Research Article

Stabilization of Cd in Soil by Biochar and Growth of Rice (*Oryza sativa*) in Artificially Contaminated Soil

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Abstract | Cadmium (Cd) accumulation in agriculture fields by the irrigation water released from industries and the commercial sector caused serious health issues. Continuous irrigation with contaminated water caused several health problems as rice (*Oryza sativa* L.) had the potential that can adsorb a greater amount of Cd. The use of metals polluted rice as a staple food now becomes the main way for exposing human health to metals, thereby the amendment of biochar gained greater attention to sorb and control the uptake of heavy metals by rice. A pot experiment at The University of Agriculture Peshawar demonstrates biochar's effectiveness in stabilizing heavy metals in soil and reducing rice plant uptake rates. All the pots were filled with 10 Kg of soil and were spiked with 20 mg kg^{-1} of Cd. $CdNO_3$ was used as the source of Cd, and biochar amendment effectively stabilized soil toxic metals. The treatments in the present research were followed as (1, 2, and 4% w/w means 100g/10 kg soil, 200g/10 kg soil and 400g/10 kg soil) of biochar were thoroughly mixed in each specified pot before spiking and were kept at 30% field capacity for 7 days. The source of urea was used for N fertilizer and was applied in two split doses (@ 60:60 kg ha^{-1}) directly after transplantation and after 4 weeks of transplantation while DAP source was used for phosphatic fertilizer (@ 90 kg ha^{-1}). In each pot, 20 days old rice nursery was selected and 10 healthy plants were transplanted into each pot. After successful and possible growth five most perfect and healthy plants were kept for experimental work. All the pots were kept in standing water condition and the pots were irrigated on the visual requirement of the water. From the experimental results, its depicted that rice yield and biological yield was increased from control to 4% BC application (4.9 and 4 g/pot to 10 and 20 g/pot), organic matter, soil N, P and K were also improved from control to 4% BC application (0.4 and 0.02%, 2.1 and 58 g/pot to 0.7 and 0.03%, 5 and 83 mg/kg). Aside these the application of BC at 4% incredibly decreased the concentration of Cd in soil thus reduced their uptake and accumulation in rice plants as AB-DTPA extractable Cd, shoot and grains Cd (Ck: 18, 2.5 and 1.1 mg/kg, 4% BC: 66, 0.9 and 0.5 mg/kg). Therefore, biochar is recommended for better crop growth under toxic metals polluted soil.

Received | December 23, 2023; **Accepted** | January 12, 2024; **Published** | February 26, 2024
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Citation | Murad, Z., S. Bibi, S.Y. Ahmad, M.A. Khan, R. Sadaf, M. Haq, U. Manan and M. Younas. 2024. Stabilization of Cd in soil by biochar and growth of rice (*Oryza sativa*) in artificially contaminated soil. *Sarhad Journal of Agriculture*, 40(1): 231-245.
DOI | https://dx.doi.org/10.17582/journal.sja/2024/40.1.231.245
Keywords | Biochar, Soil, Rice, Cadmium, Plant growth, Yield, N, P, and K

Introduction

Rice (*Oryza sativa* L.) is major source of human food after wheat consumed by 50% of the world population and also in Pakistan. Rice is grown over a large number of fields under flooded conditions but in Pakistan, the problem is the scarcity of freshwater (Murtaza *et al*., 2015; Rehman *et al*., 2017). In Pakistan, it was grown on several lands but due to the limited supply of fresh water, the growers irrigated their fields through contaminated wastewater polluted by industrial wastes and city wastes (Raja *et al*., 2015; Valipour and Singh, 2016). The higher fractions of Cd in the rhizosphere of polluted soil cause accumulation of these pollutants in crop tissues that was then transfer to food chain by accumulating in the grains of rice (Song *et al*., 2015; Wang *et al*., 2014). The growing of rice on cadmium polluted soil adversely affects rice growth through physiologically as well as morphologically and destroys grains standard grains (Kanu *et al*., 2017). Furthermore, it has a significant role in people's trade for that purpose it is necessary to minimize the risk associated with hazardous contaminants on growth (Rehman *et al*., 2020).

The consistent release of effluents from different industries to the environment adversely affects soil condition, causing serious health problems upon its accumulation in the soil (Doostikhah *et al*., 2020). Cd is considered a very mobile trace element that can contribute a significant role in polluting the soil environment and retarding plant growth. The content of Cd in plantsdisrupts the plant defense system by affecting plant physiology and morphology (Bashir *et al*., 2018). In comparison with other toxic metals, Cd has the ability of non-biodegradation once introduced in the environment (Kaya *et al*., 2019; Bashir *et al*., 2021). Therefore, the concern of restoring and the remomval of metal elements from contaminated soil gain greater attention because of their harmful effect on growth (Kaya *et al*., 2019, 2020).

The need of restoring soil from such contaminants for safe and healthy crop production has gained greater potential in the last few years. Various effective techniques were introduced for the restoration of polluted soil includes phytoremediation technique, excavation, and immobilization. From several experiments, it was discovered that trace elements accumulation in plants became dangerous rather than toxic elements content in soil environment. The minimization of metals in plants gained greater importance for the purpose to reduce positively the translocation of toxic pollutants arose from soil profile to edible plant tissues (Bashir *et al*., 2021). From the last few years, it was confirmed that biochar playing prominanat role in toxic metals removal from contaminated soil that is very useful in improving soil fertility (Salam *et al*., 2019).

Biochar has been used both as an organic fertilizer and soil conditioner and its application increases pH, CEC of the soil and improves soil nutrients regulation (Bashir *et al*., 2019; Mansoor *et al*., 2021), improving crop growth and production and considerably stabilizing the content of heavy metals and reduces its mobility (Rehman *et al*., 2020). Biochar has the ability to stabilize and reduce metals in soil and also has the potential to reuse a large number of agricultural wastes (Xu *et al*., 2020). From many experiments it was confirmed that biochar has the potential to stabilize toxic metals in the soil through different mechanisms and improves plant growth and productivity is required for decreasing environmental pollution (Bashir *et al*., 2020).

The applications of both organic and inorganic amendments to polluted soil significantly reduce soil Cd concentration that also decrease the translocation of these metals to crops (Rehman *et al*., 2020; Sohail *et al*., 2020). These organic sources significantly minimize cadmium content in soil environment through providing exchange sites, ions competition, chemical and physical sorption of Cd metals (Sohail *et al*., 2020; Shahkolaie *et al*., 2020). The biochar significantly stabilizes the content of toxic metals in soil that ultimately inhibibt its transfer from polluted soil to plants through different mechanisms (Bashir *et al*., 2020; Naeem *et al*., 2020). BC that is mostly produced through the pyrolysis process from various materials under anaerobic conditions (Yap *et al*., 2017). During the preparation of biochar polycyclic aromatic compounds were produced that have greater efficacy in the stabilization of heavy metals (Wang *et al*., 2017).

