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Full Length Article

Biochar Reduced Cadmium Uptake and Enhanced Wheat Productivity in Alkaline Contaminated Soil

Muhammad Ijaz[1], Muhammad Shahid Rizwan[2*], Muhammad Sarfraz[1], Sami Ul-Allah[1*], Ahmad Sher[1], Abdul Sattar[1], Liaqat Ali[2], Allah Ditta[3,4] and Balal Yousaf[5]
[1]*College of Agriculture, Bahadur sub Campus Layyah, Bahauddin Zakariya University (31200), Multan, Pakistan*
[2]*Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur (63100), Pakistan*
[3]*Department of Environmental Sciences, Shaheed Benazir Bhutto University, Sheringal, Dir (U), Khyber Pakhtunkhwa, 18000, Pakistan*
[4]*School of Biological Sciences, The University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia*
[5]*Key Laboratory of Crust-Mantle Materials and the Environments, School of Earth and Space Sciences, University of Science and Technology of China, Hefei 230026, P.R. China*
[*]For correspondence: samipbg@bzu.edu.pk; shahid.hzau@yahoo.com
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Abstract

Cadmium (Cd) is a toxic heavy metal present in the environment which causes severe environmental, nutritional, and ecological losses. A pot incubation study was conducted to assess the role of biochar derived from various organic feedstock's [poultry manure (PM), farmyard manure (FYM) and sugarcane press mud (PS)] and dosages (0, 2.5 and 5 g kg^{-1} soil of each) to immobilize Cd (5 mg kg^{-1}) in Cd polluted soil. Moreover, impact of applied biochar to reduce the bioavailability of Cd in wheat tissues and to improve wheat growth and yield was also observed. Among all type of applied biochar, application of farmyard manure (FYM) derived biochar improved tillers population (77%), chlorophyll SPAD value (74%), plant height (69), grains yield (77%) and biological yield (82%) of wheat. Moreover, FYM derived biochar lowered the Cd uptake and its translocation from roots (71–92%) shoots (82–92%), and grains (90–96%) as compared with control. While in Cd-contaminated soil without biochar application, the Cd concentration in roots, shoots and grains were 1.4, 1.14 and 0.9 mg kg^{-1} of dry matter, respectively. Overall, FYM derived biochar, applied at 5 g kg^{-1} of soil performed better in reducing the Cd toxicities in soil (0.12 mg kg^{-1}) and wheat roots (0.13 mg kg^{-1}), shoots (0.1 mg kg^{-1}) and grains (0.03 mg kg^{-1}) along with higher wheat yield in Cd polluted soil. In conclusion, FYM derived biochar has the potential to remediate Cd toxicities in alkaline polluted soil.

Keywords: Cadmium; Biochar; Farm yard manure; Wheat; Pollution

Introduction

The problem of soil pollution with toxic heavy metals has enormously increased which pose several environmental and health issues. Heavy metals are accrued in soils by natural and anthropogenic sources such as mining activities, weathering, domestic and industrial effluents and frequent use of fertilizers and pesticides in agriculture (Moon *et al.* 2013). Mostly, the heavy metals are non-biodegradable in nature and their occurrence in the environment and ecosystem is a main concern for healthy and safe environment (Qadir *et al.* 2013).

Cadmium (Cd) is non-essential, trace, toxic heavy metal and is hazardous at < 1 mg kg^{-1} soil (WHO 2000). It is gradually accumulated in plants' edible and non-edible parts and continuous exposure can cause various acute and chronic health problems such as kidney, prostate diseases, lungs cancer and can damage the pulmonary and skeletal system in humans (IARC 2012). The toxicity of Cd in soil also has detrimental effects on plant yield due to decreased germination and plant growth and development (Hassan *et al.* 2016; Naeem *et al.* 2016). The plants uptake Cd with uptake of minerals nutrition's and Cd translocation in plants tissues results in chlorosis and necrosis of leaves, inhibition of photosynthetic pigments, ultimately resulting in stunted plant growth and reduced food quality (Metwally *et al.* 2005). Cadmium stress may also severely affect the chlorophyll and carotenoid contents (Chen *et al.* 2014), transpiration rate, and stomatal conductance in plants (Shafi *et al.* 2011).

