Research Article

Biochar Improves Phenological and Physiological Attributes of Wheat in Soil Amended with Organic and Inorganic Nitrogen Sources

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Abstract | Application of biochar (BC) to soil has the ability to improve soil fertility on sustainable basis under nitrogen (N) and organic matter deficient environments. Therefore, the present study was conducted to enhance N availability from organic and inorganic N sources via biochar (0, 10, 20 and 30 tons ha^{-1}) under four levels of N (0, 90, 120 and 150 kg ha^{-1}) during Fall 2015-16 and 2016-17. The required N was met from urea, poultry manure (PM) and farmyard manure (FYM). Application of 20 and/or 30 t BC ha^{-1} significantly delayed booting, anthesis, physiological maturity in wheat, and resulted in higher leaf area (LA), leaf area index (LAI), plant height, number of tillers and spikes m^{-2} when compared to control. Whereas, application of 150 kg N ha^{-1} as urea, FYM and PM, delayed booting, anthesis, physiological maturity in wheat and increased plant height and spikes m^{-2} of wheat. Similarly, 120 and 150 kg N ha^{-1} applied from PM, FYM and urea resulted in higher LA, LAI, tillers and spikes m^{-2} over control plots. Hence, application of 120 kg N ha^{-1} either from organic or inorganic sources along with 20 t BC ha^{-1} shall be applied to wheat as this combination positively enhanced wheat growth and development.

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Introduction

Wheat production needs to be improved either by adopting good management or through change in genetic techniques (Borisjuk *et al*., 2019). Phenology of a crop play significant role towards yield of the crops (Ihsan *et al*., 2016). The balance between growth stages like vegetative and reproductive are vital for the whole crop performance and ultimately for yield (Mathan *et al*., 2016). During vegetative growth a carbon source in the various plant parts (shoot and root) is established which is further utilized during reproductive phase (Holland *et al*., 2019). Growth, development and the time of assimilates partitioning in plant body is generally determined by phenology (Gonzalez-Navarro *et al*., 2016). To make sure the proper balance between vegetative and reproductive growth stages of the crops there is an urgent need for nutrients management on sustainable basis (Sawan, 2013).

Nitrogen (N) is the key nutrient among essential plant nutrients which affects crop morphology, phenology, growth and yield (Abid *et al*., 2016). It is most abundant in environment, but most deficient in soil. Moreover, its deficiency affecting agriculture productivity throughout the world and particularly in Pakistan (Maqsood *et al*., 2016). The application of N to wheat from synthetic source is influential as it increases wheat tillers m^{-2} (Khattak *et al*., 2017), leaf area, leaf area index, plant height, spikes m^{-2} and delay booting, anthesis and physiological maturity in wheat (Stumpf *et al*., 2019; Sher *et al*., 2018).

Since green revolution, the productivity of cereals (especially wheat) had largely increased due to the application/success of inorganic fertilizers (Ali *et al*., 2012). Though the significance of inorganic fertilizer cannot be overlooked however, the role of inorganic fertilizer has been much lesser in term of improving soil fertility (Hammad *et al*., 2010). Therefore, there is an increasing trend for the practice of organic manures including FYM and PM in order to get higher yield without disturbing soil health (Ali *et al*., 2017). To handle this situation and pay off loses due to inorganic N fertilizations, the addition of organic sources of nutrients are considered the best possible solution. Because organic manures hold maximum potential for enhancing soil characteristics in the long run (Timsina, 2018). Organic manures are used to restore exhausted/low fertile soils Hammad *et al*. (2011), and to get maximum yield without disturbing the soil health (Arif *et al*., 2013). Due to the improvement in soil organic matter, water storage, cation exchange capacity (CEC), water infiltration, aeration, porosity and biological activity (Agbede, 2019). Jan *et al*. (2018) stated that among organic manures PM is the richest source of essential nutrients which promote vigorous vegetative growth which further delay wheat phenology. Further, integration of organic and synthetic fertilizers delayed days to 50% heading, enhanced LAI, plant height, yield and its components of wheat (Sadur *et al*., 2010).

In Pakistan the use efficiency of N fertilizers is almost 30 to 50%. This low efficiency might be due to N loses as ammonia volatilization, nitrous oxide emission as a result of de-nitrification and nitrate leaching (Haroon *et al*., 2019). Thus biochar (BC) incorporation to soil may relief this problem through nutrients addition or improving soil CEC (Silva *et al*., 2017). Furthermore, BC as a soil amendment play starring role in holding water in the soil (Jalal *et al*., 2016). Slowly releases nutrients (Arif *et al*., 2014). And reduced nutrients leaching (Sara *et al*., 2018). Thus, greater nutrients concentration in the rhizosphere (Sial *et al*., 2019). Therefore, enough food available throughout the plant growing periods which ultimately delayed maturity (Arif *et al*., 2014).

