The Agriculturists 16(2): 93-101(2018) **ISSN 2304-7321 (Online), ISSN 1729-5211 (Print)**
A Scientific Journal of Krishi Foundation ***Indexed Journal***
DOI: http://dx.doi.org/ 10.3329/agric.v16i02.40347 Impact Factor: 0.568 (GIF, 2015)

Impact of Rice Husk Biochar on Growth, Water Relations and Yield of Maize (*Zea mays* L.) under Drought Condition

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Received: 23 October 2018 Accepted: 25 December 2018

Abstract

The present experiment was conducted to study the impact of rice husk biochar on growth, water relations and yield of maize (BARI Hybrid Bhutta- 9) under drought (60 and 40% of FC) conditions. Four doses of rice husk biochar @ 0, 5, 10 and 20 t/ha were applied as an amendment in soil before sowing of seeds. Results revealed that drought stress reduced plant height, relative water content and grain yield of maize. But rice husk biochar at different doses improved the above mentioned characters under drought conditions. Under 60% of FC, the highest plan height, leaf water content and yield were 196.67 cm, 79.86% and 89.75 g/plant, respectively when biochar was applied @ 20 t/ha but it was 173.33 cm, 78.32% and 84.57 g/plant, respectively under 40% of FC when biochar was applied at the same dose. It may be concluded that, rice husk biochar @ 20 t/ha showed the best result to promote growth, water relation traits and yield of maize under drought condition.

Keywords: Rice husk biochar, growth, yield, maize, drought.

1. Introduction

Maize (*Zea mays* L.) 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 nutrient and has diversified uses. The demand of maize in Bangladesh is primarily from the commercial feed processing industry especially poultry sector is using 80% of its aggregate maize production (excluding imports) (WPSA, 2013). Therefore, production of maize needs to be increased. Growth and yield of maize are severely affected by drought (WPSA, 2013) in winter season where rainfall is low. Water absorption, imbibition and metabolic enzymatic activation are hindered under drought condition which reduces the grain germination. Drought stress inhibits the photosynthesis of plants, causes changes of chlorophyll contents and damages the photosynthetic apparatus (Escuredo *et al.,* 1998) which ultimately reduce growth promoters (Praba *et al.,* 2009). Under drought stress, cell expansion of leaf is reduced due to low turgor which is controlled by the processes related to cellular water uptake and cell wall extension that resulted in decreased leaf area and weight. The yield and biochemical composition of a plant mainly depends on growth conditions, which is markedly affected by water availability (Paclik *et al.,* 1996).

Biochar is charcoal formed from the thermal decomposition of biomass in a low or zero oxygen environment, at high temperatures

(<700°C) (Lehmann and Joseph, 2009), intended for use as a soil amendment (Lehmann and Joseph, 2009), enhanced soil water-holding capacity (Asai *et al*., 2009; Laird *et al*., 2009; Karhu and Matilla, 2011), improved soil water permeability and improved saturated hydraulic conductivity (SHC) (Asai *et al*., 2009), reduced soil strength (Chan *et al*., 2007), modification in soil bulk density (ρb) and modified aggregate stability (Busscher *et al*., 2010; Peng *et al*., 2011). Biochar improves crop productivity and mitigates drought (Thomas *et al.,* 2013; Crane *et al*., 2013), has the potential to increase the availability of plants nutrient (Lehmann *et al*., 2008) and increases growth and biomass of drought-stressed plants reported by Rizwan *et al.* (2017).

Therefore the experiment was undertaken to assess the effects of rice husk biochar on growth, water relations and yield of maize variety BARI Hybrid Bhutta-9 under drought conditions.

2. Materials and Methods

2.1 Location of the experiment

The pot experiment was conducted in the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur from November 2016 to March 2017.

2.2 Experimental soil characteristics

The soil used in the experiment was sandy loam in texture, organic carbon contain 0.60%, total N 0.05%, available P 0.08 mg/100 g, exchangeable K 0.33 $cmol_c kg^{-1}$ and CEC 14.58 $cmol_c kg^{-1}$ dry soil and the pH was 7.1.

2.3 Biochar characteristics

Biochar was produced from rice husk by pyrolysis in biochar stove developed by Mia *et al*. (2015) and modified by Mannan *et al.* (2016). The chemical properties of rice husk biochar were N 2.57%, P 0.21%, K 0.231%, Ca 1.024%, Mg 0.458%, S 0.339%, EC 1.325 mS/cm and 7.15 pH was recorded.

