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Soil amendment with biochar improves wheat (*Triticum aestivum* L.) growth, yield and post-harvest soil properties

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Abstract

The current study was conducted in the research area of the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, between November 2021 and March 2022 during the Rabi season to examine the impact of biochar on wheat yield and soil properties and to figure out the ideal dosage of biochar when used with inorganic fertilizer for maximizing wheat yield. A total of 8 treatments were used in the experiment as T_1 = Control, T_2 = RFD (Recommended Fertilizer Dose); T_3 = RFD + Biochar @ 1.0 t ha^{-1}; T_4 = RFD + Biochar @ 1.5 t ha^{-1}; T_5 = RFD + Biochar @ 2.0 t ha^{-1}; T_6 = 75% of RFD + Biochar @ 1.0 t ha^{-1}; T_7 = 75% of RFD + Biochar @ 1.5 t ha^{-1}; T_8 = 75% of RFD + Biochar @ 2.0 t ha^{-1}. Randomized Complete Block Design (RCBD) with three replications was used to set up the experiment. BARI Gom-32 was the variety that was tested. Information was gathered on the growth, yield characteristics of wheat, and nutrient content of the post-harvest soil. To assess the effectiveness of the treatment, the acquired data were statistically examined. Results revealed that when biochar was applied along with the recommended amount of chemical fertilizers, it significantly improved the development and yield of wheat as well as the soil.

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Introduction

Wheat (*Triticum aestivum* L.) is one of the leading cereals in the world. It is the world's most widely cultivated cereal crop which ranks first followed by rice. It is more preferable to rice for its higher seed protein content. It ranks first both in acreage and production among the grain crops of the world (FAO, 2008).

Wheat grain is rich in food value containing 12% protein, 1.72% fat, 70% carbohydrate, 2% fiber, 2.7% minerals and 12% moisture (Javid *et al.*, 2022). Wheat is a major staple food for more than 4.5 billion people (Grote, 2021). It is cultivated in almost every country of the world contributing about 30% of total food grain production (Halecki and Bedla, 2022). Around 780.59 million metric tons of wheat is produced globally in more than 220 million ha, with an average productivity of 3.52 t ha^{-1} (USDA, 2022).

Production of wheat in Bangladesh has increased many folds from the time of independence. The annual production of wheat grain in Bangladesh in the year 2018–2019 was 10.16 lakh metric tons obtained from 3.30 lakh hectares of land and in the year 2019–2020 it was 10.29 lakh metric tons from 3.32 lakh hectares of land (BBS, 2020). During the Rabi season of 2021-22, Bangladesh has produced 1.18 million metric tons of wheat from an area of 314 thousand hectares with an average productivity of 3.44 t ha^{-1} (BBS, 2022). Dinajpur, Rajshahi and Rangpur are the major wheat producing districts in Bangladesh (Rahman and Miah, 2017).

Bangladesh is not self-sufficient in wheat to feed her ever increasing population, but there is a possible scope to pull our food deficit by means of increasing wheat production with adoption of modern varieties scientific technologies and improved agronomic practices.

The utilization of biochar as an amendment to improve soil health and the environment has been a catalyst for the recent global enthusiasm for advancing biochar production technology and its management (Atkinson *et al.*, 2010). Biochar is carbonaceous material (Abbas *et al.*, 2020) produced by thermal pyrolysis of organic feed stocks under a very low oxygen atmosphere (Nawaz *et al.*, 2022; Coomes and Miltner, 2017) or through hydrothermal carbonization of wet organic material by high pressure and mild temperatures (Libra *et al.*, 2011). The biochar is comprised of plant macro (N, Ca, K, P etc.) as well as micro-nutrients (Cu Zn, B etc.) (Ippolito *et al.*, 2015; Qayyum *et al.*, 2015). Besides boosting soil fertility conditions, biochar application to soils can increase their nutrient retention, improve water holding capacity (Ullah *et al.*, 2023; Mukhtar *et al.*, 2020; Basso *et al.*, 2013; Kinney *et al.*, 2012), promote plant growth (Hossain *et al.*, 2011), bind with pollutants and mitigate greenhouse gas emissions (Kammann *et al.*, 2011). So, the judicious application of biochar may provide optimum yield of wheat by reducing the negative effect of water stress along with supply essential plant nutrients and improve soil physical properties such as reducing soil bulk density (Mukherjee and Lal, 2013, Busscher *et al.*, 2011; Mankasingh *et al.*, 2011), increases the water retention capacity (Li *et al.*, 2015; Karhu *et al.*, 2011; Vaccari *et al.*, 2011; Brockhoff *et al.*, 2010; Dugan *et al.*, 2010; Laird *et al.*, 2010; Briggs *et al.*, 2005) and increases soil pH, EC, CEC of acidity soil (Abewa *et al.*, 2014) and reduced fertilizers need for sustainable crop production. These changes will influence plant growth because the depth of roots and the availability of air and water within the root zone are largely determined by soil physical properties (Downie *et al.*, 2009). Considering the above perspective, the present study has been designed with the following objectives: a) To examine how biochar affects wheat yield and characteristics that contribute to yield, b) To assess how biochar affects soil physico-chemical properties for sustainable crop production.

