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Biochar - A climate smart practice for milling traits and aroma of fragrant rice under drought stress with different time of harvest

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Abstract

A pot experiment was conducted at research area under plastic net house of Sher-e-Bangla Agricultural University, Dhaka-1207 during 2019-20. BRRI dhan50 was used as planting material. The experiment was laid out in 2x2x3 factorial design with five replications and comprised of three factors *viz*., Factor-1 (Biochar-2 levels): B_1 = (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}; Factor-2 (Drought stress-2 levels): D_1= At reproductive stage, D_2= At grain filling stage and Factor-3 (Time of harvest-3 levels): H_1= 3 weeks after flowering, H_2= 4 weeks after flowering and H_3= 5 weeks after flowering. Application of biochar @ 5tha^{-1} along with drought stress imposed at grain filling stage and crop harvested 5 weeks after flowering showed the best result for brown rice yield, head rice recovery, amylose content, protein content, grain aroma and taste of BRRI dhan50. Application of biochar also increased soil organic carbon content. It can be concluded from the present study that, biochar application can help in reducing atmospheric carbon emitted from puddled rice soil in normal field condition under climate smart technology.

Keywords: Biochar, milling traits, 2-AP, drought stress, time of harvest, fragrant rice.

Introduction

Due to special appeal for aroma and acceptability, fine rice is mainly used by the people in the preparation of special traditional dishes and sold at a higher price in the market. Each year around 50 thousand tons of aromatic rice has been imported by Bangladesh from neighboring countries (Bayes, 2003). Islam *et al*., (1996) observed that the yield of aromatic rice is much lower than those of other rice growing countries due to lack of improved variety and judicious agronomic management. Still Bangladesh has a bright prospect for producing export quality aromatic rice and thus earning more foreign exchange. The long slender grains, intermediate amylose content, intermediate gelatinization temperature, high elongation ratio, strong aroma, softness, whiteness, stickiness, glossiness and translucency are the main basic standards for exporting the fine rice to the foreign countries (Deveriya, 2007). So, these characteristics should be determined and improved in local aromatic rice. The yield and aroma of fragrant rice can be increased through selection of appropriate variety and management practices *viz*., fertilizers, utilization of volatile compounds, cultivation practices and harvesting time. The production of aromatic volatile compounds are genetically controlled but the concentrations are also affected by other factors such as environment, climate, location and nutrient elements (Yoshihashi *et al*., 2004). Climate change through the increase in atmospheric CO_2 threatens the present and future agriculture in Bangladesh due to more carbon emission. Under such conditions, application of biochar to agricultural soils is considered as a promising strategy. It is attracting attention as a means for sequestering carbon and as a potentially valuable input for agriculture to rehabilitate degraded land, aid sustainable production and improve crop quality. Graber *et al*., (2010) mentioned that treating some crop plants by biochar positively enhanced yield and quality. Drought stress results in the increase of various osmotic compounds. One of the osmotic compounds from nitrogen group that significantly increase in a drought-stressed plant is proline amino acid (Arsa *et al*., 2017). In non-aromatic rice, proline will change into glutamate acid while in aromatic rice, biosynthesis process will produce 2-Acetil-1-Pyrrolin or 2AP (Fitzgerald *et al*., 2010). Hence, proline has the capacity to increase the amount of aroma in fragrant rice under optimum drought stress. Although grain yield and quality traits of aromatic rice are highly influenced by temperature particularly at the time of flowering, grain filling, at maturity and depend on the right time of harvest (Rohilla *et al*., 2000) . However, the farmers usually harvest aromatic rice at or beyond the full maturity stage and keep it in the field to dry for a long time in Bangladesh. Therefore, the present study was felt essential to evaluate the performance of aromatic rice cultivars through appropriate harvesting time to get maximum grain quality and aroma. The experiment was aimed to show the response of biochar on soil health and aroma of fragrant rice, to evaluate the proper state of drought stress on better milling traits and aroma of fragrant rice and also select the optimum time of harvest on aroma of fragrant rice.

