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

Running title: Effect of biochar and fertilizer on soil

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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 crumping, 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 & 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.

Key words: Biochar, Soil organic matter, Wheat, Natural Conditions

Introduction

Heavy metal deposition in plant and soils could be attributed to the municipal wastes, industrial effluents and also wax layer characteristics on the leaf (Khalil et al., 2011; Murtaza et al., 2003). However most of heavy metal toxicity to plants is attributed by soils (Younis et al., 2015). High metal concentrations plant toxicity can result in disturbing metabolism and photosynthesis (Zhao & Bi, 1999)

Soil organic matter (SOM) have significant effect on soil physico-chemical health, sequestration of carbon, controlling land erosion and protecting land from degradation (Galantini & Rossel, 2005). Soil microbial biomass carbon (SMBC), microbial activity and mineral transport are significantly affected by SOM (Carter et al., 1991). 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 & 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

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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 & Xu, 2009).

Biochar application on 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 effect 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).

Wheat (*Triticum aestivum* L.) is a major cereal crop and staple food in Pakistan. Wheat has the prime importance in all agricultural policies of the government. It contributes around 10.1% value addition in agriculture with 2.2% share in GDP of Pakistan (Economic survey of Pakistan, 2015). 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 well-drained hafizabad loam, mixed, semi-active, iso-hyperthermic typic calciargids having pH value of 7.8.

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 pottasium was referred as F_4. Recommended rate of biochar was 12 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 50 kg per acre in each experimental unit. Recommended cultural and plant protection measures were adopted. The crop was grown up to maturity and the following parameters were recorded.

Biochar production

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 2 mm sieve and stored in plastic bags.

Physicochemical characterization of Biochar

The pH and electrical conductivity (EC) of biochar in distilled water (1:20, w/v) was measured by the use of pH and EC meters. Ash contents were determined according to D-3173 method (ASTM, 2006). For this purpose, soil sample (1.0 g) added in the ceramic crucible and spread evenly. The oven was run at the rate of 5 K / min to 106 °C to constant mass. Then temperature was increased with 5 K / min to 550 °C. This temperature was hold for 30 minute till constant mass. The ash content was determined by the formula:

$$\% \text{ Ash} = \frac{\text{Weight}_{\text{crucible + ash}} - \text{Weight}_{\text{crucible}}}{\text{Oven Dry Weight}} \times 100$$

A Vario Micro Cube Elemental Analyzer was used for carbon, hydrogen and nitrogen (CHN) analysis. Soil sample (100 mg) of the pre-dried and crushed sample was weighed directly (relative precision 0.1%) into a tin capsule. After that the capsule was closed and put in the machine for measurement. The CHN analyzer determines the carbon content, the hydrogen content and the nitrogen content in mass percent (ASTM, 2006). Phosphorus in the biochar sample was determined by colorimetric method. Spectrophotometer was used for analysis. Amount of light absorbed by the solution at wavelength 410 nm was measured and compared with standard curve (Olsen & Sommers, 1982). Potassium was determined using flame photometer. For that a series of standards of KCl were prepared and standard curve was drawn. Flame photometer reading was compared with standard curve graph and potassium was determined (Richards, 1954). Cation exchange capacity (CEC) was determined by saturating biochar (4g) with 1 N solution of CH_3COONa (pH 8.2). Afterwards, it was washed thrice with ethanol and finally extracted with 1 N solution of CH_3COONH_4 (pH 7.0). Sodium in the extract was determined with the help of PFP-7 flame photometer using Na^+ filter (Rhoades, 1982; Richards, 1954). The CEC was calculated from following formula:

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

Bulk density of biochar was determined by core sampler's method as described by (Blake & Hartage, 1986). The core sampler was filled and pressed with sample. Volume of the sample was determined after 10 times compression by means of falling. Lid of core was

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closed carefully. Biochar was oven dried at 105^{o}C to a constant weight, cooled and weighed. Biochar volume was then taken equal to inner volume of the core sampler ($\pi r^2 h$).

$$\text{Bulk density} = \frac{\text{(Mass of oven dried Biochar)}}{\text{(Volume of Biochar including pore spaces)}}$$

Biochars particle density was determined by using pycnometer method (Blake, 1965). A known mass of biochar was put into 100 ml volumetric flask which was then placed into the pycnometer. After that we poured the water into the pycnometer up to the mark. Known mass of water (equal to the volume of the water) was poured into the flask. Biochar partial volume was determined by subtracting the volume of the water poured from 100 ml.

$$\text{Particle density} = \frac{\text{(Mass of oven dried Biochar)}}{\text{(Volume of Biochar excluding pore spaces)}}$$

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 2 mm sieve in the laboratory for physio-chemical analysis.

