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Integration of biochar and chemical fertilizer to enhance quality of soil and wheat crop (*Triticum aestivum* L.)

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Abstract

A wide variety of soil amendments like manures, compost, humic acid and bio-sorbents have been used to make nutrients available to crops as well as to protect them from toxic elements. Among soil amendments, biochar has been known to improve soil health, soil nutrients' availability to plants and ultimately the yield of crops. A field experiment was conducted by using biochar prepared from *Dalbergia sissoo* Roxb. wood by brick batch process. Two doses of biochar were applied to soil 0 and 12 t ha^{-1}. Fertilizer rates used in the experiments were 25% recommended doses of fertilizers (RDF), 50% RDF, 75% RDF and 100% RDF alone and with biochar applied under two factorial randomized complete block design in natural field conditions (RDF of NPK fertilizer is 120-60-60 kg ha^{-1}). Soil physico-chemical properties *viz.*, bulk density, particle density, porosity, pH, electrical conductivity, organic matter, soil organic carbon, total nitrogen, available phosphorus, available potassium, soil organic carbon, soil microbial biomass carbon and soil microbial biomass nitrogen were measured from the soil samples collected from 0-30 cm depth. All these parameters varied significantly among the treatments. A combined treatment of biochar and 50% of the recommended dose of NPK was most effective for soil conditioning. Agronomic parameters were also measured by standard methods. Due to chelation of heavy metal ions and availability of nutrients to the soil, yield of the crop may significantly increase due to cumulative treatment of fertilizer and biochar but upto a certain limit.

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Introduction

Wheat (*Triticum aestivum* L.) is the principal cereal crop of Pakistan. Wheat has supreme importance in agricultural policies of our country. Its contribution is about 10.1% in agriculture having 2.2% share in GDP of the country. The area under wheat cultivation is 9180 thousand $ha^{-1}$with yield per hectare was 2775 kg per hectare in 2014-15 (Pakistan Economic Survey, 2015). The production of wheat is low in Pakistan due to the imbalance application of fertilizers and organic matter decomposition at rapid rate due to severe hot climatic conditions (FAO, 2007; Khaskheli, 2013)

Soil organic matter (SOM) have significant effect on soil physico–chemical health, sequestration of carbon, controlling land erosion and protecting land from degradation (Galantini and Rosell, 2005).Soil microbial biomass carbon (SMBC), microbial activity and mineral transport are significantly affected by SOM(Carter, 1999). Organic matter decompositions are certainly rapid in tropic and arid to semiarid regions because of high decomposition rates and mineralization of SOM (Haron *et al*., 1997)

Addition of soil amendments helps to retain nutrients in soil. Biochar is more effective than other organic amendments in retaining and making nutrients available to plants for a long time. Among soil organic amendments, biochar is considered more stable nutrient source than others (Chen *et al*., 2007). Biochar is the product of thermal decomposition of organic materials under oxygen stress conditions and high temperature. It is applied to soil to achieve environmental benefits, like decreasing CO_2 gas emissions (Lehmann and Joseph, 2009). Its application to soil is an approach to decrease CO_2 emissions and to mitigate global climate change (Woolf *et al*., 2010*)*. Its surface area and complex pore structure are hospitable to bacteria and fungi that plants need to absorb nutrients from the soil. Moreover, biochar is a more stable nutrient source than compost and manure (Cheng *et al*., 2006). Properties of biochar depend upon the selection of biomass for biochar production which in turn decides the carbon (C) inputs in soil (Jeffery *et al*., 2013). Biochar produced at low temperature are more prone to rapid degradation in soil than those that produced at higher temperature and generally biochar produced from grasses are more degradable than that produced from hard wood (Zimmerman *et al*., 2011). Organic carbon contents in biochar have been reported up to 90%, depending upon its feedstock which enhances carbon sequestration in soil (Yin *et al*., 2009).