2.4 Fertilizers application

The soil in the pot was fertilized uniformly with 2.0, 1.15 and 0.9 g urea, triple super phosphate and muriate of potash corresponding to 525-250-200 kg urea, triple super phosphate and muriate of potash per hectare, respectively (BARC, 2012).

2.5 Treatments

a) Biochar doses: Rice husk biochar was mixed uniformly in the soil of each pot with 24.4, 48.8, and 97.6 g corresponding to at the rate of 5, 10 and 20 t/ha, respectively and biochar was not applied to control plot.

b) Drought: Three water regimes i) Control (80% of field capacity), ii) 60% of field capacity (FC) and iii) 40% of field capacity (FC) were maintained from 4^{th} leaf stage of seedling up to maturity.

2.6 Crop establishment and drought imposition

Ten bold seeds of BARI Hybrid Bhutta- 9 were sown in each plastic pot containing about 11 kg air dried soil. After seven days of germination, two uniform and healthy plants were allowed to grow in each pot. Drought stress was induced by withholding water completely. During the drought treatment period, wilting symptom was visually observed every day. The pots were weighed every other day to compensate the water loss by evapotranspiration according to Choudhury *et al*. (2014). In non-stress treatment, one liter water per pot was applied in alternate day up to maturity.

2.7 Experimental design and data recorded

The experiment was designed at Completely Randomized (CRD) consisting two factors with three replications. The data on plant height were recorded at vegetative (6^{th} leaf, 10^{th} leaf, 14^{th} leaf) and reproductive (tasselling, cob initiation and maturation stage) stages. Water relation traits (relative water content, water saturation deficit, water uptake capacity) of maize leaf were recorded at flowering stage. Yield and yield contributing parameters were recorded at maturity after harvest. The recorded data were statistically analyzed by "CropStat" (IRRI, 2007) software to examine the significant variation of the results due to water stress. The treatment means were compared by Least Significance Difference (LSD) test at 5% level of significance (Gomez & Gomez, 1984).

3. Results and Discussion

3.1 Plant height at vegetative stage

The height of maize at vegetative stage varied due to different doses of biochar under drought conditions (Table 1). At 6th leaf stage, plant height was reduced due to drought and higher reduction was found at 40% of FC compare to the 60% of FC. But applications of biochar increased plant height under both of these drought conditions. Highest plant height (43.80 cm) was measured when biochar was applied @ 20 t/ha and it was 42.03 cm at 40% of FC at same dose of biochar. At 10th leaf stage, under control condition plant height was measured 95.43 cm when biochar was applied @ 20 t/ha but the plant height was 90.40 cm when no biochar was applied. At 60% of field capacity and 40% of field capacity higher height of maize were 93.00 cm and 91.20 cm, respectively when biochar was applied @ 20 t/ha. At 14th leaf stage, under control condition shortest plant (150.60 cm) was obtained when no biochar was applied, on the other hand it was highest (169.33 cm) when biochar was applied @ 20 t/ha. Under 60% of field capacity and 40% of field capacity longer plant were 154.33 cm and 145.00 cm, respectively when biochar was applied @ 20 t/ha.

Table 1. Effect of rice husk biochar on plant height of maize at vegetative stages under drought conditions

Biochar doses (t/ha)	6th leaf stage (cm)			10th leaf stage (cm)			14th leaf stage (cm)		
	control	60% of FC	40% of FC	control	60% of FC	40% of FC	control	60% of FC	40% of FC
0	39.36 de	39.13 e	38.70 f	90.40 b	89.50 b	80.23 b	150.60 d	139.00 f	134.33 f
5	42.16 a-e	40.96b-e	40.16cde	91.23 ab	90.43 b	90.26 b	156.66 c	145.33 e	136.33 f
10	42.80 abc	41.90 a-e	41.16b-e	93.93 ab	91.43ab	90.70 b	164.00 b	151.33 d	138.33 f
20	44.83 a	43.80 ab	42.03 a-e	95.43 a	93.00 ab	91.20 ab	169.33 a	154.33 cd	145.00 e
CV (%)	4.2			3.1			2.0		

In a column, figures with same letters were not significant at 5% level.