To overcome the hazards of the heavy metal toxicities in environment, various strategies have been adopted including the inorganic and organic soil additives (Yousaf *et al.* 2016). Among the organic soil amendments, biochar is

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carbon rich organic soil amendment (Wardle *et al.* 2008; Farooq *et al.* 2020a). In a study, application of biochar to low fertile sandy soil enhanced the soil carbon (7–11%), phosphorus 68–70% and potassium 37–42%, in comparison with control (no biochar addition) (Laghari *et al.* 2015). In another study, wheat straw derived biochar greatly promoted the nitrogen, phosphorus and potassium availability in poor fertile acidic soil (Zhang *et al.* 2017). Mostly, the biochar has high pH, cation exchange capacity (CEC) and had more surface area and comprises of well-designed structures of micro-porous and active efficient functional groups (Rajapaksha *et al.* 2016; Hussain *et al*. 2017). Biochar could be more useful for long term carbon sequestration in soil (Yousaf *et al.* 2016). Moreover, biochar improves the soil health, physical and chemical properties, soil fertility and nutrient retention by adding potassium, sodium, magnesium and calcium for plants (Hussain *et al*. 2017; El-Naggar *et al*. 2019; Minhas *et al*. 2020). Biochar has capacity to remediate metals toxicities from soil and reduce their uptake and translocation in plants (Lu *et al.* 2014). The addition of biochar works as pollutant premeditator in heavy metals contaminated soil (Park *et al.* 2011) and remediate the metal toxicity form soil particles by raising soil pH (Zeng *et al.* 2011).

Addition of biochar reduces the metal mobility by reducing metals phytotoxicities and translocation in plants grown in polluted soil (Lu *et al.* 2014; Hussain *et al*. 2017). In a study, the addition of rice (*Oryza sativa* L.) straw and bamboo derived biochar induced the Cu, Zn, Pb and Cd immobilization in polluted soil by reducing heavy metals uptake in plants (Lu *et al.* 2017). Addition of biochar potentially reduces the Cd bioavailability in wheat as compared to farmyard manure, compost and press mud (Yousaf *et al.* 2016). The maximum Cd reduction (< 0.2 mg kg^{-1}) in plants edible parts is compulsory for safe food production in polluted soil (Rizwan *et al*. 2016a) to ensure healthy human life. Biochar has potential to reduce the hazards of Cd toxicities in plants including rice (Bian *et al.* 2013), rapeseed *(Brassica napus* L.*)* (Shaheen and Rinklebe 2015), wheat (Yousaf *et al.* 2016) and spinach (*Spinacia oleracea* L.) (Younis *et al.* 2016). The maximum reduction of Cd toxicity in various parts of plants due to lowered Cd concentration in pore water or induced Cd binding with organic matter after biochar addition (Lu *et al*. 2017).

Worldwide, bread wheat (*Triticum aestivum* L.) is widely cultivated food crop with annual yield of almost 761 million tons (FAO 2020). Wheat occupying central position in Pakistan agriculture and have significant place among cereals. The plants mostly uptake metals through roots and then translocated towards shoots and grains (Naeem *et al.* 2016). The excess of Cd decreases the plant growth and development by disturbing the photosynthesis process and interrupt mineral nutrition's in wheat (Rizwan *et al.* 2016a). Therefore, it is important to find out eco-friendly, cheap, and effective alternatives to remediate the Cd toxicity in polluted soils for the successful and safe cultivation of food crops on sustainable basis. Previously, a limited work has been reported to compare the efficiency of biochar produced from various feedstocks to immobilize Cd in alkaline polluted soil by reducing metal phytotoxicity in wheat. For this study, we hypothesized that biochar may enhance wheat growth and yield by reducing Cd hazards in polluted alkaline soil. The specific objective of this study was to evaluate the relative amendment impact of applied biochar for Cd immobilization in contaminated soil and its impact of wheat growth and yield.