Biochar (BC) had robust attraction for ammonium and nitrate ion (Fidel *et al*., 2018). Thus, enhanced fertilizers use efficiency by minimizing loses of N and ultimately increased its uptake (Du *et al*., 2019). Which further have positive impact on plant height (Agegnehu *et al*., 2015). Moreover, incorporation of 25 t BC ha^{-1} delayed booting, anthesis and maturity stages in wheat (Ali *et al*., 2015). Delayed leaf senescence by keeping photosynthesis active (Rizwan *et al*., 2018). Thus, delayed wheat phenology (Ali *et al*., 2015), and ultimately increased yield and its components (Uzoma *et al*., 2011). Similarly, Ali *et al*. (2015) noted more numbers of spikes for 25 t BC ha^{-1} amended plots. Furthermore, Batool *et al*. (2015) observed minimum LA for BC control plots when compared with BC amended plots. Moreover, application of BC at 2% positively affected number of tillers per plant during two consecutive seasons (Baronti *et al*., 2014).

Keep eyeing on the significance of wheat phenology, its contributions towards yield and its response to various fertilizers sources (organic and synthetic). The current experiment was conducted to observe the influence of BC and different N management system on phenological and physiological attributes of wheat under alkaline soils.

Materials and Methods

Description of the study area

The current field experiments were carried out during Fall 2015-16 and 2016-17 at Agriculture Research Station (ARS) Swabi Khyber Pakhtunkhwa Pakistan, located at latitude 34.12° and longitude 72.47°. Mean monthly air temperature and total monthly rainfall were recorded through an automated weather station installed at the experimental site. Total monthly rain fall was in the range of 0 mm during (April, May, Nov. Dec. 2016, March, May, June 2017) to 188 mm (March 2016) while mean monthly air temperature was in the range of 11.89 °C (Dec. 2015) to 34.68 °C (June 2017) during the crop growing season (Figure 1). Rain fall changes during the years. Therefore, to evade the water stress due to shortage of water the plants were frequently irrigated. During 2015-16 the crop was irrigated four times (6 Dec. 28 Dec. 2015 and 25 Jan. 30 Feb. 2016) while during 2016-17 the crop was irrigated six times (5 Nov. 28 Nov. 23 Dec. 2016 and 2 Feb. 27 Feb. 21 March 2017). As a result, crop received optimum supply of water. A surface (0-15cm) composite soil sample was taken from the experimental field before treatments application and was analyzed for base line data (Table 1). The soil was silt loam soil texture, alkaline (7.6) and non-saline (0.64 d Sm^{-1}) in nature having a bulk density of 1.29 g cm^{-3}. Moreover, the soil was low in organic matter (0.41%), having total C (0.24%), P (4.6 mg kg^{-1}), N (0.002 %) and K (66 mg kg^{-1}).

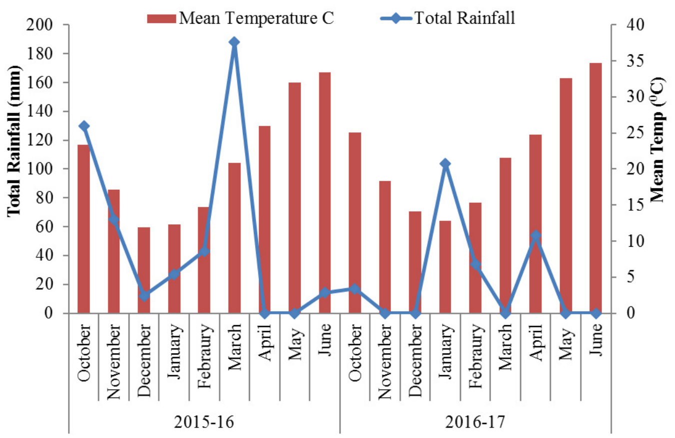

Figure 1: *Rain fall and temperature data of the study area from wheat sowing till harvesting.*

Table 1: *Physio-chemical properties of experimental field.*

Property	Unit	Value
pH	----	7.6
EC	d Sm^{-1}	0.64
C	%	0.24
N	%	0.002
P	mg kg^{-1}	4.6
K	mg kg^{-1}	66
Organic matter	(%)	0.41
Texture	----	Silt loam
Bulk density	g cm^{-3}	1. 29

Biochar production

The BC used in this experiment was produced using a 'on farm' method suitable for small-scale production of BC in Pakistan. *Dodonaea viscosa* (L.) Jacqa (Local name: Ghwraskay) wood was pyrolysed at 300-500° C for 3-4 hours. Further, it had pH of 7.05, EC 1.49 d Sm^{-1}, C (59.35%), P (0.112%) and N 0.08% (Table 2).

