 t ha^{-1} biochar, T2= 1.5 t ha^{-1} biochar, T3= 3 t ha^{-1} biochar, T4= 5 t ha^{-1} biochar, T5= 7 t ha^{-1} biochar.

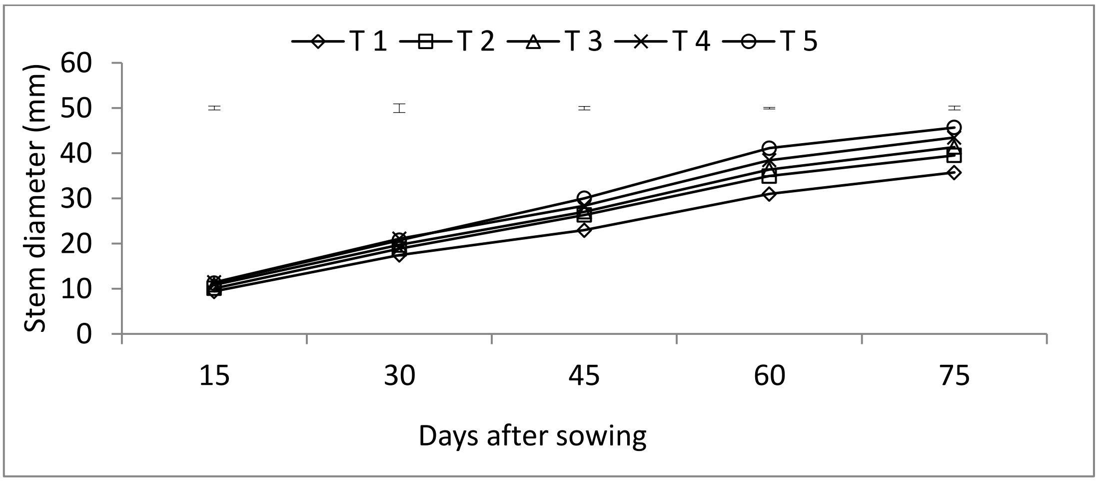

Fig 1. Effect of rice husk biochar on stem diameter of maize at different days after sowing. Bars indicate LSD at 5% level of significance. T1-0 t ha^{-1} biochar, T2- 1.5 t ha^{-1} biochar, T3- 3 t ha^{-1} biochar, T4- 5 t ha^{-1} biochar, T5-7 t ha^{-1} biochar.

Table 2. Effect of rice husk biochar on yield attributes and yield.

Treatment	Cob Length (cm)	Number of cob m^{-2}	Number of corn cob^{-1}	100 Seed wt. (g)	Grain Yield (t ha^{-1})	Straw (t ha^{-1})	Harvest index (%)
T 1	15.07	5.33	457.00	21.35	5.52	7.76	41.56
T 2	16.75	5.33	484.50	24.25	6.51	7.51	46.51
T 3	18.00	6.66	534.75	25.45	7.61	7.60	50.30
T 4	21.60	8.00	565.50	28.12	8.45	7.54	52.88
T 5	24.28	8.00	607.75	30.25	10.25	7.78	57.24
$LSD_{0.05}$	0.73	3.82	30.95	1.44	0.39	2.22	7.18
CV %	2.5	7.2	3.8	3.6	3.3	8.9	9.4

T1= 0 t ha^{-1} biochar, T2= 1.5 t ha^{-1} biochar, T3= 3 t ha^{-1} biochar, T4= 5 t ha^{-1} biochar, T5= 7 t ha^{-1} biochar.

