Chapter

Amelioration of Drought Tolerance in Maize Using Rice Husk Biochar

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Abstract

This chapter discussed on mitigating effects of rice husk biochar to the drought effect on maize ("BARI Hybrid Bhutta 9"). Four doses of rice husk biochar at 0, 5, 10, and 20 t/ha were applied in soil before sowing of seed. Drought treatments were maintained at 60% of field capacity and 40% of field capacity by watering every alternate day, and 80% of field capacity (control) was also maintained as well-watered treatment. Plant growth and physiological parameters were studied at 6th leaf, 10th leaf, 14th leaf, tasseling stage, cob initiation stage, and maturity stage, and yield contributing parameters were studied after harvest. Soil physical and chemical properties were studied before sowing and after harvest of crop. Drought stress reduced plant morphological growth and affected physiology and yield of maize. Mitigation of drought stress in maize was well associated with the reduction of proline content, maintenance of water-related traits, exudation rate and enhanced chlorophyll content and SPAD value, as well as dry matter production. Rice husk biochar improved the growth and yield performance of maize under drought condition. Biochar application at 20 t/ha was the best treatment to improving drought tolerance in maize.

Keywords: amelioration, drought, tolerance, maize, biochar

1. Introduction

The world population is increasing and is projected to rise by more than 1 billion by 2030 and over 2.4 billion by 2050 [1]. Therefore, to feed the increasing population, agricultural food production must be increased by 70% by 2050 [2]. In the event of growing concerns of uncertainties in climatic conditions, the abiotic stresses have become the major threat to agriculture production worldwide. Drought is one of the most important abiotic stresses which affect crop growth and yield. In Bangladesh drought is a major threat to agricultural production. As maize is usually a winter condition and due to low rainfall, the growth of maize and yield of maize are severely affected by drought stress [3]. Under drought stress, plant photosynthesis can significantly decrease, consequently reducing the amount and energy of metabolites [4] required for the proper development of both the above- and belowground biomass [5]. In severe water shortage conditions, the roots will shrink and in the leaves induced deposition. In drought conditions, reduced water potential and increased cell content of ABA regulate the metabolism of cells.

Increase in substances such as proline can be one of the major molecular responses to drought stress [6]. Drought stress-induced free radicals cause lipid peroxidation and membrane deterioration in plants [7].

Maize is the third most important cereal crops in Bangladesh, after rice and wheat. It can be cultivated year round. The crop is high yielding and rich in nutrient and has diversified uses. The demand of maize in Bangladesh is primarily from the commercial feed processing industry. This industry is the driving force of 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 [8].Therefore, production of maize needs to be increased. However maize production is severely affected by drought stress. Water absorption, imbibition, and metabolic enzymatic activation are hindered under limited water availability which reduces the maize grain germination. Root and shoot elongations are parameters of seedling growth, and these are subjected to reduction by drought stress. At seedling stage in maize, reduction in shoot elongation is more than root elongation under drought stress [9]. Application of biochar is such technology which can mitigate adverse effects of drought stress on maize.

Biochar is charcoal formed from the thermal decomposition of biomass in a low- or zero-oxygen environment and at high temperatures (<700°C), and biochar production and application in soils has a very high potential for the expansion of sustainable agricultural systems and also for global climate change mitigation [10]. Experimental evidence so far shows that incorporation of biochar to soil enhanced soil water-holding capacity, improved soil water permeability, and improved saturated hydraulic conductivity (SHC) [11], modification in soil bulk density [12], and modified aggregate stability [13]. Biochar has the potential to increase the availability of plant nutrient [14]. Furthermore, research has found that biochar improves crop productivity and mitigates drought, salinity, acidity, and toxic metal stresses that are commonly associated with plant stress [15]. Biochar application increases growth and biomass of drought-stressed plants as well as increased photosynthesis [16].

Therefore, the objectives of this manuscript are to know the effects of rice husk biochar to mitigate drought effects on the growth, physiology, and yield of maize at drought conditions.

2. Mitigating effects of biochar on drought stress in maize

2.1 Effect of rice husk biochar on plant height of maize at vegetative stages under drought stress

Plant height differences of maize at vegetative stages indicated that plant height varied due to different doses of biochar under drought conditions (**Table 1**).

At the sixth leaf stage, under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest plant heights of maize were 44.8, 43.8, and 42.2 cm, respectively, when biochar was applied at 20 t/ha, and lowest plant heights of maize were 39.4, 39.1, and 38.7 cm, respectively, when no biochar was applied. At the 10th leaf stage, under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest plant heights of maize were 95.4, 93.0, and1.2 cm, respectively, when biochar was applied at 20 t/ha, and lowest plant heights of maize were 90.4, 89.5, and 80.2 cm, respectively, when no biochar was applied. At the 14th leaf stage, under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest plant heights of maize were 169.3,

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	39.4de	39.1e	38.7f	90.4b	89.5b	80.2b	150.60d	139.0f	134.3f
5	42.2a–e	40.9b-e	40.2 c–e	91.2ab	90.4b	90.3b	156.6c	145.3e	136.3f
10	42.8a–c	41.9a–e	41.2b–e	93.9ab	91.4ab	90.7b	164.0b	151.3d	138.3f
20	44.8a	43.8ab	42.0a–e	95.4a	93.0ab	91.2ab	169.3a	154.3cd	145.0e
CV (%)		4.2			3.1			2.0	

Figure having similar letter did not vary significantly.