The objectives were to study the potential of biochar on cadmium stabilization in soil and on soil chemical properties. Aside these the efficacy of biochar was also studied on the growth of rice under Cd contaminated soil.

Materials and Methods

Pot experiment

A pot experiment was intiated at greenhouse of Soil and Environmental Science (SES), The University of Agriculture, Peshawar. The soil was collected randomly from the research farm of the University of Agriculture, Peshawar, and placed at the greenhouse Department of SES. In experimental pots 10 Kg of bulk soil was placed that was then polluted with Cd at the level of 20 mg kg^{-1}. The source of Cd was $CdNO_3$. After pots filling with the soil, the pots were irrigated and maintained at 60% saturation for 1 week. The 20 days old rice nursery was used for plants transplantation. After transplantation N fertilizer was applied in two split doses, half 60 kg ha^{-1} at the time of sowing and half 60 kg ha^{-1} after 4 weeks of transplantation, and P (@ 90 kg ha^{-1}) was used. A Completely Randomized Design (CRD) along with three replications were used for experiment layout. At the time of harvesting, plant parameters were recorded and plants and soil samples were taken and brought to the laboratory for further lab tests.

Sampling of soil and its spiking

The sampling of the soil was done in the depth range of 0-20 cm from the University farming area, UAP. The randomly collected soil was brought to greenhouse, Department of SES. The collected soil was placed on a sheet in the greenhouse and unwanted materials were discarded that was then passed through a net of 2 mm and the composite sample was taken for soil analysis including soil pH, EC, SOM, Soil Nitrogen, Phosphorous, Potassium, and Cd by practicing the techniques preferred by US Salinity Laboratory Staff (1954). The content of Cd in soil was determined by the procedure proposed by Soltonpour and Schawab, (1977). 10 kg of sieved soil was taken in each pot. All the pots were spiked with the prepared 20 mg kg^{-1} solution of Cd.

Biochars amendment and transplanting of rice nursery plants

All the recommended rates (1, 2, and 4% w/w means 100g/10 kg soil, 200g/10 kg soil and 400g/10 kg soil) of biochar were thoroughly mixed in each specified pot before spiking and were kept at 30% field capacity for 7 days. The source of urea was used for N fertilizer and was applied in two split doses (@ 60:60 kg ha^{-1}) directly after transplantation and after 4 weeks of transplantation while DAP source was used for phosphatic fertilizer (@ 90 kg ha^{-1}). In each pot, 20 days old rice nursery was selected and 10 healthy plants were transplanted into each pot. After successful and possible growth five most perfect and healthy plants were kept for experimental work. All the pots were kept in standing water condition and the pots were irrigated on the visual requirement of the water.

Agronomic parameters

After crop maturity, the following plant parameters were studied including plant height (cm), grain per spike, grain yield (g pot^{-1}), biological yield (g pot^{-1}), harvest index (%), flag leaf length (cm), panicle length (cm), fresh and dry biomass of plant (g). The rice plants from each pot were separately cut between the surface of the soil and the bottom of the stem and tagged specifically. The harvested plant samples were transferred to SES laboratory and placed separately on a table for 5-7 days for air drying. After air-drying the plants were taken in the oven at 70 °C until complete drying. After drying the dry shoot weight of each tagged plantwas recorded and the plant shoots were further used for lab analysis.

Collection of post-harvest soil and plant samples for lab analysis

After harvesting from each pot samples of the soil were taken and kept in SES laboratory. The collected soil samples were then openly and separately kept on a table for 5-7 days for air drying purposes under the lab. After air-drying, the soil was pressed with a wooden hammer and sieved with a 2 mm mesh and collected in a clutch bag to use in lab analysis. The plant shoot and grains were taken from each pot and brought to the laboratory and placed on a table for air drying for 4-5 days. After air drying, shoot and grains samples were kept in cotton packets and placed at a temperature range of 70°C for the duration of 48 hours under oven. The complete dried shoots and grains represntatives were powdered through a grinder machine. The plant specimens were kept under labelled plastic containers for lab different tests.

Cadmium determination in soil and plants

The soil Cd extent was tested through the technique of Soltonpour and Schawab (1977). In the method, 10 grams air dried sample of soil was added in 250 mL volumetric flask with the combination of 20 mL AB-DTPA prepared solution. The flask was runed on a shaker machine for shaking purposes for 20 minutes.

The shaked suspension was then passed from filter paper and the clean extract was stored in a plastic container. The prepared extract was then further processed by atomic absorption spectrophotometer to find out the readings of Cd in soil samples. The plant (shoot and grains) cadmium amount were determined by preparing the sample through the AOAC method of wet digestion (AOAC, 1990). In the procedure, 0.5 gram dried and powdered sample was taken in a flask assuming a volume of 250 mL with the addition of 10 mL nitric acid and left the sample overnight. After the next day in the same sample, 4 mL perchloric acid was dissolved and then kept on a hot plate. After boiling when the sample becomes transparent was taken down and cooled. The volume of the sample was made by rinsing the flask 4-5 times and the volume was made 100 mL with distilled water. The final reading of Cd concentration in plant (shoot and grains) were obtained by passing the samples from atomic absorption spectrophotometer.

Analysis of soil chemical parameters (pH, EC, Organic matter, N, P, K)

The air-dried soil samples were used for soil analysis. The pH of the soil was performed by adopting the procedure of Thomas (1996). The suspension was prepared by taking a 10-gram sample and 50 mL distilled water and shook for 20 minutes. The suspension was then passed over Whattman-42 filter paper and the extract in fresh decanter was stored. The pH of the soil was measured with pH meter instrument. The EC of the soil was performed by following the procedure of Rhoades (1996). The EC of the sample was analyzed in the same ample prepared for measuring soil pH and the sample was measured by EC meter. The SOM in soil was done through the approach of Nelson and Sommers (1996). The analysis was done through titration process, 1 gram of soil was used in the procedure with the addition of potassium dichromate and concentrated sulfuric acid, and distilled water. The sample was then passed over filter paper and was titrated against iron sulfate. The soil total nitrogen content was tested with the technique of Bremner and Mulvaney (1983). In which, 0.2 g sample was used with the addition of a 1.1 g digestion mixture and 3 mL concentrated sulfuric acid. After sample digestion, the volume was made 100 mL with distilled water and the sample was run through the distillation process. The soil AB-DTPA extractable P and K was analyzed by Soltonpour and Schawab, (1977) technique. The samples were prepared by taking a 10 g sample with 20 mL AB-DTPA solution and shaken for 20 minutes. After shaking the filtration process was done by using filter paper in soil the P concentration was measured by spectrophotometer and K was analyzed by flame photometer.