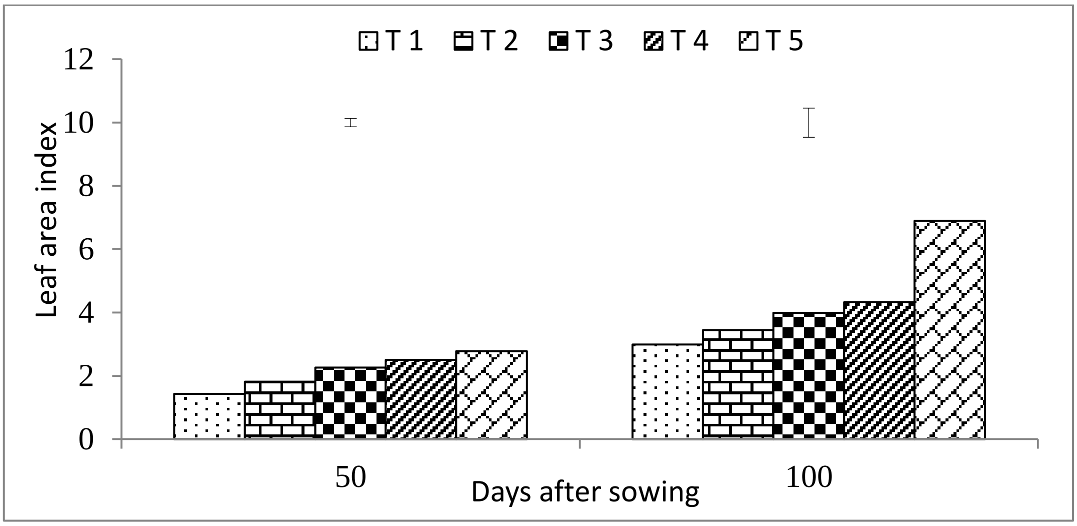

Fig 2. Effect of rice husk biochar on leaf area index of maize at different days after sowing. Bars indicate LSD at 5% level of significance. T1-0 t ha^{-1} biochar, T2- 1.5 t ha^{-1} biochar, T3- 3 t ha^{-1} biochar, T4- 5 t ha^{-1} biochar, T5-7 t ha^{-1} biochar.

Table 3. Effect of rice husk biochar on chemical properties and bulk density of soil (mean ± S.E.).

	Soil properties				
Treatments	pH	Total N (%)	OC (%)	S (mg kg^{-1})	Bulk density (g cm^{-3})
Before sowing	5.25±0.095	0.11±0.003	0.78±0.006	5.51±0.034	1.28±0.007
After harvest					
T 1	5.36±0.075	0.11±0.003	0.60±0.008	28.48±0.214	1.28±0.007
T 2	5.52±0.025	0.14±0.002	0.77±0.013	36.76±0.144	1.25±0.012
T 3	5.54±0.037	0.17±0.004	0.84±0.006	39.52±0.115	1.22±0.014
T 4	5.58±0.064	0.23±0.002	0.99±0.003	44.11±0.042	1.20±0.006
T 5	5.60±0.018	0.28±0.002	1.13±0.005	54.22±0.154	1.17±0.009

T1= 0 t ha^{-1} biochar, T2= 1.5 t ha^{-1} biochar, T3= 3 t ha^{-1} biochar, T4= 5 t ha^{-1} biochar, T5= 7 t ha^{-1} biochar.

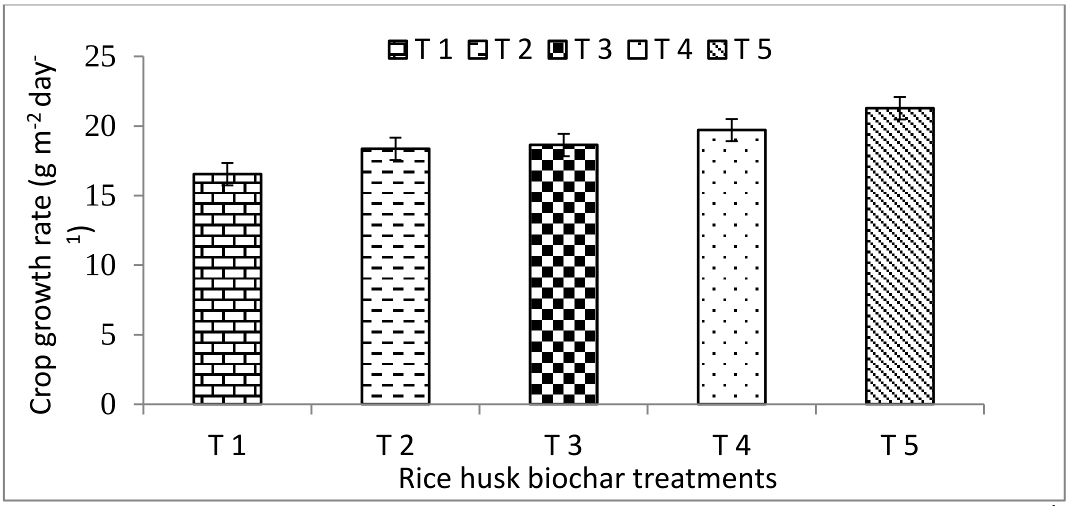

Fig 3. Effect of rice husk biochar on crop growth rate of maize. Bars indicate LSD at 5% level of significance. T1-0 t ha^{-1} biochar, T2- 1.5 t ha^{-1} biochar, T3- 3 t ha^{-1} biochar, T4- 5 t ha^{-1} biochar, T5-7 t ha^{-1} biochar.

