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RESPONSE OF BIOCHAR ON GROWTH AND YIELD OF AMAN RICE UNDER SALT STRESS

M.M. Khanam, N. Nawal, M. Hasanuzzaman, M.F. Karim and A. Rahman*

Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh
*Corresponding E-mail: anisur68@yahoo.com

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Abstract

A pot experiment was conducted in Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during *aman* season, 2018 to assess the effect of biochar on rice (BRRI dhan62) under salt stress conditions. The factorial experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Three levels of salinity were used viz. Control (S_0), 1600 ppm NaCl (S_1), and 2800 ppm NaCl (S_2) under factor A and four levels of biochar were applied viz. 0 t ha^{-1} (B_0), 2 t ha^{-1} (B_1), 4 t ha^{-1} (B_2) and 6 t ha^{-1} (B_3) under factor B. The salt materials were added on pot in two installments at 20 and 30 days after transplanting (DAT). Exposure to salinity decreased growth and yield of rice including plant height, tillers $hill^{-1}$, effective tillers $hill^{-1}$, grains $panicle^{-1}$, 1000-grain weight, grain yield and straw yield. The magnitude of growth and yield reduction increased with increasing the salinity level. Exposure of 1600 ppm and 2800 ppm NaCl declined the grain yield of rice by 28 and 100%, respectively. Straw yield (18 and 100%, respectively) and other yield contributing parameters declined by these two levels of salinity in the same way. Application of different levels of biochar ameliorated salt-induced damages to a certain extent. Under 2800 ppm NaCl stress, application of biochar extended life duration of rice plant upto 80 DAT, whereas without biochar application rice plant died after 60 DAT. Upon exposure to 1600 ppm NaCl stress, application of 2, 4 and 6 t ha^{-1} of biochar increased grain yield by 37, 42 and 30%, respectively, compared with the respective salt treatments (without biochar). Biochar enhanced yield of rice under saline conditions by enhancing yield contributing attributes including effective tillers and 1000-grain weight and by reducing salt-induced damages. However, response of 4 t ha^{-1} of biochar was best among the biochar levels (2, 4 and 6 t ha^{-1} of biochar) under both saline and non-saline conditions.

Introduction

Rice is the second most widely grown cereal and primary source of food for more than half of the world population (Haque *et al.*, 2015). It is adapted to a variety of climatic conditions. But continuous climate change induced various environmental stresses on plants including salinity, drought, heat, cold etc. Among the environmental factors, salinity is one of the detrimental abiotic stresses reducing crop growth and productivity (Rahman *et al*., 2017). Around 20% of world irrigated land are salt affected (Munns and Tester, 2008) and it is assumed that 50% of world cultivable land will be affected by salinity by 2050 (Mahajan and Tuteja, 2005). However, salinity is a major environmental threat for crop production as its negative effect starts from germination and exist till death of plant (Mahajan and Tuteja, 2005; Mishra *et al*., 2013). Salinity in the plant root region creates osmotic, ionic and oxidative stress in plants (Munns and Tester, 2008; Hussain *et al.*, 2017) which ultimately reduced growth and yield of plant (Hasanuzzaman *et al*., 2013; Rahman *et al.*, 2016a; Rahman *et al.*, 2016b). Salt induced stress reduced plant height, tiller number, effective tillers, filled grain, grain yield, straw yield even causes death of plant (Hasanuzzaman *et al*., 2013; Islam *et al*., 2022).

Biochar is carbon rich fine-grained charcoal produced by pyrolysis of biomass in a low oxygen environment and it increase soil fertility (Liu *et al*., 2016; Zhang *et al*., 2019). Biochar improves physical, chemical and biological properties of soil by increasing soil organic carbon, cation exchange capacity and stabilization of soil structure (Zheng *et al*., 2018). Chaganti and Crohn (2015) revealed that biochar application under salt stress conditions reduces salt-induced damages by reducing Na^+ uptake and increasing nutrient uptake. Biochar application decreased bulk density, electrical conductivity, exchangeable Na^+ and exchangeable Cl^- in soil under salt stress conditions that helps to mitigate salinity stress in rice (Zhang *et al*., 2019). However, Yang *et al.* (2021) revealed that application of 10 t ha^{-1} of biochar increased tropical rice production by improving soil physical properties and at the same time increased soil salinity. Application of biochar in higher rate (>10 t ha^{-1}) decreased growth and yield of rice (Chen *et al.*, 2021 and Yang *et al.*, 2021). Considering the issues discussed, the present study was conducted to identify the lower rate of biochar which can play positive role on rice under salt stress conditions.

