ISSN: 2287-688X

Annals of
Plant Sciences

Volume 10, Issue 1 (2021) pp. 4105-4116

Research Article

Effect of chromium on basic growth factors of *Pennisetum glaucum* L.

Nitesh Joshi* and Pallavi Menon

Department of Botany, Rizvi College of Science, Bandra West, Mumbai-400050, Maharashtra, India.

Abstract: One of the main concerns of agricultural production is heavy metal pollutants. The industrialization has resulted in the heavy metal contamination of agricultural soil and ecosystems. Metals are a natural component of the earth, it is when their concentration increases from natural levels, ecological deterioration occurs. In the present study, transplant experiments were conducted to evaluate the effect of chromium-contaminated soil in *Pennisetum glaucum* L. The seeds growing in petridishes were exposed to chromium, in increasing concentrations of 1, 3, 5, 10, 50, 100, 200, 300, 500 ppm. Each treatment was replicated in a randomized design and observed over a period of 7 days. The seedlings were studied for their response based on germination rate, seed vigour index, length of the radicle, length of plumule, and fresh weight against seeds germinated using distilled water as a control. Five different chromium concentrations i.e., 5, 10, 50, 100 & 200 ppm, were applied to the plants. Each treatment was replicated in a randomized design and observed for 45 days. The plants were studied for the length of root, length of shoot, fresh weight, total chlorophyll content, protein content, and heavy metal analysis compared to a set irrigated using distilled water as a control. The root and shoot lengths decreased with an increase in Cr concentrations in the transplants. A gradual decrease was observed in the selected parameters, with an increase in Cr levels. The values related well with increased Phyto-accumulation of chromium within the tissues of both roots and shoots. It was observed that chromium's harmful effects on all the parameters were directly proportional to the concentration of solution employed, with the inhibition of growth being more pronounced from 50 ppm onwards. As *Pennisetum glaucum* L. an edible crop despite showing a good potential for application in phytoremediation techniques, it can't be used to hyper accumulate chromium to remove it from the soil.

Keywords: Chromium; germination; transplants; toxicity; phytoremediation; *Pennisetum glaucum* L.

Introduction

The term heavy metal denotes metals whose density is higher than 4 g/cm^3. (Hawkes, 1997) Industrial development and urbanization have raised metals in soil, aquatic ecosystems, and the atmosphere. Some of these essential trace metals like zinc & copper act as activators of enzymatic reactions, forming metal substrate complexes (Mildvan, 1970). However, these essential metals are considered toxic when present in excessive amounts (Blay lock and Huang, 2000). A number of other heavy metals such as Cd, Hg, Cr, and As are toxic, leading to growth inhibition and death. Iron is also one of the heavy metals essential for plants and animals (Wintz *et al.* 2002). Heavy metals have been discussed to cause oxidative stress by catalyzing the formation of OH free radicals. (Fryzova R. *et al.* 2017).

Recent concerns regarding environmental pollution have given rise to developing various technologies to clean up the environment. Conventional methods of remediation and chemical methods are costly and do not produce optimum results. One of the emerging techniques to clean up contaminated soil and water is phytoremediation. This method has been eco-friendly, affordable, and an effective solution to remove heavy metal pollutants from contaminated soil. Hyper-accumulator plants have been reported to concentrate more than 10 mg/kg of mercury (Hg), 100 mg/kg of cadmium (Cd), 1000 mg/kg of cobalt (Co),

*Corresponding Author:
Dr. Nitesh Joshi,
E-mail: niteshcjoshi@gmail.com

chromium (Cr), copper (Cu), and lead (Pb), 10000 mg/kg of zinc (Zn) and nickel (Ni) (Baker and Brooks, 1989). Based on the environmental monitoring reports, edible crops grown in these contaminated soils to accumulate metals in quantities higher than permissible limits and are capable of causing health problems in animals and human beings consuming these plants (Tiller, 1986).

Several researchers have experimented with and reported the accumulation and uptake of chromium by various crops, *Arachis hypogaea* and *Cicer arietenum* (Imam Khasim D. *et al.* 1994); *Ablemoschus esculentum* (Jasuja K. *et al.* 1997). Jayaprakash *et al.* 1994 reported chromium's effect on chromosomal aberration and reduced mitotic activity in *Allium cepa*. Purohit *et al.* 2003 reported a reduction in the length of root and shoot and decreased biomass in *Solanum melongena* and *Solanum lycopersicum* upon being treated with increasing chromium concentration.