Table 2. Effect of rice husk biochar on plant height in maize at reproductive stages under drought conditions

Biochar doses (t/ha)	Tasseling stage (cm)			Cob initiation stage (cm)			Maturity stage (cm)		
	control	60% of FC	40% of FC	control	60% of FC	40% of FC	control	60% of FC	40% of FC
0	164.00 cd	161.67 d	136.67 f	174.33 cd	170.00 d	141.33 f	175.33 c	173.00 c	154.00 e
5	172.67 bc	172.00 bc	139.33 f	175.67 cd	174.67 cd	145.33 f	180.67bc	178.33bc	156.67de
10	174.33 b	174.00 b	151.33 e	186.67 b	182.67 bc	157.67 e	186.67 b	185.67 b	163.00 d
20	190.00 a	184.33 a	165.67bcd	195.67 a	190.33ab	169.00 d	202.33 a	195.67 a	173.33 c
CV (%)	3.5			2.9			2.9		

In a column, figures with same letters were not significant at 5% level.

So it is clear that plant height is affected by drought and application of rice husk biochar increase plant height that means biochar mitigate drought effects on plant height. Plant height of maize was reduced due to drought at vegetative stages reported by Abukari (2014). Hussain *et al*. (2008) reported that by affecting cell turgidity drought impaired plant height. Lehmann *et al.* (2011) also reported that biochar promoted plant height of maize under drought conditions. Kim *et al*. (2016) found that application of biochar can increase soil water holding capacity which increased tissue water status and ultimately increased plant height.

3.2 Plant height at reproductive stage

Plant height differences of maize at reproductive stages indicated that plant height varied due to different doses of biochar under drought conditions (Table 2). At tasseling stage, under control condition highest plant height was found 190.00 cm when biochar was applied @ 20 t/ha, followed by 174.33 cm and 172.67 cm when biochar was applied 10 t/ha and 5 t/ha, respectively but the lowest plant height (164.00 cm) was measured when no biochar was applied. Drought stress reduced plant height of maize compared to the control and highest reduction was found under 40% of FC. But biochar increased plant height under drought conditions. At 60% of field capacity the highest height of maize was 184.33 cm when biochar was applied @ 20 t/ha and the shortest plant was 161.67 cm and when no biochar was applied. At 40% of field capacity the highest height of maize was 165.67 cm when biochar was applied @ 20 t/ha and the shortest plant was 136.67 cm when no biochar was applied. At cob initiation stage, under 60% of field capacity highest plant height of maize was190.33 cm when biochar was applied @ 20 t/ha, followed by @ 10 t/ha biochar (182.67 cm), @ 5 t/ha biochar (174.67 cm) and lowest plant height (170.00 cm) of maize was found when no biochar was applied. Under 40% of FC same trend also found in case of height of maize plant. At maturity stage, under control condition highest plant height of maize was 202.33 cm when biochar was applied @ 20 t/ha and the shortest plant was observed in no biochar treatment. At 60% of field capacity highest plant height of maize was 195.67 cm when biochar was applied @ 20 t/ha, followed by @ 10 t/ha biochar (185.67 cm), @ 5 t/ha biochar (178.33 cm) and lowest plant height (173.00 cm) was found when no biochar was applied. At 40% of field capacity lowest plant height of maize was 154.00 cm when no biochar was applied. But application of biochar plant height was increased. The highest plant height (173. 33 cm) was recorded at the rate of 20 t/ha biochar application followed by 163.00 cm for 10 t/ha and 156.67 cm for 5 t/ha. It was found that drought stress affected plant height at reproductive stages and biochar application in soil increased plant height under drought conditions. Drought induced plant height reduction was reported by Batool *et al*. (2015) in maize. Hardy *et al*. (2014) also reported that the addition of biochar improved plant height. In rice, drought stress during the vegetative stage greatly reduced the plant height (Manikavelu *et al*., 2006).