treatment, followed by T5, T4, T2 and the lowest was in T1 treatment. The highest stem dry weight was obtained in T5 treatment, followed by T4, T3, T2 and the lowest was in Treatment T1. The highest tassel dry weight was found in T5, followed by T3, T2, T4 and the lowest was in the treatment T1. The highest total dry weight was obtained in T5 treatment, followed by T3, T4, T2 and the lowest was in treatment T1. The results found are similar to those reported by John Kovar (2012) who reported that relative differences in biomass (shoot and root dry matter) production observed at harvest 120 days after planting, tended to hold throughout the trial. Baronti et al. (2010) mentioned that the highest increase of dry matter 120% was obtained at a biochar rate of 60 t ha^{-1} and above this threshold, a general reduction of biomass was observed. Burke et al. (2012) showed that biochar contributed to increases in numerous plant developmental characteristics which increased dry weight of plants and Fagbenro et al. (2013) observed that rates of application of saw dust biochar were significantly and positively correlated with dry matter yield (r=0.96*). Iswaran et al. (1980) reported 51% increase in biomass in soybean crops with biochar additions of 0.5 t ha^{-1}.

Yield components and yield

Rice husk biochar doses had significant effect on the cob length, number of cob m^{-2}, number of corn cob^{-1}, 100 seed weight, grain yield and harvest index of maize but straw yield shows the non-significant effects (Table 2) in maize. The cob length increased with increased level of rice husk biochar. The highest cob length was recorded in T 5 treatment, followed by T4, T3, T2 and the lowest was in treatment T1. The highest cob length of the variety might be due to better nutrient use efficiency at T5 treatment. Although the influence of rice husk biochar level on number of cob m^{-2} was non-significant the number of cob m^{-2} was increased due to increasing rice husk biochar levels. The highest number of cob m^{-2} was obtained in treatment T5 and T4, followed by T3 and the lowest was in the treatment T2 and T1. Number of corn cob^{-1} of maize varied significantly due to different levels of applied rice husk biochar. The highest number of corn cob^{-1} was recorded in T5 treatment, followed by T4, T3, T2 and the lowest was in treatment T1. A pot trial was carried out by Chan et al., (2008) who found that in the absence of N fertilizer, the biochar significantly increased yield with increased levels of biochar application to 50 t·ha^{-1}. Crane et al., (2013) found that soil cation exchange capacity and organic carbon were strong predictors of yield response, with low cation exchange and low carbon associated with positive response. They also found that yield response increases over time since initial application, compared to non-biochar controls. The higher yield resulted from the mixing rate of 15.0 t ha^{-1} in comparison with the mixing rate of 20.00 t ha^{-1} was perhaps mainly due to the fact that biochar is alkaline in nature, which may affect soil pH (Suppadit et al. 2012). Other studies found increases in maize yield due to biochar amendment ranging from 20% to 140% above control plots. Application of rice husk biochar improved grain size of maize. The maximum 100 seed weight was observed in T5 treatment, followed by T4, T3, T2 and the minimum was in treatment T1. The highest grain yield was obtained in T5 treatment, followed by T4, T3, T2 and the lowest was in the treatment T1. From the table it is clear that the grain yield of maize was increased up to 60 to 80 % with the highest doses of rice husk biochar treatment compared to 0 t ha^{-1} (control) treatment. The above results are in consistence with the findings of Abukari (2014) who reported that the addition of biochar 2 t ha^{-1} and 4 t ha^{-1} increased the grain yield and improved water use efficiency of the maize crop. Oguntunde et al. (2004) conducted an experiment on charcoal site and adjacent fields and found out that there were significant differences between the charcoal and the adjacent fields. Grain and biomass yield of maize increased by 91% and 44%, respectively. Curaqueo et al. (2014) reported that barley yield (grain weight m^{-2}) significantly increased at the highest biochar dose by 31.3% and 21.9% for crops grown on the Inceptisol and Ultisol, respectively. Baronti et al. (2010) found that increase in yields (+ 10% and + 6% in terms of grain production, respectively) was detected after a biochar application of 10 t ha^{-1}. A further increase in grain production (+24%) was detected when biochar was added with maize residues. Mekuria et al. (2013) reported that the enhancement of maize yield due to soil amendments ranged from 0.77 to 3.79 t ha^{-1} at Naphok and from 1.21 to 5.14 t ha^{-1}. Yang et al. (2015) mentioned that biochar amendment could enhance yields, and biochar from rice straw showed a more positive effect on the yield of corn, peanut, and winter wheat than corn stalk biochar. Islami et al. (2011) found that increases in maize yield following biochar application. Gebremedhin et al. (2015) mentioned that biochar significantly increased grain and straw yields of wheat by 15.7% and 16.5%, respectively over the control.