Materials and methods

Experimental site

The research work was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka-1207 during November 2021 to March 2022. The experimental area was located at 23°77´ N latitude and 90°33´ E longitude at an altitude of 8.6 meter above the sea level (Anon, 2004). The field was located at the southeast-west corner of main academic building of Sher-e-Bangla Agricultural University.The experimental filed belongs to the Agro-Ecological Zone of The Madhupur Tract, AEZ-28 (Anon, 2003a). Over the Modhupur Clay, this region of complicated relief and soils that were produced with unconsolidated clay forming nearly level like topography which dissected locally having red and grey mottled compact Clay about 8m thick adjacent to Dhaka. The characteristics of the experimental soil are presented below (Table 1).

Table 1. Physical and chemical properties of experimental field soil at the beginning of experiment at a depth 0-15 cm of surface soil

Physical properties	Value	Chemical properties	Value
Mechanical fractions:		pH	5.6
% Sand (2.0-0.02 mm)	27	Organic carbon (%)	0.45
% Silt (0.02-0.002 mm)	43	Total N (%)	0.03
% Clay (<0.002 mm)	30	Available P (ppm)	20
Textural class	Clay loam	Exchangeable K (me/100g soil)	0.1
		Available S (ppm)	18

Treatments of the experiment

There were 8 treatment combinations and these were as ; T_1 = Control (no chemical fertilizer & biochar),T_2 = RFD (Recommended Fertilizer Dose), T_3= RFD + Biochar @ 1.0 t ha^{-1},T_4 = RFD + Biochar @ 1.5 t ha^{-1},T_5 =RFD + Biochar @ 2.0 t ha^{-1},T_6 = 75% of RFD + Biochar @ 1.0 t ha^{-1},T_7= 75% of RFD + Biochar @ 1.5 t ha^{-1},T_8 = 75% of RFD + Biochar @ 2.0 t ha^{-1}; RFD (Recommended Fertilizer Dose): for wheat N_{150}, P_{25}, K_{100}, S_{15}, Zn_2, B_1 kg ha^{-1} (FRG, 2012).

Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The fertilizers N, P, K, S, Zn and B in the form of Urea, Triple Super phosphate (TSP), Murate of Potash (MoP), Gypsum, Zinc sulphate and Boric acid respectively were applied. The entire amount of TSP, MoP, Gypsum, Zinc sulphate, Boric acid and 2/3rd of urea was applied during the final preparation of land. Rest of urea was top dressed after first irrigation. Biochar was collected from Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) & Bangladesh Agricultural Research Institute (BARI). Then biochar was added to the soil of each plot as per assigned treatments of the time of final land preparation just before the application of chemical fertilizers. The seeds of wheat (BARI Gom-32) were sown in rows made by hand plough at the rate of 120 kg ha^{-1}. The seeds were sown in line having a depth of 2-3 cm from the soil surface. Seeds were then covered properly with loose soil. Row to row distance was 25 cm**.** Different intercultural operations were performed to provide better growth and development of the crop.