Details description of the experiments

This research study was laid down using 2 factorial randomize complete block (RCB) design with split plot arrangements having 40 treatments each replicated 3 times. The study was consisted of four levels of wood biochar (0, 10, 20, 30 t ha^{-1}) and N management (0, 90, 120, 150 kg ha^{-1}). The required amount of N was applied from urea, FYM and PM. Moreover, FYM and PM were applied at the rate of (10341.67, 13791.67, 17241.67 and 5883.33, 7841.67, 9800 kg ha^{-1}) in order to provide 90, 120 and 150 kg N ha^{-1}. Wood BC was applied to the main plots one month before sowing and was incorporated with the help of rotavator moreover; biochar, FYM and PM were analyzed for its chemical composition (Table 2). Analysis showed that FYM had pH of 8.57, 2.39 dS m^{-1} EC, 46.4% C, 0.34% P, 0.87% N and 0.6% K while PM having pH of 6.82, 2.48 dS m^{-1} EC, 34.7% C, 0.97% P, 1.53% N and 0.9% K. Based on the aforesaid chemical analyses the required amount of N was met from FYM and PM and was properly incorporated in sub-plots by hoeing in order to avoid mixing with the adjacent sub plots. The required amount of N from urea was calculated from the percent N present and was applied to sub-plots in split doses (half at sowing and half at tillering stage) while all the FYM and PM were applied one month before sowing. Sowing was done on November 8th 2015 and November 5th, 2016. Wheat variety Pirsabaq 2013 was used as a test crop. Seed rate (120 kg ha^{-1}) was used in 3 x 4 m^2 plots by maintaining row to row distance of 30 cm. A basal dose of P and K at 90 and 60 kg ha^{-1} was calculated from both single super phosphate and potassium sulphate, respectively to all plots. Sowing was done by hand hoe in each subplot. Normal cultural practices were maintained until harvesting of the crop.

Table 2: *Characteristics of biochar, PM, FYM used in the experiment.*

Property	Unit	Biochar	PM	FYM
pH	-----	7.05	6.82	8.57
EC	d Sm^{-1}	1.49	2.48	2.39
C	%	59.35	34.7	46.4
P	%	0.112	0.97	0.34
N	%	0.08	1.53	0.87
K	%	----	0.9	0.6

Field observations

Phenological observation like days to boot stage was measured by counting total days between sowing till fifty percent plants attained booting. While counting total days between sowing till fifty percent plants extruded anthers showing clear indication of anthesis and to know about physiological maturity, difference in days was noted between sowing till fifty percent plants physiologically mature. Disappearance of green color from the glumes was considered the best sign to know about the exact time of the said stage

(Khan *et al*., 2017). Agronomic parameter like plant height was measured (at physiological maturity) by averaging height of 5 randomly selected plants in every subplot (Arafat *et al*., 2016). For measuring leaf area (at anthesis), leaves from the randomly selected five tillers were passed through the equipment (Li-car model no A-3000) while leaf area index was calculated with help of scan canopy analyzer (Delta-T Devices LTD Burwell, Cambridge, UK) (Sher *et al*., 2018). Data about tillers and spikes m^{-2} were noted down by counting the total tillers and spikes in an m^{-2} area of each subplot (Khan *et al*., 2008).

Characterization of soil, biochar, FYM and PM

Soil bulk density (BD) was calculated by the formula as described by Blake and Hartge (1986). Soil organic matter (SOM) was determined by the method of Nelson and Sommers (1982). Soil pH and EC in 1:5 soil water suspension determined by the procedure of McLean (1982); Rhoades (1996), respectively. Soil carbon was found by the procedure of Nelson and Sommers (1982). Total nitrogen data was measured calorimetrically by Kjeldahl method as described by Bremner and Mulvaney (1982). ABDTPA Extractable potassium was determined by the procedure as recommended by Ryan *et al*. (2001) through Flamephotometer (Jenway, UK). While the ABDTPA extractable P content in soil samples was determined by the method as described by Soltanpour and Schwab (1977).

Statistical analysis

The obtained data was examined statistically through Satatistix 8 (Version 8.1, Copyright©, 1985-2005) according to two factorial RCBD. In case of significant F test, further analyses of various means were done through least significant difference (LSD) test at (5%) probability value (Steel and Torrie, 1980).