Analysis of data

The present trial was performed in Completely Randomized Design (CRD) having three replications. The resulted data was run by Statitix software 8.1 (Steel, 1997). The means were used for comparison by taking LSD tests.

Results and Discussion

Physico-chemical properties of experimental soil

Before the experiment initiation, the experimental soil were used for the evaluation of several significant soil physico-chemical properties. According to the findings, the experimental soil was silt loam in texture, non-saline by nature, had a slightly alkaline reaction, highly calcareous, low in soil organic matter content, total nitrogen, AB-DTPA extractable P and K.

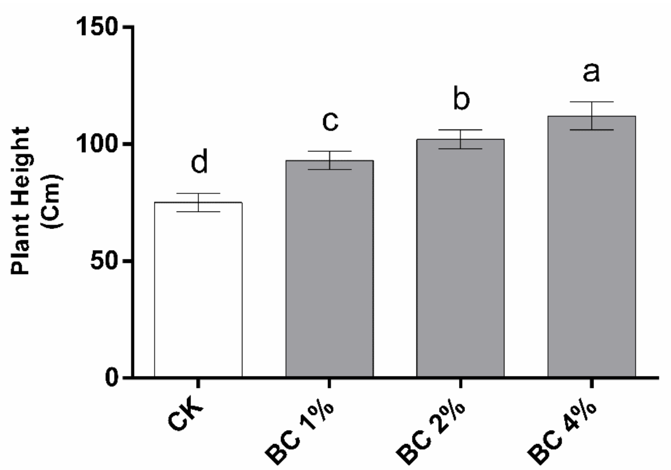

Figure 1: *Effects of different biochar concentrations on rice plant height grown in intentionally Cd-contaminated soil.*

Plants parameters

The application of biochar at various levels showed varied results over all the agronomic parameters of rice plants. The maximum height of rice (112 cm) in cm was obtained from the treatment where 4% biochar was applied, followed by a 2% rate of biochar (102 cm) while the minimum (75 cm) was noted in control (Figure 1). In polluted or control conditions, biochar has a positive effect by lowering the harmful effects of heavy metals, which can increase grain production. The grain yield is higher with BC (4% w/w) application than BC 2 and 1%, though. Pollutant damage on rice

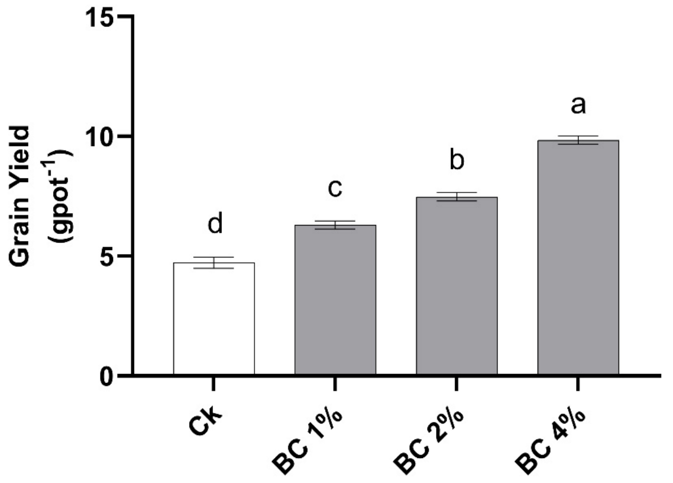

Figure 2: *Effects of different rates of biochar on rice plant grain yield grown in intentionally Cd-contaminated soil.*

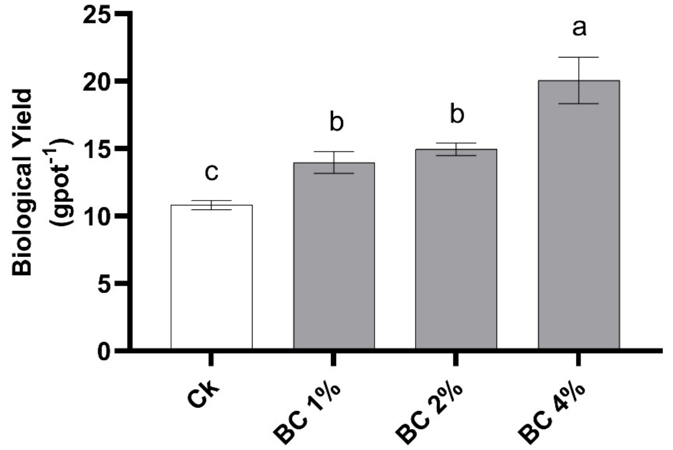

Figure 3: *Effects of different rates of biochar on the biological yield of rice plants grown in intentionally Cd-contaminated soil.*

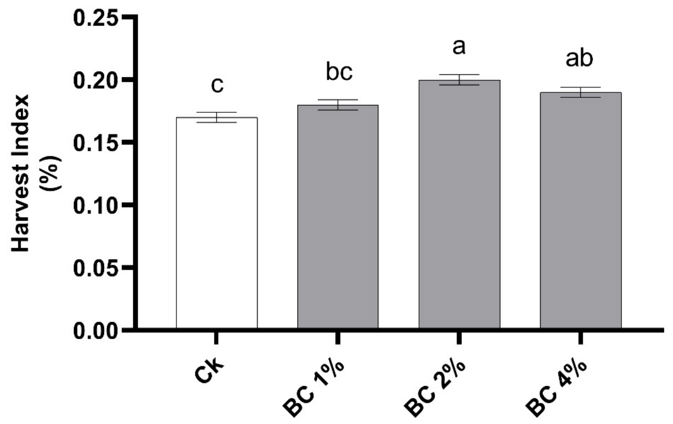

Figure 4: *Effect of different rates of biochar on the harvest index of rice plants grown in intentionally Cd-contaminated soil.*