Table 2. Methods used for soil sample analysis

Element	Extraction method	Reference
Nitrogen (N)	Micro-Kjeldahl method	Bremner and Mulvaney, 1982
Phosphorus (P)	0.5M $NaHCO_3$, pH 8.5 extraction method	Olsen and Sommers, 1982
Potassium (K)	NH_4OAc extraction, pH 7.0 (Flame photometry)	Schollenberger, Simon, 1945
Sulphur (S)	$CaCl_2$ extraction method	Fox *et al.,* 1964

Harvest and post-harvest operations

On 16th March, 2022, the crop was harvested at maturity when 90% of the plants became brown in colour. The harvested crop of each individual plot was bundled separately. After harvesting, the samples were sun dried. Enough care was taken during threshing and cleaning period of wheat grain. Fresh weight of wheat grain and straw were recorded in m^{-2} in plot wise. The grains were cleaned and weighed. The weight was adjusted to a moisture content of 14%. The yields of wheat grain and straw m^{-2} were recorded and converted to t ha^{-1}.

Harvesting of crop and collection of data

The sampling of crop and soil was done at the time of harvest. Five plants were selected randomly from each plot. The selected plants of each plot were cut carefully at the soil surface level. The crop from 1.25 m^2 harvested area (leaving the boarder lines and destructive harvest line) was harvested as per experimental treatments and then threshed. Seed were cleaned and properly dried under sun. Then seed yield in 1.25 m^{-2} was recorded and converted to t ha^{-1}.The following data were collected during the research work; these were: Plant height, Spike length, Number of spikelets $spike^{-1}$, Number of grains $spike^{-1}$, 1000-grain weight, Grain yield and Straw yield.

Soil analysis

The collected samples were cleaned, air dried, sieved (≤2 mm) and mixed properly and prepared working samples as per standard protocol. Soil samples were analyzed for determining the status of N, P, K, & S following the standard extraction methods as mentioned in Table 2. Soil analysis also includes texture, pH and organic carbon contents (Table 3).

Table 3. Analysis of soil properties

Parameter	Method	Reference
Texture	Hydrometer method	Jackson, 1973
pH	Glass electrode pH meter (1:2.5 soil-water ratio)	McLean, 1982
Organic carbon	Wet oxidation method	Nelson and Sommers, 1982

Statistical analysis

The data obtained for different parameters were statistically analysed to observe the level of significance following Statistical tool Statistix-10 and mean differences were determined using the Least Significant Difference (LSD) test at the 5% level of significance (Gomes and Gomes, 1984).

Results and discussion

Effect of biochar on Plant height (cm)

Application of various quantities of biochar coupled with chemical fertilizers had a substantial impact on plant height (Table 4). The T_5 (RFD + biochar @ 2 t ha^{-1}) treatment had the tallest plants at harvest (77 cm), while the T_1 (control) treatment had the shortest plants (60.40 cm). The use of various quantities of biochar in conjunction with RFD greatly boosted plant height. According to Schulz and Glaser (2012), adding biochar to the soil greatly increased plant growth. Both Mollick *et al.* (2020) and Carter *et al.* (2013) reported that the use of biochar considerably improved plant height.

Spike length (cm)

Spike length of wheat plant showed significant variation due to the application of different doses of biochar (Table 4). Among the different treatments T_4 (RFD + biochar @ 1.5 t ha^{-1}) showed the highest spike length (10.36cm) which was statistically similar to T_5 (RFD + biochar @ 2.0 t ha^{-1}) treatment. On the other hand, lowest spike length (6.60 cm) was observed in the treatment T_1 (control). Li and Shangguan (2018), Zee *et al.* (2017), Iqbal (2017), Gebremedhin *et al.* (2015), Alburquerque *et al.* (2013) investigated that spike length was influenced significantly by biochar application.

Spikelets spike⁻¹

Spikelets $spike^{-1}$ was significantly influenced due to application of different levels of biochar (Table 4). The maximum spikelets 18.20 at harvesting stage was recorded from T_4 (RFD + biochar @ 1.5 t ha^{-1}) treatment which was statistically similar to T5 (RFD + biochar @ 2.0 t ha^{-1}) treatment whereas, the minimum spikelets 13.06 was recorded from T_1 (control) treatment. Spikelets $spike^{-1}$ was significantly increased due to application of different level of biochar. Biochar application with chemical fertilizers was able to increase spikelets per spike (Sadaf *et al.*, 2017).