Results and Discussion

Days to boot stage

Data on phenological parameters of wheat as affected by BC and N management are presented in Table 3. Booting were significantly delayed with increasing BC level from 0 to 20 t ha^{-1} but further increasing BC level up to 30 t reduced days to booting. More days to booting (111.2) were counted for those plots where 20 t BC was applied. This was followed by 30 t BC treated plots (110.6). The treatments 20 and 30 t BC did not show any statistical differences when compared to each other however an increase of (2.77 and 2.22%) were observed respectively over control. Minimum days to booting (108.2) were taken by BC control plots, where no BC was applied. Plots treated with PM, took 109.5 to 111 days to booting when compared to those plots which received urea, whose range was 109.2 to 111 days. Similarly, plots received FYM as N source had a range of 109.2 to 109.8 days up to booting. More specifically, application of highest quantity of N (150 kg) applied from urea, PM and FYM significantly increased days to booting (4.23, 4.23 and 3.09%) over control. This was followed by 120 kg N applied from PM and FYM, having an increase of (3.91 and 3.83) over control. Interaction between BC × N showed that combined application of 20 t BC and 120 kg FYM N took more days to booting 113.83 (Figure 2).

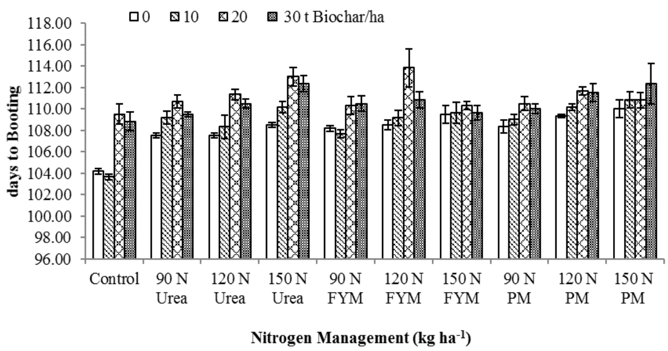

Figure 2: *BC × N interaction over years for days to boot stage of wheat. The small bars at the top of the big bars in (***Fig.** *2 to 8) represent the standard error.*

Days to anthesis stage

Anthesis (Table 3) was significantly delayed in plots subjected to 20 t BC. This was followed by 10 t BC amended plots and BC control plots. The treatments 20 and 30 t BC did not show any statistical differences when compared to each other. N control plots took less days to anthesis (131.1) when compared to N treated plots. Generally, plots having highest level of N from urea, FYM and PM delayed anthesis more when compared to lower levels of N applied from the same sources. More specifically, application of 150 kg N from urea, FYM and PM took highest days to anthesis 141.5, 142 and 142.4 when compared to other levels of N and N control plots. Similarly, the BC × N interaction (Figure 3), showed that application of 20 t BC along with 150 kg N from urea took more days to anthesis 147.17.

Table 3: *Days to booting, days to anthesis, days to physiological maturity, plant height, leaf area, leaf area index, tillers and spikes m^{-2} of wheat as affected by biochar and nitrogen management.*

Biochar (t ha^{-1})	Days to Booting	Days to Anthesis	Days to Maturity	Plant height	Leaf Area	Leaf Area Index	Tillers m^{-2}	Spikes m^{-2}
0	108.2 c	136.1 c	165.4 c	96.4 c	82.65 c	2.33 c	280.7 c	263.7 c
10	108.8 b	138.8 b	167.6 b	98.7 b	107.16 ab	3.15 ab	291.8 b	272.7 b
20	111.2 a	140.9 a	168.8 a	100.7 a	111.52 a	3.34 a	297.4 a	281.4 a
30	110.6 a	140.9 a	169.4 a	101.1 a	100.82 b	3.06 b	300.9 a	282.8 a
LSD $_{(0.05)}$	0.60	1.21	1.11	1.44	7.66	0.24	4.77	5.92
Nitrogen Management (kg ha^{-1})								
Control	106.5 d	131.1 e	161.3 e	89.4 e	76.67 d	1.91 e	249.0 e	223.5 e
90 N Urea	109.2 c	139.5 c	168.2 bc	97.6 d	86.33 cd	2.43 d	281.5 d	264.3 d
120 N Urea	109.2 c	139.5 c	167.8 bc	100.7 bc	103.45 ab	3.07 abc	295.1 bc	278.4 c
150 N Urea	111.0 a	141.5 ab	169.3 ab	103.9 a	104.49 ab	3.21 abc	305.4 a	288.1 a
90 N FYM	109.2 c	137.0 d	165.6 d	96.3 d	99.58 b	2.93 bc	293.3 bc	278.7 bc
120 N FYM	110.6 ab	140.3 bc	169.1 abc	100.1 c	107.12 ab	3.27ab	303.1 a	285.0 abc
150 N FYM	109.8 bc	142.0 ab	170.5 a	103.6 a	107.62 ab	3.31 ab	305.4 a	287.9 ab
90 N PM	109.5 c	138.7 cd	167.5 c	97.5 d	98.32 bc	2.84 c	288.6 cd	268.8 d
120 N PM	110.7 ab	139.8 c	168.1 bc	100.6 bc	109.98 ab	3.38 a	304.6 a	286.3 abc
150 N PM	111.0 a	142.4 a	170.6 a	102.6 ab	111.82 a	3.39 a	300.7 ab	290.6 a
LSD $_{(0.05)}$	0.95	1.77	1.75	2.27	12.12	0.38	7.55	**9.35**
2015-16	108.0 b	137.5 b	166.1 b	98.40 b	94.28 b	2.67 b	281.44 b	264.59 b
2016-17	111.4 a	140.8 a	169.5 a	100.05 a	106.79 a	3.26 a	303.91 a	285.71 a
Interactions								
Y x BC	0.779	0.860	0.983	0.932	1.00	0.989	1.00	0.977
Y x N	1.000	0.992	1.000	0.995	1.00	1.00	1.00	0.919
BC x N	0.000 **	0.000 **	0.000 **	0.278	0.00**	0.00**	0.00**	0.00**
Y x BC x N	0.900	1.000	1.000	1.000	1.00	1.00	1.00	1.00