yield-related traits was significantly reduced after biochar treatment. The highest grain yield (9.84 g pot^{-1}) was deduced at 4% biochar application that was statistically followed by 2% biochar application that attained the grain yield of (7.48 g pot^{-1}) whereas the lower grain yield (4.72 g pot^{-1}) was recorded in control (Figure 2). The results of biological yield depicted that 4% biochar application produced the maximum biological yield (20.07 g pot^{-1}), which was statistically followed by 2% biochar application, which produced the biological yield of (14.96 g pot^{-1}), while the control treatment resulted minimum biological yield (10.82 g pot^{-1}) as presented in (Figure 3). The harvest index was calculated in percent pot^{-1} thus the highest harvest index (0.20 %) was recorded in 2% biochar application that was followed by 4% biochar application resulted the harvest index of (0.19 %) while the lowest harvest index of (0.17 %) was recorded in control (Figure 4). The incorporation of biochar at 4% intensifies flag leaf length to (36 cm), also it was positively improved by 2% biochar (31 cm) while the minimum (20 cm) was noted in control (Figure 5). The panicle length (24 cm) was also observed maximum with the incorporation of biochar at 4% which was followed by a 2% biochar level (21 cm) whereas the minimum outcomes of panicle length (11 cm) were noticed in the treatment of control (Figure 6). The fresh weight of rice plants with the application of biochar also intensified at various levels (Figure 7). The amendment of biochar incorporation to contaminated soil at 4% enhanced fresh shoot weight (154 g) that was statistically followed by 2% biochar level which attained (135 g) of fresh shoot weight while the minimum results (87 g) were obtained from control plants which was statistically similar to 1% biochar incorporation. The dry shoot weight of rice plants per pot was also improved with the incorporation of biochar (Figure 8). The highest dry shoot weight (79 g) of rice plants resulted in the pots that were treated with 4% biochar whereas the lower dry shoot weight (40 g) was noted in control pots.

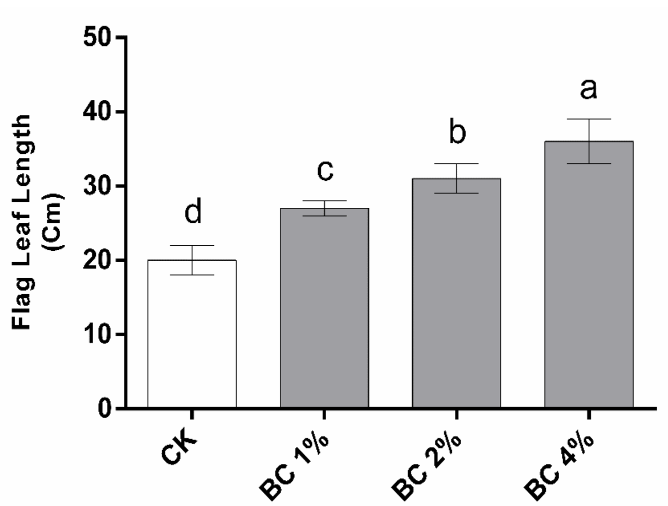

Figure 5: *Effect of different rates of biochar on the flag leaves length of rice plants grown in intentionally Cd-contaminated soil.*

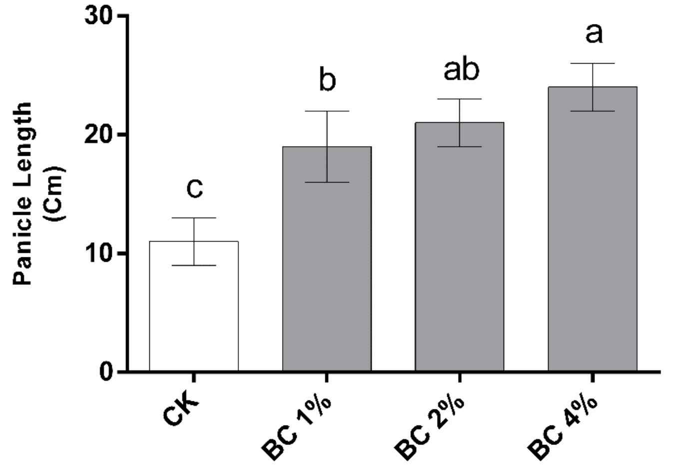

Figure 6: *Effect of different rates of biochar on the panicles length of rice plants grown in intentionally Cd-contaminated soil.*

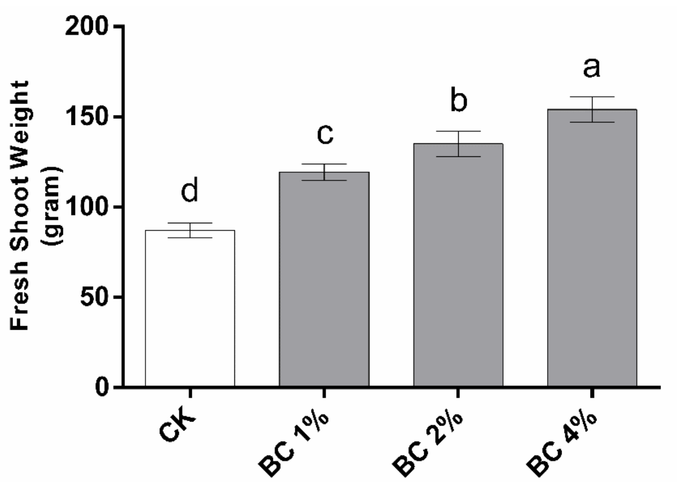

Figure 7: *Effects of different amounts of biochar on the fresh shoot weight of rice plants grown in intentionally Cd-contaminated soil.*

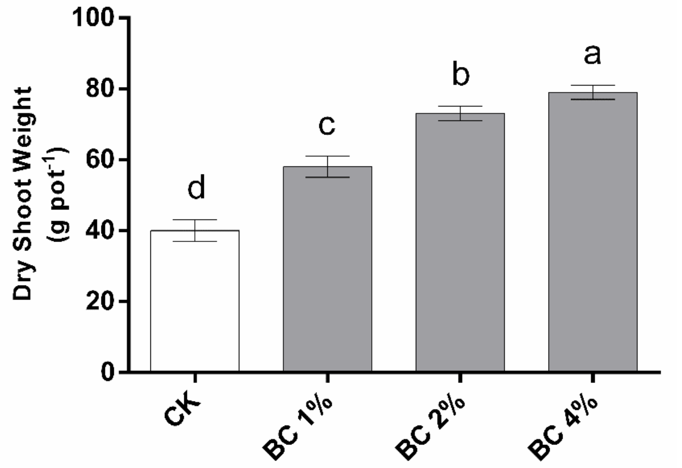

Figure 8: *Impact of various biochar levels on the dry shoot weight of rice plants cultivated in soil artificially contaminated with Cd.*

The improvement in grains fresh and dry weight with biochar incorporation to contaminated soil was also noted. The amendment of biochar to contaminated soil significantly improved plant growth thus intensified grains fresh and dry weight (Figures 9 and 10). The maximum fresh grains weight (32 g) of rice was noticed over 4% level of biochar level while the minimum fresh weight of grains (14 g) was noticed in control-treated plants. The maximum dry grains weight (21 g) was observed at 4% biochar ratefollowed by the dry weight of grains (17 g) treated with 2% biochar whereas the minimum grains dry weight (6 g) was noticed in control pots.