Number of grains $spike^{-1}$

Number of grains $spike^{-1}$ of wheat plant showed significant variation due to application of different doses of biochar (Table 4). Among the different biochar doses, T_4 (RFD + biochar @ 1.5 t ha^{-1}) treatment showed the maximum number of grains $spike^{-1}$ (47.08) which is statistically similar to T_5 (RFD + biochar @ 2.0 t ha^{-1}) treatment having of grains $spike^{-1}$ (46.33). On the other hand, minimum number of grains $spike^{-1}$ (28.33) was observed in T_1 (control) treatment. Application of biochar in soil significantly increased the number of grains $spike^{-1}$ over control treatment (Sadaf *et a,l.* 2017).

1000-seed weight (g $plot^{-1}$)

1000-seed weight of wheat showed non-significant variation due to the application of different doses of biochar (Table 4).

Among different treatments T_5 (RFD + biochar @ 2.0 t ha^{-1}) showed the maximum 1000-seed weight (50.4g) whereas the minimum 1000-seed weight (48.2g) was recorded in T_1 (control) treatment but such variation was statistically non-significant. The rest of the treatments also showed non-significant effect on the 1000-seed weight. Zaheer *et al.* (2019) reported that a higher 1000-grain weight results in a larger grain production per plant. Akter (2017) found that 1000-seed weight of wheat significantly influenced due to different doses of biochar.

Grain yield of wheat

Grain yield of wheat (t ha^{-1}) showed significant variation due to different doses of biochar application in combination with chemical fertilizers (Table 4). Among the different treatments T_5 (RFD + biochar @ 2.0 t ha^{-1}) treatment showed the highest grain yield (4.21 t ha^{-1}). On the other hand, minimum grain yield (2.10 t ha^{-1}) was observed in the T_1 (control) treatment. The second highest grain yield (4.02 t ha^{-1}) was recorded in T_4 (RFD + biochar @ 1.5 t ha^{-1}), which was statistically at par with rest of the treatments except control (T_1). The treatment T_2 (RFD), where only chemical fertilizers were used also produced identical yield (3.77 t ha^{-1}) with biochar recommended treatments (T_3-T_8). This result revealed that integrated use of biochar and chemical fertilizers did not bring significant yield variation over chemical fertilizers alone although biochar recommended treatments produced 4-12% higher yield over sole application of chemical fertilizer (T_2). Similar results were also found in Jeffery *et al.* (2022), Mollick *et al.* (2020), Gebremedhin *et al.* (2015), Nair *et al.* 2014, Cartar *et al.* (2013), Zhang *et al.* (2012), Van-Zwieten *et al.* (2010). Integrated application of biochars and chemical fertilizer resulted in higher grain yield, nitrogen uptake and soil carbon content than control or from the sole application of biochar (Sadaf *et al.*, 2017).

Table 4. Effect of biochar on plant height (cm), spike length (cm), spikelet spike-1, grains spike-1, 1000-seed weight (g plot-1), grain yield (ton ha-1) and straw yield (ton ha-1)

Treatment	Plant height (cm)	Spike length (cm)	Spikelet spike^{-1}	Grains spike^{-1}	1000-seed weight (g plot^{-1})	Grain yield (ton ha^{-1})	straw yield (ton ha^{-1})
T_1	60.40^{d}	6.60^{c}	13.06^{c}	28.33^{e}	48.2	2.10^{c}	1.96^{c}
T_2	71.26^{bc}	9.30^{ab}	16.73^{ab}	42.38^{abcd}	49.77	3.77^{ab}	3.09^{ab}
T_3	71.53^{bc}	9.33^{ab}	17.13^{ab}	44.86^{abc}	50.03	3.96^{ab}	3.45^{a}
T_4	76.16^{ab}	10.36^{a}	18.20^{a}	47.08^{a}	49.77	4.02^{b}	3.45^{a}
T_5	77.0^{a}	9.80^{ab}	17.96^{a}	46.33^{ab}	50.4	4.21^{a}	3.18^{ab}
T_6	72.16^{abc}	8.70^{ab}	15.56^{b}	37.80^{d}	48.4	3.79^{ab}	3.22^{ab}
T_7	69.76^{c}	8.40^{b}	15.60^{b}	38.86^{cd}	48.47	3.81^{ab}	2.61^{bc}
T_8	72.56^{abc}	8.90^{ab}	15.93^{ab}	40.60^{bcd}	48.77	3.91^{ab}	2.71^{b}
LSD (0.05)	5.2109	1.6915	2.3593	6.2667	NS	0.98	0.72