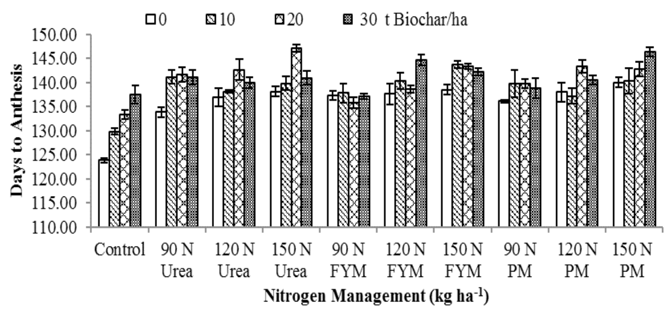

Figure 3: *BC × N interaction over years for days to anthesis stage of wheat.*

Days to physiological maturity

Both BC and N management had significantly delayed days to physiological maturity in wheat (Table 3). Physiological maturity was delayed by169.4 days in plots treated with 30 t BC when compared 10 t BC ha^{-1} and BC control plots (167.6 and 165.4 days) but were not significantly varied from plots treated with 20 t BC (168.8 days). Generally, N treated plots took more days to maturity (from 168.2 to 170.6) when compared to N control plots (161.3 days). More specifically, plots received 150 kg of N applied from PM, FYM and urea delayed maturity by (170.6, 170.5 and 169.3 days), followed by 120 kg N applied from FYM (169.1 days). Similarly, BC × N interaction showed that 30 and 20 t BC treated plots took more days to maturity when 120 and 150 kg N were applied from PM and urea. Furthermore, 30 t BC along with 120 and 150 kg N applied from FYM also took more days to maturity (Figure 4).

Plant height

Significant effect of BC and N were observed for plant height of wheat (Table 3). Visually tallest plants were recorded for 30 and 20 t BC incorporated plots (101.1 and 100.7 cm), when compared 10 t BC (98.7 cm) and

BC control plots (96.4 cm). The treatments 30 and 20 t BC did not show any significant differences when compared to each other. Application of N resulted in increased plant height when compared to N control plots. Generally, plant height was increased as N levels were increased from lower to higher. For urea it was in the range of (97.6 to 103.9 cm), for FYM (96.3 to 103.6 cm) and for PM the range was (97.5 to 102.6 cm). Moreover, tallest plants (103.9, 103.6 and 102.6 cm) were noted in those plots where 150 kg N was applied from urea, FYM and PM respectively. In case of years maximum plant height (100.05 cm) were observed during 2016-17.

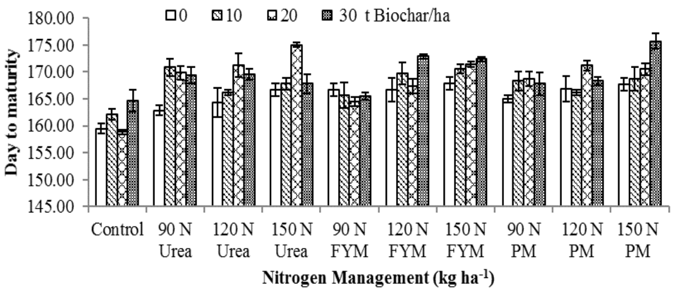

Figure 4: *BC × N interaction over years for days to physiological maturity of wheat.*