Materials and Methods

Soil collection and analysis

The cultivated soil was collected (0–20 cm) from Experimental Research area of College of Agriculture, Bahadur Sub-Campus Layyah of Bahauddin Zakariya University Multan, Pakistan. The soil was air dried, crushed and sieved (2 mm) and then was brought to laboratory for further analysis. The physio-chemical characteristics of tested soil are presented in Table 1. The soil texture and organic matter were measured by Hydrometer method (Day 1965) and Walky and Black method (Walkely and Black 1934), respectively. Soil pH and electrical conductivity (EC) were analyzed with pH meter (PHS-1701, China) and EC meter (CD-350, China) by using soil to water ratio of 1:1 (*w/w*). Moreover, soil nitrogen, available potassium and phosphorus were measured and values are described in Table 1.

Preparation of biochar

Feedstock's, poultry manure, sugarcane press mud, and farmyard manure, were chosen for biochar preparation on their extensive availability. Sugarcane press mud was obtained from nearby Layyah Sugar Mills Limited Layyah, while the poultry manure and farmyard manure were obtained from suburb of Layyah city, Pakistan. No special approval was required to collect experimental material and to conduct experiment. All soil amendments were individually managed during shade drying and handling. Before biochar preparation, Cd contents were analyzed from each feedstock. Briefly, 0.5 g of each feed stock was added di-acids mixture H_2SO_4–H_2O_2 and stay overnight in fume hood. The samples were digested on hotplate until clear liquor obtained and then filtered and diluted with distilled water. The prepared samples were analyzed for Cd determination by using atomic absorption spectrophotometer (Agilent AA-240FS Varian, U.S.A.). The obtained Cd values from each feedstock's were found to be safe (Cd < 0.001 mg kg^{-1}) for experimental use. Biochar was prepared by pyrolysis of each feedstock under minimal oxygen condition according to methods detailed in Rizwan *et al.* (2016b). Briefly, desired material (5 g) was placed in ceramic crucibles and covered with lid and placed in laboratory muffle furnace and temperature was adjusted to 400°C and pyrolysis for 4 h after constant temperature was obtained. The prepared biochar was grinded and sieved (2 mm) for experimental use. The pH of poultry manure derived biochar was 10.4, farmyard manure 10.8 and sugarcane press mud 10.2, while electrical conductivity of these biochar were 4.6, 4.9, and 4.5 ms cm^{-1}, respectively.

Pot experiment

The soil was synthetically polluted with Cd 5 mg kg^{-1} of soil (highly toxic) and applied by dissolving $CdNO_3.4H_2O$ in deionized water and then incubated for one month. The contaminated soil was amended with biochar derived from poultry manure (PM), farmyard manure (FYM) and sugarcane press mud (PS) with various levels and mixed thoroughly except control (only Cd contaminated soil) and further incubated for 60 days (60% moisture). The soil moisture contents were carefully maintained for each pot on weekly basis and the reduction of water difference was maintained by adding water to each pot according to the calculation (Reeuwijk 2002).

$$\text{Moisture \%} = \frac{\text{weight of fine earth} - \text{oven dried weight}}{\text{oven dried weight}} \times 100$$

Each earthen pot (40 cm × 20 cm) was filled with 5.5 kg of amended soil. The treatments were control (only Cd polluted soil), PM-5 (2.5 g kg^{-1}), PM-10 (5 g kg^{-1}), FYM-5 (2.5 g kg^{-1}), FYM-10 (5 g kg^{-1}), PS-5 (2.5 g kg^{-1}), PS-10 (5 g kg^{-1}). No amendment was applied in control treatment. The soil was contaminated with Cd on 15 August 2017 and after one month of contamination, biochar treatments were applied on 15 September 2017. After two months of biochar application, wheat seeds were sown on 16 November 2017. The experiment was arranged by following complete randomized design (CRD) and each treatment was replicated thrice. There were three pots in each replication. In each pot, ten wheat seeds of wheat cultivar Galaxy-13 were sown and after germination five plants were maintained in each pot. Recommended fertilizers nitrogen 90 mg kg^{-1}, phosphorus 81 mg kg^{-1}, and potassium 69 mg kg^{-1} per pots were applied from urea, di-ammonium phosphate and sulphate of potash, respectively in each pot (Agricultural Department Punjab, Pakistan www.agripunjab.gov.pk). The pots were placed in open environmental conditions. The pots were uniformly irrigated to avoid drought stress. The plants from each pot were harvested at maturity on May 01, 2018.

