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**Original Research Article**

# Improvement in Growth Parameters of Rice (*Oryza sativa* L.) in Chromium Contaminated Soil due to Biochar Application

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**A B S T R A C T**

Anthropic activities like mining, transport, farming, industrial waste disposal etc. release inorganic contaminants in great concentrations that are toxic to natural ecosystems. Heavy metal like chromium that poses severe human health risks through intake of contaminated agricultural produces when present in high concentrations in soil. To address this problem pot experiment was conducted in *kharif* season of 2018-19to know the effect of biocharon growth parameters of rice (*Oryza sativa* L.)in chromium contaminated soil in the net house. Five chromium levels (0, 25, 50, 75 and 100 mg/kg) with and without three levels of biochar@ 20 ton/ha, 40 ton/ha and 60 ton/ha respectively were taken. Plant height, chlorophyll content, number of tillers hill$^{-1}$ and productive tillers hill$^{-1}$ of rice were recorded. Results indicated that chromium had negative impact on these growth parameters of rice. Growth of rice decreased significantly by the increasing rate of chromium application. Results obtained from the experiments also revealed that addition of biochar significantly increased these growth parameters of rice. In general, the application of biochar has shown the ability to reduce the toxic effect of chromium on growth of rice.

**Keywords**

Biochar, Chromium, Effect, Growth, Parameters, Rice

## Introduction

Heavy metal pollution owing to anthropogenic events is a global problem and has numerous undesirable effects on soil and plant systems. This problem is becoming more serious, particularly in developing nations (Bashir *et al.,* 2017). Heavy metals are usually denoted to as those metals which have a specific density of more than 5 g/cm$^3$ and adversely affect the living organisms (Ujah *et al.,* 2019). Undue poisonous metal concentrations in polluted soils lead to degradation of soil quality, reduction in crop yield and metal accrual in agricultural produces and thus generate accumulative hazards to human health as well as plants and animals (Wang *et al.,* 2013a).In recent times chromium (Cr) pollution in soil and water is severe concern. Cr gained demanding consideration because of its toxic properties on plant systems as well as human beings (Kumar *et al.,* 2020). In the environment Cr is mainly found as hexavalent chromate and trivalent chromite however Cr might be present in several oxidation forms (−2 to +6) (Ashraf *et al.,* 2017). Because of strong oxidizing properties, solubility and permeability through cellular membranes, Cr(VI) is thought to be greatly existing(Hu *et al.,* 2016). The greater consumption of Cr in various procedures (Qiu *et al.,* 2014; Wang *et al.,* 2013b) originated pollution of soil and water (Ertani *et al.,* 2017) in the past decades. Hexavalent chromium is normally detected in soil with improvement of industrial events together with electroplating, chromate production and leather tanning (Su *et al.,* 2016). Consequentally, Cr toxicity is currently a significant threat to different water forms and agricultural land (Choudhary *et al.,* 2012).

Remediation of these polluted soils through conventional practices, comprising land filling and excavation are unrealistic on large scale as these are environmentally disruptive and cost-prohibitive (Houben *et al.,* 2013a) because they produce substantial disruption in environment and are economically impracticable on a large scale (Houben *et al.,* 2013b). Therefore to restrain solubility and bioavailability of metal(oid)s in polluted soil some distinct soil-management practices are compulsory (Hattab *et al.,* 2015). Phytoavailability and mobility of metals in soils can be decreases via in-situ metals immobilization in polluted soils by using amendments (Rehman *et al.,* 2017; Rizwan *et al.,* 2016b). To immobilize the metals in soils, organic and inorganic amendments can be used (Chaiyarat *et al.,* 2011) with variable profits but organic amendments might be the superior preference owing to the capacity of organic amendments to upgrading in biological, physical, chemical properties and fertility of soil (Kant *et al.,* 2018a; 2018b). Organic amendments are very resourceful to decontaminate the effects of metals in soil and plant systems as they are derivatives of raw biological waste and slight pretreatment is needed prior to their application (Yin *et al.,* 2016; Bashir *et al.,* 2017). Several organic amendments can decrease the bioavailability, solubility and leaching of metals (Angelova *et al.,* 2013; Kumar *et al.,* 2018). Organic amendments can enrich fertility and microbial activity of soil which resulting to amelioration of soil quality as whole (Kumar and Sharma, 2018). Among organic amendments, biochar is extensively used currently and demonstrates several profits for soil and crop (Du *et al.,* 2017; Hussain *et al.,* 2017; Xu *et al.,* 2013). Biochar (BC) is solid biological substance manufactured from slow pyrolysis of waste organic materials likemanures and agricultural remainders (Rizwan *et al.,* 2016c) or biochar is carbonaceous black porous substance acquired through pyrolysis of biomass in oxygen-free environment (Choudhary *et al.,* 2017). It might influence the toxicity, transport and fate of different heavy metals in the soil (Nigussie *et al.,* 2012). Biochar exhibited to decrease metal bioavailability in soil and uptake and translocation by plants (Li *et al.,* 2016; Mohamed *et al.,* 2015).