Materials and Methods

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during *aman* season (July to December) 2018 in net house conditions on plastic pot (14 inches diameter and 18 inches depth). The experimental pots were filled with 12 kg well dried and fertilized soil. Urea, TSP, MoP and Gypsum fertilizers were applied at the rate of 150, 50, 80 and 60 Kg ha^{-1} as per recommendation of Bangladesh Rice Research Institute (BRRI). Four levels of biochar were applied on plastic pot as per treatment. After growing in seedbed, 25 days old seedlings were transplanted in experimental pot. Two seedlings were transplanted in each hill and three hills set in each pot. Different intercultural operations were done as per requirement of the crop. After establishment of seedlings, three levels of NaCl were added on pot in two equal installments at 20 and 30 DAT. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Three levels of salinity viz. Control (S_0), 1600 ppm NaCl (S_1), and 2800 ppm NaCl (S_2) were under factor A and four levels of biochar viz. 0 t ha^{-1} (B_0), 2 t ha^{-1} (B_1), 4 t ha^{-1} (B_2) and 6 t ha^{-1} (B_3) were under factor B.

All plants from each pot were considered for different growth, yield and yield contributing parameters like plant height, tiller $hill^{-1}$, effective tillers $hill^{-1}$, grains $panicle^{-1}$, 1000-grain weight, grain yield and straw yield. The collected data analyzed by Statistix 10 software by following two-way ANOVA model and mean separation was done by least significant difference (LSD) test at the 5% level of significance.

Results and Discussion

Plant height

Salinity significantly influenced plant height of rice (Table 1). In response to 1600 ppm NaCl stress, rice plant showed statistically similar plant height compared with control. Upon exposure to 2800 ppm NaCl, the plant height of rice declined by 19, 48, 71 and 100% at 40, 60 and 80 DAT, and at harvest, respectively, compared with untreated control. Our results in agreement with Islam *et al.* (2022) who stated that salinity decreased plant height of rice and magnitude of decreases increased with the advancement of the growth period. Under saline conditions, Na^+ enter into shoot of rice through apoplastic pathway which disrupts cell division and cell elongation and ultimately reduced growth of rice (Hussain *et al.*, 2017).

Biochar application had significant influence on plant height of rice upto 40 DAT (Table 1). AT 20 DAT, the longest plant recorded for the application of 4 t ha^{-1} of biochar. Application of 2 and 6 t ha^{-1} of biochar had no impact on plant height compared with control at 20 DAT. At 40 DAT, the longest plant recorded for the application of 6 t ha^{-1} of biochar.

Biochar application influenced plant height of rice under salt stress conditions (Table 1). Upon exposure to 1600 ppm NaCl, all treatment combinations showed statistically similar plant height. Under 2800 ppm NaCl stress conditions, rice plant survived upto 60 DAT without biochar application, whereas rice plant survived upto 80 DAT when combined with biochar application. Upon exposure to 2800 ppm NaCl, plant height increased by 56, 68 and 76%, respectively at 60 DAT for the application of 2, 4 and 6 t ha^{-1} of biochar.

Table 1. Effect of NaCl and biochar on plant height of *aman* rice (BRRI dhan62)