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

154.3, and 145.0 cm, respectively, when biochar was applied at 20 t/ha, and lowest plant heights of maize were 150.6, 139.0, and 134.3 cm, respectively, when no biochar was applied. So it is clear that plant height is affected by drought conditions and application of rice husk biochar mitigated the effect of drought condition by increasing plant height. Similar result was reported in maize by [17]. Biochar promoted plant height of maize under drought conditions [18]. By affecting cell turgidity, drought impaired plant height [19]. Application of biochar can increase soil water-holding capacity which increased tissue water status and ultimately increased plant height [20].

2.2 Effect of rice husk biochar on plant height of maize at reproductive stages under drought stress

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 (80% of FC), 60% of field capacity, and 40% of field capacity, highest plant heights of maize were 190.0, 184.3, and 165.6 cm, respectively, when biochar was applied at 20 t/ha, and lowest plant heights of maize were 164.0, 161.6, and 136.6 cm, respectively, when no biochar was applied. At cob initiation stage, under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest plant heights of maize were 195.6, 190.3, and 169.0 cm, respectively, when biochar was applied at 20 t/ha, and lowest plant heights of maize were 174.3, 170.0, and 141.3 cm, respectively, when no biochar was applied. At maturity stage, under control condition (80% of FC), 60%

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	164.0cd	161.6 d	136.6 f	174.3cd	170.0d	141.3 f	175.3c	173.0c	154.0 e
5	172.6bc	172.0 bc	139.3 f	175.6cd	174.6cd	145.3 f	180.6bc	178.3bc	156.6de
10	174.3b	174.0 b	151.3 e	186.6b	182.6bc	157.6 e	186.6b	185.6b	163.0 d
20	190.0a	184.3 a	165.6bcd	195.6a	190.3ab	169.0 d	202.3a	195.6a	173.3 c
CV (%)		3.5			2.9			2.9	

Figure having similar letter did not vary significantly.

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

of field capacity, and 40% of field capacity, highest plant heights of maize were 202.3, 195.6, and 173.3 cm, respectively, when biochar was applied at 20 t/ha, and lowest plant heights of maize were 175.3, 173.0, and 154.0 cm, respectively, when no biochar was applied. Drought conditions affected plant height, and biochar application increased plant height under drought conditions. Similar result was reported in maize by [21]. Addition of biochar improved plant height [22]. In rice, drought stress during the vegetative stage greatly reduced the plant height; [23] and [24] found that biochar increased the plant height of maize.

2.3 Effect of rice husk biochar on days to flowering of maize under drought stress

Under drought conditions plant growth as well as days to flowering of maize was affected. Days to flowering of maize varied appreciably with different doses of biochar under drought conditions (**Figure 1**).

Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, lowest days to flowering of maize were 52, 57, and 61 days, respectively, when biochar was applied at 20 t/ha, and highest days to flowering of maize were 60, 62, and 63 days, respectively, when no biochar was applied. Drought stress affected plant physiological process and biochar helps to maintain physiological activities thereby flowering of plants, improved plant growth and influenced days to flowering. [25] observed that the mung bean plants grown in soil amended with 8.5% and 15.75% wood biochar started flowering, pod filling, and maturing 6 to 7 days earlier than those grown in unamended soil.

2.4 Effect of rice husk biochar on days to maturity of maize under drought stress imposition

Plants try to avoid drought conditions by completing their life cycle within the short times. Biochar helped to reduce the effects of drought stress on crops. Days to

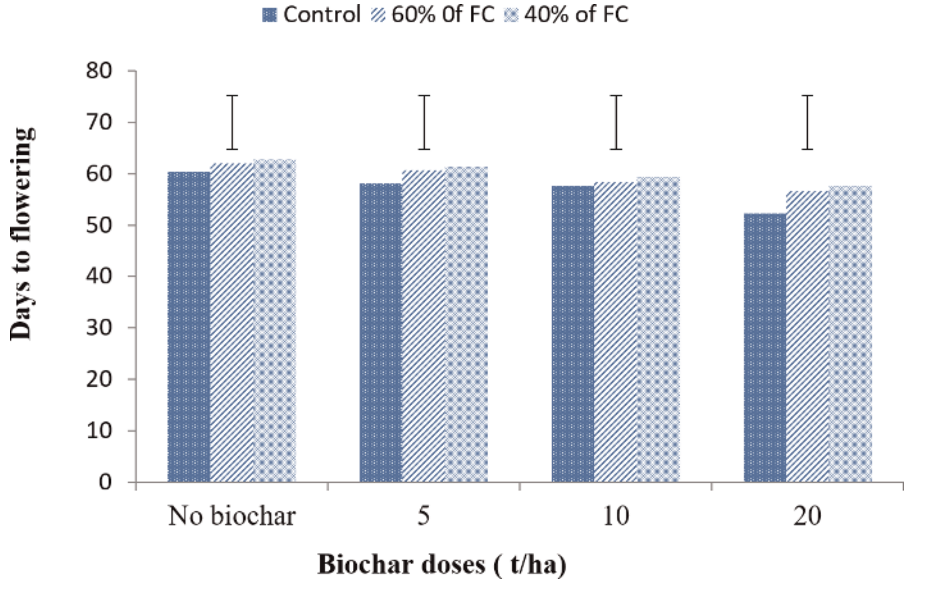

Figure 1.
Effect of rice husk biochar on days to flowering of maize under drought conditions. Bar indicates LSD at 5% level of significance.

maturity of maize plant were varied significantly at different doses of biochar under drought conditions (**Figure 2**).

Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest days to maturity of maize were 136, 135, and 133 days, respectively, when biochar was applied at 20 t/ha, and lowest days to flowering of maize were 131, 130, and 128 days, respectively, when no biochar was applied. Application of biochar increased the water-holding capacity of silty sand under maize cultivation in pots; [26] and [27] reported that biochar helped in maintaining normal physiological functions including maturity of wheat under saline conditions. [28] observed that biochar application increased tomato growth and life cycle under saline conditions.

2.5 Effect of rice husk biochar on relative water content (RWC), water uptake capacity (WUC), and water saturation deficit (WSD) in maize under drought stress

Relative water content of maize plant was reduced significantly at drought stress conditions because of low water content of soil. Application of rice husk biochar at different doses helped to increase water-holding capacity of soil under drought conditions and thereby increased relative water content of maize plant (**Table 3**). Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest RWC of maize were 83.37, 79.86, and 78.32%, respectively, when biochar was applied at 20 t/ha, and lowest RWC of maize were 66.93, 63.75, and 62.25%, respectively, when no biochar was applied.

Water saturation deficit of maize plant was increased significantly at drought stress conditions, and it is varied with different doses of biochar under drought conditions (**Table 3**).Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, lowest WSD of maize were 16.6, 20.1, and 21.1%, respectively, when biochar was applied at 20 t/ha, and highest WSD of maize were 33.0, 36.2, and 37.7%, respectively, when no biochar was applied.

Water uptake capacity of maize plant was increased significantly under drought stress because soil contained low moisture to be uptaken by plant. WUC depended

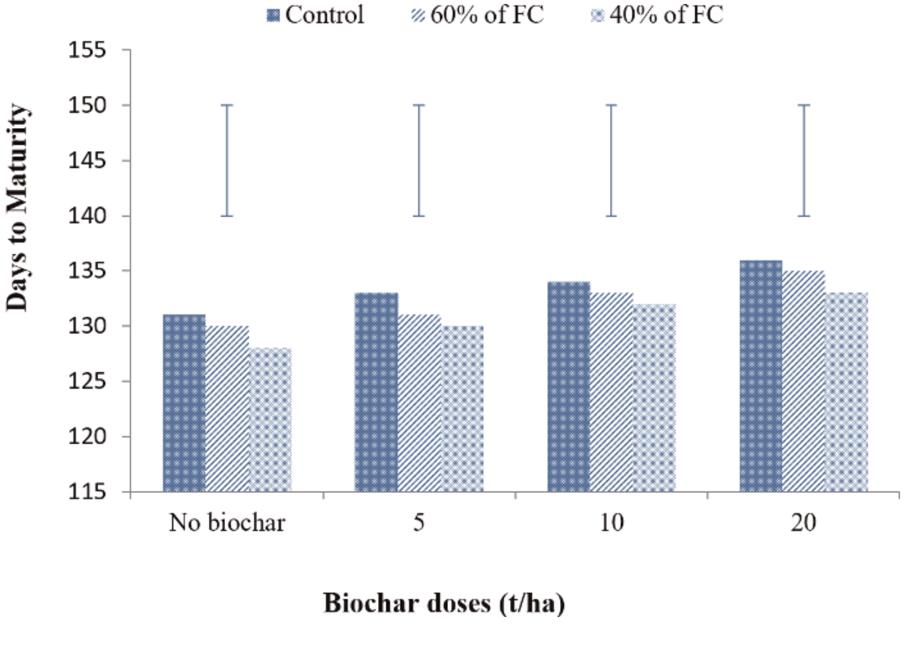

Figure 2.
Effect of rice husk biochar on days to maturity of maize under drought conditions. Bar indicates LSD at 5% level of significance.

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	66.9bc	63.7bc	62.2c	33.1a–c	36.2ab	37.7 a	1.9ab	1.9a	2.0a
5	71.2bc	70.2a–c	66.4bc	28.8a–c	29.7a–c	33.5a–c	1.8a–d	1.8a–c	1.9a
10	76.8bc	75.7a–c	72.8a–c	23.1a–c	24.3a–c	27.1a–c	1.7a–d	1.7a–d	1.8a–d
0	83.3a	79.8ab	78.3bc	16.6c	20.1bc	21.1a–c	1.5d	1.5cd	1.6b–d
CV (%)		14.1			36.8			10.7	

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Table 3.
Effect of rice husk biochar on RWC, WSD, and WUC of maize under drought conditions.

on water-holding capacity of soil, and it was varied with different doses of biochar under drought condition (**Table 3**). Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, lowest WUC of maize were 1.5, 1.5, and 1.6, respectively, when biochar was applied at 20 t/ha, and highest WUC of maize were 1.9, 1.9, and 2.0, respectively, when no biochar was applied. [29] reported biochar increased water-holding capacity. [30] found that biochar increased RWC and water use efficiency of drought-stressed tomato plants. [31] also reported that biochar increased tissue water status of maize in sandy soil.