Materials and Methods

1) *Experimental location with edaphic status*

A pot experiment was conducted under plastic net house of Sher-e-Bangla Agricultural University, Dhaka-1207. The experimental area was located in 23°7'N latitude and 93°E' longitude at an altitude of 8.6 meter above the sea level (Anon, 2004) and belonged to agro-ecological zone of "Madhupur Tract", AEZ-28. The experimental site was characterized by winter with a significant monsoon climate with sub-tropical cropping zone during the months of October 25, 2019 to April 10, 2020 (Rabi season). The soil above the sub-surface soil termed "Surface soil" was silty clay with slight sandy loam in texture, olive-slight grayish white with common fine to medium distinct dark whitish, brownish-light brown mottles was used as top soil in the study. The experimental area was medium flat and medium high topography with available easy irrigation and drainage system for setting the pots.

2) *Crop characters*

BRRI dhan50 variety was used for the study. The seeds were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The varietal characteristics include plant height of 82 cm, very low lodging, long, slender, white and aromatic kernel and grain protein per cent of 8.2. It has pleasant aroma similar to that of Basmati rice.

3) *Experimental treatments and design*

The experiment comprised of three factors *viz*., Factor-1 (Biochar-2 levels): B_1 = (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}; Factor-2 (Drought stress-2 levels): D_1= At reproductive stage, D_2= At grain filling stage and Factor-3 (Time of harvest-3 levels): H_1= 3 weeks after flowering (WAF), H_2= 4 WAF and H_3= 5 WAF. A 2×2×3 factorial design was followed under present study. Each treatment was represented by a single pot and replicated 5 times. Hence, a total of 60 pots were used in the study.

4) ***Seed sowing, pot preparation and seedling transplanting***

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and kept tightly in gunny bags. After 48 hours the seeds started sprouting and were sown in the pot after 72 hours. The seedbed was prepared with 1 m width adding nutrients as per the requirements of soil. Sprouted seeds were sown in the seed bed @ 70 g m^{-2} on 25 October, 2019. A 12 cm diameter plastic pot was used in the present study and 10 Kg field soil was poured per pot. Thirty-five (35) days old seedlings were transplanted in the puddled pot with intensive care. Initially two to three seedlings were planted per pot and then after recovery stage a single healthy seedling was maintained per pot.

5) ***Application of biochar, fertilizer and drought stress***

Biochar was collected from biochar production farm, Savar, Dhaka. After collection, the larger sized biochar was pressed by hammer to convert into fine sized particles for application in pot . The biochar was applied as per treatment during the final pot preparation. Chemical fertilizers such as urea, TSP, MOP, Gypsum, and Zinc sulphate was applied @ 260-90-150-110-11 kg ha^{-1}, respectively (BRRI, 2016) by using hectare slice as weight basis taking the weight of soil 2.0×10^6 Kg/ha. All the fertilizer was applied as basal dose except urea which was applied as top dressing in 3 equal installments, at 15 DAT, tillering and before panicle initiation stage. No water was applied to induce two levels of drought stress at reproductive stage and at grain filling stage, while during the remaining period, water application was done as per crop the requirement.

6) ***Phytosanitary approaches***

Timely uprooting and removal of weeds from the pots was done wherever required at first tiller initiation stage, heading stage, anthesis stage and grain filling stage to maintain healthy and clean micro climate in the pots. Need based pesticide application was done to keep the potted plants free from insect and pathogen attack.

7) ***Crop harvest***

The crop was harvested at full maturity when about 80% of the seeds became golden yellow on April 10, 2020. The harvested crop was bundled separately, properly tagged before transfer to threshing floor. The grains of each pot were dried, cleaned and weighed after adjusting to 12% moisture content.

8) ***Data collection*:** The following parameters were recorded.

i) ***Brown rice (BR) yield***

Using a standard dehusker, 100 grams of rough rice seeds were dehulled and the average whole-grain BR yield was determined (Cruz and Khush, 2000; Chakraborty *et al*., 2016).

ii) ***Head rice recovery (HRR)***

Hundred grams' weight of de-hulled rice grains that had no visible breakage and ¾ size grains were used to determine the head rice recovery. Using the standard formula, the percentage of HRR and broken rice were calculated (Chakraborty *et al*., 2016).

iii) ***Chalkiness of endosperm***

By observing under stereo-zoom microscope the degree of chalkiness was determined using milled rice. Based on the observation the chalkiness of the endosperm was classified into white belly (WB), white center (WC) and white back (WB) (Cruz and Khush, 2000; Chakraborty *et al*., 2016).

