



## Research Article

# Impact of Biochar on the Growth and Physiology of Tomato Grown in the Cadmium Contaminated Soil

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**Abstract** | Heavy metals Pollutants are not only dangerous to human life but also to fauna and flora. The existence of cadmium (Cd) in soil, atmosphere or water may unfavorably affect growth and physiology of plants. The experiment was conducted to study the impacts of biochar on the growth and physiology of tomato grown in Cd contaminated soil and activity of biochar in the contaminated soil. In this study different treatments of Cd were applied in the presence of certain portion of biochar. The order of treatments was 0 mg Cd as control with biochar (12%), low Cd (10mg), high Cd (15mg), low cadmium + biochar (10mg+12%) and high cadmium + biochar (15mg+12%) with distilled water as control. Growth and physiological parameters of plant were studied and prominent results were observed. The results showed that biochar has significant progressive effects on the growth and physiology of tomato by limiting the uptake of Cd by plants. As the concentration of Cd increased to high i.e. 15 mg/kg of soil, the limiting capacity of biochar was also seen less effective.

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## Introduction

Pollution of heavy metal limits the development and safety of agricultural goods produced in soil and can create remarkable ecological destruction to the environment. Cadmium is one of the greatest threatening components for human health as well as for environment. It is also a needless and non-renewable component for plants (Zhu et al., 2020). Its existence in the soil is deliberated a thoughtful environmental problem chiefly due to its entrance

in the human food chain with hazardous special effects on living entities (De Maria et al., 2013). Toxicity of Cd causes irregularities and inhibition of overall development in numerous species of plant. After extended period exposure to Cd, roots become mucilaginous, decomposing, and browning, and disintegrating; lessening of roots and shoots elongation, rolling and chlorosis of leaves can occur (Tran and Popava, 2013).

Biochar is accepted as a soil amendment having

the potential to improve soil management; biochar application has been shown to have a positive influence on soil properties. Biochar can change the soil microbial population, promote mycorrhizal fungi, and neutralise phytotoxic compounds in the soil (Lehmann et al., 2011). In addition, the application of biochar is suggested to increase plant growth by supplying several nutrients to growing plants or by leaching of nutrients (Graber et al., 2010; Lairdet al., 2010). Biochar is accepted as a soil amendment having the potential to improve soil management; biochar application has been shown to have a positive influence on soil properties. Biochar can change the soil microbial population, promote mycorrhizal fungi, and neutralise phytotoxic compounds in the soil (Lehmann et al., 2011). In addition, the application of biochar is suggested to increase plant growth by supplying several nutrients to growing plants or by leaching of nutrients (Graber et al., 2010; Lairdet al., 2010). Biochar can improve plant productivity directly as a result of its nutrient content and release characteristics.

Biochar is basically a charcoal resembling material that is made from plant constituents such as grass, forest and agricultural remains that are disintegrated at very high temperature, frequently during renewable production of energy. It usually has the prospective to be utilized as a soil-conditioner and as a container substrate modification in the field of horticulture and agriculture (Basiri et al., 2019). Application of biochar to soils is deliberated as an encouraging approach to withstand fertility of soil while instantaneously sequestering atmospheric carbon dioxide. It is also well recognized that “all types of biochars are not produced identical” and as a result the impacts on crop yields are both site particular and biochar particular (Vaccari et al., 2015). Biochar can restrain heavy-metals in soil through numerous maintenance mechanisms (Younis et al., 2015).

Biochar has numerous progressive effects on the properties of soil, such as enhancing water holding capacity of soil, enhancing cation exchange capacity, as well as addition of nutrients and develop plants nutrients uptake and biological possessions. Properties of biochar differ considerably on the behalf of their corresponding feedstock and manufacture procedure which can in turn affect their enactment in field level, farming applications, and their capability to sequester carbon (Agbna et al., 2017; Hameeda et

al., 2019; Biederman and Harpole 2013). Application of biochar can improve content of organic matter in soil which usually leads to increase the fertility soil (Glodowska and Lyszcz). Biochar can modify the soil microscopic population, stimulate mycorrhizal fungi, and neutralize phytotoxic mixtures present in the soil. In addition, biochar application is recommended to intensify the growth of plants by providing numerous nutrients to raising plants or by nutrients leaching (Petrucelli et al., 2015).