Soil analysis

Soil bulk density, particle density and CEC was determined as for measuring biochar bulk density, particle density and CEC analysis. Soil porosity (%) was calculated by using the following formula (Blake & Hartage, 1986).

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

Soil organic carbon was determined at up to 30 cm depths by titration method following the method described by (Ryan et al., 2001). Soil pH and EC was determined by pH meter and EC (dS m^{-1}) was measured by using Jenway Conductivity meter Model-4070 (Mckeague, 1978; Mclean, 1982). Formula for determination of EC is given below:

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

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 CO2 evolved was measured by titrating the NaOH solution against standard HCl solution. The amount of mineral N was also measured both in fumigated and unfumigated samples. The amount of MBC and MBN were calculated as described by (Shah et al., 2010)

Plant sampling and analysis

Plant height, spike length, number of tillers, number of spikelets, biomass yield, grain weight and harvest index were measured from an area of 1 x 1 m^2. At maturity, wheat was harvested from an area of 1 x 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

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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

Different parameters of biochar and soil without biochar before starting the experiment are given in table 1 and table 2.

Soil pH

Soil pH was significantly different among soil samples of different treatments. Highest soil pH (8.06±0.01) was found in the experimental unit having B_1F_2 treatment while the lowest was found in B_0F_4i.e. 7.59±0.02 (P=0.004, F=7.73, DF=24) (Table 3).

Electrical Conductivity

Similarly, soil EC also varied significantly in soil samples obtained from different treatments. Highest EC i.e. 0.52±0.02 dSm^{-1} was found in B_1F_1 and the lowest was in B_0 F_1 viz. 0.29±0.00 dSm^{-1} (P=0.00, F=47.79, DF=24) (Table 3).

Cation exchange capacity

Regarding cation exchange capacity (CEC), a bell shaped trend was observed i.e. increase in value to optimum and then decline. 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_3 i.e. 17.27±0.01 $cmol_c$ kg^{-1} (P=0.04, F=1.02, DF=24) (Table 3).

Organic matter

Organic matter contents were directly proportional with the amount of biochar while inversely proportional to the amount of fertilizer. Highest organic matter contents (1.07±0.02%)

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were calculated from the treatment receiving biochar amendments alone i.e. B_0F_1 and lowest organic matter contents (0.58±0.01%) were found in B_0F_4 (P=0.00, F=155.34, DF=24) (Table 3).

Soil microbial biomass carbon

The SMBC was directly proportional to the amount of fertilizer and biochar. 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 3).

Soil microbial biomass nitrogen

The SMBN was directly proportional to the amount of biochar (only). Highest SMBN calculated was in treatment B_1F_1 i.e. 77.17±0.26 mg/kg and lowest SMBN was in B_0F_0 i.e. 44.13±0.42 mg/kg (P=0.00, F=96.19, DF=24) (Table 3).

Plant height

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) (Table 4).

Spike length

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 cm m^{-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) (Table 4).

Number of tillers

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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 4).

Number of spikelets

Though numbers of spikelets were directly proportional to combined treatment of biochar and fertilizer but upto an extent. Highest number of spikelets 27.07±0.42 m^{-2} were recorded in B_1F_3 while the minimum number of spikelets 20.125±0.43 m^{-2} were found in B_0F_1 (P=0.00, F=11.64, DF=24) (Table 4).

Biomass yield

A trend similar to plant height 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) (Table 4).

Grain weight

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

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 4).

Discussion

Biochar addition may cause significant decrease in bulk density (Laird et al., 2010; Jones et al., 2010; Chen et al., 2011). This decreased bulk density may improve porosity and soil water holding capacity (Briggs et al., 2005). Biochar application can significantly enhance the soil meso-porosity at the expense of macro porosity in soil (Jones et al., 2010).

Many researchers had reported increase in soil pH due to biochar introduction (Laird et al., 2010; Peng et al., 2011). Increase in pH increase not only improve soil health but also improve plant growth due to higher availability of nutrients (Brady & Weil, 2008).