iv) ***Chalk index determination***

Ten de-husked rice grains were placed on light box and the grain with more than 50% of chalkiness was visually identified, weighed and percentage of chalkiness was calculated (Cruz and Khush, 2000; Chakraborty *et al*., 2016).

v) Amylose percentage

The amylose content of the rice samples was worked out using method of Juliano (1971). Hundred mg of the powdered rice sample was taken in a volumetric flask and added with 1 ml of 95% ethanol and 9 ml of 1M NaOH followed by heating in boiling water bath to gelatinize starch. Five ml of the starch extract was taken in 100 ml volumetric flask and added with 1 ml of 1N acetic acid and 2 ml iodide solution making up the volume to 100 ml. The solution was shaken and allowed to stand for 20 min. Then the absorbance was measured at 620 nm using Agilent Technologies Cary 60 UV-VIS spectrophotometer and amylose content was determined with reference to the standard curve of potato amylose and expressed in per cent basis.

vi) Protein content

The protein content of rice grains was determined by the Micro-Kjeldahl method using automated nitrogen determination system (AOAC, 1990*).*

vii) Aroma and taste

Five grams of rice was added with 15 mL of water soaked for 10 min followed by cooking for 15 min and transferred into a Petri dish before placing in refrigerator for 20 min. The cooked rice then evaluated for aroma by a random panel and categorized as: strongly scented (SS); mild scented (MS) and non-scented (NS) (Sood and Siddiq, 1978 and Chakraborty *et al*., 2016). The panel consisted of twenty (20) randomly selected undergraduate and post-graduate students divided into four replications with, 5 students in each replication and the responses from each replication were summarized into SS, MS, and NS as described above. Same procedure was followed to assess by tasting the cooked rice and classifying it as sweet, salty or sour.

viii) Soil pH and soil carbon (%)

Data on soil pH and carbon (%) was collected on pre-transplanting and post-harvest basis from pots using a digital pH meter and standard methods of carbon determination, respectively.

9) Statistical package used

The data obtained for different parameters were statistically analyzed by computer-based software Statistix-10 using ANOVA technique and mean separation was done by LSD at 5% level of significance.

Results and discussion

i) Brown rice yield

A significant response was found in case of brown rice yield against biochar levels **(Table 1)**. B2 yielded higher (72.858 %) than B_1 (62.997 %). Drought stress also significantly influenced the brown rice yield **(Table 2)** and higher brown rice yield was recorded in D_2 (69.937 %) compared to D_1 (65.918 %). The data on influence of harvesting time **(Table 3)** revealed that highest brown rice yield was found from H_3 (69.589 %) on par with $H_{2,}$ while the lowest yield was in H_1 (63.477 %). There was a significant interaction effect of the combination application of biochar, drought and harvesting time on the brown rice yield **(Table 4)**. The highest brown rice yield was found from $B_2D_2H_3$ (80.247 %) statistically similar to $B_2D_2H_2$ and $B_2D_1H_2$ while the lowest was in $B_1D_1H_1$ (56.557 %).

ii) Head rice recovery

In case of head rice recovery, there was a significant response due to biochar levels **(Table 1).** The HRR higher in B_2 (64.428 %) compared to B_1 (56.425 %). Drought stress also significantly influenced the head rice recovery **(Table 2)**. D_2 (62.238 %) showed higher HRR than D_1 (58.615 %). Harvesting time showed a significant effect on HRR **(Table 3)**. The highest head rice recovery was found from H_3 (62.149 %) which was statistically similar to H_2, while there was lowest in H_1 (56.422 %). Interaction effects were significant **(Table 4)** and $B_2D_2H_3$ (71.367 %) showed highest HRR on par with $B_2D_2H_2$ and $B_2D_1H_2$. HRR was least in $B_1D_1H_1$ (50.557 %).

iii) Chalk index determination

In case of chalk index, there was a significant response due to biochar levels **(Table 1)** and B_1 (40.920 %) showed higher index than B_2 (33.395 %). Effect of drought stress on chalk index was also evident as D_1 (38.972 %) and D_2 (35.343 %) showed significant differences **(Table 2)**. Similar trend was observed in the effect of harvesting time **(Table 3)**. The highest chalk index was found in H_1 (38.497 %) followed by H_2 and the lowest was in H_3 (36.072 %). Interaction effects showed highest chalk index in $B_1D_1H_1$ (43.067 %) statistically similar to $B_1D_1H_2$ while the lowest was in $B_2D_2H_2$ (30.207 %) on par with $B_2D_2H_3$ and $B_2D_2H_1$ **(Table 4)**.