Biochar application to soil and crop as well as its effect on the nitrogen (N) cycle also proved helpful (Anderson *et al*., 2011). Biochar have potential to improve the growth and action of microorganisms which are directly or indirectly involved in soil N cycling. So, due to the activation of microorganisms it can mineralize complex soil organic carbon (SOC), and can enhance the effect of biochar application on native SOC (Belay-Tedla *et al.,* 2009). Biochar application could also increase net microbial immobilization of inorganic N because biochar comprise by small labile C fractions with high C:N ratio (Deluca *et al*., 2009).

Based upon the significance of wheat and biochar this experiment was conducted to find out the cumulative effect of biochar along with different rates of fertilizer improves on SOM pools by improving microbial biomass accumulation, its effect on soil physico-chemical properties and yield of wheat crop.

Materials and methods

Experimental site and climate

A field experiment was conducted to study the influence of biochar and chemical fertilizer on soil physical and chemical parameters. Its effect on growth and yield of wheat crop (*Triticum aestivum* L.) was also studied at the farm of Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan (31.25° N, 73.09° E). Two factorial randomized complete block design was used for this study. Soil of the experimental area was classified as a welldrained hafizabad loam, mixed, semi–active, iso–hyperthermic typic calciargids.

The soil bulk density of the top 30 cm of soil before the biochar amendment was 1.42Mg m^{-3}, while the particle density and porosity were2.61 Mg m^{-3} and 45.50% respectively. Soil organic matter (SOM) content was 0.69% of soil. The soil pH was 7.87, electrical conductivity (EC) was 1.25dS $m^{-1}$and cation exchange capacity (CEC) was 17.30 $Cmol_c$ kg^{-1}. Measured soil microbial biomass carbon (SMBC) and soil microbial biomass nitrogen (SMBN) were 136.6 and 44.13 per kg of soil, respectively.

Biochar preparation

Wood of *Dalbergia sissoo* was selected as feedstock. Feedstock was pyrolyzed using brick batch process (Brown, 2009) with estimated pyrolysis temperature of 500°C and residence time of 6 hours. After that biochar was ground and sieved through 2mm sieve and stored in plastic bags.

The biochar contained 49.71% carbon and 1.03 N g/Kg measured by elemental analysis apparatus (ASTM, 2006). Available phosphorus content was 2.06 g/Kg (extracted at410 nm wavelength using spectrophotometer, measured by colorimetric method), and available potassium content was 9.21 g/Kg (extracted with 2.0 M solution of HNO_3, determined by the use of flare photometer, FP640, Cany, China). Ash contents of the biochar were 27.2% (analyzed by D–3173 method i.e. in a muffle furnace at 550°C for 2 h). Bulk density was 0.38 Mg m^{-3} (oven dried at 105°C using core sampler technique). However, recorded particle density was 1.58 Mg m^{-3} (Pycnometer method, Blake 1965). The pH of the biochar was 8.85, while the EC was 1.74 dS m^{-1} and CEC was 17.30 $cmol_c$ kg^{-1}.

Field experiment

Field was ploughed and prepared before application of biochar and fertilizer. Soil composite samples were taken at random with auger before sowing and at harvest from (0–30 cm depth) from each experimental unit. The soil samples were air dried, ground, well mixed and passed through a 2 mm sieve and analyzed for different characteristics.

All macro-nutrients i.e. nitrogen, phosphorus and potassium (NPK) and biochar amendments were applied in respective experimental unit plots at different doses and mixed thoroughly. Recommended dose for nitrogen, phosphorus and potassium is 120 kg/ha, 60 kg/ha and 60 kg/ha, respectively which was referred as F_4. Urea was used as a nitrogen source, while SSP was used as phosphorus and SOP was used as potassium sources. Five different levels viz., 0%, 25%, 50% and 75% of the recommended dose of NPK, and the original recommended dose of NPK were used in the experiment. Different doses applied in each plot were: no NPK at 0% level referred as F_0; nitrogen (30 kg/ha), phosphorus (15 kg/ha) and potassium (15 kg/ha) were used at 25% level of the recommended dose referred as F_1. Similarly nitrogen (60 kg/ha), phosphorus (30 kg/ha) and potassium (30 kg/ha) were used at 50% level of the recommended dose referred as F_2; while nitrogen (90 kg/ha), phosphorus (45 kg/ha) and potassium (45 kg/ha) were used at 75% level of the recommended dose referred as F_3. Recommended dose for nitrogen, phosphorus and potassium was referred as F_4. Recommended rate of biochar was 12 t ha^{-1} so two levels of biochar were used in the experiment which were referred as B_0 (0%) and B_1 (recommended dose). All the possible combinations of fertilizer and biochar gave rise to ten treatments i.e. B_0F_0,B_0F_1, B_0F_2,B_0F_3, B_0F_4, B_1F_0,B_1F_1, B_1F_2, B_1F_3 and B_1F_4.Each treatment was replicated four times. Size of each experimental unit was 3.66×2.44 m^2. Wheat crop (cultivar "Faisalabad–2008") was sown using manual hand drill at the rate of 123.5 kg per hectare in each experimental unit. Recommended cultural and plant protection measures were adopted. The crop was grown up to maturity and different parameters were recorded.