Tomato (*Solanum lycopersicum*, L.) relates to the family known as *Solanaceae* also entitled *Nightshades*, which consist of more than three thousand species. Tomato remains to be the most significant vegetable in the whole world all because of increasing dietary and commercial worth, extensive production of tomato as well as exemplary plant to carry out research (Melomey et al., 2019). It is a significant currency and industrialized crop in several regions of the whole world (Qasim et al., 2018). Tomato contributes to a well-proportioned and healthy nutrition. They are rich in vitamins, minerals, important amino acids, dietary fibers and sugars. Tomato comprises abundant vitamin B as well as C, phosphorus and iron. Tomatoes are processed fresh in salads or cooked in pastes, soup and fish or meat dishes. They can also be consumed into squashes, ketchup and juices. Preserved and dehydrated tomatoes are economically significant processed foodstuffs (Dam et al., 2005). In present study, an effort has been made in order to study the impacts of biochar on the growth and physiology of tomato grown in the cadmium contaminated soil.

## Materials and Methods

The experiment was conducted in Botanical Garden, Bahauddin Zakariya University Multan during March 2020. For conducting experiment, certified seeds of tomato were taken from Cotton Research Institute of Multan. Soil was prepared after crushing, drying and stone free by sieving to 2mm. Before sowing of tomato, soil was spiked with Cd salt. Already synthesized Biochar was taken from Department of soil sciences, Bahauddin Zakariya University, Multan for experimental work. The order of concentrations of Cd with biochar in the form of treatments levels was control with no Cd and biochar, low cadmium (10mg/kg of soil), high cadmium (15mg/kg of soil), low cadmium + biochar 12% and high cadmium + biochar 12% were applied to the

tomato plants. Growth Parameters including shoot and root length, shoot and root fresh and dry weight, leaves fresh and dry weights, number of leaves were studied. While physiological parameters were in the form of chlorophyll a and b, total chlorophyll, total protein, total amino acid, total phosphorus, total potassium, total magnesium and total calcium. All the data obtained was analyzed by using the Microsoft excel for statistical analysis. Digital balance was used for the weighing the fresh and dry weights of root, shoots and leaves while chlorophyll a, b and total chlorophyll ratio were calculated by using chlorophyll meter (SPAD-502). Folin phenol reagent was used to measure protein. The analysis of amino acids was carried out with the help of an automatic amino acid analyzer. Ca, Mg, P and K were determined by using inductively coupled plasma atomic emission spectrometer.

## Results and Discussion

### *Impacts of biochar and Cd on growth parameters*

Results shown in the [Table 1](#), biochar significantly reduced the impact of cadmium on the shoot length of tomato plant. Maximum shoot length 19.16 cm was recorded in presence of biochar. While minimum shoot length 11.23 cm was obtained in the presence of high cadmium. Control showed normal growth i.e. 18 cm of shoots while in case of shoot length biochar showed its maximum impact in reducing the toxicity of Cd. Low cadmium showed minimum effects as more growth trend was noted, the length of shoots was 16.6cm as compared to that of high level of Cd which showed reduction in the shoot lengths. While combination of low cadmium and biochar showed more growth in the plants 17.5cm of shoots than the plants with high cadmium and biochar that was 8.5cm. Similar findings have been already found by many authors when biochar was used in the presence Cr ([Puga et al., 2015](#); [Abbas et al., 2017](#)). Biochar synthesized from wheat straw has also shown strong interaction with bindings and translocation of copper and cadmium in the soil. It was observed that biochar elevated the soil fertility and increased the annual yield of rice. Biochar was also seen helpful in changing the toxic severity of Cd when applied in hydrated soil ([Medyńska-Juraszek et al., 2020](#)) Biochar significantly reduced the impact of cadmium on the root length of tomato plant. Maximum root length 10.43cm was observed in presence of biochar solo. While minimum root length 6.3cm was