It was observed that with the aging of biochar soil EC improves and it decreases with time. Application of biochar with high ash content increase soil EC (Renner, 2007).

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).

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, 2003). 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).

A cumulative application of biochar and inorganic fertilizer is more effective for beneficial microbes in soil (Wardle et al., 2008; Brunn et al., 2011).

Plant height may increase due to more phosphorus availability, enhanced root growth and increased nutrient adsorption (Hussain 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). 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).

References

Abdullah GH, Khan IA, Khan SA, Ali H. 2008. Impact of planting methods and herbicides on weed biomass and some agronomic traits of maize. *Pakistan* Journal of *Weed Science* Research **14**:121-130.

Analytical software. 2005. Statistix 8.1 for windows Tallahassee, Florida: Analytical Software.

Anderson CR, Condron LM, Clough TJ, Fiers M, Stewart A, Hill RA, Sherlock, RR. 2011. Biochar induced soil microbial community change: Implications for biogeochemical cycling of carbon, nitrogen and phosphorus. *Pedobiologia* **54**:309-320.

Asai H, Samson BK, Stephan HM, Songyikhangsuthor K, Homma K, Kiyono Y, Inoue Y, Shiraiwa T, Horie T. 2009. Biochar amendment techniques for upland rice production in Northern Laos: 1. Soil physical properties, leaf SPAD and grain yield. *Field Crops Research* **111**:81-84.

ASTM. 2006. Petroleum Products, Lubricants, and Fossil Fuels: Gaseous Fuels; Coal and Coke. ASTM Inter, West Conshohocken, PA.

Ayub M, Nadeem MA, Shara MS, Mahmood N. 2002. Response of maize (*Zea mays* L) fodder to different levels of nitrogen and phosphorus. Asian. *Journal of Plant Sciences* **1**:352-354.

Balesdent J, Besnard E, Arrouays D, Chenu C. 1998. The dynamics of carbon inparticle size fractions of soil in a forest-cultivation sequence. *Plant and Soil* **201**:49-57.

Balota EL, Colozzi A, Andrade DS, Dick RP. 2004. Long-term tillage and crop rotation effects on microbial biomass and C and N mineralization in a Brazilian Oxisol. *Soil and Tillage Research* **77**:137-145.

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Belay-Tedla A, Zhou X, Su B, Wan SQ, Luo YQ. 2009. Labile recalcitrant and microbial carbon and nitrogen pools of a tall grass prairie soil in the US Great Plains subjected to experimental warming and clipping. *Soil Biology and Biochemistry* **41**:110-116.

Blackwell P, Krull E, Butler G, Herbert A, Solaiman Z. 2010. Effect of banded biochar on dry land wheat production and fertilizer use in south-western Australia. *Soil Research* **48**:531-545.

Blake GR, Hartage KH. 1986. Bulk density. In: Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. A. Klute (Ed.) Agronomy Monograph No. 9, 2nd Ed., Madison, WI, USA. 363-375.

Blake GR. 1965. Particle density: In Methods of Soil Analysis, Part I, Agronomy, No. 9, C.A. Black (ed.), American Society of Agronomy Madison, Wise, 371-373.

Brady NC, Weil RR. 2008. The Nature and Properties of Soils, 14th edition Pearson Prentice Hall.

Briggs CM, Breiner JM, Graham RC. 2005. Contributions of Pinus Ponderosa Charcoal to Soil Chemical and Physical Properties. In the ASACSSA-SSSA International Annual Meetings Salt Lake City, USA.

Brookes PC, Landman A, Pruden G, Jenkinson DS. 1985. Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method to measure microbial biomass nitrogen in soil. *Soil Biology and Biochemistry*. **17**:837-842.

Brown RC. 2009. Biochar production technology. Centre for sustainable environment Technical Department of Mechanical Engineering. M.S. Thesis, Iowa State University USA.

Brunn WE, Ambus P, Egsgaard H, Nielsen HH. 2012. Effects of slow and fast pyrolysis biochar on soil C and N turnover. *Soil Biology and Biochemistry* **46**:73-79.

Carter MR. 1999. Ninhydrin-reactive N released by the fumigation-extraction method as a measure of microbial biomass under field conditions. *Soil Biology and Biochemistry* **23**:139-143.