Soil sampling

A composite soil sample at the depth of 0–30 cm was obtained from 3 sub samples collected using a core sampler from each treatment plot. Soil samples were collected after the harvesting of crop at three points from each treatment plot. Samples for each depth were composited, placed in tagged plastic bags and dried at room temperature. These samples were air dried grinded and sieved through 2mm sieve in the laboratory for physio–chemical analysis.

Soil analysis

Soil bulk density was determined by core sampler's method as described by (Blake and Hartage, 1986). Soil particle density was determined by using pycnometer method (Blake, 1965). Soil porosity (%) was calculated by using the following formula (Blake and Hartage, 1986)

$$\text{Porosity} (\phi) = [1 - \frac{(\text{Bulk density})}{(\text{Particle density})} \times 100$$

Soil pH was measured by using a pH meter HM – 12 and EC was determined and EC (dS m^{-1}) was measured by using Jenway Conductivity meter Model-4070 (Mckeague, 1978; Mclean, 1982)

$$K = \frac{1.4118\, dSm^{-1}}{EC\ of\ 0.01\, NKCl\, (dSm^{-1})}$$

For CEC measurements four gram of soil was saturated with 1 N CH_3COONa (pH 8.2), then it was washed thrice with ethanol and finally extracted with 1 N CH_3COONH_4 (pH 7.0). Sodium in the extract was determined with the help of PFP-7 flame photometer using Na+ filter. CEC was calculated from following formula (Richards, 1954; Rhoades, 1982)

$$\text{CEC} (\text{cmol}_c\, \text{kg}^{-1}) = \frac{\text{Na} (\text{mmol}_c\, \text{L}^{-1})}{1000} \times \frac{100}{\text{Weight of Soil}} \times 100$$

Soil organic matter was determined at up to 30 cm depths by titration method following the method described by (Ryan *et al.,* 2001). Total nitrogen was measured using the Kjeldhal digestion method (Richards, 1954). The SMBC and SMBN were determined by fumigation–extraction method (Brookes *et al.*, 1985; Vance *et al.*, 1987). Briefly, soil samples were fumigated with chloroform to the extent to kill all microbes present in the soil sample. The fumigated samples were inoculated with 1.0 g of unfumigated same soil sample. Both fumigated and unfumigated soil samples were incubated in the presence of NaOH solution. The amount of CO_2 evolved was measured by titration the NaOH solution against standard HCl solution.

The amount of mineral N was also measured both in fumigated and unfumigated samples. The amount of SMBC and SMBN were calculated as described by (Shah *et al.*, 2010).

Plant sampling and analysis

Plant height, spike length, number of tillers, biomass yield, grain weight and harvest index were measured from an area of 1 × 1 m^2. At maturity, wheat was harvested from an area of 1 × 1 m^2 per plot. The fresh weight was determined in the field. The samples of grains and straws were kept at 65 °C for 48 h, and then their dry weight was obtained.

Statistical analysis

Statistical analysis of the data was carried out using two factorial RCBD. Analysis of variance and post ANOVA analysis was carried out on Statistix 8.1. (Analytical Software, 2005).