Biochar is noble alternative for stabilization of heavy metal in polluted soil which decreases heavy metals uptake by plants (Lu *et al.,* 2014). Use of biochar in comparison with the other chemical and biological methods in pollutant removal has remarkable potential (Zeng *et al.,* 2015) because it is eco-friendly and economical in production (Tan *et al.,* 2015).Keeping in view the above, the experiment is planned to find the effect of biochar on rice growth and reduction of chromium (VI) toxicity in soil.

## Materials and Methods

Pot experiment was conducted in the net house during kharif season of 2018-19. Five Chromium levels (0, 25, 50, 75 and 100 mg/kg) with and without three levels of Biochar @ 20 ton/ha, 40 ton/ha and60 ton/ha respectively were taken. Bulk soil was taken from Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Soil was air dried gently, ground to pass through a 2 mm sieve and homogenized. The soil sample was analyzed for different soil properties and results are presented in Table 1.Processed 10 kg soil was filled in polythene lined pots. The moisture level in pots was maintained up to field capacity. The experiment was arranged in completely randomized design (CRD) comprising20treatments.Rice (var. HUR-105) was used as test crop in *kharif* season of 2018-19. $N:P_2O_5:K_2O$ were applied @ 150:75:60kg/ha through Urea, Di-ammonium phosphate, muriate of potash (MOP), respectively as per recommendation in all the pots. Required amount of Cr for 10 kg of soil was applied through potassium dichromate ($K_2Cr_2O_7$)solution to the pots and allowed to keep for maintaining equilibrium. After 15 days of chromium application, the biochar 20, 40, and 60 ton/ha were applied to the soil and thoroughly mixed. The biochar was collected from a private rice mill situated at Kollanapur village of Mirzapur district. Pots were incubated for next 15 days with biochar and watered at field capacity almost on a daily basis after a month of incubation (four-week old-seedlings) was transplanted @ 5 seedlings $pot^{-1}$.

The height of plants was measured with meter scale from base of plant to tip of uppermost fully expanded leaf. After emergence of panicle, height was measured up to tip of panicle. Total number of tillers $hill^{-1}$ and productive tillers $hill^{-1}$ were counted from each pot. The Chlorophyll content (SPAD) was recorded from each pot by SPAD meter and average value was reproduced.

For determining significance between treatment means and to reach a valid conclusion, statistical analysis was made. Difference of treatment means were tested using least significant difference or critical difference (CD) at 1% probability level (Gomez and Gomez, 1984)by following Complete Randomized Design (CRD) to draw a valid differences among treatments.

## Results and Discussion

### Effect of biochar on growth of rice in chromium contaminated soil

### Plant height

The data related to the height of the rice plant was recorded at 30 DAT, 60 DAT, and 90 DAT. The height of the rice plant in Cr-contaminated soil as affected by biochar is presented in Table 2. The plant height increased at 30, 60, 90 DAT was observed. Chromium exposure reduced the height (cm) of rice plant at a different level of chromium at all growth stages. The plant height decreased with increased concentration of chromium from 0, 25, 50, 75, 100 ppm, respectively. Similar result reported by Nagarajan (2014).