Chen HX, Du ZL, Guo W, Zhang Q. 2011. Effects of biochar amendment on cropland soil bulk density, cation exchange capacity, and particulate organic matter content in the North China. *Chinese* Journal of *Applied Ecology* **22**:2930-2934.

Chen KY, Van ZL, Meszaros I, Downie A, Joseph S. 2007. Agronomic values of green waste biochar as a soil amendment. *Australian Journal of Soil Research* **45**:629-634.

Cheng CH, Lehmann J, Thies JE, Burton SD, Engelhard MH. 2006. Oxidation of black carbon by biotic and abiotic processes. *Organic Geochemistry* **37**:1477-1488.

Deluca TH, MacKenzie MD, Gundale MJ. 2009. Biochar effects on soil nutrient transformations. In: Lehmann, J. and Joseph, S. (Eds), Biochar for Environmental Management. Earthscan, London 251-270.

Galantini J, Rosell R. 2005. Long term fertilization effects on soil organic matter quality and dynamics under different production systems in semiarid pampean soils. *Soil Tillage Research* **87**:72-79.

Haron K, Brookes PC, Anderson JM, Zakaria ZZ. 1997. Microbial biomass and soil organic matter dynamics in oil palm plantations, west Malaysia. *Soil Biology and Biochemistry* **30**:547-552.

Hussain N, Khan AZ, Akbar H., Akhtar S. 2006. Growth factors and yield of maize as influenced by phosphorus and potash fertilization. *Sarhad Journal of Agriculture* **22**:579-583

Jeffery S, Bezemer TM, Cornelissen G. 2013. The way forward in biochar research: targeting trade-offs between the potential wins. *Global Change Biology and Bioenergy* **98**:1011–1213.

Jones BEH, Haynes RJ, Phillips IR. 2010. Effect of amendment of bauxite processing sand with organic materials on its chemical, physical and microbial properties. *Journal* of *Environmental Management* **91**:2281-2288.

Khalil S, Kakar MK. 2011. Agricultural use of untreated urban wastewater in Pakistan. Asian *Journal of Agriculture and Rural Development* **1**:21-26.

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Kumar S, Masto RE, Ram LC, Sarkar P, George J, Selvi VA. 2013. Biochar preparation from parthenium hysterophorus and its potential use in soil application. *Ecological Engineering* **55**: 67-72.

Laird DA, Fleming F, Davis DD, Horton R, Wang BQ, Karlen DL. 2010. Impact of biochar amendments on the quality of a typical midwestern agricultural soil. *Geoderma*. **158**:443-449.

Lal R. 2006. Enhancing crop yields in the developing countries through restoration of soil organic carbon pool in agricultural lands. *Land Degradation and Development*. **17**:197–209.

Lehmann J, Joseph S. 2009. Biochar for environmental management: science and technology, Earthscan, London.

Liu E, Yan C, Mei X, He W, Bing SH, Ding L, Liu S, Fan T. 2010. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*. **158**:173-180.

Mckeague JA. 1978. Manual on soil sampling and methods of analysis. 2nd ed. Canadian Society of Soil Science, AAFC, Ottawa, Ontario, Canada.

Mclean, EO. 1982. Soil pH and lime requirement. In A.L. Page (ed.), Method of soil analysis, Part 2: chemical and microbiological properties. *American Society of Agronomy* Madison, WI, USA.199-224.

Murtaza G, Ghafoor A, Qadir M, Rashid MK. 2003. Accumulation and bioavailability of Cd, Co and Mn in soils and vegetables irrigated with city effluent. *Pakistan Journal of Agricultural Sciences* **40**:18-24.

Novak JM, Busscher WJ, Laird DL, Ahmedna M, Watts DW, Niandou MAS. 2009. Impact of Biochar Amendment on Fertility of a Southeastern Coastal Plain Soil. *Soil Science* **174**:105-112.

Olsen SR, Sommers LE. Phosphorus. 1982. In A.L. Page (ed.). Methods of soil analysis, Agron. No. 9, Part 2: Chemical and microbiological properties, 2nd ed., American Society of Agronomy, Madison, WI, USA 403-430.

Pakistan Economic Survey. 2015. Ministry of Finance, Agriculture and Livestock, Federal Bureau of Statistics, Islamabad, Pakistan.