Straw yield of wheat

Biochar in combination with chemical fertilizers also produced significantly higher straw yield over control (Table 4). The highest straw yield (3.45 t ha^{-1}) was observed in both T_3 (RFD + biochar @ 1.0 t ha^{-1}) and T_4 (RFD + biochar @ 1.5 t ha^{-1}) and they were significantly higher over T_1, T_7 and T_8 but significantly identical to rest of the treatments. The combination of biochar over sole application of RDF (T_2) was 3 to 12% only. According to Biederman and Harpole, (2013) and Liu *et al.* (2013) application of biochar in soil has been reported to increase by 10% plant productivity and 25% for aboveground biomass.

Bulk density

There was a decreasing trend of soil bulk density due to application of different levels of biochar in combination with chemical fertilizers (Table 5). The highest bulk density (1.40 g/cc) was recorded in T_1 (control) and T_2 (100% RFD) which was exactly similar to that of initial soil. However due to application of biochar the bulk density of soil slightly reduced to (1.30 g/cc) at the best T_8 (75% of RFD + biochar @ 2.0 t ha^{-1}) treatment. Bulk density decreased with the biochar concentration increased. Chen *et al.* (2010), Laird *et al.* (2010) investigated that biochar application significantly decreased SBD compared to the control group.

Low SBD can enhance soil structure, aid in nutrient release and retention and significantly lessen soil compaction. This is due to the fact that biochar typically has a lower bulk density than soil, which lowers the bulk density of the soil (Verheijen *et al.,* 2009). After the addition of biochar, the soil influence soil fungal growth and microbial activity and enhances soil agglomeration besides SBD also affects the development of roots and hyphae (Steiner *et al.* 2007). Adding biochar to soil has been recorded to greatly reduce SBD and raise total porosity (Oguntunde *et al.,* 2008; Qin *et al.,* 2016). Blanco-Canqui (2017) stated that biochar application may reduce BD and its ability to improve soil aggregation and stability, which in turn improves soil porosity.

Particle density

Soil particle density was significantly influenced due to application of different levels of biochar (Table 5). Among the different biochar doses T_1 (control) treatment showed the highest particle density (2.62 g/cc). On the other hand, lowest particle density (2.35 g/cc) was observed in T_8 (75% of RFD + biochar @ 2.0 t ha^{-1}) treatment. Particle density decreased with the biochar concentration increased. Githinji (2014) found that particle density decreased linearly (r_2 = 0.915) with biochar application at rates of 0, 25, 50, 75, and 100% by volume. The particle density values were 2.62 g cm^{-3} for 0%, 2.43 g cm^{-3} for 25%, 2.37 g cm^{-3} for 50%, 2.09 g cm^{-3} for 75%, and 1.60 g cm^{-3} for 100% application rate of biochar, indicating that application of biochar at 100% by volume can reduce particle density by 64%. In a field study, Usowicz *et al.* (2016) reported that application of 30 Mg ha^{-1} of wood biochar reduced soil particle density from 2.55 to 2.20 g cm^{-3} (14% decrease).