Table-1. Effect of biochar levels on the milling traits of BRRI dhan50

Biochar levels	Brown rice yield (%)	Head rice recovery (%)	Chalk index determination (%)
B_1	62.997 b	56.425 b	40.920 a
B_2	72.858 a	64.428 a	33.395 b
CV (%)	4.79	5.79	3.63
LSD $_{(0.05)}$	2.250	2.419	0.931
F-test	**	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. **, indicate 1% level of probability; B_1= (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}

Table-2. Effect of drought stress on the milling traits of BRRI dhan50

Drought stress	Brown rice yield (%)	Head rice recovery (%)	Chalk index determination (%)
D_1	65.918 b	58.615 b	38.972 a
D_2	69.937 a	62.238 a	35.343 b
CV (%)	4.79	5.79	3.63
LSD $_{(0.05)}$	2.250	2.419	0.931
F-test	**	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. **, indicate 1% level of probability; D_1= At reproductive stage, D_2= At grain filling stage

Table-3. Effect of harvesting time on the milling traits of BRRI dhan50

Time of harvest	Brown rice yield (%)	Head rice recovery (%)	Chalk index determination (%)
H_1	63.477 b	56.422 b	38.497 a
H_2	70.717 a	62.709 a	36.904 b
H_3	69.589 a	62.149 a	36.072 c
CV (%)	4.79	5.79	3.63
LSD $_{(0.05)}$	2.756	2.962	1.141
F-test	**	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. **, indicate 1% level of probability; WAF: weeks after flowering; H_1= 3 WAF, H_2= 4 WAF, H_3= 5 WAF

Table-4. Combination effect of biochar levels, drought stress and time of harvest on the milling traits of BRRI dhan50

Combinations	Brown rice yield (%)	Head rice recovery (%)	Chalk index determination (%)
$B_1D_1H_1$	56.557 f	50.557 d	43.067 a
$B_1D_1H_2$	64.317 de	56.647 c	42.547 ab
$B_1D_1H_3$	64.757 c-e	58.207 c	41.607 a-c
$B_1D_2H_1$	63.557 e	57.107 c	40.757 bc
$B_1D_2H_2$	65.547 c-e	59.017 c	39.657 cd
$B_1D_2H_3$	63.247 e	57.017 c	37.887 d
$B_2D_1H_1$	64.547 de	57.607 c	38.057 d
$B_2D_1H_2$	75.227 ab	66.667 ab	35.207 e
$B_2D_1H_3$	70.107 bc	62.007 bc	33.347 ef
$B_2D_2H_1$	69.247 cd	60.417 c	32.107 fg
$B_2D_2H_2$	77.777 a	68.507 a	30.207 g
$B_2D_2H_3$	80.247 a	71.367 a	31.447 fg
CV (%)	4.79	5.79	3.63
LSD $_{(0.05)}$	5.513	5.925	2.281
F-test	*	*	*

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. *, indicates 5% level of probability; B_1 = (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}; D_1= At reproductive stage, D_2= At grain filling stage; H_1= 3 weeks after flowering (WAF), H_2= 4 weeks after flowering (WAF) and H_3= 5 weeks after flowering (WAF)

iv) Amylose content

Higher amylose content was recorded in B_2 (27.380 %) and D_2 (27.223 %) compared to B_1 (25.900 %) and D_1 (26.057 %), respectively indicating significant effects due to biochar **(Table 5)** and drought stress levels **(Table 6).** Data on harvesting time showed highest amylose content in H_3 (27.277 %) on par with H_2 and lowest was recorded in H_1 (25.999 %). Interaction effect was significant and the highest amylose content was found from $B_2D_2H_3$ (29.567 %) and $B_2D_2H_2$ which were at par **(Table 8)**, $B_1D_1H_1$ showed lowest value (25.017 %).

v) Protein Content

Biochar levels, drought stress and harvesting time had significant effect on protein content. **(Tables 5 to 8).** The highest protein content was found in B_2 (7.833 %), D_2 (7.795 %) and H_3 (7.726 %) and it was lowest in B_1 (7.243 %), D_1 (7.281 %) and H_1 (7.246 %). A significant interaction effect was found among application of biochar, drought and harvesting time on the protein content **(Table 8)**. The highest protein content was found from $B_2D_2H_3$ (8.9067 %) followed by $B_2D_2H_2$ while the lowest was in $B_1D_1H_1$ (7.0167 %) on par with $B_1D_1H_2$.