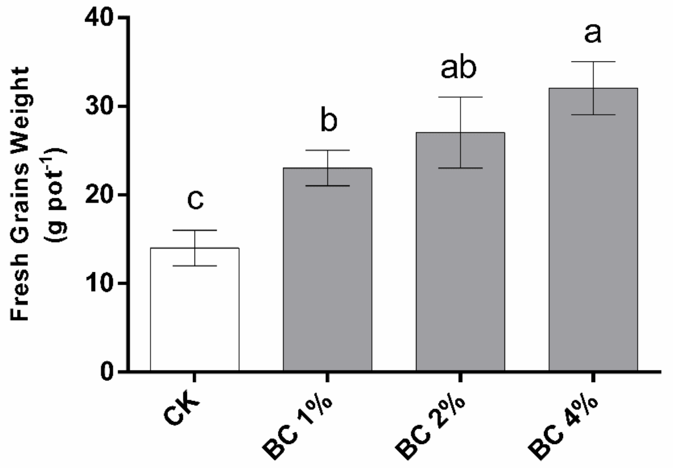

Figure 9: *Effect of different rates of biochar on fresh grains weight grown in intentionally Cd-contaminated soil.*

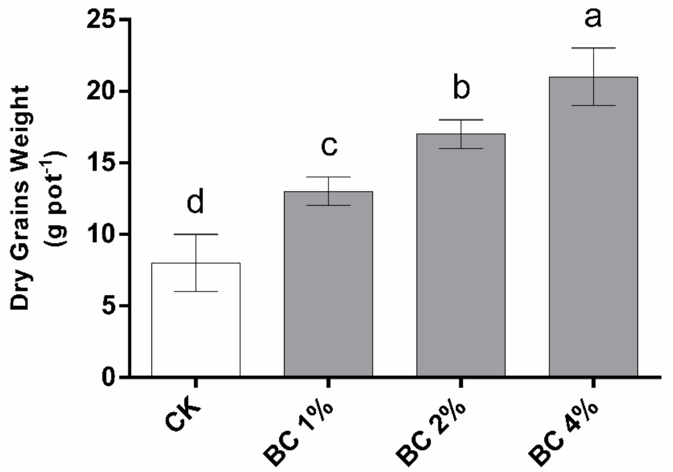

Figure 10: *Effects of different rates of biochar on the dry grain weight of rice plants grown in intentionally Cd-contaminated soil.*

Cadmium plant (shoots and grains) content, soil and total uptake

The use of biochar as a stabilizing agent over artificially Cd spiked soil affects the degree of Cd in soil (Figure 11). The mobility of Cd in soil was efficiently stopped by biochar application. From the results, it was confirmed that with increasing levels of biochar the amount of Cd in soil was stabilized thus their accumulation in plant was ultimately controlled. The maximum amount of Cd content (18.5 mg kg^{-1}) in soil was observed in the soil samples of control pots while the minimum (7.2 mg kg^{-1}) was

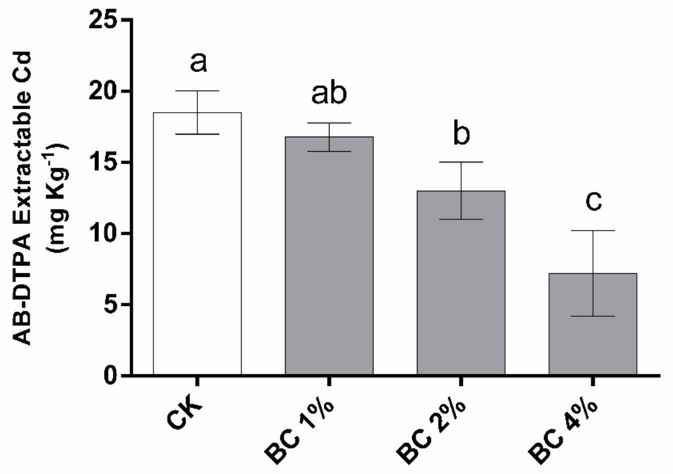

Figure 11: *Impact of different rates of biochar on soil AB-DTPA extractable Cd.*

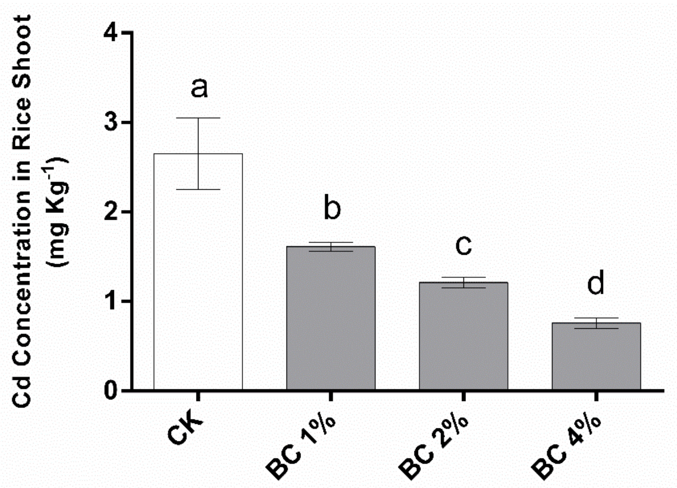

Figure 12: *Effects of different rates of biochar on the content of Cd in rice shoot grown in intentionally contaminated soil.*