Treatments	Plant height (cm)				
	20 DAT	40 DAT	60 DAT	80 DAT	At harvest
Effect of NaCl					
S_0	45.36	63.64 a	87.17 a	87.96 a	86.8 a
S_1	45.278	62.06 a	79.35 a	86.67 a	85.99 a
S_2	45.22	51.36 b	45.45 b	25.34 b	0 b
$LSD_{(0.05)}$	NS	3.63	14.68	12.49	4.73
CV (%)	7.07	8.54	28.88	26.05	11.43
Effect of biochar					
B_0	45.24 ab	56.42 b	64.789	57.05 b	58.691
B_1	43.47 b	56.64 b	71.237	69.99 ab	57.762
B_2	46.597 a	59.73 ab	72.649	75.99 a	59.118
B_3	45.833 ab	63.28 a	73.948	63.59 ab	54.824
$LSD_{(0.05)}$	2.66	4.19	NS	NS	NS
CV (%)	7.07	8.54	28.88	26.05	11.43
Combined effect of NaCl and biochar					
S_0B_0	44.27 a-c	61.25 bc	87.21 a	87 a	86.74 a
S_0B_1	45.85 ab	63.43 a-c	85.52 a	87.42 a	87.26 a
S_0B_2	48.28 a	68.11 ab	88.09 a	91.50 a	89.67 a
S_0B_3	42.49 bc	61.78 bc	87.86 a	85.92 a	83.53 a
S_1B_0	45.53 ab	58.85 c	76.85 a-c	84.15 a	89.33 a
S_1B_1	43.74 a-c	56.96 c	80.90 ab	89.32 a	86.03 a
S_1B_2	44.74 a-c	63.38 a-c	78.98 a-c	86.10 a	87.69 a
S_1B_3	47.44 a	69.05 a	80.66 ab	87.12 a	80.95 a
S_2B_0	45.93 ab	49.17 d	30.31 d	0 e	0 b
S_2B_1	40.83 c	49.54 d	47.29 d	33.25 bc	0 b
S_2B_2	46.78 ab	47.72 d	50.88 cd	50.38 b	0 b
S_2B_3	47.58 a	59.03 c	53.33 b-d	17.75 cd	0 b
$LSD_{(0.05)}$	4.61	7.25	29.31	24.98	9.47
CV (%)	7.07	8.54	28.88	26.05	11.43

Here,

S_0= 0 ppm NaCl	B_0= 0 t ha^{-1} Biochar	B_0= 6 t ha^{-1} Biochar
S_1= 160 ppm NaCl	B_1=2 t ha^{-1} Biochar	NS= Non significant
S_2= 280 ppm NaCl	B_2= 4 t ha^{-1} Biochar	

Tillers hill^{-1}

Exposure to NaCl stress declined the tillers hill^{-1} in entire life of rice except 20 DAT (Table 2). At 40 DAT, application of 1600 and 2800 ppm NaCl declined the tillers hill^{-1} of rice by 11% and 46 %, respectively, compared with control. Upon exposure to 1600 and 2800 ppm NaCl, the tillers hill^{-1} of rice declined at 60 DAT (12% and 76%, respectively), 80 DAT (8% and 86%, respectively) and at harvest (11% and 100%, respectively) in the same way. The present study revealed that the magnitude of tiller decreasing trend increased with the advancement of the growth period and increment of the salinity level. The immediate response of salinity to plant is osmotic and ionic stress which reduces cell elongation, cell division, stomatal closure and leaf area as well as photosynthesis, plant height and tiller number (Rahman *et al.*, 2017). The number of tillers hill^{-1} of rice enhanced by different levels of biochar application (2, 4 and 6 t ha^{-1}) at 20 DAT, 80 DAT and at harvest (Table 2). At 40 and 60 DAT, Biochar had no impact on tiller production or on mortality.

Interaction effect of biochar and salinity had significant impact on tiller production at 60 DAT, 80 DAT and at harvest (Table 2). Under controlled conditions, biochar treated plant produced statistically similar number of tiller hill^{-1} throughout the growth period of rice. In response to 2800 ppm NaCl, all tillers of rice plant died without biochar application at 80 DAT whereas few tillers remained alive for the application of 2, 4 and 6 t ha^{-1} of biochar. At harvesting time, no tiller remained alive in response to 2800 ppm NaCl irrespective of biochar levels.

Table 2. Effect of NaCl and biochar on number of tiller hill^{-1} of *aman* rice (BRRI dhan62)

Treatments	**Tiller hill^{-1} (No.)**				
	20 DAT	**40 DAT**	**60 DAT**	**80 DAT**	**At harvest**
Effect of salt					
S_0	5.1913	12.12 a	12.49 a	11.18 a	10.41 a
S_1	5.3856	10.83 b	10.94 a	10.32 a	9.29 b
S_2	5.3437	6.59 c	2.94 b	1.53 b	0 c
$LSD_{(0.05)}$	NS	1	1.57	1.15	0.7
CV (%)	15.13	14.15	24.84	20.76	14.75
Effect of biochar					
B_0	4.57 b	9.08	7.9133	6.13 c	5.63 b
B_1	5.35 a	9.96	8.6975	8.26 ab	6.97 a
B_2	5.41 a	10.47	9.5333	8.88 a	7.05 a
B_3	5.90 a	9.89	9.0167	7.44 bc	6.60 a
$LSD_{(0.05)}$	0.67	NS	NS	1.32	0.8
CV (%)	15.13	14.15	24.84	20.76	14.75
Combined effect of Salt and biochar					
S_0B_0	4.51	12.25	12.97 a	10.31 ab	9.65 ab
S_0B_1	5.19	12	12.28 ab	11.49 a	10.72 a
S_0B_2	5.22	13	13.15 a	11.38 a	10.70 a
S_0B_3	5.85	11.25	11.58 ab	11.56 a	10.56 ab
S_1B_0	4.70	9.63 c	9.40 b	8.08 b	7.25 c
S_1B_1	5.70	11.47	11.32 ab	11.55 a	10.2 ab
S_1B_2	5.38	11.40	12.05 ab	11.90 a	10.45 ab
S_1B_3	5.77	10.83	10.98 ab	9.750 ab	9.25 b
S_2B_0	4.50	5.38	1.38 c	0 d	0 d
S_2B_1	5.15	6.40	2.50 c	1.75 cd	0 d
S_2B_2	5.65	7	3.40 c	3.38 c	0 d
S_2B_3	6.08	7.59	4.50 c	1 d	0
$LSD_{(0.05)}$	NS	NS	3.14	2.29	1.39
CV (%)	15.13	14.15	24.84	20.76	14.75