Leaf area

Both BC and N management and its interaction significantly affected leaf area (LA) of wheat (Table 3). Plots treated with 20 t BC had increased LA up to (37.18 cm^2) when compared to 30 t BC (33.60 cm^2) and BC control plots (27.54 cm^2), but not significantly different from 10 t BC (35.72 cm^2). Generally, LA was increased as N levels were increased from lower to higher. For urea it was in the range of (28.77 to 34.83 cm^2), for FYM (33.19 to 35.87 cm^2) and for PM the range was (32.77 to 37.28 cm^2). More specifically, higher LA (37.28 cm^2) was obtained in those plots where 150 kg N was applied from PM when compared to 90 kg N applied from urea, FYM and PM (28.77, 33.19 and 32.77 cm^2), but significantly not different from 120 kg N applied from urea, FYM and PM. Significantly lower LA was noted by N control plots (25.56 cm^2). In case of years maximum LA (35.59 cm^2) was observed during 2016-17. In case of BC × N interaction, enhanced LA was measured for 30 t BC along with 120, 150 and 120 kg N applied from FYM, FYM and PM. Furthermore, 20 t BC along with 150, 150, 90 and120 kg N applied from urea, PM and FYM also resulted in maximum LA. Similarly, those plots where 10 t BC and 150 kg N was applied from PM and FYM also gives maximum LA (Figure 5).

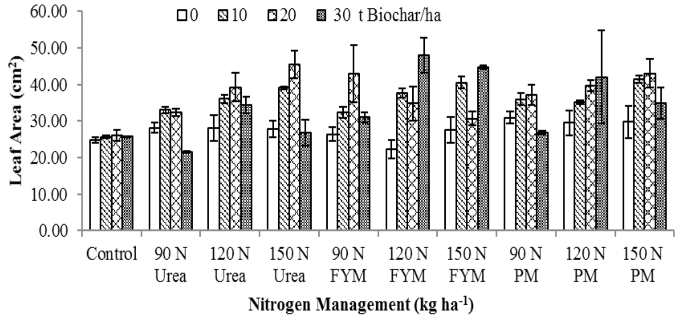

Figure 5: *BC × N interaction over years for leaf area of wheat.*

Leaf area index

Both BC and N management and its interaction significantly affected leaf area index (LAI) of wheat (Table 3). Plots amended with 20 t BC had increased LAI up to (3.34) when compared to 30 t BC (3.06) and BC control plots (2.33), but not significantly different from 10 t BC (3.15). Furthermore, LAI was in the range of (2.43 to 3.21) for urea, for FYM (2.93 to 3.31) and for PM it was in the range of (2.84 to 3.39). Significantly greater LAI (3.39 and 3.38) was measured by those plots where 150 and 120 kg N was applied from PM, this was followed by 90 kg N applied from urea, FYM and PM (2.43, 2.93 and 2.84), but significantly not different from those plots where 150 and 120 kg N was applied from urea and FYM. Significantly lower LAI was measured for N control plots (1.91). Mean data of years showed that maximum LAI (3.26) was measured during 2016-17. In case of BC × N interaction, significantly maximum LAI was measured for 30 t BC treated plots when combined with 120, 150 and 120 kg N applied from FYM, FYM and PM. Furthermore, 20 t BC incorporated plots also resulted in maximum LAI when applied with 150, 150, 90 and120 kg N applied from PM, urea, FYM and PM. Similarly, those plots where 10 t BC and 150 kg N was applied from FYM also gives maximum LAI (Figure 6).

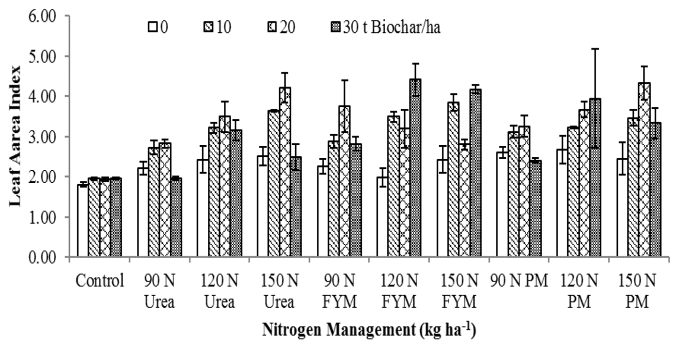

Figure 6: *BC × N interaction over years for leaf area index of wheat.*

Tillers m⁻²

BC, N management and its interaction significantly affected tillers m^{-2} of wheat (Table 3). Those plots where 30 t BC was applied produce maximum tillers (300.9) compared to 10 t BC (291.8) and BC un-treated or control plot (280.7) but were not significantly different from those plots where 20 t BC was applied. Furthermore, tillers were significantly increased by N when compared to N control plots. Specifically, Plots treated with 150 kg N applied from urea produced more tillers (305.4), when compared to 90 kg N applied from urea, FYM and PM (281.5, 293.3 and 288.6), but not significantly different from 120 and 150 kg N applied from FYM and PM (303.1, 305.4, 304.6 and 300.7). In case of years, maximum tillers (303.92) were observed during the 2nd year (2016-17). In case of interaction between BC × N, maximum number of tillers was produced by those plots where 20 t BC and 150 kg N was applied from PM (Figure 7).