The traditional method of heavy metal stabilization in the soil is excavation and removal, it is known to be disruptive to the environment and presents us with a problem of generated waste and is an expensive process. Another viable alternative is soil amendments in-situ to decrease the bioavailability of heavy metals, it is a less disruptive and cost-effective alternative. Recently phytostabilization of heavy metal contaminated land has emerged as a low-cost and environment-friendly alternative to traditional remediation techniques. Phytovolatiliza-tion, sequestration, microbial extraction are some of the methods employed in phytoremediation.

Chromium (Cr) – Selected heavy metals as a contaminant

Chromium is a natural element in the soil, yet the increasing concentration makes it a potential toxin. In low doses, it is considered a necessary element in human and animal nutrition, however, large quantities have been known to cause devastating effects on humans, animals, and plants. Cr^{3+} is one of the elements essential in low concentrations for human health, but long-term exposure to it has been reported to cause dermatitis, shortness of breath, ulceration of septum, bronchitis, pneu-monia, and pulmonary problems, kidney disorders, weakened immunity, and may cause cancer.

Studies have suggested that chromium acts as a stimulant for plant growth, but certain studies have shown otherwise that it does more harm than good, posing more of a health concern in modern times due to industrialization. The problem of soil pollution due to industrial advancement has become a severe threat in India. Effluents from distilleries, electroplating plants, fertilizer and pesticide units, steel and paper industries, pharmaceuticals, petrochemical, oil refineries, thermal power plants, textile, tannery and dye industries are a source of pollutants with chromium.

Large amounts of chromium have been found in agricultural soils due to organic waste as fertilizers and wastewater for irrigation. Chromium does not degrade biologically and will remain stable for several months in the soil without changing its oxidation state. Chromium exists in several oxidation states, but the most stable and common forms are Cr (0), the trivalent Cr^{3+}, and the hexavalent Cr^{6+} species. The valency of chromium plays an important role in determining its toxicity, Cr^{6+} is highly toxic and soluble compared to Cr^{3+} as it cannot quickly transfer across cell membranes (Mertz, 1992). Phytotoxic symptoms include inhibition of seed germination, reduced root, shoot growth, and adverse effects on physiological processes. Higher concentrations of chromium also produce an adverse effect on several physiological parameters such as reduction of the rate of photosynthesis, impairment of mineral nutrition (Sundara Moorthy, *et al.* 2010), causing oxidative stress (Shanker *et al.* 2005), leaf chlorosis, and depressed biomass (Sharma *et al.* 1995) ultimately leading to loss of plant life. Cr^{3+} is considered a micronutrient in humans, being necessary for sugar and lipid metabolism (Agency for Toxic Substances and Disease Registry, 2000) instead of Cr^{6+}, which is considered a carcinogen and can enter the human body through consumption of contaminated plant material. The Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health, 2007, recommends soil should contain less than 64mg/kg of total chromium and 0.4mg/kg of the form hexavalent chromium. The permissible limit of chromium for plants is 1.30mg/kg recommended by WHO.

Chromium (Cr) has been selected as a test metal since it has been employed in the leather industry, steel, and chemicals, to name a few. Since the effects and uptake of Cr^{6+} on *Pennisetum glaucum* L. have not been extensively studied yet; the present study was conducted to understand the Cr^{6+} toxicity by observing the morphological and physiological responses stress. Therefore, our study focuses on chromium's role in plant growth, emphasizing that *Pennisetum glaucum* L. as a potential candidate for phytoremediation of chromium from contaminated sites.

Material and Methods

A) Plants Selected: The seeds of *Pennisetum glaucum* L. were purchased from a local seed dealer.

B) Heavy metal treatment:

A 1000 ppm stock solution was prepared for the selected heavy metal. This was then diluted to prepare 1, 3, 5, 10, 50, 100, 200, 300, 500 ppm to treat seeds. All the standards were prepared by non – serial dilutions.

Chromium – Accurately weighed 2.828 g of 99.9 % of analytical grade Potassium dichromate ($K_2Cr_2O_7$) in 1000 mL of distilled water.

C) Experimental studies:

Ten surface-sterilized seeds of each species uniform in color, weight, and size were selected and individually placed in a Petri dish of 9 cm diameter on double-layered filter paper. The filter paper was moistened with varying concentrations of heavy metal solutions with 5 ml on the first day, followed by 2 ml on alternate days for 7 days or depending on the moisture every day. Each experiment's triplicates were studied in a completely randomized design and a separate control series using distilled water. Plants of *Pennisetum glaucum* L. were grown in bags filled with garden soil using cuttings after 15 days of growth. One sapling was grown in each bag, and each treatment was replicated in a randomized design. Normal growth conditions were provided to all the plants for their growth. The plants were grown for 15 days before treatment application and continued for 45 days after treatment application of 5, 10, 50, 100, 200 ppm i.e. before harvest.