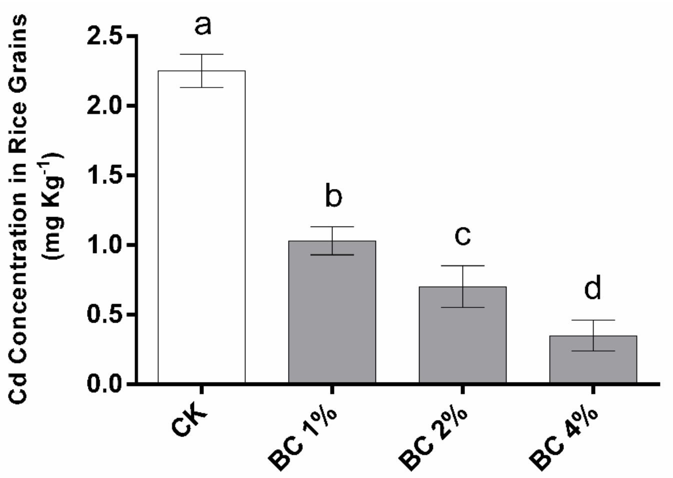

Figure 13: *Impact of varying levels of biochar on the content of Cd in rice grains cultivated in intentionally Cd-contaminated soil.*

observed in the pots that received 4% biochar. The rice shoots and grains Cd concentration was analyzed by the method of wet acid digestion. The biochar incorporation to contaminated soil at different levels showed significant variation in the Cd content of plant shoots and grains (Figures 12 and 13). The use of optimum biochar level to polluted soil inhibits accumulation of Cd in plants compared to control. The maximum content of Cd (2.65 mg kg^{-1}) in the shoot of rice was observed at control pots while biochar implementation at the rate of 4% significantly reduced the uptake of Cd (0.76 mg kg^{-1}) by plants. The amount of Cd that was accumulated in the grains was adversely affected by biochar. The maximum Cd level (2.25 mg kg^{-1}) of grains was noticed in the control treatment whereas the minimum (0.35 mg kg^{-1}) was noticed in grains of rice plants that were treated with 4% biochar application. The biochar incorporation to contaminated soil at different levels positively stabilized the fractions of Cd in soil thus inhibit their translocation to plants that helps in the reduction of Cd total uptake by plants (Figure 14). The results depicted that with biochar application at different rates reduced significantly the uptake of Cd at 4% BC level compared to control plants thus the maximum Cd total uptake (1.05 mg kg^{-1}) was observed in no treated plants whereas the minimum total uptake of Cd (0.59 mg kg^{-1}) was noticed at 4% BC application.

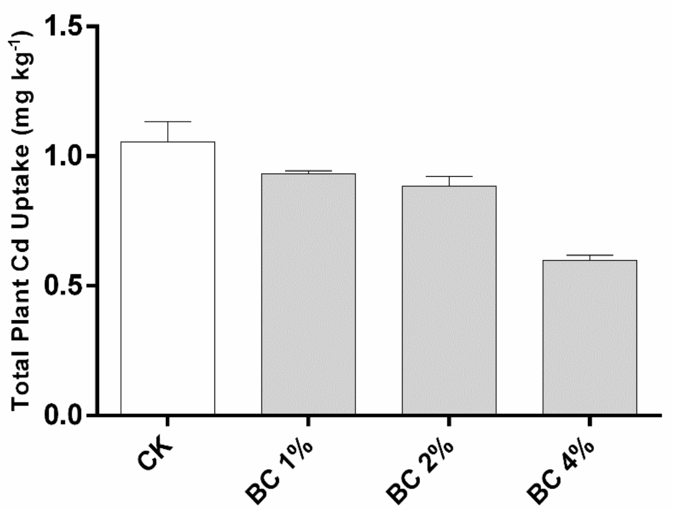

Figure 14: *Effects of different quantities of biochar on the Cd total uptake by rice plants grown in intentionally Cd-contaminated soil.*

Soil analysis after biochar incorporation

After harvesting of rice plants, soil was taken from each pot and prepared by proposed techniques. The biochar implementation to contaminated soil intensified the properties of soil. The pH, electrical conductivity, organic matter content, soil P, K, and soil total N was adversely affected with biochar incorporation. Biochar application at 4% intensified pH of the soil like (7.88) as compared to control pot (7.61) as presented in Figure 15. The electrical conductivity of the soil was slightly altered with biochar application (Figure 16). In the present results, higher electrical conductivity (0.23 dSm^{-1}) obtained from the soil samples where 4% biochar was used as compared to the control treatment (0.17 dSm^{-1}). As biochar is used commonly as a soil conditioner, the organic matter content of the soil was improved with biochar application significantly (Figure 17). The maximum organic matter content (0.81 %) was noted in the pots where 4% biochar application was incorporated while the minimum values were recorded in control pots (0.43 %). The macronutrients N, P, and K were improved with biochar amendment as biochar is a charcoal material that significantly improved soil holding capacity. The enhancement in phosphorous was observed with biochar application like (2.32 mg kg^{-1}) in control pot and (5.01 mg kg^{-1}) at 4% biochar amendment (Figure 18). The present outcomes depicted that biochar improved the concentration of potassium in soil from (57 mg kg^{-1}) control to (87 mg kg^{-1}) (Figure 19). Due to the higher mobility of nitrogen, it can easily leach or volatilized from soil which reduces the availability of N for plants. The biochar improves the holding capacity of the soil that's why the content of total soil N was significantly increased (Figure 20). The maximum soil total N (0.03 %) was recorded in the plots treated with 4% biochar amendment whereas the minimum was noted in control pots (0.014 %).

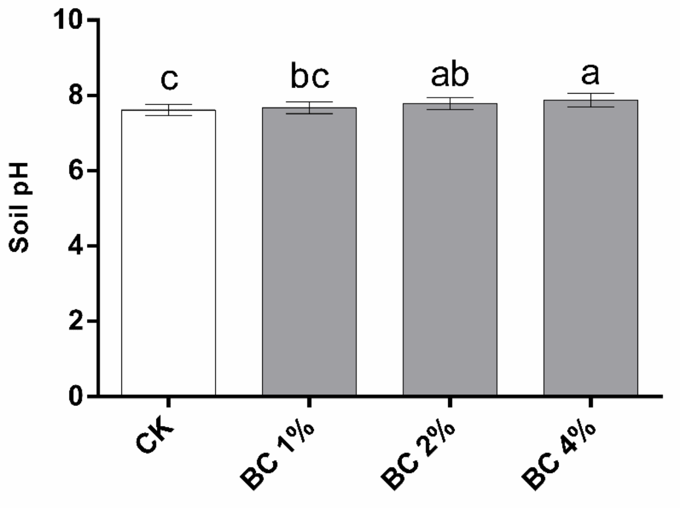

Figure 15: *Impacts of different biochar concentrations on soil pH that has been artificially Cd-contaminated.*

According to the results of different researchers like (Rizwan *et al*., 2016a, b; Li *et al*., 2016; Thind *et al*., 2021), they confirmed that Cd toxicity adversely affects growth performance due to the scarcity of plant essential nutrients. The source of biochar inhibit the uptake level of Cd by rice plants due to the