Peng X, Ye LL, Wang CH, Zhou H, Sun B. 2011. Temperature and duration dependent rice straw derived biochar: Characteristics and its effect on soil properties of an ultisol in southern China. *Soil Tillage Research* **112**:159-166.

Renner R. 2007. Rethinking biochar. *Environmental Science and Technology* **41**:5932-5933.

Rhoades, JD. 1982. Cation exchange capacity. In A.L. Page (ed.). Methods of soil analysis, Agron. No. 9, Part 2: Chemical and microbiological properties. American Society of Agronomy Madison, WI, USA, 149-157.

Richards LA. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook 60. Washington, DC.

Ryan J, Estefan G, Rashid A. 2001. Soil and Plant Analysis Laboratory Manual. 2nd Ed. International Center for Agricultural Research in the Dry Areas (ICARDA). Alleppo, Syria. 46–48.

Shah Z, Ahmad RS, Rahman HU. 2010. Soil microbial biomass and activities as influenced by green manure legumes and N fertilizer in rice–wheat system. *Pakistan Journal of Botany* **42**:2589–2598.

Solaiman ZM, Blackwell P, Abbott LK, Storer P. 2010. Direct and residual effect of biochar application on mycorrhizal root colonisation, growth and nutrition of wheat. *Australian Journal of Soil Research* **48**:546–554.

Spokas KA, Baker, JM, Reicosky DC. 2010. Ethylene: potential key for biochar amendment impacts. *Plant and Soil* **333**:443–452.

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Strong DT, Sale PWG, Helyar KR. 1998. The influence of the soil matrix on nitrogen mineralisation and nitrification. The pore system as a framework for mapping the organisation of the soil matrix. *Australian Journal of Soil Research* 36: 855–872.

Van Zwieten L, Chan KY, Meszaros I, Downie A, Joseph S. 2007. Agronomic values of greenwaste biochar as a soil amendment. *Australian Journal of Soil Research* **45**:629.

Vance ED, Brookes PC, Jenkinson DS. 1987. An extraction method for measuring soil microbial biomass C. *Soil Biology and Biochemistry* 19: 703–707.

Wardle DA, Nilsson MC, Zackrisson O. 2008. Fire-derived charcoal causes loss of forest humus. *Science* **320**:629.

Woolf D, Amonette J, Perrott FAS, Lehmann J, Joseph S. 2010. Sustainable biochar to mitigate global climate change. *Nature Communications* **1**:1–9.

Yamato M, Okimori Y, Wibowo IF, Anshori S, Ogawa M. 2006. Effects of the application of charred bark of *Acacia mangium* on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. *Soil Science* and *Plant Nutrition* **52**:489–495.

Yin C, Xu KZ, 2009. Biochar: nutrient properties and their enhancement. In: Lehmann, J, Joseph S. (Eds.). Biochar for Environmental Management. Earthscan, USA.

Younis U, Qayyum MF, Shah M, Danish S, Shahzad AN, Malik SA, Mahmood S. 2015. Growth survival and heavy metal (Cd and Ni) uptake of spinach (Spinacia oleracea) and fenugreek (Trigonella corniculata) in a biochar-amended sewage irrigated contaminated soil. *Journal* of *Plant Nutrition* and *Soil Science* **178**:209−217.

Zhao B, Bi H. 1999. Research advances on toxicology of heavy metals in plant cells. J Zibo University **1**:86-88.

Zimmerman AR, Gao B, Ahn MY. 2011. Positive and negative carbon mineralization priming effects among a variety of biochar-amended soils. *Soil Biology and Biochemistry* **4**:1169-1179.

Table 1. Analysis of different parameters of biochar

Biochar parameter	UNIT	VALUE
pH	-	8.85
EC	dS m^{-1}	0.738
CEC	$cmol_c$ kg^{-1}	132.8
Bulk density (ρ_b)	Mg m^{-3}	0.38
Particle density (ρ_p)	Mg m^{-3}	1.58
Porosity	%	75.95
Ash contents	%	27.2
Total carbon	%	49.71
Total hydrogen	%	8.05
Total nitrogen	g kg^{-1}	1.03
Total phosphorus	g kg^{-1}	2.06
Total potassium	g kg^{-1}	9.21