3.3 Water relation traits

Relative Water Content (RWC) of maize plant was reduced significantly under drought stress. Application of rice husk biochar at different doses increased water holding capacity of soil under drought conditions and thereby increased relative water content (RWC) of maize leaves (Table 3). Under control condition, 60% and 40% of field capacity the highest RWC of maize were 83.37%, 79.86% and 78.32%, respectively when biochar was applied @20 t/ha. The lowest RWC of maize were 66.93%, 63.75% and 62.25%, respectively when no biochar was applied. Water saturation deficit (WSD) of maize plant was increased significantly under drought stress and varied due to application of biochar with different doses (Table 3). Under control condition, the lowest WSD of maize leaf was 16.62%, when biochar was applied @ 20 t/ha and highest WSD of maize leaf was 33.06%, when no biochar was applied. At 60% of field capacity highest water saturation deficit of maize leaf was 36.24% when no biochar was applied but lowest water saturation deficit (20.13%) was found when biochar was applied @ 20 t/ha. At 40% of field capacity lowest water saturation deficit was 21.17% when biochar was applied @ 20 t/ha. On the other hand highest water saturation deficit was 37.74% when no biochar was applied. Water uptake capacity (WUC) of maize was increased significantly under drought conditions but application of biochar decreased water uptake capacity (Table 3).At control condition the lowest WUC of maize was 1.52, when biochar was applied @20 t/ha and highest WUC of maize leaf was 1.90, when no biochar was applied. At 60% of field capacity highest water uptake capacity was 1.97 when no biochar was applied but lowest water uptake capacity was 1.55 when biochar was applied @ 20 t/ha. At 40% of field capacity lowest water uptake capacity was 1.61 when biochar was applied @ 20 t/ha but the highest water uptake capacity was 2.02 when no biochar was applied. Akhtar *et al.* (2014) found that biochar increased RWC and water use efficiency of drought stressed tomato plants. Uzoma *et al.* (2011) also reported that biochar increased water status of maize tissue in sandy soil.

3.4 Reproductive growth of maize

The number of cob was 1.0 per plant which did not varied with drought levels and treatments (Table 4). Drought stress affected length of cob. When biochar was applied at different doses the cob length was gradually increased (Table 4).

Table 3. Effect of rice husk biochar on relative water content, water saturation deficit and water uptake capacity of maize under drought conditions

Biochar doses (t/ha)	Relative water content (%)			Water saturation deficit (%)			Water uptake capacity		
	control	60% of FC	40% of FC	control	60% of FC	40% of FC	control	60% of FC	40% of FC
0	66.93abc	63.75bc	62.25c	33.06abc	36.24ab	37.74a	1.90ab	1.97a	2.02a
5	71.17abc	70.20abc	66.42abc	28.83abc	29.79abc	33.58abc	1.81a-d	1.83abc	1.98a
10	76.87abc	75.78abc	72.82abc	23.13abc	24.31abc	27.18abc	1.71a-d	1.79a-d	1.82a-d
20	83.37a	79.86ab	78.32abc	16.62c	20.13bc	21.17abc	1.52d	1.55cd	1.61bcd
CV (%)		14.1			36.8			10.7	

In a column, figures with same letters were not significant at 5% level..

Table 4. Effect of rice husk biochar on reproductive growth of maize under drought conditions

Biochar doses (t/ha)	Number of cob			Length of cob (cm)			Diameter of cob (cm)		
	control	60% of FC	40% of FC	control	60% of FC	40% of FC	control	60% of FC	40% of FC
0	1.0 a	1.0 a	1.0 a	15.93abc	13.23 bc	12.10 c	3.50 abc	3.20 c	3.15 c
5	1.0 a	1.0 a	1.0 a	16.53ab	14.73abc	14.63abc	3.60 abc	3.35 bc	3.25 c
10	1.0 a	1.0 a	1.0 a	17.23ab	15.13 abc	15.03abc	3.83 ab	3.50 abc	3.35 abc
20	1.0 a	1.0 a	1.0 a	17.66 a	15.33 abc	15.30abc	3.90 a	3.65 abc	3.50 abc
CV (%)		0.0			15.7			2.15	

In a column, figures with same letters were not significant at 5% level.

Under control condition the highest length of cob (17.66 cm) was found at 20 t/ha of biochar treatment and the lowest one (15.93 cm) was for control (no biochar). Under 60% of field capacity the highest length of cob was 15.33 cm at 20 t/ha of biochar and the lowest 13.23 cm was for control. Under 40% of field capacity the highest length of cob was 15.30 cm with was applied @ 20 t/ha of biochar and the lowest (12.10 cm) was for control. Cob diameter of maize reduced under drought stress. The highest reduction was for 40% of field capacity compare to that for 60% of FC but application of biochar increased diameter of cobs (Table 4). Under control condition highest cob diameter (3.90 cm) was found when biochar was applied @ 20 t/ha and it was lowest (3.50 cm) when no biochar was applied. Under 60% of field capacity highest cob diameter (3.65 cm) was found when biochar was applied @ 20 t/ha and it was lowest (3.20 cm) when no biochar was applied. Under 40% of field capacity highest cob diameter (3.50 cm) was found when biochar was applied @ 20 t/ha and it was lowest (3.15 cm) when no biochar was applied.