Results

Bulk Density is an important physical property of soil. The soil having lower bulk density enables root proliferation ultimately that will affect growth and yields of whole crop as a whole so applied biochar assist in significantly lowering the bulk density of soil alone and with fertilizer application than the fertilizer alone amended plots. The maximum decreased bulk density was calculated from B_1 F_0i.e. 1.15±0.01 Mg m^{-3} and highest was with B_0 F_0 1.45±0.01 Mg m^{-3} (Table 1)

In biochar amended soil an increasing trend in pH was observed due to the liming effect of Soil and may be due to the intrinsic basic nature pH used in our experiment. On the other hand the plots amended with fertilizer and biochar showed significantly the lower pH than the biochar alone amended plots. Highest soil pH (8.15±0.01) was found in the experimental unit having B_1F_0treatment while the lowest was found in B_0F_4i.e. 7.59±0.02 ($P=0.004$, $F=7.73$, $DF=24$) (Table 1).

Similarly, soil EC also varied significantly in soil samples obtained from different treatments block. EC value represents the health of soil which directly affects the different physical properties of soil.

In our studies biochar also assist in the lowering of EC .Highest EC i.e. 1.25±0.02 dSm^{-1} was found in B_0F_0 and the lowest was in B_1 F_0viz. 0.88±0.01 dSm^{-1} (P=0.00, F=47.79, DF=24) (Table 1).

Regarding cation exchange capacity (CEC), a bell shaped trend was observed i.e. increase in value to optimum and then decline. The CEC also increases due to the large surface area and having high porosity biochar these factors help influence the CEC of the soil. It may be due to the fact upon biochar addition spontaneous oxidation reactions occur, resulting in an increase in the net negative charge and hence an increase in CEC Highest soil CEC viz. 24.26±0.04 $cmol_c$ kg^{-1} was observed in B_1F_2 and the lowest was in B_0F_3i.e. 17.27±0.01 $cmol_c$ kg^{-1} (P=0.04, F=1.02, DF=24) (Table 1).

Table 1. Soil chemical parameters recorded at different combined applications of chemical fertilizers and biochar.

Treatments	Soil chemical parameters				
	Bulk Density ($Mg\ m^{-3}$)	pH	EC (dSm^{-1})	CEC ($Cmol_c\ kg^{-1}$)	Porosity %
B_0 F_1	1.40±0.02ab	7.70±0.02c	1.32±0.04bc	17.35±0.01c	44.02±0.03e
B_0 F_2	1.39±0.01b	7.67±0.02cd	1.39±0.04ab	17.34±0.00c	43.05±0.01f
B_0 F_3	1.37±0.03c	7.61±0.02d	1.42±0.03a	17.27±0.01c	43.00±0.02f
B_0 F_4	1.34±0.02d	7.59±0.02d	1.48±0.04a	19.03±0.01b	42.00±0.02g
B_1 F_0	1.15±0.01g	8.15±0.01a	0.88±0.01f	24.20±0.01a	56.05±0.01a
B_1 F_1	1.22±0.01e	7.99±0.02ab	0.95±0.03ef	24.02±0.01a	55.01±0.03ab
B_1 F_2	1.25±0.02e	7.95±0.01bc	0.98±0.0.4ef	24.26±0.04a	54.00±0.01bc
B_1 F_3	1.27±0.01f	7.92±0.02bc	1.02±0.03de	24.05±0.04a	52.00±0.01c
B_1 F_4	1.28±0.03f	7.90±0.01bc	1.10±0.03d	24.08±0.03a	51.50±0.02c
B_0 F_0	1.45±0.01a	7.87±0.04bc	1.25±0.01c	17.30±0.04c	45.50±0.01d

*Mean values followed by the different letter in the same column are statistically different (P ≤ 0.05).

Organic matter contents were directly proportional with the amount of biochar while inversely proportional to the amount of fertilizer. The cause of the increase in O.M was biochar has greater retention capacity and it facilitate slow release of nutrients and favors stabilization of organic matter. Highest organic matter contents (1.07±0.02%) were calculated from the treatment receiving biochar amendments alone i.e. B0F1 and lowest organic matter contents (0.58±0.01%) were found in B0F4 (P=0.00, F=155.34, DF=24) (Table 2).