Table 2. Pre soil analysis of different soil parameters

Soil parameter	UNIT	VALUE
Texture class	-	Loam
Bulk density (ρ_b)	Mg m^{-3}	1.42
Particle density (ρ_p)	Mg m^{-3}	2.61
Porosity	%	45.59
pH	-	7.83
EC	dS m^{-1}	0.41
CEC	$cmol_c$ kg^{-1}	17.30
Organic matter	%	0.69
Soil Microbial Biomass carbon	mg kg^{-1}	136.6
Soil Microbial Biomass nitrogen	mg kg^{-1}	44.13

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

Sr. No.	Treatments	Soil chemical parameters					
		Organic matter (%)	Soil microbial biomass carbon mg/kg	Soil microbial biomass nitrogen mg/kg	CEC $cmol_c\ kg^{-1}$	pH	EC dSm^{-1}
1	B_0 F_1	0.65±0.03fg	138.85±0.61h	58.13±0.43e	17.35±0.01c	7.70±0.02c	0.29±0.00f
2	B_0 F_2	0.64±0.02gh	157.15±0.86g	63.12±0.44d	17.34±0.00c	7.67±0.02bc	0.37±0.01d
3	B_0 F_3	0.62±0.03h	167.75±0.91f	49.14±0.40h	17.27±0.01c	7.61±0.02b	0.34±0.02e
4	B_0 F_4	0.58±0.01h	170.88±0.82e	51.12±0.46g	19.03±0.01b	7.59±0.02bc	0.38±0.01b
5	B_1 F_0	1.07±0.02a	230.20±0.82d	53.75±0.32f	24.20±0.01a	7.89±0.01bc	0.48±0.02b
6	B_1 F_1	0.98±0.01b	235.20±0.77c	77.17±0.26a	24.02±0.01a	7.99±0.02ab	0.52±0.01d
7	B_1 F_2	0.88±0.01c	238.93±0.69b	75.05±0.21b	24.26±0.04a	8.06±0.01a	0.38±0.02d
8	B_1 F_3	0.76±0.02d	240.80±0.66b	68.07±0.22c	24.05±0.04a	7.97±0.02ab	0.37±0.03d
9	B_1 F_4	0.72±0.03e	245.20±0.38a	64.08±0.22d	24.08±0.03a	7.93±0.11b	0.39±0.02a
10	B_0 F_0	0.69±0.01f	136.63±0.82i	44.13±0.42i	17.30±0.04c	7.87±0.04bc	0.41±0.00c

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

Table 4. Different agronomic parameters recorded at different combined applications of chemical fertilizers and biochar

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

Sr. No.	Treatments	Agronomic parameters						
		Plant Height cm	Spike Length	No of Tillers	Spikelets (S)	Biomass Yield	Grain Weight	Harvest Index
1	B_0 F_1	99.35±1.65c*	8.12±0.42d	419.95±0.51h	20.125±0.43g	9.80±0.42h	2.66±0.12gh	0.27±0.01b
2	B_0 F_2	101.18±1.06bc	9.22±0.41c	458.58±0.93g	21.45±0.41f	10.65±0.41g	2.85±0.04f	0.27±0.02b
3	B_0 F_3	105.63±1.02am	9.01±0.41c	484.38±0.84f	23.10±0.42de	11.37±0.39f	3.05±0.04e	0.26±0.03c
4	B_0 F_4	99.63±2.02c	9.03±0.41c	512.23±0.45d	24.45±0.41c	13.27±0.40c	3.29±0.04d	0.25±0.02e
5	B_1 F_0	101.73±0.73bc	8.35±0.45bc	512.13±0.44d	26.05±0.39ab	13.72±0.41b	3.52±0.04c	0.26±0.02d
6	B_1 F_1	104.65±1.34ab	10.17±0.42b	496.50±0.45e	22.02±0.40ef	12.15±0.41e	3.28±0.04d	0.27±0.03bc
7	B_1 F_2	107.75±1.44a	10.65±0.18a	592.13±0.45a	24.05±0.45cd	13.13±0.41c	3.58±0.04b	0.32±0.02a
8	B_1 F_3	107.65±1.79a	10.5±0.45a	540.13±0.45c	27.07±0.42a	14.65±0.40a	3.68±0.05a	0.32±0.04a
9	B_1 F_4	105.10±0.72ab	8.47±0.12d	516.23±0.45d	25.07±0.47bc	12.72±0.42d	2.77±0.04h	0.20±0.03g
10	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	0.21±0.04f