Here,

S_0= 0 ppm NaCl B_0= 0 t ha^{-1} Biochar B_0= 6 t ha^{-1} Biochar
S_1= 160 ppm NaCl B_1=2 t ha^{-1} Biochar   NS= Non significant
S_2= 280 ppm NaCl B_2= 4 t ha^{-1} Biochar

Effective tillers hill^{-1}

Application of NaCl in BRRI dhan62 decreased the number of effective tillers hill^{-1} to a great extent (Table 3). Increase in salinity strength proportionally decreased the number of effective tillers hill^{-1} in rice. Exposure to 1600 and 2800 ppm NaCl decreased the number of effective tillers hill^{-1} by 19 and 100%, respectively, compared with control (Table 3). Our results in line with Hussain *et al*. (2017) who reported that salinity delayed flowering and even arrest panicle initiation by decreasing nutrient uptake, photosynthesis and ultimately reduced productive tillers.

The number of effective tiller hill^{-1} of rice was influenced by different levels of biochar application (Table 3). The present study revealed that the number of effective tillers hill^{-1} of BRRI dhan62 increased by 16 and 20% by the application of 2 and 4 t ha^{-1} of biochar, respectively. The present finding corroborates with Sriphirom *et al.* (2020) who reported that biochar application increases productive tiller and yield by increasing nutrient uptake efficiency. However, compared with control, application of 6 t ha^{-1} of biochar showed no impact on productive tiller production.

Combined application of NaCl and biochar showed significant effect on the number of effective tillers hill^{-1} of rice. The highest number of effective tiller hill^{-1} (9.33) recorded for the application of 4 t ha^{-1} of biochar under controlled condition (0 ppm NaCl). At 1600 ppm NaCl stress, application of 2, 4 and 6 t ha^{-1} of biochar increased the effective tillers hill^{-1} of BRRI dhan62 by 41, 48 and 22%, respectively, compared with salt-treated alone (Table 3). Exposure to 2800 ppm NaCl stress, BRRI dhan62 failed to produce productive tillers in absence or presence of any doses of biochar.

Filled grains panicle^{-1}

Treatment of rice plant with 1600 and 2800 ppm NaCl decreased the number of filled grains panicle^{-1} by 15 and 100%, respectively, compared with untreated control (Table 3). The reduction of the filled grains panicle^{-1} was 100% under severe salinity as there was no plant alive and effective tiller production under this treatment. This result is in line with Nahar *et al.* (2009) who reported that increase in salinity decreased the number of filled grains panicle^{-1}.

The number of filled grains panicle^{-1} varied significantly for the application of different levels of biochar (Table 3). Compared with control, application of 2 and 4 t ha^{-1} of biochar increased the filled grains panicle^{-1} by 9 and 10 %, respectively. Chen *et al.* (2021) reported that biochar application increased the number of productive tillers, number of filled grain and grain yield of rice. Addition of 6 t ha^{-1} of biochar showed similar result compared with control.

Interaction effect of NaCl treatment and biochar application had significant impact on the production of filled grains panicle^{-1} (Table 3). Under controlled condition, application of 2 and 4 t ha^{-1} of biochar showed no impact on the production of filled grains panicle^{-1}. Application of 6 t ha^{-1} of biochar slightly decreased the number of filled grains panicle^{-1}. However, in 1600 ppm NaCl treated rice plant, the production of the filled grains panicle^{-1} enhanced by 22, 28 and 20% for the application of 2, 4 and 6 t ha^{-1} of biochar, respectively, compared with salt treated plant alone. Upon exposure to 2800 ppm NaCl stress, BRRI dhan62 failed to produce filled grain in absence or presence of any doses of biochar.