The total nitrogen was found to be higher among the amended plots in comparison to the control. The highest contribution to total nitrogen was in soil having high fertilizer dose with biochar i.e. B_1F_4 502.25±0.01 and lowest with B_0F_0 plot 315.00±0.02 mg kg^{-1} (P=0.00, F=45.43, DF=24) (Table 2).
Soil microbial biomass carbon reflects the growth and mortality of microbes and organic matter decomposition.

In our experiment biochar effects microbial population and showed increase in SMBC with the combination biochar with fertilizer application. The SMBC was directly proportional to the amount of fertilizer and biochar. The cause of increase in SMBC may be due to the biochar itself as a source of carbon. It contains much higher amount of carbon than other amendments. Concluding, highest SMBC (245.20±0.38) was calculated in B_1F_4 and lowest amount of SMBC (136.63±0.82) was found in B_0F_0 (P=0.00, F=113.86, DF=24) (Table 2).

Biochar influences soil microbial biomass nitrogen due to biochars labile fraction induces microbes population. It also provides favorable growth conditions to microbes in soil due to higher porosity and water holding capacity The SMBN was directly proportional to the amount of biochar (only). Highest SMBN calculated was in treatment B_1F_2i.e. 77.17±0.26 mg/kg and lowest SMBN was in B_0F_0i.e. 44.13±0.42 mg/kg (P=0.00, F=96.19, DF=24) (Table 2).

Table 2. Soil chemical parameters recorded at different combined applications of chemical fertilizers and biochar.

Treatments	Soil chemical parameters			
	Organic matter (%)	Total Nitrogen mg kg^{-1}	Soil microbial biomass carbon mg kg^{-1}	Soil microbial biomass nitrogen mg kg^{-1}
B_0 F_1	0.65±0.03fg	436.00±0.02b	138.85±0.61h	58.13±0.43e
B_0 F_2	0.64±0.02gh	440.38±0.01c	157.15±0.86g	63.12±0.44d
B_0 F_3	0.62±0.03h	465.00±0.0.3c	167.75±0.91f	49.14±0.40h
B_0 F_4	0.58±0.01h	487.75±0.01d	170.88±0.82e	51.12±0.46g
B_1 F_0	1.07±0.02a	430.75±0.01de	230.20±0.82d	53.75±0.32f
B_1 F_1	0.98±0.01b	437.88±0.03e	235.20±0.77c	75.05±0.21b
B_1 F_2	0.88±0.01c	450.25±0.01e	238.93±0.69b	77.17±0.26a
B_1 F_3	0.76±0.02d	469.88±0.02e	240.80±0.66b	68.07±0.22c
B_1 F_4	0.72±0.03e	502.25±0.01f	245.20±0.38a	64.08±0.22d
B_0 F_0	0.69±0.01f	315.00±0.02a	136.63±0.82i	44.13±0.42i

* Mean values followed by the different letter in the same column are statistically different ($P \le 0.05$).

Plant height increased with increase in biochar and fertilizer upto an extent after that they depicted less or even negative effect on plant height. Highest plant height was found in B_1F_2 viz. 107.75±1.44 cm m^{-2}, while lowest plant height was found in B_0F_1 i.e. 99.35±1.65 cm m^{-2} (P=0.04, F=2.79, DF=24). Like that of plant height, spike length also increased with increase in biochar and fertilizer upto an extent after that less or even negative effect was observed. Highest spike length was recorded in B_1F_2 i.e. 10.65±0.18 cmm^{-2} and lowest spike length viz. 8.10±0.42 cm m^{-2}was observed in B_0F_0 (P=0.02, F=3.30, DF=24). A fashion similar to plant height and spike length was observed in case of number of tillers. Highest numbers of tillers i.e. 592.13±0.45m^{-2} were counted from the treatment plot B_1F_2 while lowest numbers of tillers viz. 419.95±0.51m^{-2} were found in B_0F_1 (P=0.00, F=14.31, DF=24). (Table 3)