It was observed that the addition of biochar significantly increased the plant height (30 DAT) as compared to control pots. Highest plant height (100.95cm) was recorded with treatment Cr0 + BC60 followed by the treatment Cr25 + BC60 i.e., (99.23cm). On the other hand, the lowest value of plant height was obtained from control pot with treatment Cr100 (46.96cm). The similar trend was perceived at 60 DAT and 90 DAT except for a slight increase in plant height. Results were showed that biochar application significantly increased plant height of rice at 30, 60, and 90 DAT.

Abbas *et al.,* (2017) found that biochar application increased plant height of wheat in dose additive mode in cadmium contaminated soil when compared with control treatment. Khan *et al.,* (2013; 2018) described that addition of Sewage Sludge Biochar significantly aggravated plant growth of rice compared to control. Height of tillers, number of tillers, shoot biomass and grain yield all significantly increased. Saengwilai *et al.,* (2017) noticed that rice cultivars sown in amended soils demonstrated greater percent of growth rates compared with control. However, Cui *et al.,* (2012) reported that plant growth is not affected by biochar.

## Chlorophyll content

The chlorophyll data was recorded by SPAD meter at different growth stages and is presented in Table 2. A perusal of data presented that chlorophyll content increased slowly from 30 to 60 DAT and afterwards gradual decrease was detected at 90 DAT.

Compared to control the amount of chlorophyll content was significantly decreased with the increasing levels of chromium at all growth stages. Data showed that as the level of chromium increases from 0 to 100ppm the amount of chlorophyll content decreased. The highest chlorophyll content (38.40) was observed with treatment Cr0+ BC60 followed by treatment Cr0+ BC40 (37.53). The lowest chlorophyll content was found (28.87) with treatment Cr100. A similar trend followed in 60 DAT but during 90 DAT gradual declines in chlorophyll content due to the effect of Cr (VI) toxicity. Chromium toxicity in plants arises by impeding growth more or less, showing chlorosis. High chromium concentration prevents photosynthesis and seriously obstructs root growth as reported by Dheeba *et al.,* (2012). Decrease in chlorophyll content due to chromium was also reported by Kumar *et al.,* (2018).

It was also observed that chlorophyll content increased with the application of biochar. The application biochar increased chlorophyll a, b, total chlorophyll and carotenoid concentration compared to control is also reported by Younis *et al.,* (2016). Rizwan *et al.,* (2016a; 2016b) also reported increased chlorophyll content and propound that it could be due to reversal of Cd induced toxicities in plants due to biochar application. Liu *et al.,* (2020) described that addition of organic amendments in Cd contaminated soil increased chlorophyll contents of rice.

## Number of tillers hill$^{-1}$

Data associated with number of tillers per hill and productive tillers per hill was recorded at different stages of rice growth and offered in Table 3. A perusal of data presented that number of tillers per hill increased from 30 to 60 DAT and afterwards gradual reduction was observed. Different levels of chromium generally affect the tiller number. As the chromium concentration increased there was a decreased in the number of tillers and productive tiller per hill. Cr-treated rice plants showed stunted growth and produced a smaller number of tillers and leaves compared to counterparts grown in control has reported by Ahmad *et al.,* (2011).

The results also showed that a number of tillers per hill of rice and productive tillers per hill were significantly affected due to the application of biochar in the pot experiments. The highest total tillers hill$^{-1}$ (12.89) and productive tillers hill$^{-1}$ (12.24) was observed in Cr0+ BC60.