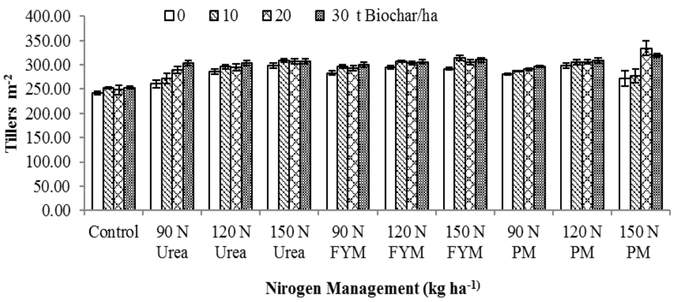

Figure 7: *BC × N interaction over years for tillers m^{-2} of wheat.*

Spikes m⁻²

BC, N management and its interaction had significant impact on spikes m^{-2} of wheat (Table 3). Those Plots where 30 t BC was applied produce maximum spikes (282.8) compared to 10 t BC (272.7) and BC control plot (263.7) but were not significantly different from those plots where 20 t BC was applied. Number of spikes was enhanced by N application when compared to N control plots. For N management it was range from (264.3 to 290.6). More specifically, those plots where 150 kg N was applied from PM produced more number of spikes (290.6), when compared to 90 kg N applied from urea, FYM and PM (264.3, 278.7 and 268.8), but were not significantly varied from 150 kg N applied from urea, FYM (288.1 and 287.9) and 120 kg N from PM and FYM (286.3 and 285.0). in case of years, highest number of spikes (285.71) were produced during 2nd year (2016-17). Moreover, interaction between BC × N showed that, maximum spikes (332) were produced by 20 t BC treated plots along with 150 kg N applied from PM (Figure 8).