Total grains panicle^{-1}

Imposition of 1600 and 2800 ppm NaCl decreased the number of total grains panicle^{-1} in rice by 26 and 100%, respectively, compared with untreated control (Table 3). Imposition of 2800 ppm NaCl caused death of all plant at harvesting time as a result reduction of total grains panicle^{-1} was 100% under this treatment. These results were in line with previous studies (Nahar *et al.*, 2009; Islam *et al.*, 2022) who reported that salinity decreases number of grains in rice.

The number of total grains panicle^{-1} showed positive relation with biochar application in BRRI dhan62 (Table 3). When rice plants were exposed to 2, 4 and 6 t ha^{-1} of biochar, the production of the total grains' panicle^{-1} uplift by 21, 27 and 10%, respectively, compared with control.

The combination of different levels of salinity and biochar showed significant effect on the production of total grains panicle^{-1} (Table 3). In untreated control conditions, application of different levels of biochar, statistically produced similar number of total grains panicle^{-1}. When rice plants were exposed to 1600 ppm NaCl with the application of 2, 4 and 6 t ha^{-1} of biochar, the total grains panicle^{-1} enhanced by 52, 64 and 33%, respectively, compared with 0 t ha^{-1} of biochar. In 2800 ppm NaCl stressed-plant, application of any dose of biochar failed to produce any number of grains in BRRI dhan62 as all plants died under this treatment.

Thousand grains weight

Upon exposure to 1600 ppm NaCl, 1000-grain weight reductions were insignificant compared with control (Table 3). Application of 2800 ppm NaCl caused death of all plant before harvesting time. As a result, reduction of 1000-grain weight was 100% compared with untreated control. Different levels of biochar application had non-significant influence on 1000-grain weight of BRRI dhan62.

The interaction effect of NaCl and biochar had significant influence on 1000-grain weight of rice (Table 3). Under controlled conditions, application of different level of biochar showed no variation on 1000-grain weight of rice. In 1600 ppm NaCl-treated rice plant, application of different levels of biochar uplift 1000-grain weight and showed statistically similar results. Exposure of 2800 ppm NaCl caused death of all rice plant in all biochar treated rice plant.

Grain yield

Exposure to 1600 and 2800 ppm NaCl decreased grain yield by 28 and 100%, respectively, compared with control (Table 3). Salinity reduced grain yield in rice by decreasing yield attributes including effective tillers, number of grain and 1000-grain weight (Islam *et al*., 2022). The present study revealed that salinity decreased grain yield by decreasing the number of effective tiller hill^{-1}, total grains and filled panicle^{-1} which is in line with previous studies (Zeng *et al*., 2002; Islam *et al*., 2022).

Application of biochar increased grain yield of rice by promoting nutrient uptake (Liu *et al*., 2016). Yang *et al*. (2021) stated that biochar increased rice yield by increasing soil physical properties, soil organic carbon, nutrient uptake and maintaining soil temperature. The present study revealed that, biochar increased grain yield by increasing the number of effective tillers and filled grain. Application of 2, 4 and 6 t ha^{-1} of biochar enhanced grain yield of rice by 15, 18 and 10%, respectively, compared with control (Table 3). This result was in agreement with Zhang *et al.* (2012) who noticed that application of rice biochar at the rate of 10 t ha^{-1} enhanced rice grain yield by 10%. Chen *et al.* (2021) also stated that biochar application increased grain yield and yield attributes.

Application of biochar under salt stress conditions increased grain yield of rice. Upon exposure to 1600 ppm NaCl, grain yield enhancement was 37, 42 and 30% for the application of 2, 4 and 6 t ha^{-1} of biochar, respectively (Table 3). However, in response to 2800 ppm NaCl, all rice plants died before harvesting time irrespective of different biochar levels. Zhang *et al.* (2019) revealed that biochar application reduces salt induced damages and increased rice yield under salt stress conditions.