recorded in the presence of high cadmium. Control plants showed normal growth 9.2cm of roots while application of biochar showed maximum impacts of cd on root length. Plants with low cadmium application showed more growth 7.3cm of roots than the plants with high cadmium. While combination of low cadmium and biochar showed more tendency of growth in roots 8.15cm than the plants with high cadmium and biochar 4.6 cm. These results matched with the experimental study of [Fiaz et al. \(2014\)](#); [Brennan et al. \(2014\)](#) in which growth pattern in the fresh as well as root, shoot and leaves was observed high with the supplements of charcoal biochar. While [Ali et al. \(2019\)](#) observed the biochemical changes in the cd contaminated soil when biochar was added. The mechanism of absorption of cd in the soil in the presence of biochar and ions exchange were also observed by [Ali et al. \(2019\)](#). In case of fresh weight of tomato plants, similar impacts of biochar and cd were observed. Maximum shoot fresh weight 30.83 g was recorded in presence of 12% of biochar while minimum shoot fresh weight 17.5g was noted in the presence of high cadmium. Control treatments showed normal shoot fresh weight of 25.3g as compared to that of rest of the treatments level of cd and biochar. Biochar also showed maximum shoot fresh weight. Plants with low cadmium application showed more shoot fresh weight 24.13 g than the plants with high cadmium 17.5g. While combination of low cadmium and biochar showed more shoot fresh weight of 25.83 than the plants with high cadmium and biochar 17.8g. ([Alaboudi et al., 2019](#); [Medyńska-Juraszek et al., 2020](#)) observed the same pattern of growth in the wheat crops and their findings have shown the increase in the yield, biomass and leaf surface area. According to their study, low temperature also hindered the mobility of pollutants in soil surface and biochar efficiency was also elevated. It was also clear by the study of [Alaboudi et al. \(2019\)](#) in case of green chili when biochar and chromium were supplied together as high translocation of chromium was observed at high temperature. Biochar significantly reduced the impact of cadmium on the root fresh weight of tomato plant. Maximum root fresh weight of 9.4g was obtained in presence of only biochar. While minimum root fresh weight of 4g was obtained in the presence of high cadmium. Control treatments showed normal root fresh weight of 8.4g. Application of biochar showed maximum root fresh weight as compared to that of plants with low cd and biochar in which root fresh weight of 7.13g as compared

to that of high cd 4g. While combination of low cadmium and biochar showed more root fresh weight of 5.73g than the plants with high cadmium and biochar 4.66g. Brennan et al. (2014); Liu et al. (2020) noted the same pattern of growth and biochemical processes during the research work on the biochar applications in the presence of copper in the soil.

Same pattern of biochar and cd treatments were observed in case of dry weights of roots, shoot and leaves. Biochar reduced the toxic impacts of cd in case of shoot dry weights which was found maximum 14.7g in presence of biochar only. While minimum shoot dry weight of 9.2g was achieved in the presence of high cadmium. Application of biochar showed maximum shoot dry weight by reducing the toxicity of Cd. Tomato plants with low cadmium application showed more shoot dry weight of 10.8g than the plants with high cadmium 9.2g. While combination of low cadmium and biochar showed more shoot dry weight of 11.8g than the plants with high cadmium and biochar 7.766g. Maximum root dry weight of 6.06 g was observed in presence of only biochar while minimum root dry weight of 3.46 g was obtained due to the toxic impacts of Cd. Plants with low cadmium application showed more root dry weight of 4.4g than the plants with high cadmium 3.46 g. While combination of low cadmium and biochar showed more root dry weight of 4.63 g than the pants with high cadmium and biochar 2.66 g. Biochar significantly reduced the impact of cadmium on the leaves fresh weight of tomato plant. Maximum leaves fresh weight of 10.5g was recorded in presence of only biochar. While minimum leaves fresh weight of 7.5g was obtained in the presence of high cadmium. Control treatments showed normal leaves fresh weight of 10.5g. Plants with low cadmium application showed more leaves fresh weight of 8.4g than the plants with high cadmium 7.5g. Combination of low cadmium and biochar showed more leaves fresh weight of 8.66 g than the plants with high cadmium and biochar 6.56 g. Biochar also elevated the leaves dry weight of 6.16 g at low level of Cd and also in single form. The combination of low level of Cd and biochar showed significant impacts of biochar on dry weight of leaves while in the presence of high level of Cd the impact of biochar was found slightly. Authors like Coumar et al. (2016); Bashir et al. (2018); Ghori et al. (2019) and Zhu et al. (2020) conducted their studies in line with the current research work and found that biochar having various compositions increased the