Agronomic traits

Chlorophyll contents (SPAD value) were recorded with SPAD meter (portable SPAD-502 Chlorophyll Meter (Minolta Co., Ltd.). The leaf area of flag leaf of mother tiller was measured with digital leaf area meter (JVC TK-5310). The numbers of tillers of each plant were manually counted and mean value of five plants was calculated. The plant height was manually calculated from soil surface to spike tip by scale rod.

The biological yield of harvested plants (averaged five plants) was measured using electric balance. From each pot the total numbers of grains per spike of all tillers were counted manually. Grains yield was determined after threshing the plants.

Plant and soil analysis

Soil sample from each pot was taken with hand steel auger. For separation of root, pots were irrigated overnight to make the soil soft and plants were uprooted along with soil then soil was removed by washing with distilled water. Harvested plants were further washed with distil water, dried under shade and oven dried at 110°C for 2–4 h. Plants roots, stems and grains were separately divided and crushed. The Cd contents in shoots, roots and grains were determined by following Parkinson and Allen (1975). Briefly, plant sample (0.5 g) was added di-acids mixture H_2SO_4–H_2O_2 and stay overnight in fume hood. Then, these samples were digested on hotplate until clear liquor obtained and then filtered and diluted with distilled water. The prepared samples were analyzed for Cd determination by using atomic absorption spectrophotometer (Agilent AA-240FS Varian, USA).

Statistical analysis

Experimental data were analyzed using 'Statistix 8.1' software. The analysis of variance and Tukey's HSD test was applied to check the significance of treatments and compare the means of treatments at 0.01% probability level, respectively (Steel *et al.* 1997).

Results

Analyses of variance showed significant ($P \leq 0.05$) effect of all biochar treatments on all plant and soil studied traits. Soil pH increased with addition of biochar to polluted soil (Fig. 1–3; Table 1–3) Among the applied biochar types, FYM derived biochar significantly enhanced the soil pH and values increased (7.8–15.7%) with increasing farmyard manure derived biochar addition to polluted soil as compare to control. The results highlighted that minimum soil pH was observed in control soil (Fig. 1). The addition of biochar enhanced the numbers of tillers per plants in polluted soil. Incorporation of FYM-5 and FYM-10 to polluted soil resulted in greater numbers of tiller (63.6–77%) in wheat as compared with control soil and the ratio of tillers was gradually increased with increasing addition of FYM derived biochar rate. While, the minimum increase in numbers of tillers per plants were noticed in control soil (Table 2).

Addition of biochar significantly increased the leaf

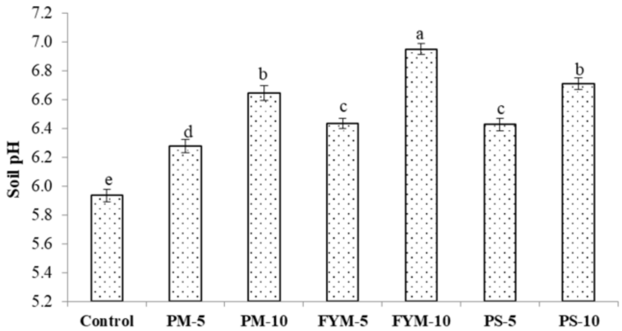

Fig. 1: Effect of biochar on pH of cadmium contaminated soil after crop harvest

Each value represents the mean of three replicates ± standard deviation and ($P < 0.01$)
Control= Cd-polluted soil; PM-5= Poultry manure biochar 2.5 g kg^{-1}; PM-10= Poultry manure biochar 5 g kg^{-1}; FYM-5= Farmyard manure biochar 2.5 g kg^{-1}; FYM-10= Farmyard manure biochar 5 g kg^{-1}; PS-5= Sugarcane press mud biochar 2.5 g kg^{-1}; PS-10= Sugarcane press mud biochar 5 g kg^{-1}

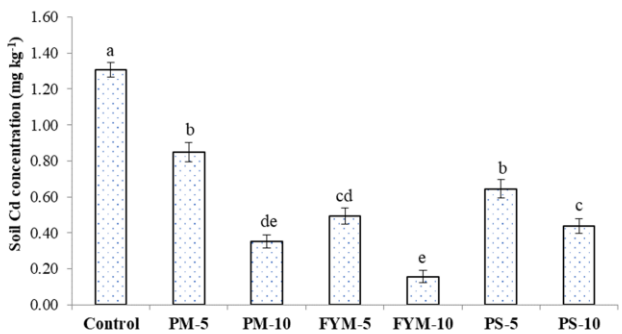

Fig. 2: Effect of biochar on cadmium (mg kg^{-1}) in contaminated soil after crop harvest