D) Selection of plant parameters:

Following morphological characters were noted: Length of the root (cm), length of the shoot (cm), and fresh weight (g) of the plants after 45 days using a centimeter-scale and a digital balance. Biochemical tests were performed for recording the Chlorophyll Content – (Arnon's Method, 1949), Total Protein Content – (Lowry's Method, 1951), and Heavy Metal Analysis for chromium was done on the Inductive Coupling Plasma Atomic Absorption Spectroscopy (ICP – AAS) facility.

E) Statistical analysis:

To determine the significance between samples, a "Student's t – test" was carried out at $p<0.05$ level of significance. The data were analyzed using analysis of variance (ANOVA). Box and

Whiskers plot, along with histograms, were used for data analysis. Statistical analysis was carried out using SPSS software version 11.0.

Result and Discussion

Effect of Chromium on Total Germination (%)

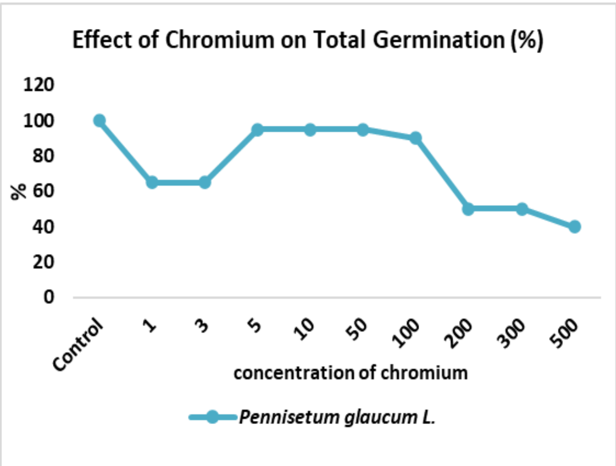
The present study showed a trend that higher chromium concentrations affected the plants' germination (Table 1, Figure 1). The total germination of the selected plants subjected to the highest chromium concentrations showed a significant difference compared to control. *Pennisetum glaucum* L. showed 90% at 100 ppm, and the least was 40% observed at 500 ppm.

Table 1. Effect of Chromium on Total Germination (%)

Ppm	*Pennisetum glaucum* L.
Control	100
1	65
3	65
5	95
10	95
50	95
100	90
200	50
300	50
500	40

values are an average of 30 samples.

Figure 1. Trend graph showing the effect of chromium on total germination (%)



Effect of Chromium on the Length of Radicle

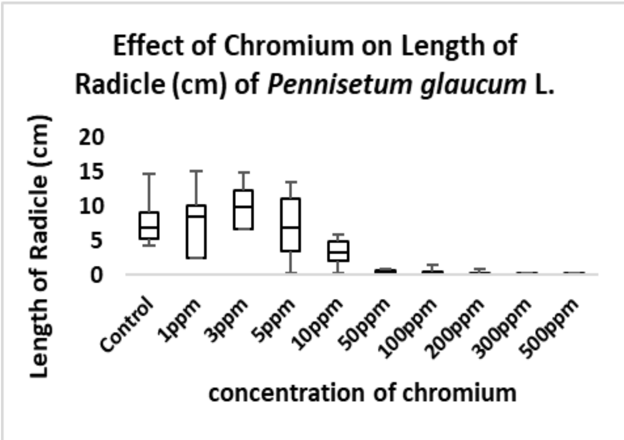
Table 2. Effect of Chromium on Length of Radicle (cm)

Ppm	Length of radicle	Length of plumule	Fresh weight
Control	7.63±3.10	5.95±1.10	0.0663±0.01
1	7.47±3.45**	3.98±1.74*	0.0642±0.02**
3	9.89±2.75#	5.13±1.29*	0.0462±0.01*
5	7.12±3.84**	4.58±1.29#	0.0629±0.03#
10	3.30±1.66*	4.91±1.19*	0.0444±0.01**
50	0.41±0.26*	2.96±1.67*	0.0321±0.01**
100	0.32±0.32*	2.4±1.07*	0.0296±0.01**
200	0.17±0.18*	1.27±0.72*	0.0199±0.00#
300	0.14±0.60*	0.94±0.40*	0.0178±0.00*
500	0.13±0.05*	0.49±0.46*	0.0141±0.00*

*significant at $p < .01$ ** not significant at $p < .05$
#significant at $p < .05$ values are average of 30 samples

***Pennisetum glaucum* L.:** The length of the control value was 7.63 cm. The highest length was 9.89 cm at 3 ppm and 0.13cm at 500ppm. (Fig. 2)

Figure 2. Effect of Chromium on Length of Radicle (cm) of *Pennisetum glaucum* L.