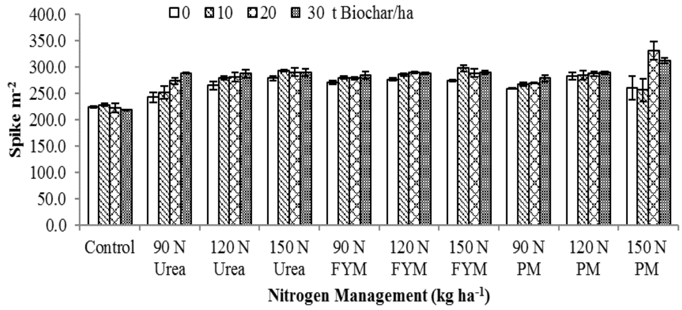

Figure 8: *BC × N interaction over years for spikes m^{-2} of wheat.*

Biochar (BC) incorporation significantly delayed different growth stages, occurred during the growth period of wheat. Because as a soil amendment BC played a starring role in improving water holding capacity (WHC) of the soil, slowly release nutrients, reduced nutrients leaching, improves nutrients concentration and nutrients use efficiency (NUE), hence enough food available during the growing period of the plants, which delayed maturity (Mierzwa *et al*., 2019). Our results of late flowering and maturity were also confirmed by (Ali *et al*., 2015). Such delay in flowering and maturity is the result of late leaf senescence in wheat and maize due to active photosynthesis (Uzoma *et al*., 2011; Ali *et al*., 2015; Ali *et al*., 2017). Moreover, early booting in BC un-treated plots might be due to the scarcity or shortage of nutrients in these plots which pushed the plants to quickly complete his life cycle. Delayed booting, anthesis and maturity in N treated plots might be due to the enhanced leaf area duration, improved vegetative growth and use efficiency of light with further improvement in use efficiency of N (Sher *et al*., 2018). Furthermore, delayed in different growth phases due to organic fertilizer sources may be due to the greater concentration of available nutrients throughout the plant life which extended the growth period and ultimately delayed phenology. One of the richest sources of nutrients is PM, which promotes vigorous vegetative growth that further delayed wheat phenology (Jan *et al*., 2018). Khan *et al*. (2014) described that too much uptake of N would lead to lengthen maturity stage in plants. Furthermore, delayed maturity in FYM treated plots may possibly be due to maximum availability of nutrients in FYM incorporated plots (Koroto *et al*., 2017). The change in plant height in BC incorporated plots may possibly be due to the nutritional value of BC. Furthermore, BC had robust attraction for ammonium and nitrate (Atkinson *et al*., 2010), thus enhanced use efficiency of fertilizer by minimizing loses of nitrogen through leaching (Shi *et al*., 2020), hence resulted in increased plant height in BC incorporated plots (Zee *et al*., 2017). Alike result was also obtained by (Sial *et al*., 2019). Cells protein content increased as the application of N increased and size of plant cell increases, as a result of that greater leaf area (LA), improved photosynthesis rate, more production of assimilates and plant dry matter which eventually make the plant taller (Rahman *et al*., 2014). Greater availability of both (macro and micro) nutrients and increased WHC of the soil (Ali *et al*., 2017), as a result fertilized treated plots had more taller plants when compared to fertilizer un-treated or lower fertilized treated plots. Emmanuel (2018); Abbas *et al*. (2012) described that increasing level of FYM and PM fed the crop in initial as well as in later stage, thus better vegetative growth and development resulted in maximum plant height. Similarly, application of BC increases LA and leaf area index (LAI) of wheat as compared to no BC treated plots. Because BC as a soil amendment strongly attract ammonium and nitrate ion thus reduced its leaching and making it more available in the rahizosphere, thus increased vegetative growth which ultimately improved LA and LAI (Salim, 2016). Parallel results were also achieved by (Batool *et al*., 2015; Akhtar *et al*., 2015). The better LA and LAI in N nourished plots may probably be due to the delayed leaf senescence, persistent, and continuous leaf photosynthesis (Sadur *et al*., 2010), which further increased number of tillers and size of the successive leaves (Ruisi *et al*., 2015). Moreover, the improved LA and LAI in PM amended plots might be due to the higher consumption of nutrients released through the decomposition of PM, which led to enhanced chlorophyll content, captured maximum solar radiation, increased net photosynthesis and cell division in the leaves (Kareem *et al*., 2017; Ahmed *et al*., 2017; Bashir *et al*., 2017). Similarly, the improved LA of wheat in FYM amended plots might be due to the enhanced N availability and its uptake (Singh *et al*., 2019). Tillers m^{-2} of wheat was considerably enhanced by BC and N management. Because the enhanced soil physical properties were expected to benefit wheat tillering and root elongation (Oussible *et al*., 1993), and therefore improved the wheat vegetative growth with higher tiller number. In addition, BC itself might also provide available phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) etc., having the potential to boost soil fertility (Silber *et al*., 2010). The above statement was also supported by (Zhang *et al*., 2013). The maximum number of tillers production in fertilized plots may possibly be due to the sufficient N availability (Lee *et al*., 2017), which caused in enhanced photosynthetic activities (Guo *et al*., 2019), vigorous plant growth (Belete *et al*., 2018) and eventually more productive tillers. Further, the increased number of tillers in organic amendment plots (especially PM) may possibly be due to the improvement in soil fertility; organic matter, microbial activities and improved soil structure (Mukhtiar *et al*., 2018). Moreover, Enujeke (2013) stated that incorporation of PM improved plant growth due to the availability of more moisture and nutrients (Abbasi and Khaliq, 2016), leading to bumper growth and development (Jan *et al*., 2018), and eventually more tillers m^{-2} (Rasul *et al*., 2015). Spikes (fertile tillers) contribute directly to the yield of crop. Incorporation of BC had an encouraging influence on it. This might be due to soil reclamation properties of BC, which enhance fertility and use efficiency of nutrients (Negussie *et al*., 2012). Furthermore, Rahim *et al*. (2019) observed that application of BC enhanced soil WHC, total N content in the soil and encouraged crop growth, development and improved yield attributes through enhanced physio-chemical properties of the soils. Similarly, Olmo *et al*. (2016) also counted more spikes of wheat, may possibly be due to the greater nutrient uptake in BC practiced plots. Moreover, N-treated plots produced more spikes when compared to control (Mukhtiar *et al*., 2018), this might be due to the sufficient N, timely available which may influence the tillering power of the plants and bring about significant changes in number of spikes per plant (Yang *et al*., 2019). Among the N sources, organic manures are the exceptional sources of nutrients supply to crop plants (Timsina, 2018). Because Organic manures like PM and FYM decomposed slowly, improved water and nutrients retaining ability of the soil and supply nutrients throughout the plant growth (Ahmed *et al*., 2017), resulted in more number of spikes (Khan *et al*., 2018; Ali *et al*., 2011).

Conclusions and Recommendations

Biochar (BC) incorporation into soil improved wheat growth over control regardless of the nitrogen (N) sources used. However, organic sources like PM and FYM performed significantly better than mineral

N sources (urea) at both with and without BC application. Thus, N should be applied as organic sources along with BC for improving wheat growth under alkaline calcareous soil in echo friendly manner.

Novelty Statement

In alkaline calcareous soils the exogenously applied nitrogen (N) as mineral fertilizers is lost in many ways. We assumed that, application of N as organic manures could be a best way for reducing N losses in alkaline soils. Furthermore, Biochar incorporation into such soils may relief this problem directly through nutrients addition and/or indirectly through nutrients retention, because biochar had strong attraction for ammonium ion released by N fertilizers. In this study we tried to evaluate the potential of biochar in enhancing N availability from different N sources and improving crop growth under alkaline calcareous soils.

Author's Contributions

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Conflict of interest
The authors have declared no conflict of interest.

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