**Table.1** Physio-chemical characteristics of the initial experimental soil

| Properties | Value | Method | Reference |
|---|---|---|---|
| a) Mechanical properties | | | |
| Soil separates (%) | | | |
| Sand | 50.21 | International Pipette method | Piper (1966) |
| Silt | 26.13 | | |
| Clay | 23.66 | | |
| Textural class | Sandy clay loam | Textural Triangle USDA | Black *et al*. (1967) |
| b) Physical analysis | | | |
| Bulk density | 1.39 | Core sampler | Piper (1966) |
| Particle density | 2.66 | Core sampler | Piper (1966) |
| Pore space (%) | 47.74 | | Volmacil (1965) |
| c) Chemical analysis | | | |
| pH (1:2.5) soil: water suspension | 8.03 | Glass electrode digital pH meter | Jackson (1973) |
| Electrical conductivity ($dSm^{-1}$ at $25^0$ C) | 0.18 | Electrical conductivity meter | Jackson (1973) |
| Organic carbon (%) | 0.39 | Chromic acid Wet digestion | Walkley and Black's (1934) |
| Available N ($kg\ ha^{-1}$) | 171.62 | Alkaline Permanganate Method | Subbiah and Asija (1956) |
| Available P ($kg\ ha^{-1}$) | 18.19 | 0.5M $NaHCO_3$ Extractable method | Olsen *et al*., (1954) |
| Available K ($kg\ ha^{-1}$) | 212.57 | 1N $NH_4OAC$ (Flame photometer) | Hanway and Heidel (1952) |
| Available Cr ppm | 0.081 | Atomic Absorption Spectrophotometer | Lindsay and Norwell (1978) |
| Available Fe ppm | 17.83 | | |
| Available Mn ppm | 6.07 | | |
| Available Cu ppm | 1.80 | | |
| Available Zn ppm | 1.08 | | |

**Table.2** Effect of biochar on plant height and chlorophyll (SPAD) content of rice in chromium contaminated soil

| **Treatments** | **Plant height** | | | **Chlorophyll content (SPAD)** | | |
|---|---|---|---|---|---|---|
| | **30 DAT** | **60 DAT** | **90 DAT** | **30 DAT** | **60 DAT** | **90 DAT** |
| Cr0 | 53.60 | 78.60 | 92.67 | 35.03 | 33.97 | 24.70 |
| Cr25 | 52.56 | 75.46 | 91.50 | 34.20 | 33.43 | 24.23 |
| Cr50 | 50.10 | 71.80 | 90.15 | 32.27 | 31.10 | 22.37 |
| Cr75 | 49.16 | 69.86 | 89.16 | 29.23 | 28.37 | 21.23 |
| Cr100 | 46.96 | 65.66 | 87.34 | 28.87 | 26.63 | 19.53 |
| Cr0+BC20 | 56.93 | 83.13 | 96.25 | 36.33 | 34.26 | 25.80 |
| Cr0+BC40 | 58.33 | 86.33 | 98.53 | 37.53 | 34.97 | 26.26 |
| Cr0+BC60 | 63.93 | 89.93 | 100.95 | 38.40 | 35.40 | 27.77 |
| Cr25+BC20 | 53.76 | 78.40 | 94.12 | 35.27 | 33.87 | 24.85 |
| Cr25+BC40 | 55.20 | 81.20 | 96.33 | 36.87 | 34.03 | 26.43 |
| Cr25+BC60 | 57.73 | 83.92 | 99.23 | 37.33 | 35.00 | 26.96 |
| Cr50+BC20 | 52.13 | 74.15 | 92.95 | 33.60 | 31.63 | 22.94 |
| Cr50+BC40 | 54.63 | 77.93 | 95.31 | 34.30 | 33.07 | 23.65 |
| Cr50+BC60 | 56.73 | 80.76 | 97.44 | 35.40 | 34.30 | 24.69 |
| Cr75+BC20 | 51.20 | 72.24 | 92.63 | 32.77 | 30.63 | 22.70 |
| Cr75+BC40 | 52.33 | 75.33 | 96.83 | 33.43 | 31.47 | 23.62 |
| Cr75+BC60 | 54.06 | 78.56 | 98.33 | 34.03 | 33.07 | 24.43 |
| Cr100+BC20 | 47.20 | 68.20 | 90.34 | 29.67 | 28.57 | 19.89 |
| Cr100+BC40 | 49.78 | 71.84 | 93.98 | 30.30 | 29.12 | 20.46 |
| Cr100+BC60 | 51.36 | 74.36 | 95.24 | 31.60 | 30.67 | 21.96 |
| SEm± | 0.58 | 0.55 | 0.75 | 0.57 | 0.48 | 1.61 |
| CD ($p=0.01$) | 1.65 | 1.57 | 2.15 | 1.64 | 1.38 | 4.62 |