An increasing trend was also found in biomass yield i.e. increased to an extent with increase in amount of combined treatment of biochar and fertilizer. Highest biomass yield i.e. 14.65±0.40 t ha^{-1} was calculated from the experimental plot treated with B_1F_3 and lowest was in B_0F_1 (9.80±0.42 t ha^{-1}) (P=0.00, F=789.16, DF=24). Grain weight, also, increased to an extent with increase in amount of combined treatment of biochar and fertilizer. Grain weight was highest i.e. 3.68±0.05 t ha^{-1} in plot treated with B_1F_3 treatment which gradually decreased to minimum in B_0F_0 (2.60±0.04 t ha^{-1}) (P=0.00, F=213.64, DF=24) (Table 4). Harvest index firstly increased up to certain limit i.e. B_1F_2 where 0.32±0.02% was observed which afterwards decreased to minimum i.e. 0.20±0.03% in plot treated with B_1F_4 (P=0.00, F=2051.00, DF=24) (Table 3).

Table 3. Different agronomic parameters recorded at different combined applications of chemical fertilizers and biochar.

Treatments	Agronomic parameters					
	Plant Height Cm	Spike Length cm	Number of Tillers m^{-2}	Biomass Yield t ha^{-1}	Grain Weight t ha^{-1}	Harvest Index %
B_0 F_1	99.35±1.65c*	8.12±0.42d	419.95±0.51h	9.80±0.42h	2.66±0.12gh	0.27±0.01b
B_0 F_2	101.18±1.06bc	9.22±0.41c	458.58±0.93g	10.65±0.41g	2.85±0.04f	0.27±0.02b
B_0 F_3	105.63±1.02am	9.01±0.41c	484.38±0.84f	11.37±0.39f	3.05±0.04e	0.26±0.03c
B_0 F_4	99.63±2.02c	9.03±0.41c	512.23±0.45d	13.27±0.40c	3.29±0.04d	0.25±0.02e
B_1 F_0	101.73±0.73bc	8.35±0.45bc	512.13±0.44d	13.72±0.41b	3.52±0.04c	0.26±0.02d
B_1 F_1	104.65±1.34ab	10.17±0.42b	496.50±0.45e	12.15±0.41e	3.28±0.04d	0.27±0.03bc
B_1 F_2	107.75±1.44a	10.65±0.18a	592.13±0.45a	13.13±0.41c	3.58±0.04b	0.32±0.02a
B_1 F_3	107.65±1.79a	10.5±0.45a	540.13±0.45c	14.65±0.40a	3.68±0.05a	0.32±0.04a
B_1 F_4	105.10±0.72ab	8.47±0.12d	516.23±0.45d	12.72±0.42d	2.77±0.04h	0.20±0.03g
B_0 F_0	100.68±1.26c	8.10±0.42d	550.13±0.46b	25.07±0.81bc	13.05±0.41c	2.60±0.04fg

* Mean values followed by the different letter in the same column are statistically different ($P \le 0.05$).

Discussion

Soil compaction can change the interactions between air–soil and water–soil which in turn influence the water retention, microbiological activity and nutrient uptake (Martinez and Zinck, 2004). Mixing of organic amendments with more dense mineral fractions of soils causes a decrease in bulk density majorly due to increase in total porosity and decreased soil bulk density (Bronick and Lal, 2005; Tejada and Gonzales, 2008).

Biochar significantly improves pH, total nitrogen, cation exchange capacity (CEC), organic carbon, exchangeable bases (Nigussie *et al*., 2012).Soil pH improved significantly with Biochar addition possibly due to higher concentration of metal ions in biochar (Kumar *et al*., 2013). It was observed that with the addition of biochar soil EC improves and it decreases with time (Renner, 2007).

The application of organic amendments may enhance the pH and CEC in highly weathered soils (Glaser *et al*., 2002). High surface area, abiotic oxidation and charge density of the biochar can attribute to increased CEC and pH increase (Cheng *et al*., 2006; Liang *et al*., 2006). Increase in pH increase not only improve soil health but also improve plant growth due to higher availability of nutrients (Brady and Weil, 2008).