Table-5. Effect of biochar levels on the amylose and protein content of BRRI dhan50

Biochar levels	Amylose content (%)	Protein content (%)
B_1	25.900 b	7.243 b
B_2	27.380 a	7.833 a
CV (%)	3.73	4.21
LSD $_{(0.05)}$	0.686	0.219
F-test	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. **, indicate 1% level of probability; B_1 = (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}

Table-6. Effect of drought stress on the amylose and protein content of BRRI dhan50

Drought stress	Amylose content (%)	Protein content (%)
D_1	26.057 b	7.281 b
D_2	27.223 a	7.795 a
CV (%)	3.73	4.21
LSD $_{(0.05)}$	0.686	0.219
F-test	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. **, indicate 1% level of probability; D_1= At reproductive stage, D_2= At grain filling stage

Table-7. Effect of harvesting time on the amylose and protein content of BRRI dhan50

Time of harvest	Amylose content (%)	Protein content (%)
H_1	25.999 b	7.246 b
H_2	26.644 ab	7.641 a
H_3	27.277 a	7.726 a
CV (%)	3.73	4.21
LSD $_{(0.05)}$	0.840	0.268
F-test	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. **, indicate 1% level of probability. H_1= 3 weeks after flowering (WAF), H_2= 4 weeks after flowering (WAF) and H_3= 5 weeks after flowering (WAF)

Table-8. Combination effect of biochar levels, drought stress and time of harvest on the amylose and protein content of BRRI dhan50

Combina-tions	Amylose content (%)	Protein content (%)
$B_1D_1H_1$	25.017 c	7.0167 d
$B_1D_1H_2$	25.437 bc	7.1067 d
$B_1D_1H_3$	25.887 bc	7.2567 cd
$B_1D_2H_1$	26.087 bc	7.1867 cd
$B_1D_2H_2$	26.227 bc	7.5367 cd
$B_1D_2H_3$	26.747 b	7.3567 cd
$B_2D_1H_1$	26.887 b	7.2467 cd
$B_2D_1H_2$	26.207 bc	7.6767 c
$B_2D_1H_3$	26.907 b	7.3867 cd
$B_2D_2H_1$	26.007 bc	7.5367 cd
$B_2D_2H_2$	28.707 a	8.2467 b
$B_2D_2H_3$	29.567 a	8.9067 a
CV (%)	3.73	4.21
LSD $_{(0.05)}$	1.680	0.537
F-test	*	*

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. *, indicates 5% level of probability; B_1 = (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}; D_1= At reproductive stage, D_2= At grain filling stage; H_1= 3 weeks after flowering (WAF), H_2= 4 weeks after flowering (WAF) and H_3= 5 weeks after flowering (WAF)

vi) Chalkiness of endosperm

Visual detection of kernel reported that, biochar, drought and time of harvest influenced chalkiness of rice kernel **(Table 9)**, which is a significant trait for marketing standard of aromatic rice. White center chalk is only allowed for market sale while others are generally discarded. In the present study, $B_2D_2H_3$, $B_2D_2H_2$ and $B_2D_2H_1$ treatment combinations showed the significant effect of biochar application, drought stress imposed at grain filling stage and harvesting the grains at 3-5 weeks after flowering that resulted in the white center chalky endosperm.

vii) Aroma (Retronasal-by nose)

Random panel test of aroma indicated that, biochar, drought and time of harvest also influenced the aroma of rice kernel **(Table 9).** The application of biochar along with drought stress at grain filling stage and harvesting 3-5 weeks after flowering resulted in higher 2-AP content, the precursor of the grain aroma. Stronger aroma was found from $B_2D_2H_{3,}$ $B_2D_2H_{2,}$ $B_2D_2H_1$ and $B_2D_1H_3$ treatment combinations.

viii) Taste (Orthonasal-by mouth)

Cooking test results of grain also revealed similar trend and $B_2D_2H_{3,}$ $B_2D_2H_2$ and $B_2D_2H_1$ treatment combinations resulted in sweet cooked rice preferred for market sale. Thus, it was evident that application of biochar along with drought stress imposed at grain filling stage and harvesting the grains at 3-5 weeks after flowering gave the sweet kernel after cooking.