Each value represents the mean of three replicates ± standard deviation and ($P < 0.01$)
Control= Cd-polluted soil; PM-5= Poultry manure biochar 2.5 g kg^{-1}; PM-10= Poultry manure biochar 5 g kg^{-1}; FYM-5= Farmyard manure biochar 2.5 g kg^{-1}; FYM-10= Farmyard manure biochar 5 g kg^{-1}; PS-5= Sugarcane press mud biochar 2.5 g kg^{-1}; PS-10= Sugarcane press mud biochar 5 g kg^{-1}

area in Cd polluted soil as compared to control. Among all applied soil amendments, the maximum increase in leaf area was observed where farmyard manure derived biochar was applied. The leaf area increased from 18.7–23.3% for FYM5-10, and 62.4–79.6% for PS-5 and PS-10, as compared to control (Table 2). Wheat biomass was relatively increased with increasing biochar amount from 2.5 to 5 g kg^{-1} to Cd polluted soil as compared with control soil. Moreover, the biological yield was increased with addition of FYM 5–10 from 18.7–21.7%, 26.2–28.8% and 71.3–81.8% with respect to poultry manure and sugarcane press mud derived biochar and control soil, respectively. While, minimum biological yield was noticed in control where no soil amendment was applied (Table 2). Biochar addition enhanced the grains yield under Cd polluted soil in comparison with control. The significant increment in grains yield 61.2–77.5% was noted with addition of FYM derived biochar at 2.5 to 5 g kg^{-1} to polluted soil with respect to control soil.

The chlorophyll SPAD value in wheat plants were

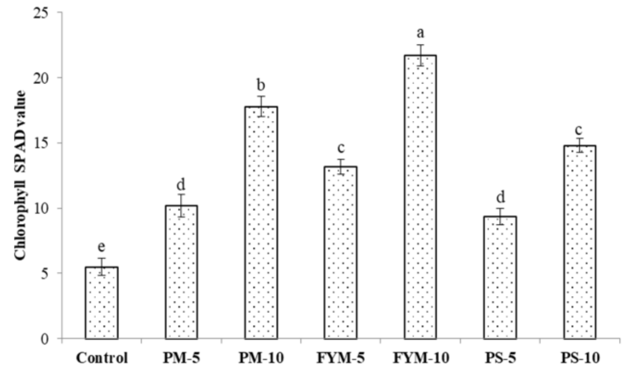

Fig. 3: Effect of biochar on chlorophyll SPAD value of wheat grown in cadmium contaminated soil after crop harvest

Each value represents the mean of three replicates ± standard deviation and ($P < 0.01$)
Control= Cd-polluted soil; PM-5= Poultry manure biochar 2.5 g kg^{-1}; PM-10= Poultry manure biochar 5 g kg^{-1}; FYM-5= Farmyard manure biochar 2.5 g kg^{-1}; FYM-10= Farmyard manure biochar 5 g kg^{-1}; PS-5= Sugarcane press mud biochar 2.5 g kg^{-1}; PS-10= Sugarcane press mud biochar 5 g kg^{-1}

considerably increased with addition of press mud, FYM derived biochar and poultry manure as compared to control (Fig. 3). Among all applied soil amendments, the addition of FYM 5-10 greatly improved the chlorophyll SPAD value by 28.8–31.8% as compared with plants grown in control soil; the lowest chlorophyll SPAD value was measured in control where no soil amendment was applied.

Cadmium concentration was affected by addition of poultry manure, FYM derived biochar and press mud to polluted soil and concentration reduced with increasing the amendment amount. The addition of FYM derived biochar to polluted soil reduced the Cd in soil (with FYM-5 and FYM-10 by 20.3–63.6 and 64.3–88.1%, respectively) after crop harvest as compared to control (Fig. 2).

