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Evaluation of Chromium Induced Stress on Growth of Barley (*Hordeum vulgare* L.)

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Abstract

Heavy metals are harmful for plants growth. Chromium is one of them which affect growth and yield of plants negatively. Aim of present study was to access the effects of chromium on barley growth. Barley seeds were sown in pots filled with acid washed sand. Different levels (0, 25, 50, 75 and 100 µM) of chromium treatments were applied. Chromium (III) chloride hexahydrate was taken as a source of chromium. Distilled water was used as control (0 µM) treatment. Results showed that root, shoot and total plant length gets reduced significantly and the reduction percentage over control was also increased with increasing Cr concentrations. Leaf surface area was also decreased non-significantly. Chromium also caused a negative impact on fresh and dry weight of (root, shoot and whole plant). Root, shoot fresh weight was diminished by chromium non-significantly at lower concentrations (25 and 50 µM) but significant reduction was observed at higher concentrations (75 and 100 µM). Fresh weight of whole plant was reduced significantly over control by all chromium treatments (25, 50, 75 and 100 µM). A significant reduction was also recorded for plant dry weight (root, shoot and whole plant).

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INTRODUCTION

Various types of pollutants affect the environment; heavy metal emission due to urbanization is one of the major factors which cause serious problems for motherland and atmosphere (Kumar et al., 2015; Kumar et al., 2021b). Chromium has second rank in heavy metals which contaminated the soil, water through sedimentation (Kumar et al., 2017; Kumar et al., 2021a). Chromium is used in various industries viz. leather, textile and steel industries. Overuse of fertilizers and pesticides created severe conditions (Nath et al., 2005; Shrestha et al., 2007; Ogundiran and Afolabi, 2008; Wang and Chen, 2009). Extreme amount of chromium reduced seed germination, plant growth and photosynthetic rate of plants. Chlorophyll content and enzymatic activities were also affected by chromium stress (Ali et al., 2012; Dotaniya et al., 2014; Ali et al., 2015). Phytotoxicity induced by chromium may cause high oxidative injury in plant cells (Panda and Patra, 2002; Ali et al., 2011).

Chromium contaminated soil and water damage the crop tissues and very much harmful for human beings through food chains. When chromium absorbed by roots only a little amount of chromium translocate in higher parts of plants and great amount of chromium retained in roots. Chromium can be taken by plants in both Cr (III) and Cr (VI) form but there is no specific mechanism found in plants for chromium uptake (Vernay et al., 2007; Babula et al., 2008). The natural substrates can play significant role in the removal of different pollutants (Singh et al., 2018; Singh et al., 2021; Singh et al., 2022).

Barley belongs to grass family Poaceae and an important grain crop. It has fourth rank in production all around the world after maize, wheat and rice (Kumar et al., 2012). It has high nutritional value. It is also used for animal feeding, brewing, baking, confectionary, beverage, dairy products and condiments. Barley has a rich amount of soluble dietary fibers (Idehen et al., 2017; Tobiasz- Salach and Augustynska- Prejsnar, 2020). Object of the present investigation was to identify the chromium induced effects on barley growth.

MATERIAL AND METHODS

Seed of barley (*Hordeum vulgare* var. RD 2552) were collected from local market of Agra, Uttar Pradesh, India. Different seedling growth parameters were observed under different concentrations of chromium. To observe heavy metal tolerance of barley test cultivar, Chromium (III) chloride hexahydrate ($CrCl_3.6H_2O$) was used as a source of chromium.

Experiment and Treatments

Experiments were conducted at Department of Botany, Agra College Agra, U.P., India. At first, seeds of barley (*Hordeum vulgare* var. RD 2552) were disinfected with mercuric chloride, and then washed with water to remove mercuric chloride. After that seeds were sowed in pots filled acid washed sand. The nutrients were provided by Long Aston nutrient solution having KNO_3, 5 mM; $Ca(NO_3)_2$, 4 mM; $NaH_2PO_4.2H_2O$, 1.33mM; $MgSO_4.7H_2O$, 3mM; Ferric citrate.$5H_2O$, 0.10 mM; $MnSO_4$, 0.01; $CuSO_4.5H_2O$, 0.001; Zn $SO_4.7H_2O$, 0.001; $(NH_4)_6Mo_7O_{24}.4H_2O$, 0.0002 mM and NaCl, 0.10 mM. Four treatments of Cr (25, 50, 75 and 100µM) were given to evaluate the seedling characters of barley. Distilled water was used as control (0µM) treatment. Three replicates were used for each treatment. The plants were taken out from sand after 21 DAS and different parameters under consideration were recorded.