Table-9. Combination effect of biochar levels, drought stress and time of harvest on the chalkiness, aroma and taste of BRRI dhan50

Combinations	Chalkiness of endosperm	Aroma (Retronasal-by nose)	Taste (Orthonasal-by mouth)
$B_1D_1H_1$	White back	NS	Sour
$B_1D_1H_2$	White back	MS	Sour
$B_1D_1H_3$	White back	MS	Sour
$B_1D_2H_1$	White back	NS	Salty
$B_1D_2H_2$	White back	MS	Salty
$B_1D_2H_3$	White back	OTB	Sour
$B_2D_1H_1$	White belly	OTB	Salty
$B_2D_1H_2$	White belly	OTB	Salty
$B_2D_1H_3$	White belly	SS	Salty
$B_2D_2H_1$	White center	SS	Sweet
$B_2D_2H_2$	White center	SS	Sweet
$B_2D_2H_3$	White center	SS	Sweet

B_1 = (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}; D_1= At reproductive stage, D_2= At grain filling stage; H_1= 3 WAF, H_2= 4 WAF, H_3= 5 WAF; Strongly scented (SS); mild scented (MS); non-scented (NS) and other than basmati (OTB).

ix) *Soil status*

The pre-planting and post-harvesting soil analysis revealed that application of biochar increased the status of organic carbon **(Table 10)** The cultivation of aromatic rice with normal puddling cultivation system in pots along with combination of biochar increased the amount of organic carbon content in post-harvest soil. The puddled condition normally increased the amount of atmospheric carbon as methane form, while biochar application improved the porosity of soil due to presence of more organic carbon in soil. The emitted methane was also sequestrated as organic carbon in the increased porus particles of soil. Lowering of pH followed by a lower solubility of SOC (soil organic carbon) will therefore decrease the ability of microbes to utilize energy and nutrients of SOC leading to decrease in decomposition and biomass production. Bot and Benites (2005) reported that H+ ions bind to COO-sites of humus at decreasing pH value thereby reducing the cation exchange capacity. This resulted in post-harvest increase of SOC. It has also been hypothesized that biochar may increase microbial biomass in soil by the complexation of SOM (soil organic matter) with biochar particles and yet simultaneously induce the 'negative priming' of native soil carbon mineralization (Woolf and Lehmann, 2012).

Table 10. Soil data, before transplanting of seedlings and after harvesting of crop

Treatments	Before transplanting of seedlings		After harvesting of crop	
	pH	Organic carbon (%)	pH	Organic carbon (%)
$B_1D_1H_1$	6.3	0.42	6.2	0.44
$B_1D_1H_2$	6.2	0.41	6.1	0.40
$B_1D_1H_3$	6.1	0.29	5.9	0.30
$B_1D_2H_1$	6.5	0.37	6.4	0.36
$B_1D_2H_2$	6.5	0.24	6.0	0.25
$B_1D_2H_3$	6.7	0.36	6.1	0.38
$B_2D_1H_1$	6.5	0.41	4.5	0.71
$B_2D_1H_2$	6.4	0.32	4.6	0.77
$B_2D_1H_3$	6.6	0.41	4.6	0.81
$B_2D_2H_1$	6.7	0.31	4.5	0.89
$B_2D_2H_2$	6.5	0.39	4.5	0.95
$B_2D_2H_3$	6.4	0.37	4.3	0.93

B_1 = (Control) 0.0 t ha^{-1}, B_2 = 5.0 t ha^{-1}; D_1= at reproductive stage, D_2= at grain filling stage; H_1= 3 WAF, H_2= 4 WAF, H_3= 5 WAF

Conclusions

Overall, in the present study, application of biochar @ 5tha^{-1} along with drought stress imposed at grain filling stage and crop harvested 5 weeks after flowering showed the best result for milling traits and aroma of fragrant rice (BRRI dhan 50). However, in case of chalk index and no biochar application, drought stress at reproductive stage and crop harvested 3 weeks after flowering gave the best result.

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