The phytotoxicity of Cd in wheat was decreased with application of poultry manure, FYM derived biochar and press mud in alkaline contaminated soil (Table 3). Cadmium was more translocated in roots as followed by shoots and grains in alkaline polluted soil. Cd was reduced in roots with addition of biochar to polluted soil, and it was more effective and pronounced with addition of FYM derived biochar as compared with control and other treatments. As compared to control, addition of FYM-5 and FYM-10 greatly reduced Cd toxicities 72.9–90.5%, 91–104% and 83–89% from roots, shoots and grains of wheat, respectively.

The influence of biochar on soil N, P and K in Cd polluted soil after wheat harvesting was also observed (Table 4). The statistical analysis highlighted that addition of biochar positively influenced the soil N, P and K under Cd toxicity. The maximum nutrient retention was noted with addition of FYM derived biochar and values increased for N by 29.6–63.5%, for P by 57.5–72.5% and for K by 45.4–75.5% with increasing FYM derived biochar amount 2.5 to 5 g kg^{-1} as compared to control, respectively (Table 4). The results highlighted that minimum soil N, P and K

Table 1: Physiochemical characteristics of experimental soil

Parameter	Unit	Value
pH	-	7.3
Electrical conductivity	dS m^{-1}	3.7
Organic matter	%	0.67
Nitrogen	mg kg^{-1}	0.14
Phosphorous	mg kg^{-1}	7.7
Potassium	mg kg^{-1}	101
Sodium	mmole L^{-1}	0.4
Textural class		Sandy clay loam
Sand	%	66
Silt	%	02
Clay	%	32

Table 2: Effect of biochar on allometric traits and yield related parameters of wheat in cadmium contaminated soil

Treatments	Flag leaf area (cm^2)	Number of tillers (pot)	Plant height (cm)	Gains yield (g pot^{-1})	Biological yield (g pot^{-1})
Control	10.03E	6.06F	22.6E	4.9E	10.2E
PM-5	18.0D	13.9E	41.1D	10.03D	29.0D
PM-10	41.2B	22.0B	63.0B	17.2B	44.2B
FYM-5	26.7C	16.6D	48.7C	12.7C	35.7C
FYM-10	49.1A	27.0A	74.5A	21.9A	56.5A
PS-5	21.7D	11.6E	35.7D	8.7D	26.3D
PS-10	37.6B	19.3C	54.8C	14.6C	40.2BC

Each value represents the mean of three replicates ± standard deviation and ($P < 0.01$)
Control= Cd-polluted soil; PM-5= Poultry manure biochar 2.5 g kg^{-1}; PM-10= Poultry manure biochar 5 g kg^{-1}; FYM-5= Farmyard manure biochar 2.5 g kg^{-1}; FYM-10= Farmyard manure biochar 5 g kg^{-1}; PS-5= Sugarcane press mud biochar 2.5 g kg^{-1}; PS-10= Sugarcane press mud biochar 5 g kg^{-1}

Table 3: Effect of biochar on cadmium (Cd) uptake in roots, shoots, and grains of wheat in contaminated soil

Treatments	Cd in roots (mg kg^{-1})	Cd in shoots (mg kg^{-1})	Cd in grains (mg kg^{-1})
Control	1.4A	1.14A	0.9A
PM-5	0.7BC	0.3B	0.1B
PM-10	0.5BC	0.2BC	0.07BC
FYM-5	0.4BC	0.2CB	0.09CD
FYM-10	0.1C	0.1E	0.03D
PS-5	0.5B	0.3D	0.15B
PS-10	0.35BC	0.1CD	0.09BC

Each value represents the mean of three replicates ± standard deviation and ($P < 0.01$)
Control= Cd-polluted soil; PM-5= Poultry manure biochar 2.5 g kg^{-1}; PM-10= Poultry manure biochar 5 g kg^{-1}; FYM-5= Farmyard manure biochar 2.5 g kg^{-1}; FYM-10= Farmyard manure biochar 5 g kg^{-1}; PS-5= Sugarcane press mud biochar 2.5 g kg^{-1}; PS-10= Sugarcane press mud biochar 5 g kg^{-1}

Table 4: Effect of biochar on soil nitrogen (N), phosphorus (P), and potassium (K) in cadmium polluted soil after crop harvest