Table 5. Effect of biochar on Organic carbon, Organic matter, Total nitrogen (N) Available phosphorus (P), Exchangeable potassium (K) and Available sulphur(S)

Treatment	Bulk density (g/cc)	Particle density (g/cc)	Porosity (%)	pH	Organic C (%)	Total N (%)	Available P(ppm)	Exchangeable K(cmol/kg soil)	Available Sulphur (ppm)
T_1	1.40^{a}	2.62^{a}	44.68^{d}	6.0	0.67^{h}	0.05^{h}	16.5^{e}	0.12^{e}	12.25^{c}
T_2	1.40^{a}	2.54^{ab}	43.88^{h}	6.0	0.69^{g}	0.063^{g}	20.66^{d}	0.15^{d}	15.75^{bc}
T_3	1.38^{ab}	2.47^{ab}	44.13^{g}	6.07	0.70^{f}	0.078^{c}	$22.2c^{d}$	0.16^{c}	16.25^{b}
T_4	1.35^{cd}	2.42^{ab}	44.21^{f}	6.15	0.72^{e}	0.084^{b}	27.2^{a}	0.17^{c}	19.25^{ab}
T_5	1.32^{ef}	2.39^{b}	44.77^{c}	6.17	0.74^{c}	0.086^{a}	26.67^{ab}	0.21^{a}	21.33^{a}
T_6	1.36^{bc}	2.44^{ab}	44.26^{e}	6.09	0.73^{d}	0.069^{f}	25.5^{abc}	0.19^{b}	20.5^{a}
T_7	1.33^{de}	2.37^{b}	44.88^{b}	6.10	0.75^{b}	0.072^{e}	23.25^{cd}	0.17^{c}	16.0^{bc}
T_8	1.30^{f}	2.35^{b}	46.56^{a}	6.13	0.76^{a}	0.075^{d}	23.5^{bcd}	0.16^{c}	19.25^{ab}
LSD (0.05)	0.022	0.2313	0.0351	NS	8.10	0.04	3.34	0.02	3.98

Porosity

Soil porosity was significantly influenced due to application of different levels of biochar (Table 5). It was found that T_8 (75% of RFD + biochar @ 2.0 t ha^{-1}) treatment showed the highest (46.56%) porosity and lowest porosity (43.88%) was observed in T_2 (RFD) treatment. Porosity increased with the biochar concentration increased. Devereux *et al.* (2013) investigate that compared to the control soil, when the 1.5% biochar soils had lower porosities and the 5% biochar soils had higher porosities, with the 2.5% biochar decreasing porosity in the first scan and increasing in the second scan. The variable effect of biochar on soil total porosity. Jones *et al.* (2010) found that the percentage of total porosity decreased with increasing biochar. The application of biochar causes the soil pore size distribution to change to smaller pore size and positively effects crop growth (Dokoohaki *et al.,* 2017). The change in soil porosity was detected in the range of 5–10 and 25 µm after adding biochar (Rasa *et al.,* 2018). Sun and Lu (2014) observed that the addition straw biochar increases the number of macropores and mesopores in clay soils. The use of biochar not only changes soil porosity but also promotes pore reorganization, which alters soil pore distribution.

In addition to modifying soil porosity and pore distribution and enhancing soil pore connectivity, biochar can also boost air and water circulation, reduce soil compaction, and enhance soil fertility (Zhang *et al.,* 2021).

Soil pH

Soil pH was non-significantly influenced due to application of different levels of biochar (Table 5).It was found that almost all the treatment brought approximately same value, but among them T_5 slightly better. Though all the treatment resulted in statistically similar pH value, yet numerically the maximum soil pH (6.17) was recorded in T_5 (RFD + Biochar @ 2.0 t ha^{-1}) while the lowest soil pH was found in T_1 when the plot treated with no biochar. Alburquerque *et al.* (2013) disagreed with present investigation, they investigated that implementation of the wheat crop, biochar significantly increased soil pH from 6.5 in the control soil to 8.2 and 7.6 in the soil treated with the highest biochar application rate. Indawan *et al.* (2018), Yang *et al.* (2015), Collins *et al.* (2013), Dou *et al.* (2012) and Moses (2011) reported that Biochar had the potentiality to increase soil pH. The agricultural soil pH increased by almost 1 pH unit for biochar treatment (Laird *et al.,* 2010).