2.6 Effect of rice husk biochar on exudation rate of maize under drought stress

Exudation rate of maize plant was reduced significantly at drought conditions. Exudation rate depends on available water in soil to be uptaken by the plant. Exudation rate of maize varied due to different doses of biochar under drought conditions (**Figure 3**). Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest exudation rates of maize were 2.3, 1.5, and

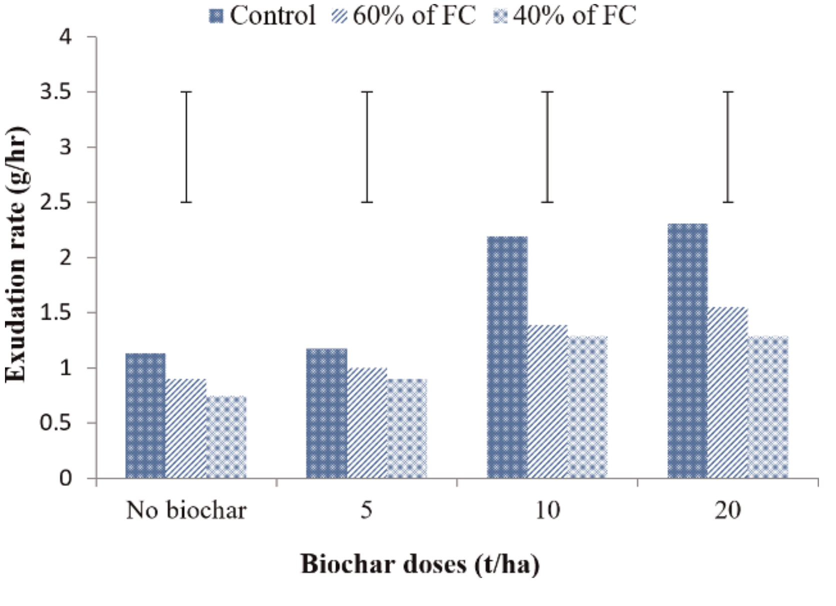

Figure 3.
Effect of rice husk biochar on exudation rate of maize under drought conditions. Bar indicates LSD at 5% level of significance.

1.5 g/hr., respectively, when biochar was applied at 20 t/ha, and lowest exudation rates of maize were 1.1, 1.0, and 0.7 g/hr., respectively, when no biochar was applied. Similar result was observed by [32]. [33] found biochar application increased water retention capacity of soil. [34] reported application of biochar increased water-holding capacity of field-grown wheat and exudation rate.

2.7 Effect of rice husk biochar on chlorophyll contents of maize under drought stress

Chlorophyll content of maize leaf was reduced significantly at drought stress conditions. Chlorophyll a content varied significantly with different doses of biochar under drought conditions (**Table 4**).

Under control condition highest chlorophyll a (1.4 mg/g) was found when biochar was applied at 20 t/ha, and it was lowest (1.2 mg/g) when no biochar was applied. Under 60% of field capacity, highest chlorophyll a (1.4 mg/g) was found when biochar was applied at 20 t/ha, and it was lowest (1.1 mg/g) when no biochar was applied. Under 40% of field capacity, highest chlorophyll a was observed when plant was treated with biochar at 20 t/ha (1.3 mg/g), and it was lowest (1.1 mg/g) when no biochar was applied. Chlorophyll b increased with the application of biochar under drought stress conditions, although it was insignificant (**Table 4**). Under control condition highest chlorophyll b (1.1 mg/g) was found when biochar was applied at 20 t/ha, and it was lowest (0.9 mg/g) when no biochar was applied. Under 60% of field capacity, highest total chlorophyll b (1.0 mg/g) was found when biochar was applied at 20 t/ha, and it was lowest (0.9 mg/g) when no biochar was applied. Under 40% of field capacity, highest chlorophyll b was observed when plant was treated with biochar at 20 t/ha (1.0 mg/g), and it was lowest (0.9 mg/g) when no biochar was applied. Under control condition highest total chlorophyll (2.0 mg/g) was found when biochar was applied at 20 t/ha, and it was lowest (1.5 mg/g) when no biochar was applied. Under 60% of field capacity, highest total chlorophyll (1.7 mg/g) was found when biochar was applied at 20 t/ha, and it was lowest (1.4 mg/g) when no biochar was applied. Under 40% of field capacity, highest total chlorophyll was observed when plant was treated with biochar at 20 t/ha (1.6 mg/g), and it was lowest (1.3 mg/g) when no biochar was applied. [39] marked reduction in chlorophylls in wheat cultivars subjected to water stress. [35] reported that biochar increased chlorophyll content in milk thistle under drought conditions.

Biochar doses (t/ha)	Chlorophyll a (mg/g fresh weight)			Chlorophyll b (mg/g fresh weight)			Total chlorophyll (mg/g fresh weight)		
	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC
0	1.2c–e	1.1de	1.1e	0.9a	0.9a	0.9a	1.5ab	1.4ab	1.3b
5	1.2c	1.2de	1.2c–e	1.0a	0.9a	0.9a	1.5ab	1.5ab	1.4ab
10	1.2c	1.2cd	1.2c–e	1.0a	1.0a	0.9a	1.9ab	1.5ab	1.5ab
20	1.4a	1.4ab	1.3bc	1.1a	1.0a	1.0a	2.0a	1.7ab	1.6ab
CV (%)		6.1			3.3			2.3	

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Table 4.
Effect of rice husk biochar on chlorophyll content in maize under drought conditions.

2.8 Effect of rice husk biochar on SPAD value of maize at vegetative stages under drought stress

At vegetative stage SPAD value of maize plant was reduced significantly at drought stress conditions. SPAD value varied with different doses of biochar under drought conditions (**Table 5**).