Treatments	Soil N (%)	Soil P (mg kg^{-1})	Soil K (mg kg^{-1})
Control	0.01C	3.1D	57D
PM-5	0.02BC	5.3CD	64CD
PM-10	0.02B	7.7BC	80BC
FYM-5	0.02BC	7.3BC	81BC
FYM-10	0.05A	11.3A	156A
PS-5	0.02BC	6.0BCD	71BCD
PS-10	0.036B	9.3AB	91B

Each value represents the mean of three replicates ± standard deviation and ($P < 0.01$)
Control= Cd-polluted soil; PM-5= Poultry manure biochar 2.5 g kg^{-1}; PM-10= Poultry manure biochar 5 g kg^{-1}; FYM-5= Farmyard manure biochar 2.5 g kg^{-1}; FYM-10= Farmyard manure biochar 5 g kg^{-1}; PS-5= Sugarcane press mud biochar 2.5 g kg^{-1}; PS-10= Sugarcane press mud biochar 5 g kg^{-1}

nutrition was recorded in control soil where no biochar was applied.

Discussion

Addition of biochar (poultry manure, FYM, and sugarcane press muds) reduced the Cd uptake in wheat by inducing Cd immobilization in alkaline polluted soil. Soil amendment with various type of biochar slightly increased soil pH in Cd polluted soil. Farmyard manure derived biochar caused maximum increase in soil pH in Cd-polluted soil that might be due to its alkaline nature (Ok *et al.* 2011; Rizwan *et al.* 2016b). Alkaline nature of biochar, containing $CaCO_3$, that dissociate to Ca^{2+} and CO_3^{2-} subsequently the reaction of CO_3^{2-} with water liberate OH^{-1} ions, hence the pH of soil consequently raised (Ok *et al.* 2011; Al-Qurainy 2009; Yousaf *et al.* 2016).

Addition of biochar enhanced the wheat growth and productivity by altering the organic matter mineralization which is associated with nutrients retention, especially nitrogen (Sarman *et al.* 2018; Olszyk *et al.* 2018; Minhas *et al.* 2020). Addition of FYM derived biochar improved the numbers of tillers through positive influence on plant growth and development (Liu *et al.* 2007). The improvement might be attributed to positive impact of biochar which improves soil field capacity, fertilizer use efficiency, nutrients availability from soil to plants, pH, CEC, and biological properties of soil (Fornazier *et al.* 2000) that improve soil health and nutrients retention, resultantly improving plant growth and increasing the tillers growth under Cd contamination.

Reduction in plant growth is most common symptom of heavy metals stress. Various factors for inhibition of plant growth due to heavy metals stress depends on many physical and chemicals reactions between heavy metals and soil components (Chang *et al.* 2003). Moreover, it reduces the process of nutrient bioavailability and photosynthesis of plants that affects optimum plant growth and development under heavy metals toxicities.

The plant leaf area is imperative physiological parameter to determine plant growth and development. The results indicated that plant height and leaf area were decreased under Cd stress and these values improved with addition of FYM derived biochar. Plant height and leaf area increase might be due to addition of biochar to polluted soil which improved the nutritional equilibrium by reducing Cd toxicities. The prominent declined in Cd toxicities might be lowered Cd solubility in pore water or better soil organic matter capacity to bind with Cd after biochar addition to contaminated soil (Lu *et al.* 2017).

Biochar amendment in Cd contaminated soil enhanced the biological yield and economic yield of wheat. The improvement in wheat yield was due to better soil properties like soil porosity, microbial activity and physical properties of soil that provided favorable environment to microorganism's (Lehmann and Joseph 2009; Laird *et al.* 2010). Addition of biochar also provided nitrogen to plants through ammonia adsorption which improved the plant growth and enhanced the yield (Thapar *et al.* 2008; Awad *et al.* 2017) as was observed in this study.