**Table.3** Effect of biochar on total tillers and productive tillers counthill$^{-1}$ of rice crop in chromium contaminated soil

| **Treatments** | **No. of Tillers hill$^{-1}$** | | | **Productive tillers hill$^{-1}$** |
|---|---|---|---|---|
| | **30 DAT** | **60 DAT** | **90 DAT** | |
| Cr0 | 5.20 | 8.28 | 9.05 | 8.76 |
| Cr25 | 4.65 | 7.40 | 8.14 | 7.85 |
| Cr50 | 3.96 | 6.16 | 7.33 | 6.33 |
| Cr75 | 2.85 | 5.12 | 6.72 | 5.89 |
| Cr100 | 2.56 | 4.65 | 5.10 | 4.16 |
| Cr0+BC20 | 6.40 | 9.42 | 10.15 | 9.18 |
| Cr0+BC40 | 7.06 | 11.26 | 11.95 | 10.53 |
| Cr0+BC60 | 7.78 | 12.52 | 12.89 | 12.24 |
| Cr25+BC20 | 6.16 | 8.83 | 9.36 | 8.55 |
| Cr25+BC40 | 6.66 | 9.36 | 10.32 | 9.23 |
| Cr25+BC60 | 7.26 | 11.46 | 11.76 | 10.21 |
| Cr50+BC20 | 4.83 | 7.78 | 8.26 | 7.31 |
| Cr50+BC40 | 5.74 | 8.96 | 9.33 | 8.43 |
| Cr50+BC60 | 6.40 | 10.46 | 10.88 | 9.13 |
| Cr75+BC20 | 3.76 | 6.80 | 7.13 | 6.44 |
| Cr75+BC40 | 4.24 | 7.56 | 8.20 | 7.36 |
| Cr75+BC60 | 5.33 | 9.35 | 9.65 | 8.71 |
| Cr100+BC20 | 3.53 | 5.72 | 6.28 | 5.85 |
| Cr100+BC40 | 3.93 | 6.28 | 7.47 | 6.84 |
| Cr100+BC60 | 4.65 | 8.63 | 8.97 | 7.83 |
| SEm± | 0.32 | 0.36 | 0.48 | 0.36 |
| CD ($p=0.01$) | 0.91 | 1.02 | 1.37 | 1.02 |

The application of biochar resulted in a significantly greater number of tillers per hill and productive tillers hill$^{-1}$ of rice. Generally, because of the supply of better micronutrient by organic sources resulted in better tillering.

Results directed that Cr can affect all growth parameters of rice even though it was reported as an accumulator and tolerant to heavy metals, so upon addition of biochar will reduce the toxicity generated by Cr and significantly increased growth of plants. The variation in the above-mentioned parameters recorded might be attributed to the availability of nutrients. Release of Nutrient from organic sources is mainly because of microbial activity which is slow and steady and further through improved physical conditions of the soils (Hasanuzzaman *et al.*, 2010). Biochar showed the better result because of its chemical stability as it widens the possibility of sequestering carbon besides that it also increased soil fertility and acts as a soil conditioner, application of biochar could also reduce metal uptake in various plants species and increased available nutrient uptake for the plant (Houben and Sonnet, 2015).

Results indicated that chromium had negative impact on growth of rice. Plant height, chlorophyll content, number of tillers hill$^{-1}$, and productive tillers hill$^{-1}$decreased with increasing doses of chromium in soil i.e., (0, 25, 50, 75, 100 ppm). The addition of biochar significantly increased these parameters of rice. The application of biochar reduced chromium toxicity to some extent but not completely.

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