3.5 Yield and yield contributing characters

Number of seed per cob, 100 grain weight and grain yield varied significantly with biochar doses under drought conditions (Table 5). Under control condition highest number of seed per cob was 353.00 when biochar was applied @ 20 t/ha and lowest number of seed per cob was 163.00 when no biochar was applied. At 60% of FC highest number of seed per cob was 335.00 when biochar was applied @ 20 t/ha and lowest number os seed per cob was 147.33 when no biochar was applied. Under 40% of FC highest number of seed per cob was 334.66 when biochar was applied @ 20 t/ha and lowest number of seed per cob was 139.00 when no biochar was applied. Under control condition highest 100 grain weight (27.74 g) was found when biochar was applied @ 20 t/ha and it was lowest (21.88 g) when no biochar was applied. Under 60% of field capacity highest 100 grain weight (26.51 g) was found when biochar was applied @ 20 t/ha and it was lowest (20.71 g) when no biochar was applied. At 40% of field capacity highest 100 grain weight (25.00 g) was found when biochar was applied @ 20 t/ha and it was lowest (20.00 g) when no biochar was applied. Grain yield reduced due to drought but application of biochar maize grain yield increased (Table 5). Under control condition highest grain yield was 96.70 g/plant when biochar was applied @ 20 t/ha and lowest grain yield was 40.71 g/plant, when no biochar was applied. At 60 % of FC the highest grain yield was 89.78 g/plant when biochar was applied @ 20 t/ha and lowest grain yield was 35.92 g/plant when no biochar was applied. Under 40% of FC the highest grain yield was 84.57 g/plant when biochar was applied @ 20 t/ha and lowest grain yield was 27.84 g/plant when no biochar was applied.

Table 5. Effect of rice husk biochar on number of seed/cob, 100 grain wt. (g) and grain yield (g) of maize under drought conditions

Biochar doses (t/ha)	Number of seed /cob			100 grain weight (g)			Grain yield (g/plant)		
	control	60% of FC	40% of FC	control	60% of FC	40% of FC	control	60% of FC	40% of FC
0	163.00bcd	147.33 cd	139.00 d	21.88abc	20.71 bc	20.00 c	40.71 cd	35.92 cd	27.84 d
5	273.00a-d	244.00a-d	164.33bcd	23.48abc	21.73abc	21.40abc	58.61a-d	57.54a-d	34.97 cd
10	300.00 ab	297.00abc	288.33a-d	26.88 ab	23.07abc	21.53abc	79.59 ab	68.92abc	61.09a-d
20	353.00 a	335.00 a	334.66 a	27.74 a	26.51abc	25.00abc	96.70 a	89.78 ab	84.57 ab
CV (%)		35.5			16.70			37.40	

In a column, figures with same letters were not significant at 5% level.

Estrada-Campuzano *et al.* (2008) observed that water stress reduced yield of triticale and reductions of yield have been reported in snap bean by Lakitan *et al*. (1992). Drought stress affect negatively on anthesis, grain filling of maize associated with reduction of number seed/cob, 100 grain weight and ultimately grain yield. Decrease of photosynthesis under drought conditions also affected grain yield. Drought stress affect negatively on anthesis, grain filling of maize associated with reduction of number seed/cob, 100 grain weight and ultimately grain yield. Increasing of cassava yield with biochar application has been shown by Islami *et al* (2011) and Mannan *et al*. (2016) reported that biochar increased pod yield of soybean under saline stress. Foster *et al*. (2016) observed biochar application increased maize yield semi arid conditions. Application of biochar increased photosynthesis efficiency, anthesis and grain filling thereby increased yield of maize.

4. Conclusions

From the obtained results it might be concluded that application of rice husk biochar had positive impact on growth, water relation traits and yield of maize under drought conditions. Among the doses of rice husk biochar, the rate of 20 t/ha dose presented the best performance to enhance plant height, leaf water content and yield of maize. So rice husk biochar might be used as a soil amendment to mitigate drought effects in maize.

5. Acknowledgement

We are grateful to University Grants Commission (UGC), Bangladesh for funding the research.

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