Organic carbon

Significant different in soil organic carbon was found due to application of different level of biochar (Table 5). It was found that the highest organic carbon (0.76%) was recorded in T_8 (75% of RFD + Biochar @ 2.0 t ha^{-1}) treatment while the lowest organic carbon (0.67%) was recorded from T_1 (control) treatment. The increase in soil organic matter was due to increase in organic carbon as the rate of biochar application increased. The results of our findings were in line with the findings of Indawan *et al.* (2018), Yang *et al.* (2015), Borchard *et al.* (2014), Zheng *et al.* (2013) and Baronti *et al.* (2010) who found that soil amended with biochar increased the soil organic carbon. Increase in organic C (up to 69%) due to biochar application was found by Laird *et al.* (2010), Haque *et al.* (2021) investigate that carbon contents were increased by 25–33% from the initial levels. Diatta (2016) stated that biochar application to soils significantly increased total soil C compared to un-amended soils. Xu *et al.* (2015) reported that addition of biochar improves total soil C. Wang *et al.* (2016) observed similar results after application of biochar.

Total Nitrogen (N)

Application of Biochar significantly influence the total nitrogen (%) content of soil. The maximum total nitrogen (0.086%) was recorded in T_5 (RFD + Biochar @ 2 t ha^{-1}) treatment and minimum was recorded from control treatment (Table 5). We found that biochar application increased the total nitrogen (%) content of soil. Such an effect could be interpreted as CEC was increased due to the presence of cation exchange sites on the biochar surface (Lehmann, 2007; Sohi *et al.* , 2010). This contributed to retain higher NH_4^+ concentrations leading to improved N nutrition in the biochar-amended soil (Hollister *et al.,* 2013). Liard *et al.* (2010) found that the biochar amendments significantly increased total N (up to 7%).

Available phosphorus

Available phosphorus in soil significantly influenced due to application of different levels of biochar (Table 5). It was found that the maximum available phosphorus (27.2 ppm) was recorded in T_4 (RFD + biochar @ 1.5 t ha^{-1}) which was statistically similar with T_5 (RFD + biochar @ 2.0 t ha^{-1}) (26.67 ppm), T_6 (RFD + biochar @ 1.5 t ha^{-1}) (25.5 ppm) while the lowest available phosphorus (16.5 ppm) was recorded in T_1 (control) treatment. Xu *et al.* (2014) showed that biochar affects P availability by interaction with other organic and inorganic components in the soil, including organic matter or other base cations in the soil. Atkinson *et al.* (2010) reviewed that biochar can enhance availability and plant uptake of P and it acts as source of soluble P salts and exchangeable P forms. Most of the applied P becomes unavailable to plant due to sorption, precipitation, and microbial immobilization processes, which can remove phosphate ions from the soil solution (Zhu *et al.,* 2018). The biochar surface is often negatively charged and can directly adsorb cations such as Ca^{2+}, Al^{3+}, Fe^{2+}, and Fe^{3+}, resulting in a decrease in P sorption and precipitation (Xu *et al.*, 2014).

Exchangeable potassium (K)

Exchangeable potassium was significantly influenced by different treatment. The highest exchangeable potassium (0.21 cmol/kg soil) was recorded in T_5 treatment while the lowest exchangeable potassium (0.12 cmol/kg soil) was recorded in T_1 treatment (Table 5). Wang *et al.* (2014) indicated that the amounts of the extractable K increased by biochar addition and they found that the K content of soil increased from 0.11 to 0.83 cmol kg^{-1} soil.

Available Sulphur (S)

The available Sulphur (ppm) in soil significantly influenced due to the application of different level of biochar (Table 5). From figure 15, it was found that the maximum available Sulphur (21.33 ppm) was recorded in T_5 (RFD + biochar @ 2.0 t ha^{-1}) treatment while the minimum (12.25 ppm) was recorded in T_1 (control) treatment. But Liard *et al.* (2010) found that extractable S decreased with increasing levels of biochar.

Conclusion

Wheat growth, grain yield and postharvest soil quality were significantly increased by the application of recommended dose of fertilizer along with Biochar at different level. Application of 2kg tha^{-1} along with recommended dose of fertilizer showed the best results in respect of crop yield, yield contributing parameters like, spike length , spikelets $spike^{-1}$, grains $spike^{-1}$, 1000-seed weight , grain yield and straw yield and postharvest soil bulk density (g/cc), particle density (g/cc), porosity (%), pH, organic carbon (%), organic matter (%), available P (ppm), available S (ppm).

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