Growth Parameters

Randomly, three plants were taken from each treatment to calculate the athematic mean for a respective parameter. Growth parameters recorded for study were as follows:

Root, shoot and total length of plant; Root, shoot and whole plant fresh weight; Root, shoot and whole plant dry weight and leaf surface area.

Statistical Analysis

The results of phytotoxicity under the chromium induced stress are shown as the mean ± standard error (SE) with three replicates of each treatment and statistical analysis of collected data were exposed by using analysis of variances (ANOVA) and variances were determined by least significance differences (LSD) at 0.05 probability by using SPSS software.

RESULTS AND DISCUSSION

The impact of heavy metal (Cr) was observed on barley (*Hordeum vulgare* var. RD 2552) and its consequences were assessed on different plant growth parameters.

Plant Length and Leaf Surface Area

Root, shoot and leaves of barley are heavily affected by chromium stress (Table 1.). Root, shoot and total plant length; Leaf surface area were negatively influenced with increasing Cr concentrations. A significant retardation in plant length and leaf surface area was observed in all treatments (Figure 1.). Similar findings were observed earlier by Chatterjee and Chatterjee, 2000; Sundaramoorthy et al. 2010; Ding et al., 2019 and Singh et al., 2020.

Table 1: Effect of different concentrations of chromium on root length, shoot length, total plant length (cm) and leaf surface area (cm^2) of barley

Chromium concentrations (µM)	Root length (cm)	Shoot length (cm)	Total length of plant (cm)	Leaf surface Area (cm^2)
Control (0)	8.97 ± 0.10	18.65 ± 0.17	27.62 ± 0.24	11.02 ± 0.72
25	8.14 ± 0.29*	17.18 ± 0.24*	25.32 ± 0.27*	10.73 ± 0.52 ^{ns}
50	7.39 ± 0.25*	16.25 ± 0.26*	23.65 ± 0.33*	10.67 ± 0.68 ^{ns}
75	6.80 ± 0.16*	15.11 ± 0.10*	18.54 ± 0.22*	9.82 ± 0.54 ^{ns}
100	6.20 ± 0.18*	13.90 ± 0.42*	17.01± 0.45*	8.84 ± 0.53 ^{ns}

Data is average of three replicates. Average ± Standard Error (SE)
* Significant at $P < 0.05$

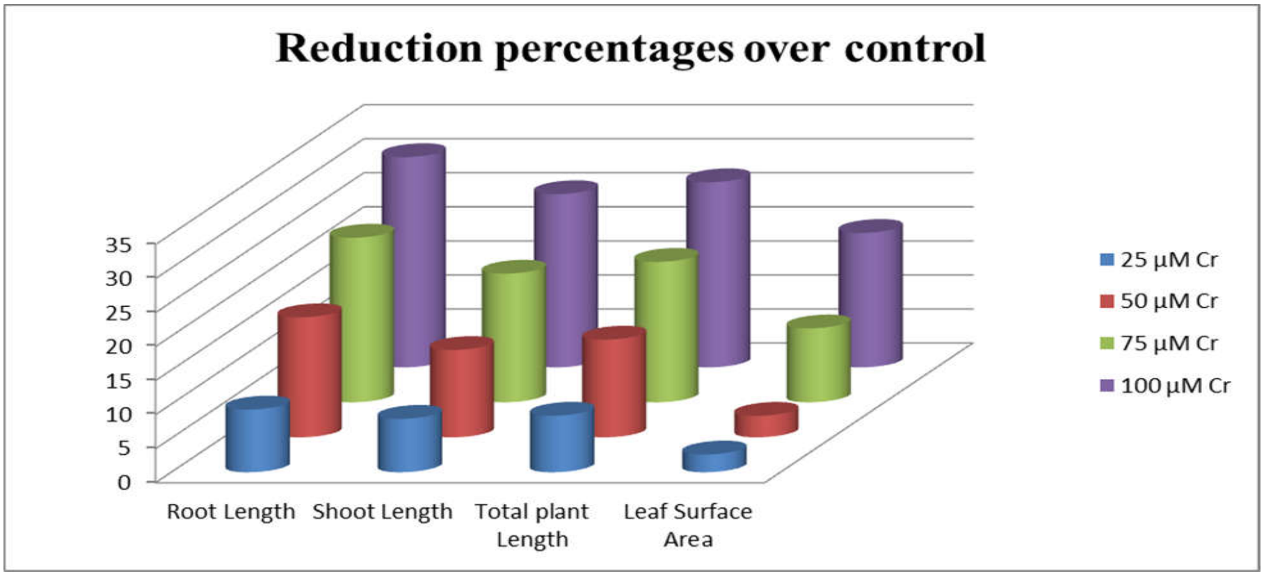

Figure 1: Reduction percentages over control for root length, shoot length, total plant length and leaf surface area of barley