Biochar can significantly enhance nutrient cycling, cation exchange capacity and the ability of soils to retain plant available water (Liang *et al*., 2006). Increase in soil meso-porosity or increased weathering at the expense of macro porosity strongly influences CEC of soil (Cheng *et al*., 2006; Yamato *et al*., 2006), but it is not a fact in all types of soil or conditions (Novak *et al*., 2009). Thus the use of biochar as a soil amendment is anticipated to increase both nutrient and water use efficiency and thereby crop productivity (Glaser *et al*., 2001; Liang *et al*., 2006).

Inorganic fertilization is necessary to obtain higher yields but it has very little positive impact on organic matter. It may increase mineralization rate which cause decline in soil organic matter (Lal, 2006).

It may also favor positive response to improve microbial populations and organic matter mineralization (Balesdent *et al*., 1998). However, biochar addition to soil is important for the C sequestration and soil fertility, and having residence time up to millennial in soil (Kumar *et al*., 2013). Biochar has a habitable pore area therefore biochar is considered favorable for microbial habitation (Strong *et al*., 1998). Accumulation of organic substances (biochar) at surface soil provides a substrate for microorganism that result in higher rates of SMBC (Balota *et al*., 2004). The readily metabolizable C and N in organic amendments are the most influential factors contributing to the biomass increase (Hao *et al*., 2008; Liu *et al*., 2010). A cumulative application of biochar and inorganic fertilizer is more effective for beneficial microbes in soil (Wardle *et al*., 2008; Brunn *et al*., 2012). Accumulation of organic amendment i.e. biochar at the soil surface enhances microbial activity which ultimately results in greater amount of SMBC (Balota *et al*., 2004).

Biochar addition increases pH which enhances N_2O reductase activity (Yanai *et al*., 2007) simultaneously inhibits nitrite conversion i.e. nitrate to nitrous oxide (Van-Zwieten *et al*., 2009). This phenomenon may improve the total nitrogen in our studies.

Biochar also has strong influence on plant growth by changing soil nutrient conditions (Chan *et al*., 2008; Taghizadeh *et al*., 2012). The decreased bulk density of soil by biochar amendment promotes root proliferation consequently the growth of plant (Atkinson *et al*., 2010; Laird *et al*., 2010). Therefore, a decreased bulk density has a positive influence on plant growth because of a lower resistance to root penetration. This effect may be due to the involvement of species, compaction of soil and environmental factors (Alameda *et al*., 2011). Plant height may increase due to more phosphorus availability, enhanced root growth and increased nutrient adsorption (Hussnain *et al*., 2006). It can also be attributed to improved phosphorus availability (Asai *et al*., 2009; Abdullah *et al*., 2008).

Biochar can increase crop growth and productivity (Spokas *et al*., 2010) Spike length, plant height and tillers also increase with increase of chemical fertilizers but upto a limit (Hussain *et al.,* 2006; Asai *et al.,* 2009). Biochar also can significantly increase crop growth and productivity (Spokas *et al*., 2010).

Maize grain yield was reported to be doubled when plots were amended with a combination of biochar and NPK fertilizer compared with NPK fertilizer alone (Steiner *et al*., 2007). Biochar addition may also increase biomass of crops (Van-Zwieten *et al*., 2007). Nitrogen fertilizer and biochar together can increase the wheat biomass and grain yield (Ayub *et al*., 2002; Blackwell *et al*., 2010; Solaiman *et al*., 2010). In a field study, biochar amended plots receiving NPK fertilizers sustained higher crop yield compared with control plots (Steiner *et al*., 2008). In another study in Australian semiarid soils, positive significant effect on plant growth was observed by the use of biochar and fertilizer (Chen *et al*., 2007). Biochar amendment increased grain yield up to 91% and biomass yield up to 44% than control (Oguntunde *et al*., 2004). The effects of biochar-amended soil on wheat production were also evaluated. Biochar applied at a rate of 6 t ha^{-1} with half the recommended rate of soluble fertilizer increased yields of wheat by 18% over the control (Solaiman *et al*., 2010). Wheat grown with mineral fertilizer and 1.5 t ha^{-1} biochar increased grain yield by 46% over the control (Blackwell *et al*., 2010).

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