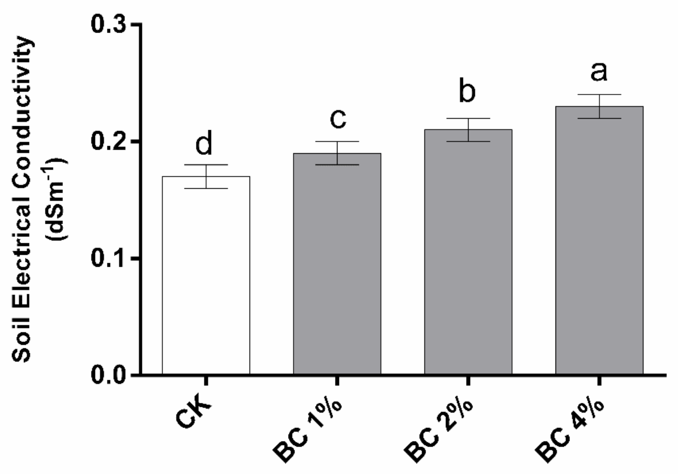

Figure 16: *Effects of varying rates of biochar on soil electrical conductivity under artificially contaminated.*

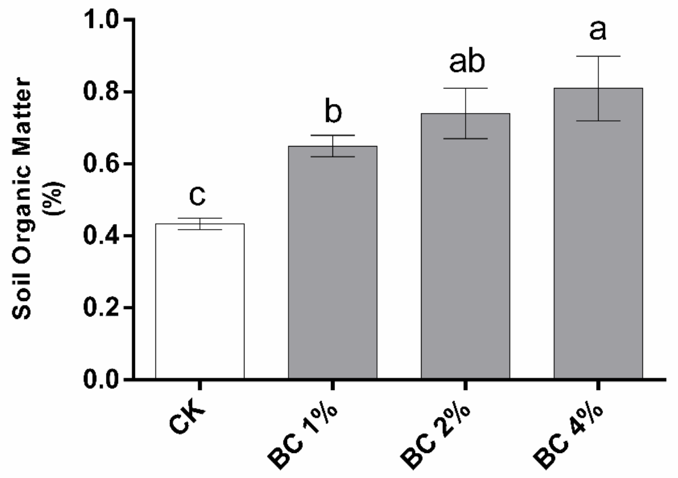

Figure 17: *Impact of different rates of biochar on soil organic matter in artificially Cd-contaminated.*

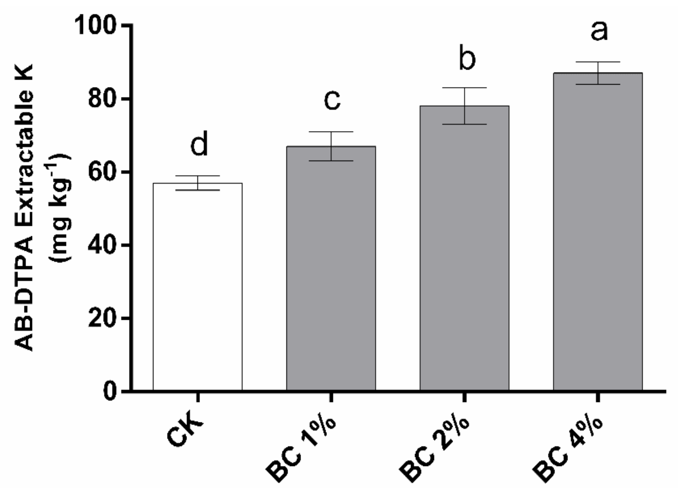

Figure 18: *Impact of different biochar levels on soil AB-DTPA extractable P in soil that has been intentionally Cd-contaminated.*

formation of Cd insoluble complexes (Majeed *et al*., 2022). According to Zulfiqar *et al*. (2022) who reported that plant growth attributes enlighten the adverse effect of Cd toxicity and the damages originated with Cd stress. The research work of Haider *et al*. (2021)

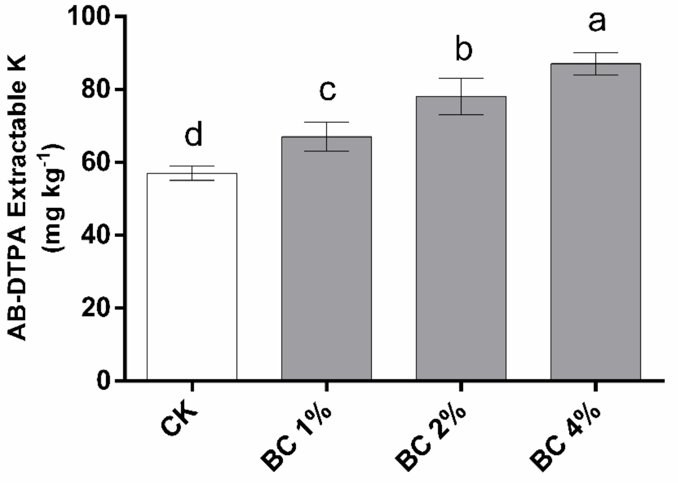

Figure 19: *Effect of varying rates of biochar on soil AB-DTPA extractable K in intentionally Cd-contaminated soil.*

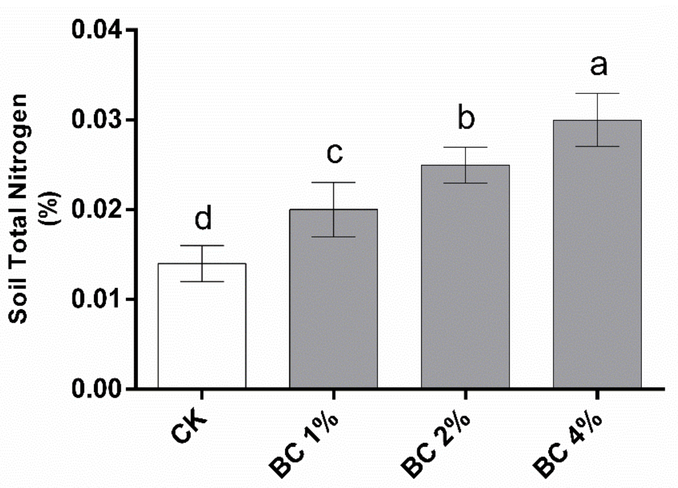

Figure 20: *Impact of different rates of biochar on soil total N content in intentionally Cd-contaminated soil.*