In this study, chlorophyll SPAD value was decreased in Cd polluted soil owing to changes occurring in leaf anatomy and chloroplast cells structure in the leaf mesophyll which negatively affect the thylakoid formation in chloroplasts bundle sheath cells (Anjum *et al.* 2015). Addition of FYM derived biochar significantly enhanced the chlorophyll SPAD value. The improvement in chlorophyll SPAD value by addition of FYM derived biochar was due to more phosphorus, iron, aluminum, and magnesium contents than other applied biochar (Woldetsadik *et al.* 2016). Addition of biochar reduced the Cd toxicities in polluted soil (Younis *et al.* 2016) by reducing oxidative stresses and antioxidant enzymatic activities (Nagajyoti *et al.* 2010; Gallego *et al.* 2012). Interaction of heavy metals with cell wall polysaccharides or indirect disturbance of metabolic processes results in reduced plant growth and development (Seregin *et al.* 2004). Mostly, Cd enters into cell membrane and attach with cell membranes constitutive (phospholipids groups and proteins). The excess of Cd translocation in plants may create various problems in the functioning of cell membrane such as exchange and transportation of calcium ions, reduces plasma membrane H^+-ATPase MRNA level (Janicka-Russak *et al.* 2008) and substrate of ATPase is lowered by binding with ATP (Sanz *et al.* 2009).

In current study, the Cd concentration in wheat grains was below the permissible limits (0.2 mg kg^{-1} dry weight) (FAO 2012). The possible reduction of metals (below permissible limits) in plants edible parts (grains, fruits etc.) after addition of soil amendments is considered as the optimum key additive for safe production (Rizwan *et al.* 2016a). Many processes are involved to immobilize the heavy metals by biochar in contaminated soil such as electrostatic interaction, ion exchange, precipitation, surface complexation and substitution for Ca by metals during co-precipitation (Uchimiya *et al.* 2010; Beesley *et al.* 2011).

Mostly, Cd was accumulated in plants roots followed by shoots and grains. Indeed, more Cd accumulation in plants roots followed by shoots and wheat grains might be due to decreased translocation of Cd hazards to shoots by localization of Cd toxicities in plants tissues (Rizwan *et al.* 2012). Moreover, the prominent reduction of Cd toxicity in various parts of wheat with addition of FYM derived biochar might be due to high soil pH that was increased negatively on charged sites of polluted soil, which resultantly enhanced cationic metal adsorption (Bradl 2005; Ok *et al.* 2007).

Nitrogen, phosphorus, and potassium are important essential macro-nutrients and are required for optimum plant growth and development. Proper mineral nutrition regulates the adverse environmental effect on plants and may lower the Cd availability in plants due to nutritional competition among Cd and essential nutrients (Rizwan *et al.* 2016a).

Biochar have capacity to retain macronutrients (Randolph *et al.* 2017) that is beneficial for recycling of plant nutrients, reducing nutrient loses by leaching, and increasing nutrients use efficiency and retention, ultimately improved soil fertility (Randolph *et al.* 2017). Biochar addition to soil promoted the nutrients retention that mostly based on biochar properties such as porosity, surface area, pH and cation exchange capacity (Yuan *et al.* 2011; Farooq *et al.* 2020b). Biochar prepared at higher temperature found to be more efficient in promoting nutrients retention in soil (Hussain *et al.* 2017), while biochar pyrolyzed at lower temperature greatly improved the soil cation exchange capacity (Mukherjee *et al.* 2011). In acidic soils biochar induced slight change in soil pH, while minimal decrease in soil pH with addition of biochar was observed in alkaline soil (Laghari *et al*. 2015). Hence, direct and indirect effect of biochar may occur when one assesses the impact of biochar on nutrient retention supply in soils.

Conclusion

Biochar has showed its potential to induce the immobilization of Cd in polluted soil and improved the plant growth and development as compared to non-amended Cd contaminated soil. Among all biochar amendments, FYM derived biochar (5 g kg^{-1} of soil) performed better to remediate Cd toxicity in soil, reduced phytotoxicity in wheat shoots, roots and grains by improving soil nutrition, which ultimately promoted the wheat growth and productivity in Cd polluted soil.

Author Contributions

Muhammad Ijaz, Abdul Sattar, Ahmad Sher – conceptualization, methodology and experiment layout; Muhammad Ijaz – Supervision; Muhammad Shahid Rizwan, Muhammad Sarfraz– conducted the experiment and wrote the original draft; Allah Ditta, Balal Yousaf, Liaqat Ali – wrote introduction and discussion section; Sami Ul-Allah – review, discussion, editing and proof reading.

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