Fresh and dry weight

Fresh weight of root, shoot and whole plant of barley were decreased in all heavy metals stress treatments (Table 2. , Figure 2.). Fresh weight inhibition for 25 and 50 µM treatments was non-significant but significant at 75 and 100 µM concentrations. Dry weight of root, shoot and whole plant of barley followed the same pattern as for fresh weight resulted, the decrement in dry weight of root, shoot and whole plant for all Cr concentrations. Retardation in dry weight of whole plant was non-significant at 25 µM but significant results were observed for 50, 75 and 100 µM. These results are in conformity with those of Vernay et al., 2007; Salvatore et al., 2008; Nematshahi et al., 2012;Gill et al., 2015; Ghani et al., 2017; Ding et al., 2019.

Table 2: Effect of different concentrations of chromium on fresh and dry weight of root, shoot and whole plant

Chromium concentrations (µM)	Fresh weight of root (g)	Fresh weight of shoot (g)	Total fresh weight/ plant (g)	Dry weight of root (g)	Dry weight of shoot (g)	Total dry weight/ plant (g)
Control (0)	0.086± 0.0033	1.503 ± 0.0232	1.59 ± 0.0244	0.0128 ± 0.0002	0.172 ± 0.002	0.185 ± 0.002
25	0.076± 0.0026^{ns}	1.424 ± 0.0195^{ns}	1.5 ± 0.0197*	0.0119 ± 0.0002*	0.162 ± 0.0023*	0.177 ± 0.0023^{ns}
50	0.067± 0.0029^{ns}	1.29 ± 0.0412*	1.36 ± 0.0435*	0.0115 ± 0.0002*	0.146 ± 0.0035*	0.162 ± 0.0033*
75	0.063± 0.0022*	1.09 ± 0.0389*	1.16 ± 0.0394*	0.011 ± 0.0002*	0.136 ± 0.0029*	0.150± 0.0029*
100	0.061 ± 0.0022*	0.98 ± 0.0279*	1.04 ± 0.0264*	0.0103 ± 0.0002*	0.122 ± 0.0031*	0.134 ± 0.0032*

Data is average of three replicates. Average ± Standard Error (SE)
*Significant at P < 0.05

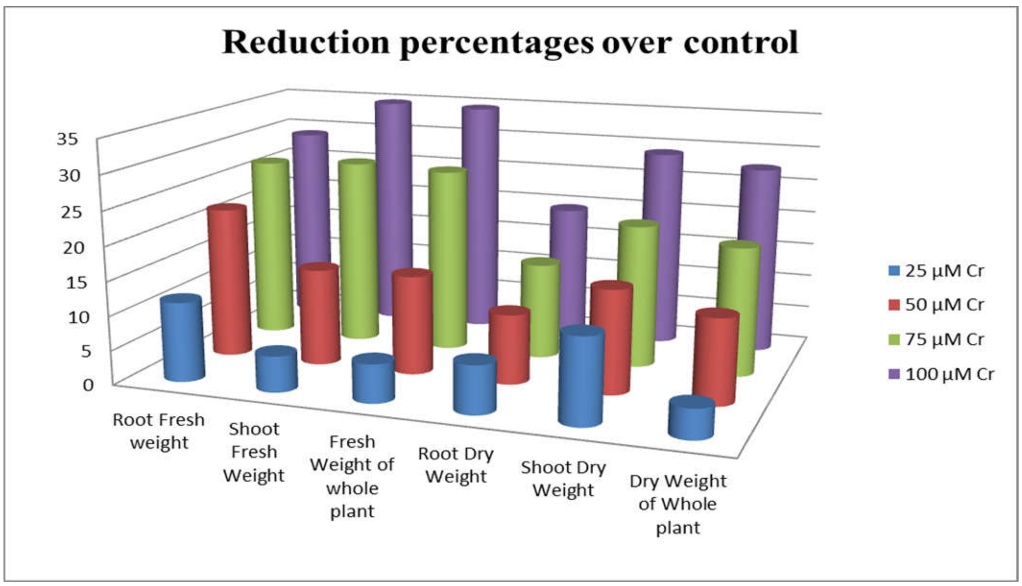

Figure 2: Reduction percentages over control for the fresh and dry weight of root, shoot and whole plant of barley

CONCLUSION

Heavy metals are toxic for plants. Chromium induced stressful conditions resulted in retardation of growth attributes of the test crop. Available literature of earlier studies concludes that heavy metals stress declined the crop productivity by producing reactive oxygen species (ROS). Present study is a short step which advocates the development of heavy metal resistant crop varieties.

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