At the 6th leaf stage of maize after under control condition, highest SPAD value (30.7) was found when biochar was applied at 20 t ha^{-1}, and it was lowest (25.3) when no biochar was applied. Under 60% of field capacity, highest SPAD value (30.5) was found when biochar was applied at 20 t/ha, and it was lowest (23.7) when no biochar was applied. Under 40% of field capacity, highest SPAD value (29.5) was found when biochar was applied at 20 t/ha, and it was lowest (20.4) when no biochar was applied. At the 10th leaf stage of maize after under control condition, highest SPAD value (33.3) was found when biochar was applied at 20 t/ha, and it was lowest (29.3) when no biochar was applied. Under 60% of field capacity, highest SPAD value (30.2) was found when biochar was applied at 20 t/ha, and it was lowest (29.3) when no biochar was applied. Under 40% of field capacity, highest SPAD value (29.8) was found when biochar was applied at 20 t/ha and at 5 t/ha (29.4), and it was lowest (29.0) when no biochar was applied. At the 14th leaf stage of maize after under control condition, highest SPAD value (35.3) was found when biochar was applied at 20 t/ha, and it was lowest (29.5) when no biochar was applied. Under 60% of field capacity, highest SPAD value (32.0) was found when biochar was applied at 20 t/ha, and it was lowest (27.7) when no biochar was applied. Under 40% of field capacity, highest SPAD value (31.8) was found when biochar was applied at 20 t/ha, and it was lowest (27.2) when no biochar was applied. It indicates that the longer the exposure to drought stress, the higher the decreases of the SPAD value. The decrease of SPAD reading under drought conditions is reported by [36]. [37] showed that biochar may alleviate water stress in plants and increased SPAD value.

2.9 Effect of rice husk biochar on SPAD value of maize at reproductive stages under drought stress

SPAD value of maize plant was reduced significantly at drought conditions, and reduction was higher at 40% field capacity than 60% of field capacity at tasseling stage and cob initiation stage (**Table 6**).

Biochar doses (t/ha)	6th leaf stage			10th leaf stage			14th leaf stage		
	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC
0	25.3c–e	23.7e	20.4f	30.4cd	29.3ef	29.0f	29.5de	27.7e	27.2e
5	27.5bc	25.2de	24.4de	30.7c	29.9de	29.4ef	33.0a–c	29.9b–e	28.9de
10	29.5ab	26.4cd	26.2cd	32.0b	30.0cd	29.7d–f	33.3ab	31.1bd	29.7c–e
20	30.7a	30.5a	29.5ab	33.3a	30.2cd	29.8d–f	35.3a	32.0a–d	31.8b–d
CV (%)	5.0			1.6			6.6		
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Table 5.
Effect of rice husk biochar on SPAD value in maize at vegetative stages under drought conditions.

Biochar doses (t/ha)	Tasseling stage			Cob initiation stage		
	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC
0	30.2bc	28.0cd	27.8d	28.2b–d	27.6cd	27.1d
5	30.6b	29.4c–d	29.2b–d	29.8a–c	29.3a–d	29.2a–d
10	30.9b	29.8b–d	29.7b–d	30.7ab	29.5a–d	29.5a–d
20	33.5a	31.2b	30.7b	31.3a	31.0a	30.7ab
CV (%)		4.4			5.0	

Figure having similar letter did not vary significantly.

Table 6.
Effect of rice husk biochar on SPAD value in maize at reproductive stages under drought conditions.

When biochar was applied at different doses, SPAD value was increased. At tasseling stage of maize under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest SPAD values were 33.5, 31.2, and 30.7, respectively, when biochar was applied at 20 t/ha, and lowest SPAD values were 30.2, 28.0, and 27.8, respectively, when no biochar was applied. At cob initiation stage of maize under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest SPAD values were 31.3, 31.0, and 30.7, respectively, when biochar was applied at 20 t/ha, and lowest SPAD values were 28.2, 27.6, and 27.1, respectively, when no biochar was applied. Similar result was reported by Mannan et al. (2016) in soybean plant under salinity stress due to poultry litter biochar. With increasing drought stress levels, SPAD readings were decreased [38]. [39] reported biochar increased soil moisture level and maize yield.

2.10 Effect of rice husk biochar on proline of maize under drought stress

Proline is a kind of stress protein. Proline accumulation under stress condition occurred because the Calvin cycle of photosynthesis is affected by drought; as a result N content could not be properly metabolized. In drought soil biochar increases photosynthesis and proper metabolism of N content. Proline content of maize varied significantly with different doses of biochar under drought conditions (**Figure 4**).

Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, lowest proline contents were 1.1, 1.1, and 3.2 μ mole/g, respectively, when biochar was applied at 20 t/ha, and highest proline contents were 1.8, 2.9, and 6.1 μ mole/g, respectively, when no biochar was applied. [40] reported biochar decreased proline content in plants. [41] marked drought stress caused overproduction of proline content. [42] also reported biochar increased photosynthesis in grape leaves.

2.11 Effect of rice husk biochar on dry weight of cob sheath, leaf, and stem of maize under drought stress

A major effect of drought is reduction in photosynthesis, which is associated with reduction in food production and ultimately reduced dry weight of plant parts. Dry weight of cob sheath, leaf, and stem of maize is greatly affected by drought conditions. Application of rice husk biochar increased dry matter of cob sheath, leaf, and stem of maize under drought conditions. Dry weight of cob sheath, leaf, and stem of maize varied significantly with different doses of biochar under drought conditions (**Table 7**).