Effect of Chromium on Length of Plumule

Table 3. Effect of Chromium on Length of Plumule (cm)

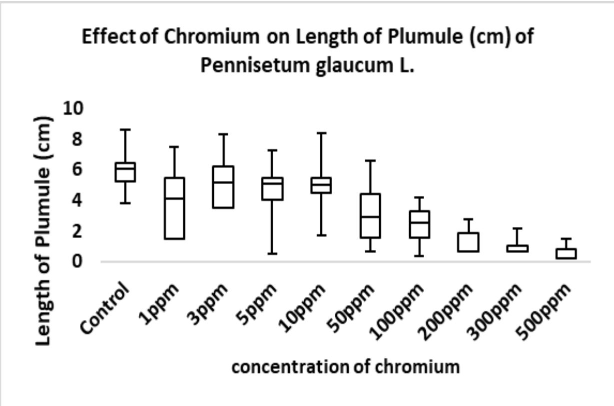
Ppm	*Pennisetum glaucum* L.
Control	5.95±1.10
1	3.98±1.74*
3	5.13±1.29*
5	4.58±1.29#
10	4.91±1.19*
50	2.96±1.67*
100	2.4±1.07*

200	1.27±0.72*
300	0.94±0.40*
500	0.49±0.46*

*significant at p < .01 ** not significant at p < .05
#significant at p < .05 values are average of 30 samples.

***Pennisetum glaucum* L.:** Seedlings had a maximum value of 5.13cm length of plumule at 3 ppm and the lowest average length of plumule of 0.49cm at 500ppm. 5ppm and 10ppm concentrations also showed a length of 4.91cm and 4.98cm. The control values were 5.95 cm. (Fig 3)

Figure 3. Effect of Chromium on Length of Plumule (cm) of *Pennisetum glaucum* L.



Effect of Chromium on Fresh weight

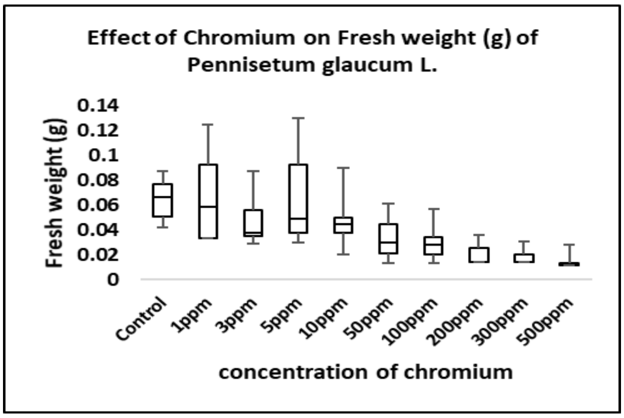
Table 4. Effect of Chromium on Fresh weight (g)

Ppm	*Pennisetum glaucum* L.
Control	0.0663±0.01
1	0.0642±0.02**
3	0.0462±0.01*
5	0.0629±0.03#
10	0.0444±0.01**
50	0.0321±0.01**
100	0.0296±0.01**
200	0.0199±0.00#
300	0.0178±0.00*
500	0.0141±0.00*

*significant at p < .01 ** not significant at p < .05
#significant at p < .05 values are average of 30 samples

***Pennisetum glaucum* L.:** The lowest values of fresh weight were recorded in *Pennisetum glaucum* L. plants. Maximum fresh weight of 0.0663g for control followed by 0.0642g was noted at 1ppm and 0.0141g was the lowest average fresh weight at 500pppm. (Fig 4)

Figure 4. Effect of Chromium on Fresh weight (g) of *Pennisetum glaucum* L.



Effect of Chromium on Seed Vigour Index (SVI)

Based on the collective data of the total germination percentage and early seedling growth, which shows a decline in the overall length of radicle, plumule, and fresh weight, the SVI also follows a similar trend for the selected plant. All the plants showed a significant drop in SVI with an increasing concentration of chromium. *Pennisetum glaucum* L. recorded a drop in vigor from 1111.97 to 25.20 when the concentrations were increased from 5ppm to 500ppm.

Table 5. Effect of Chromium on Seed Vigour Index (SVI)

Ppm	*Pennisetum glaucum* L.
Control	1362.50
1	657.47
3	974.35
5	1111.97
10	780.90
50	321
100	244.80
200	72
300	54.25
500	25.20

values are average of 30 samples.