porosity of soil by which absorption of heavy metals like Cd, Cu and Ni was found very effectively. This pattern of translocation of heavy metals then shifted the critical load of such heavy metals in soil as the digestion process of biochar was occurred in the soil. This showed that biochar worked multipurpose in the soil in the presence of heavy metals. The studies of (Rehman et al., 2011; Suppadit et al., 2012; Suskabye et al., 2016; Brennan et al., 2014; Woldetsadik et al., 2016; Ghori et al., 2019; Awad et al., 2020; Medyńska-Juraszek et al., 2020) also noted the interaction of biochar with soil and pollutants particles and found the findings e.g. (i) biochar increased the fertility of soil (ii) pollutants degradation was occurred with the supplements of biochar (iii) High movement of pollutants and exchange of ions was occurred (iv) critical shifting of heavy metals load was seen within the tranlocation of biochar in the soil. The studies of these authors also confirmed the detoxification of pollutants in the presence of biochar supplied to the soil which increased the growth of plants.

#### *Impacts of biochar and Cd on physiological parameters*

The impacts of biochar in the presence of Cd have been shown in the Table 2 which showed the similar trends as in case of growth parameters. Biochar significantly reduced the impact of cadmium on the chlorophyll a of tomato plant. Maximum chlorophyll a (0.51 mg/g) was observed in presence of solo biochar. While minimum chlorophyll a 0.35 mg/g was obtained in the presence of high cadmium. Control treatments showed normal chlorophyll a content 0.45 mg/g. Plants under low cadmium level also showed more chlorophyll a 0.41 mg/g than the pants growing under high cadmium 0.35mg/g. Combination of low cadmium and biochar showed more chlorophyll a 0.42mg/g than the combination of high cadmium and biochar 0.27mg/g. Biochar significantly reduced the impact of cadmium on the chlorophyll b of tomato plant. Maximum chlorophyll b 0.44mg/g was obtained under biochar in single form. While minimum chlorophyll b 0.3mg/g was obtained in the presence of high cadmium. Control group showed normal chlorophyll b content 0.41mg/g. Application of biochar on solo basis showed maximum chlorophyll b content. While combination of low cadmium and biochar showed more chlorophyll b content 0.39mg/g than the combination of high cadmium and biochar 0.28mg/g. The total chlorophyll of tomato plant also showed the same trend of interaction under the stress of Cd and biochar addition.

**Table 1:** Effects of biocar and heavy metals on the growth parameters of tomato plant.

Treatments	Shoot length (cm)	Root length (cm)	Shoot fresh weight (g/plant)	Root fresh weight (g/plant)	Shoot dry weight (g/plant)	Root dry weight (g/plant)	Leaves fresh weight (g)	Leaves dry weight (g)	Number of leaves
CK	18± 0.5	9.2±0.26	25.3±0.43	8.46±0.45	13.86±0.35	5.13±0.15	10.5±0.5	5.43±0.40	24.33±0.57
BC	19.17±0.37	10.43±0.30	30.83±0.76	9.4±0.36	14.7±0.2	6.07±0.20	11.9±0.36	6.16±0.15	27±1
Cd <sub>low</sub>	16.6±0.52	7.3±0.45	24.13±0.32	7.13±0.32	10.8±0.26	4.4±0.36	8.4±0.36	5.43±0.40	22±1
Cd <sub>high</sub>	11.23±1.12	6.3±0.2	17.5±0.5	4±0.1	9.2±0.25	3.47±0.45	7.5±0.5	4.23±0.25	18±1
Cd <sub>low</sub> + BC	17.5±0.5	8.15±0.30	25.83±0.76	5.73±0.25	11.8±0.26	4.63±0.15	8.66±0.49	5.76±0.15	24±1
Cd <sub>high</sub> + BC	8.5±0.45	4.6±0.43	17.8±0.75	4.67±0.58	7.77±0.25	2.67±0.15	6.57±0.49	3.3±0.36	15.67±1.52