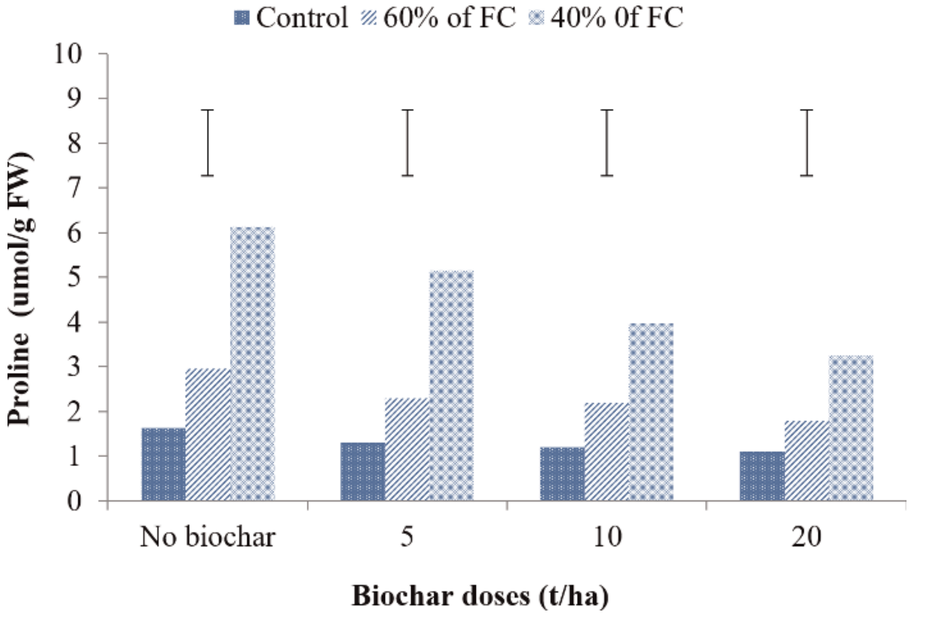

Figure 4.
Effect of rice husk biochar on proline content of maize under drought conditions. Bar indicates LSD at 5% level of significance.

Biochar doses (t/ha)	Cob sheath (g/plant)			Leaf (g/plant)			Stem (g/plant)		
	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC
0	12.8bc	11.7bc	10.3c	37.2d–g	35.2fg	34.4g	24.8ab	21.4ab	19.0b
5	13.1bc	12.6bc	11.4bc	39.8a–d	36.4e–g	36.2e–g	25.4ab	22.3ab	20.6ab
10	14.5bc	14.2bc	12.9bc	40.3a–c	39.4a–d	37.7c–f	26.8a	25.2ab	21.3ab
20	19.7a	15.5ab	14.8abc	42.0a	41.5ab	38.6b–e	27.2a	26.2a	22.7ab
CV (%)		21.9			4.6			17.3	

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Table 7.
Effect of rice husk biochar on dry weight of cob sheath, leaf and stem of maize under drought conditions.

The highest dry weight of stem were 27.28 g, 26.25 g and 22.75 g in control, 60% of field capacity and 40% of field capacity, respectively, when biochar was applied at 20 t/ha, and lowest dry weights of cob sheath were 12.8, 11.7, and 10.3 g, respectively, when no biochar was applied. Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest dry weights of leaf were 42.0, 41.5, and 38.6 g, respectively, when biochar was applied at 20 t/ha, and lowest dry weights of leaf were.

Table 7. Effect of rice husk biochar on dry weight of cob sheath, leaf, and stem of maize under drought conditions, 37.2, 35.2, and 34.4 g, respectively, when no biochar was applied. Under control condition (80%of FC), 60% of field capacity, and 40% of field capacity, highest dry weights of stem were 27.2, 26.2, and 22.7 g, respectively, when biochar was applied at 20 t/ha, and lowest dry weights of stem were 24.8, 21.8, and 19.0 g, respectively, when no biochar was applied. [43] found drought stress reduced dry weight of plant parts by affecting photosynthesis. [44] reported that application of biochar increased dry weight of field-grown wheat.

2.12 Effect of rice husk biochar on shoot, root, and total dry weight of maize under drought stress

In drought stress shoot dry weight of maize reduced, but root dry weight increased, because under drought conditions for searching water, root growth increased, thereby increasing dry weight of root. Application of rice husk biochar reduced the effects of drought. The dry weight of root and shoot varied significantly with the application of biochar under drought conditions (**Table 8**).

Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest dry weights of shoot were 84.1, 83.1, and 75.9 g, respectively, when biochar was applied at 20 t/ha, and lowest dry weights of shoot were 75.4, 68.4, and 63.8 g, respectively, when no biochar was applied. Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, lowest dry weights of root were 12.4, 15.6, and 16.8 g, respectively, when biochar was applied at 20 t/ha, and highest dry weights of root were 17.5, 26.8, and 27.3 g, respectively, when no biochar was applied. Total dry weight of maize plant was reduced at drought stress conditions, but reduction was not significant. When biochar is applied at different doses under drought conditions, total dry weight increased (**Table 8**). Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest total dry weights were 98.8, 97.0, and 93.9 g, respectively, when biochar was applied at 20 t/ha, and lowest total dry weights were 93.1, 91.1, and 89.3 g, respectively, when no biochar was applied. [45] found that root dry weight increased, while shoot dry weight decreased under drought conditions. [46] marked shoot dry weight increased under drought conditions due to application of biochar.

2.13 Effect of rice husk biochar on number of cob, length of cob, and diameter of cob of maize under drought stress

The number of cob was one per plant, and there is no significant difference among numbers of cob per plant under drought stress condition with different biochar doses (**Table 9**).