Table 3. Effect of NaCl and biochar on yield attributes and yield of rice (BRRI dhan62)

Treatments	**Effective tillers hill^{-1} (No.)**	**Filled grains panicle^{-1} (No.)**	**1000-grain wt. (g)**	**Grain yield pot^{-1} (g)**	**Straw yield pot^{-1} (g)**
Effect of salt					
S_0	9.099 a	61.07 a	22.90 a	39.21 a	141.46 a
S_1	7.34 b	51.89 b	22.32 a	28.09 b	116.16 b
S_2	0 c	0 c	0 b	0 c	0 c
$LSD_{(0.05)}$	0.35	2.41	0.67	1.24	5.13
CV (%)	8.87	8.90	6.21	7.7	8.31
Effect of biochar					
B_0	4.93 b	35.58 b	15	20.27 c	82.31 b
B_1	5.74 a	38.91 a	15.25	23.31 ab	85.99 ab
B_2	5.94 a	39.22 a	15.04	23.84 a	91.37 a
B_3	5.3 b	36.91 ab	14.99	22.31 b	83.81 b
$LSD_{(0.05)}$	0.40	2.79	NS	1.43	5.93
CV (%)	8.87	8.90	6.21	7.7	8.31
Combined effect of Salt and biochar					
S_0B_0	9.03 ab	62.65 a	23.250 a	38.66 a	141.24 a
S_0B_1	9.09 ab	62.82 a	22.750 ab	39.58 a	141.99 a
S_0B_2	9.33 a	61.17 ab	22.625 ab	40.19 a	145.74 a
S_0B_3	8.95 ab	57.67 bc	22.975 ab	38.39 a	136.87 a
S_1B_0	5.75 e	44.08 d	21.750 b	22.13 d	105.70 d
S_1B_1	8.12 c	53.92 c	23.000 ab	30.35 bc	116.00 c

S_1B_2	8.5 bc	56.50 bc	22.500 ab	31.34 b	128.37 b
S_1B_3	7 d	53.07 c	22.020 ab	28.54 c	114.56 c
S_2B_0	0 f	0 e	0 c	0 e	0 e
S_2B_1	0 f	0 e	0 c	0 e	0 e
S_2B_2	0 f	0 e	0 c	0 e	0 e
S_2B_3	0 f	0 e	0 c	0 e	0 e
$LSD_{(0.05)}$	0.70	4.83	1.35	2.48	10.27
CV (%)	8.87	8.90	6.21	7.7	8.31

Here,

S_0= 0 ppm NaCl | B_0= 0 t ha^{-1} Biochar | B_0= 6 t ha^{-1} Biochar
S_1= 160 ppm NaCl | B_1=2 t ha^{-1} Biochar | NS= Non significant
S_2= 280 ppm NaCl | B_2= 4 t ha^{-1} Biochar

Straw yield

Straw yield of rice decreased upon exposure to different level of salinity (Table 3). Upon exposure to 1600 and 2800 ppm NaCl, straw yield of rice declined by 18 and 100%, respectively, compared with control. Salinity drastically reduced the straw yield of rice by decreasing photosynthesis, nutrient uptake (Siddique *et al*., 2015), and tiller number (Islam *et al.*, 2022).

The present study revealed that application of 2 and 6 t ha^{-1} of biochar have no impact on straw yield of rice (Table 3). However, application 4 t ha^{-1} of biochar in BRRI dhan62 uplifted straw yield production by 11%.

The combined effect of application of biochar and NaCl had significant influence on straw yield of rice. In non-saline conditions, all level of biochar showed similar results whereas in 1600 ppm NaCl-treated rice plant, application of 2, 4 and 6 t ha^{-1} of biochar increased straw yield by 9, 21 and 8%, respectively. However, upon exposure to 2800 ppm NaCl, all rice plants died before harvesting time irrespective of biochar levels. Zhang *et al.* (2019) revealed that biochar application improved anatomical structure and ultra-structure of root which increased leaf mesophyll cell activity, photosynthetic capacity and dry matter accumulation.

Conclusion

Salinity decreased growth and yield of *aman* rice (BRRI dhan62). Exposure of 1600 and 2800 ppm NaCl decreased grain yield of rice by 28 and 100%, respectively, by decreasing the number of effective tillers, filled grain and 1000-grain weight. The magnitude of growth and yield reduction increased with increasing the salinity level. Application of 2, 4 and 6 t ha^{-1} of biochar facilitates to recover the salt-induced damages under 1600 ppm NaCl stress and extended life duration of rice upto 80 DAT under 2800 ppm NaCl stress. Among the different rates of biochar, application of 4 t ha^{-1} of biochar showed better result in ameliorating salt-induced damages and yield loss under 1600 ppm NaCl stress in rice.

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