Chemical properties and bulk density of soil

Application of rice husk biochar showed significant changes in the soil chemical properties (Table 3). The initial pH was 5.25 and after crop harvest the highest pH 5.60 was obtained in treatment T5, followed by T4 T3, T2 and the lowest pH was in treatment T1. Results revealed that application of different doses biochar in soil increased pH of the experimental soil. The highest N was recorded in T5 treatment, followed by T4, T3, T2 and the lowest was in treatment T1. The highest OC was recorded in T5 treatment, followed by T4, T3, T2 and the lowest was in treatment T1. The highest S was recorded in the T5 treatment, followed by T4, T3, T2 and the lowest was in treatment T1. The lowest soil bulk density was recorded in the T5 treatment, followed by T4, T3, T2 and the highest was in treatment T1. The results are in consistent with the findings of Chan et al. (2007), Laird et al. (2010) and Van Zwieten et al. (2010) who found that biochar increased soil pH thus reducing lime requirements. Reduced N leaching thereby can possibly reduce fertilizer requirements (Chan et al., 2007; Van Zwieten et al., 2010). Biederman et al. (2013) observed that the addition of biochar to soils resulted, on an average, in increased soil phosphorus (P), soil potassium (K), total soil nitrogen (N), and total soil carbon (C) compared with control conditions. Major (2011) reported that biochar has a very low density and is highly porous. Cao et al. (2009) mentioned that biochar application reduced soil bulk density (SBD).

Materials and methods

Location: Field experiment was carried out at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh located at 24˚5'N latitude and 90˚16'E longitude at an elevation of 8.4 m from the mean sea level. The soil type of the experimental field belongs to the Shallow Red Brown Terrace type. The climate of the experimental site is subtropical in nature characterized by heavy rainfall during June to September and scanty in winter with gradual fall of temperature from September.

Planting material: The maize variety BARI Hybrid Bhutta 9 was sowing on 03 November, 2015.

Treatments: The rice husk biochar levels 0, 1.5, 3, 5 and 7 t ha^{-1} constituted the treatment variables denoted as T1 (control), T2, T3, T4 and T5, respectively. Rice husk was used for feedstock or raw material to produce biochar. The biochar has been produced in biochar stove developed by (Mia et al., 2015). Chemical composition of rice husk biochar is presented in the following table

Biochar	pH	N %	P %	K %	Ca %	Mg %	S %	EC ms/cm
Rice husk Biochar	7.15	2.57	0.21	0.231	1.024	0.458	0.339	1.325

Experimental design and conduction: The experiment was laid out in randomized complete block design with four replications. The unit plot size was 3m × 2m. Rice husk biochar was also applied to the each plot according to treatment before seed sowing. The soil of the plot was fertilized uniformly with 41.07 g N, 40 g P and 37.5 g K according to fertilizer nutrient required for given soil test value corresponding to 253 kg N, 52 kg P and 110 kg K per ha, respectively. One third of urea and all other fertilizers were applied at final land preparation. Rest of urea was applied at two installments; one at 30 days after germination and the other at 50 days after germination. Irrigation, weeding and other agronomic practices were done whenever necessary.

Traits measured: Data on different growth parameters, yield components and yield were recorded. The above ground plant parts were segmented into different components as leaf, leaf sheath stem, tassel and cob. Leaf area was measured by an automatic leaf area meter (AAM-8, Hayashi Dehnko, Japan) immediately after sampling. The partitioned plant parts were then dried in an oven at 70˚C for 72 hours and weighed. For determination of yield attributes, five plants were selected and cob length, number of cob, number of corn, 100 seed weight, grain yield, straw yield and harvest index was measured. The harvested yield was converted into t ha^{-1} at 14% moisture content. Based on dry matter accumulated by crop over times, crop growth rate (CGR) and net assimilation rate (NAR) were calculated. Chemical analysis of soil was done for pH, total nitrogen, available phosphorus, potassium, available sulfur, and organic carbon. Bulk density of the soil was measured before sowing and after harvest of the crop.

Statistical Analysis: All collected data were subjected to CROPSTAT 7.2 software package to perform analysis of variance (ANOVA) and arithmetic means of the treatments were compared by employing least significant difference (LSD) test.

Conclusion

From the results it may be concluded that growth and yield of maize variety were significantly influenced by different levels of rice husk biochar. The plant growth was increased applying biochar levels. Consecutively, the variety produced the highest yield with 7 t ha^{-1} rice husk biochar with the highest nutrient use efficiency. Rice husk biochar increased soil pH, organic carbon, nitrogen and sulphur and decreased soil bulk density to favorable level.

Acknowledgement

The authors are grateful to RMC, BSMRAU for funding the research work.

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