Drought affected growth of maize. Length of cob of maize was reduced under drought conditions. When biochar was applied at different doses, the cob length was increased under drought conditions (**Table 9**). Under control condition highest cob length (17.6 cm) was found when biochar was applied at 20 t/ha, and it was lowest (15.9 cm) when no biochar was applied. Under 60% of field capacity, highest

Biochar doses (t/ha)	Shoot dry weight (g/plant)			Root dry weight (g/plant)			Total dry weight (g/plant)		
	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC
0	75.4a–d	68.4cd	63.8d	17.5a–c	26.8a	27.3a	93.1a	91.1a	89.3a
5	77.8a–c	71.5b–d	68.2cd	16.7a–c	17.7a–c	24.4ab	95.2a	94.6a	92.6a
10	81.2ab	79.3a–c	72.9a–d	15.7bc	16.3a–c	21.7a–c	95.6a	95.5a	92.8a
20	84.1a	83.1ab	75.9a–c	12.4c	15.6bc	16.8a–c	98.8a	97.0a	93.9a
CV (%)		9.3			34.4			8.7	

Figure having similar letter did not vary significantly.

Table 8.
Effect of rice husk biochar on shoot, root, and total dry weight 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	1.0a	1.0a	1.0a	15.9a–c	13.2bc	12.1c	3.5a–c	3.2c	3.1c
5	1.0a	1.0a	1.0a	16.5ab	14.7a–c	14.6a–c	3.6a–c	3.3bc	3.2c
10	1.0a	1.0a	1.0a	17.2ab	15.1a–c	15.0a–c	3.8ab	3.5a–c	3.3a–c
20	1.0a	1.0a	1.0a	17.6a	15.3aa–c	15.3a–c	3.9a	3.6a–c	3.5a–c
CV (%)		0.0			15.7			2.15	

Figure having similar letter did not vary significantly.

Table 9.
Effect of rice husk biochar on number of cob, length of cob, and diameter of cob of maize under drought conditions.

cob length (15.3 cm) was found when biochar was applied at 20 t/ha, and it was lowest (13.2 cm) when no biochar was applied. Under 40% of field capacity, highest total cob length (15.3 cm) was found when biochar was applied at 20 t/ha, and it was lowest (12.1 cm) when no biochar was applied. Cob diameter of maize was reduced under drought stress conditions, and reduction was higher at 40% of field capacity than at 60% of field capacity. Biochar application increased cob diameter under drought conditions (**Table 9**). Under control condition highest cob diameter (17.6 cm) was found when biochar was applied at 20 t/ha, and it was lowest (15.9 cm) when no biochar was applied. Under 60% of field capacity, highest cob diameter (15.3 cm) was found when biochar was applied at 20 t/ha, and it was lowest (13.2 cm) when no biochar was applied. Under 40% of field capacity, highest total cob diameter (15.3 cm) was found when biochar was applied at 20 t/ha, and it was lowest (12.1 cm) when no biochar was applied. [47] reported biochar increased yield of lettuce. Reductions in plant yield have been reported in snap bean by [48]. [49] observed biochar application increased maize yield in semiarid conditions.

2.14 Effect of rice husk biochar on number of seed/cob, 100 grain weight (g), and grain yield (g) of maize under drought stress conditions

Drought stress affected 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. Application of biochar increased photosynthesis efficiency, anthesis, and grain filling, thereby increasing yield of maize. The number of seed per cob, 100 grain weight, and grain yield varied significantly with biochar doses under drought conditions (**Table 10**).

Under control condition (80%of FC), 60% of field capacity, and 40% of field capacity, highest numbers of seed per cob were 353.0, 335.0, and 334.6, respectively, when biochar was applied at 20 t/ha, and lowest seeds per cob were 163.0, 147.3, and 139.0, respectively, when no biochar was applied. Under control condition highest 100 grain weight (27.7 g) was found when biochar was applied at 20 t/ha, and it was lowest (21.8 g) when no biochar was applied. Under 60% of field capacity, highest 100 grain weight (26.5 g) was found when biochar was applied at 20 t/ha, and it was lowest (20.7 g) when no biochar was applied. Under 40% of field capacity, highest 100 grain weight (25.0 g) was found when biochar was applied at 20 t/ha, and it was lowest (20.0 g) when no biochar was applied. Under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest

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	163.0bcd	147.3cd	139.0d	21.8a–c	20.7bc	20.0c	40.7cd	35.9cd	27.8d
5	273.0a–d	244.0a–d	164.3b–d	23.4a–c	21.7a–c	21.4a–c	58.6a–d	57.5a–d	34.9cd
10	300.0ab	297.0a–c	288.3a–d	26.8ab	23.0a–c	21.5a–c	79.5ab	68.9a–c	61.0a–d
20	353.0a	335.0a	334.6a	27.7a	26.5a–c	25.0a–c	96.7a	89.7ab	84.5ab
CV (%)		35.5			16.70			37.40	

Figure having similar letter did not vary significantly.

Table 10.
Effect of rice husk biochar on the number of seed/cob, 100 grain wt. (g), and grain yield (g) of maize under drought conditions.

grain yields were 96.7, 89.7, and 84.5 g/plant, respectively, when biochar was applied at 20 t/ha, and lowest grain yields were 40.7, 35.9, and 27.8 g/plant, respectively, when no biochar was applied. Similar result was reported by [50]. [51] observed water stress reduced yield of triticale. [52] reported biochar increased pod yield of soybean under saline conditions.

2.15 Effect of rice husk biochar on N, P, and K in soil under drought stress

Under drought conditions biological activities as well as nutrients in soil are greatly affected. As a result macronutrients such as N, P, and K are reduced. Application of rice husk biochar showed positive effects on total nitrogen content and P and K under stress and nonstressed conditions (**Table 11**).