exposed that Cd toxicity depressed the growth rate due to the unavailability of essential nutrients. In the present study, plant biomass was reduced under polluted soil without application which might be due to scarcity of plant essential nutrients. According to the experimental results of Azhar *et al.* (2019) who found the reduction in plant biomass as it was significantly decreased upon the presence of higher levels of heavy metals under soil. The application of biochar positively stabilized Cd under soil by the formation of complexes and reduced the rate of Cd uptake by plants that significantly improved the biomass (Sohail *et al.*, 2020). According to the research work of Abdelrhman *et al.* (2022) who found that biochar implementation to soil at different rates efficiently stabilized Cd in soil that ultimately control the uptake. The biochar implementation to metals-polluted soil had the ability in improving the growth rate of crop and biomass production through the enhancement of CEC and nutrients availability in soil solum (Mohebzadeh *et al.*, 2021). The research work of Huang *et al.* (2019) depicted that biochar applications at various rates caused efficient increased in grain and biological yield and this increment may be due to the optimum availability of plant essential nutrients. The present results deduced that rice grain and biological yield was significantly enhanced with biochar doses and the same outcomes were reported from the research work of Chen *et al.* (2021). The results of Huang *et al.* (2019) enlightened that biochar treatments to soil significantly increased plant physiological traits. The results of the experiment shown that applying biochar at a specified % level improved crop performance in terms of crop yield, and crop quality (Sarwar *et al.*, 2023). Khan *et al.* (2021) and Aziz *et al.* (2023), who applied various feedstock-based biochars on alkaline soils and noticed a considerable improvement in crop development, nitrogen uptake, and grain yield, provide support for our findings. As an organic amendment, BC improves crop agronomic and production metrics by decreasing soil compaction, nutrient loss, and water holding capacity while also increasing nutrient usage efficiency (Khan *et al.*, 2021). According to our research Aziz *et al.* (2023), biochar significantly improved wheat crop growth and yield characteristics. The present outcomes supported by Liu *et al.* (2013) as biochar treatments in various supplements considerably boost up plant growth that lead to yield increment. The soil application of biochar showed effective role in nutrients availability that considerably enhanced crop yield (Jeffery *et al.*, 2017). From the research outcomes of Salam *et al.* (2019) established that biochar application to soil positively enhanced yield. As plant nutrients are more soluble and accessible in moist or wet circumstances, biochar amendments considerably boosted rice yields in the current study (Korai *et al.*, 2021).

The presence of Cd in paddy fields hurt plant growth and soil behavior (Qiao *et al.*, 2019). To restore the damages and harmful effect of Cd on plant growth an efficient technique needs to be practiced for controlling accumulation of toxic metals in plants. Also Abdelrhman *et al.* (2022) experimented and noticed the least concentrations of Cd in the shoots and roots of Chinese cabbage over biochar. From several experiments, it was confirmed that biochar application had the potential in reducing Cd uptake by Chinese cabbage (Bashir *et al.*, 2018; Kamran *et al.*, 2019). The source of biochar significantly reduced the content of

Cd in rice plants as evident from the research work of Wang *et al*. (2020). It was also confirmed by Rizwan *et al*. (2018), found that biochar incorporation to soil had the potential to control the uptake of Cd. Due to unique characteristics of biochar, the amendment decreased the concentration of Cd in rice plants (Sui *et al*., 2018). The uptake of Cd by rice plants efficiently reduced with the amendment of biochar as reported by Wang *et al*. (2019). Park *et al*. (2011) performed several types of research and confirmed that biochar efficiently decreased the content of Cd in plants. As biochar contains various functional groups and can make complexes with cationic metals thus stabilizes soil metals and decreasing its accumulation in plant (Bashir *et al*., 2018).

Biochar had the potential for metals stabilization under contaminated soil and also enhances the rate of essential plant nutrients (Majeed *et al*., 2022). The findings of different researchers like Zhang *et al*. (2016); Rizwan *et al*. (2016a, b); and Afzal *et al*. (2019) confirmed that with biochar amendment the concentration of essential plant macro-nutrients like N and P was positively enhanced which in turn increased the uptake of these nutrients. Another study performed by Awad *et al*. (2021), found that biochar application to metals polluted soil improved nutrients content and cation exchange capacity and also improved soil chemical properties. The present experimental data showed that biochar application in various rates significantly stabilized Cd in soil and also enhanced the level of plant essential micro and macro-nutrients. According to the findings of Afzal *et al*. (2019) and Azhar *et al*. (2019), confirmed that implementation of biochar at different rates positively immobilized Cd content through adsorption. The results of Sabir *et al*. (2020) and Rehman *et al*. (2021) depicted that amount of Cd in soil was significantly adsorbed over biochar application. It was also noted that biochar incorporation enhanced pH and EC of the soil. As an evident pH has a vital role in controlling the uptake of Cd by crops. According to the results of Diatta *et al*. (2020) who found that pH of the soil might be enhanced due to the functional groups present in the surface of biochar. The research work of Xu *et al*. (2016) confirmed that the amendment of biochar significantly increased the pH of the soil. It was also found from different researches that biochar significantly increased the pH of the soil through its higher alkalinity (Lu *et al*., 2014; Puga *et al*., 2015). According to Zhu *et al*. (2014) who found the biochar amendment significantly improved the level of organic C under polluted soil. The findings of Zhu *et al*. (2015) showed that biochar application significantly enhanced the level of organic matter in the soil. Similar results were obtained from the research works of Hu *et al*. (2014) and Zhu *et al*. (2014) confirmed that biochar had the potential in enhancing soil organic C.

Conclusions and Recommendations

Biochar implementation to contaminated soil improved significantly the performance of rice growth under Cd contamination that significantly lead to the enhancement in yield. In the present experiment, the results depicted that biochar incorporation at the level of 4% significantly stabilized soil Cd interms of lower biochar rates. Also biochar incorporation at 4% efficienctly minimized the uptake of Cd. Present study ensured that biochar implementation at 4% level can be effective in soil improvement and toxic metals stabilization that ultimately improved crop growth.

Acknowledgments

The authors would like to extend their sincere appreciation to the Department of Soil and Environmental Science, The University of Agriculture Peshawar.

Novelty Statement

This research explored the potential of Biochar in the stabilization of heavy metals and their efficacy in crop growth improvement under contaminated condition.

Author's Contribution

Zaryab Murad: Principal author, conducted the research and wrote first draft, data collection and analysis, Scientific writing.
Sobia Bibi: Helped in data collection and relevant literature.
Shehr e Yar Ahmad, Mohsin Ali Khan, Rimsha Sadaf, Mauz ul Haq, Umair Manan and Muhammad Younas: Helped in data collection.

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

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