**Table 2:** Effects of biocar and heavy metals on the physiological parameters of tomato plant.

Treatments	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total Chlorophyll (mg/g)	Total protein (mg/g)	Total amino acids (mg/g)	Total phosphorus (mg/g)	Total potassium (mg/g)	Total Magnesium (mg/g)	Total Calcium (mg/g)
CK	0.45±0.02	0.41±0.01	0.86±0.01	2.52±0.02	1.48±0.02	0.62±0.02	1.73±0.01	1.22±0.02	2.11±0.02
BC	0.51±0.01	0.44±0.01	0.96±0.01	2.94±0.03	1.94±0.02	0.79±0.01	1.83±0.01	1.34±0.02	2.62±0.02
Cd <sub>low</sub>	0.41±0.01	0.38±0.01	0.78±0.01	2.18±0.10	1.42±0.02	0.49±0.01	1.6±0.01	1.05±0.05	2.18±0.10
Cd <sub>high</sub>	0.35±0.01	0.3±0.01	0.64±0.01	1.79±0.08	0.90±0.03	0.34±0.03	1.28±0.02	0.82±0.02	1.48±0.02
Cd <sub>low</sub> + BC	0.42±0.01	0.39±0.01	0.81±0.01	3.21±0.10	1.49±0.01	0.58±0.01	1.69±0.01	1.21±0.02	2.4±0.05
Cd <sub>high</sub> + BC	0.27±0.02	0.28±0.01	0.55±0.02	1.25±0.05	0.71±0.02	0.29±0.01	0.97±0.02	0.60±0.01	0.98±0.02

Maximum total chlorophyll contents of 0.96 mg/g were obtained in presence of biochar when supplied in single form. While minimum total chlorophyll content 0.64 mg/g was noted in the presence of high cadmium. Plants with low cadmium application showed more total chlorophyll 0.78mg/g than the plants with high cadmium 0.64 mg/g. While combination of low cadmium and biochar showed more total chlorophyll 0.81mg/g than the combination of high cadmium and biochar 0.55mg/g. These results have also find same in line of results (Haouari et al., 2012; Younis et al., 2015; Abid et al., 2017; Zeeshan et al., 2020) during the working of biochar in the form of saw dust on the biochemical activities of pea plants in which they found that due to chlorosis, the chlorophyll activities were reduced. Similarly, the studies of (Haouari et al., 2012; Younis et al., 2015, 2016; Zafar-ul-Hye et al., 2020) have found the fast mobility of pollutants in the soil when added with biochar. In their studies they observed that after addition of biochar synthesized by leafy debris accelerated the movement of Cd and Cu in the soil solution. Such type of research was also conducted by (Haouari et al., 2012; Younis et al., 2015; Moradi et al., 2019) in which interaction of chlorophyll contents with Cr and bichar was seen. Chlorophyll contents were found reduced in the presence of Cr ions in the soil. Biochar significantly reduced the impact of cadmium on the total protein of

tomato plant. Maximum total protein 2.94mg/g was recorded in presence of biochar supplied singly. While minimum total protein 1.79 mg/g was obtained in the presence of high cadmium. Control group of plants showed normal range of total protein content 2.52 mg/g. Group of plants with low cadmium application showed more total protein 2.18 mg/g than the group of plants with high cadmium 1.79 mg/g. While combination of low cadmium and biochar showed more total protein 3.21 mg/g than the group of plants with high cadmium and biochar 1.25mg/g. Similar findings were obtained in case of the total amino acids of tomato plant. Maximum 1.946667 mg/g of total amino acids was in the presence of solo addition of biochar. While less amount of 0.90 mg/g total amino acids was obtained in the presence of high cadmium. Normal amount of total amino acids content of 1.48 mg/g was detected under control. 1.42 mg/g of total amino acid was noted in the presence of low cadmium while 0.90 mg/g was recorded at high level of Cd. Similarly, 1.49mg/g and 0.71 mg/g of total amino acid was recorded at low and high Cd in combination with biochar, respectively. Biochar also showed its impact in case of total phosphorus. Maximum total phosphorus content of 0.79 mg/g was obtained in presence of only biochar. While minimum total phosphorus content of 0.34 mg/g was obtained in the presence of high cadmium. Plants under control