The initial total N was 0.17%, and after crop harvest under control condition, the highest total N (0.14%) was found when biochar was applied at 20 t/ha; it was lowest (0.10%) when no biochar was applied. Under 60% of field capacity, highest total N (0.13%) was found when biochar was applied at 20 t/ha, and it was lowest (0.10%) when no biochar was applied. Under 40% of field capacity, highest total N (0.11%) was found when biochar was applied at 20 t/ha, and it was lowest (0.09%) when no biochar was applied. The initial P was 7.24 ppm, and after harvest under control condition (80% of FC), 60% of field capacity, and 40% of field capacity,

Before sowing	Total N (%)			P (ppm)			K (meq/100 g soil)		
	0.172			7.24			0.169		
	After harvest								
Biochar doses (t/ha)	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC	Control	60% of FC	40% of FC
0	0.10a	0.10a	0.09a	7.49bc	7.48bc	7.44c	0.17a	0.17a	0.17a
5	0.11a	0.11a	0.10a	7.96bc	7.74bc	7.61bc	0.17a	0.17a	0.17a
10	0.12a	0.11a	0.11a	9.13a	7.98bc	7.64bc	0.18a	0.17a	0.17a
20	0.14a	0.13a	0.11a	9.18a	8.00b	7.96bc	0.18a	0.18a	0.17a
CV (%)		7.0			4.0			1.5	

Figure having similar letter did not vary significantly.

Table 11.
Effect of rice husk biochar on N, P, and K in soil under drought conditions.

highest P were 9.18, 8.00, and 7.96 ppm, respectively, when biochar was applied at 20 t/ha, and lowest P were 7.49, 7.48, and 7.44 ppm, respectively, when no biochar was applied. The initial K was 0.16 meq/100 g soil, and after crop harvest under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest K were 0.18 meq/100 g soil, 0.18 meq/100 g soil, and 0.17 meq/100 g soil, respectively, when biochar was applied at 20 t/ha, and lowest K were 0.17 meq/100 g soil, 0.17 meq/100 g soil, and 0.17 meq/100 g soil, respectively, when no biochar was applied. [53] reported biochar increased plant available nutrient in soil. [54] reported drought reduced N, P, and K levels in soil. [55] observed that the addition of biochar to soils increased soil phosphorus (P), soil potassium (K), and total soil nitrogen (N).

2.16 Effect of rice husk biochar on Zn, pH, and organic carbon (OC) in soil under drought stress

Drought stress adversely affected soil chemical properties such as Zn, pH, and OC. Application of rice husk biochar increased Zn, pH, and OC in soil. Zn and soil pH varied significantly with different doses of rice husk biochar under drought conditions, but OC varied insignificantly (**Table 12**).The initial Zn content was 17.4 meq/100 g soil, and after crop harvest under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest Zn were 17.4 meq/100 g soil, 15.3 meq/100 g soil, and 14.9 meq/100 g soil, respectively, when biochar was applied at 20 t/ha, and lowest Zn were 13.9 meq/100 g soil, 13.2 meq/100 g soil, and 12.6 meq/100 g soil, respectively, when no biochar was applied. The initial pH was 6.1, and after crop harvest under control condition (80% of FC), 60% of field capacity, and 40% of field capacity, highest pH were 7.0, 6.9, and 6.7, respectively, when biochar was applied at 20 t/ha, and lowest pH were 6.7, 6.7, and 6.6, respectively, when no biochar was applied. The initial OC was 1.4%, and after crop harvest under control condition (80% of FC), 60% of field capacity, and 40% field capacity, highest OC were 0.7, 0.7, and 0.6%, respectively, when biochar was applied at 20 t/ha, and lowest OC were 0.54, 0.53, and 0.52%, respectively, when no biochar was applied. Similar result was reported by [56]. [57] marked biochar improved soil chemical properties of saline soil and biochar increased organic carbon. [58] found that biochar increased soil pH, thus reducing lime requirements.

Before sowing	**Zn (meq/100 g soil)**			**pH**			**OC (%)**		
	17.49			**6.18**			**1.45**		
	After harvest								
Biochar doses (t/ha)	**Control**	**60% of FC**	**40% of FC**	**Control**	**60% of FC**	**40% of FC**	**Control**	**60% of FC**	**40% of FC**
0	13.9b–e	13.2de	12.6e	6.7ab	6.7b	6.6b	0.5a	0.5a	0.5a
5	14.3b–e	14.0b–e	13.2de	6.7ab	6.7ab	6.7ab	0.5a	0.5a	0.5a
10	15.7ab	14.8b–d	13.9c–e	6.9a	6.7ab	6.7ab	0.6a	0.6a	0.59a
20	17.4a	15.3bc	14.9b–d	7.0a	6.9a	6.7ab	0.7a	0.7a	0.6a
CV (%)		7.4			2.9			6.8	

Figure having similar letter did not vary significantly.

Table 12.
Effect of rice husk biochar on Zn, pH, and organic carbon in soil under drought conditions.

3. Conclusions

Application of rice husk biochar increased plant height, days to maturity, total dry weight, chlorophyll content, plant water relations, SPAD value, exudation rate and reduced proline content, and days to flowering of maize under drought conditions. In maize plant drought stress tolerance ameliorate rice husk biochar and increased cob diameter, cob length, 100 grain weight of cob, seed /cob and finally maize yield at drought conditions.

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Conflict of interest

There is no conflict of interest.

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