treatment showed total phosphorus content of 0.62 mg/g. Low level of Cd showed less effect and total phosphorus content of 0.49 mg/g than high cadmium in which 0.34 mg/g of phosphorus was noted. While under combination of low cadmium and biochar slightly higher total phosphorus content of 0.58 mg/g was found than high cadmium and biochar which was 0.29 mg/g. Similar results were also obtained in case of total potassium of tomato plant. Maximum total potassium content of 1.83 mg/g was obtained in presence of only biochar. While minimum amount of total potassium content of 1.28 mg/g was obtained in the presence of high cadmium. Under control treatment total potassium content was 1.73 mg/g while at low Cd 1.6 mg/g and 1.28 mg/g at high Cd was obtained. At low Cd and high Cd in combination with biochar produced total potassium of 1.69 mg/g and 0.97 mg/g, respectively. The result in case of total magnesium were also in same line with the rest of parameters of plants similarly 1.34 mg/g of total magnesium content obtained in presence of single application of biochar while 0.82 mg/g was obtained in the presence of high cadmium. While combination of low cadmium and biochar showed more total magnesium content of 1.21 mg/g than the combination of high cadmium and biochar 0.60 mg/g. Plant total calcium also showed the same trend as biochar significantly reduced the impact of cadmium on the total calcium of tomato plant. Maximum total phosphorus content of 2.62 mg/g was obtained in presence of only biochar. While minimum total calcium content of 1.48 mg/g was obtained in the presence of high cadmium. Control treatment showed normal total calcium content of 2.11 mg/g. Low and high levels of Cd in combination with biochar showed 2.18 mg/g and 0.98 mg/g of total calcium respectively. Previously similar type of results were also presented by (Khan et al., 2018; Gondek et al., 2019; Almaroai and Eissa, 2020) during their work on the elevating effects of biochar and biochar produced antagonistic effects on the combinations of different heavy metals. Younis et al. (2015); Shahkolaie et al. (2020) proved the strong contribution of biochar when supplied in the presence of some organic complexes in the saline soil and found that biochemical parameters of cotton cultivars were altered. Research work of (Sehar et al., 2018; Gondek et al., 2019) also have reported the similar findings of association of biochar and some heavy metals. Similar type of work has also been conducted by (Suskabye et al., 2012; Gondek et al., 2019) in which biochemical and growth parameters

of alfalfa plants showed the elevated growth after supplementation of biochar while already Cd, Zn, Cu has impacted the plants adversely.

## Conclusions and Recommendations

From the present research work it can be concluded that Cd which belongs to family of heavy metals has adverse impacts on the biological activates more or less. The impacts of Cd can be encountered by the addition of biochar. The addition of biochar minimized the effects of Cd in this study. Low and high levels of Cd supplied singly effected the growth and biochemical parameters of tomato plants while in combination with biochar, their effects were minimized to a greater extent. Biochar with low Cd did not allow it to produce drastic impacts on the growth and physiological activities of tomato plant while along with high level of Cd, although Cd produced negative impacts but these were very less as compared to that of high level of Cd when it was supplied in solo form. So, from these results it is evident that biochar can be helpful in eliminating the impacts of different pollutants in soil.

## Novelty Statement

Biochar can minimize the adverse impacts of toxic heavy metals.

## Author's Contribution

**Khaliq Dad:** Planned the work.

**Muhammad Nawaz:** Overall supervised.

**Rumsha Hassan:** Wrote the article.

**Kainat Javed:** Performed statistical analysis.

**Asma Shaheen:** Collected data.

**Fengliang Zhao:** Suggestions and reviewed.

**Muhammad Imran:** Analyzed parameters

Syed Tansir Hussain Shah: Helped in write up.

**Muhammad Faraz Anwar:** Corrected and revised.

**Muhammad Aurangzaib:** Conducted experiments.

## Conflict of interest

The authors have declared no conflict of interest.

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