Figure 5. Trend graph showing the Effect of Chromium on Seed Vigour Index (SVI)

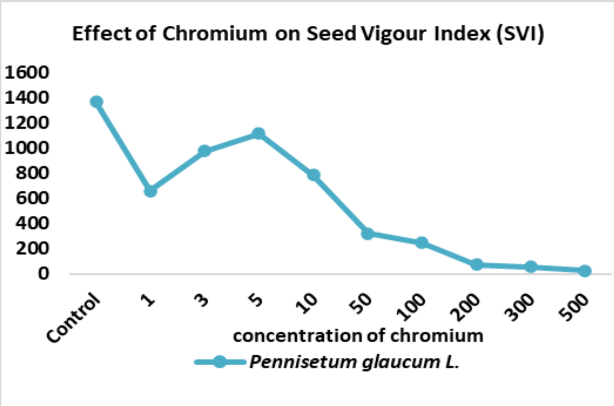
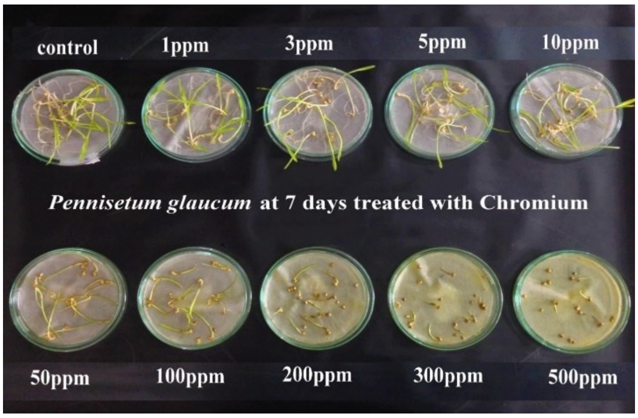


Figure 6. Effect of Chromium on *Pennisetum glaucum* L.



The transplants of the selected plants were harvested after 45 days, and the following parameters were studied. Length of root, length of shoot, fresh weight, chlorophyll a, chlorophyll b, total chlorophyll, total protein content and chromium uptake.

Effect of Chromium on root length

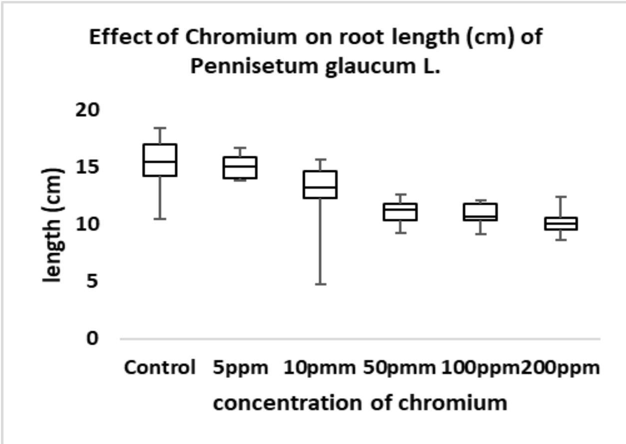
Table 6. Effect of Chromium on root length (cm) of selected plants

Concentration	Root length	Shoot length	Fresh weight
Control	15.18±2.30	73.82±0.97	8.02±1.79
5 ppm	15.03±1.03**	65.56±1.90*	7.81±1.11**
10 ppm	12.93±2.87*	63.37±1.55*	6.12±1.05*
50 ppm	11.09±0.95*	65.11±1.33*	7.31±1.50**
100 ppm	10.87±0.93*	43.9±1.95*	3.74±0.78*
200 ppm	10.15±1.02*	29.00±1.53*	3.20±0.71*

*significant at p < .01 ** not significant at p < .05
#significant at p < .05 values are average of 20 samples

***Pennisetum glaucum* L.:** The control value of the length of the radicle was 15.18 cm, the highest value for plants treated with chromium was 15.03 cm was recorded in *P. glaucum* L. at 5ppm, followed by a gradual decrease with the lowest noted length of 10.15 cm at 200 ppm. (Table 6, Fig 7)

Figure 7. Effect of Chromium on root length (cm) of *Pennisetum glaucum* L.



Effect of Chromium on shoot length

Table 7. Effect of Chromium on shoot length (cm) of selected plants

Concentration	*Pennisetum glaucum* L.
Control	73.82±0.97
5 ppm	65.56±1.90*
10 ppm	63.37±1.55*
50 ppm	65.11±1.33*
100 ppm	43.9±1.95*
200 ppm	29.00±1.53*

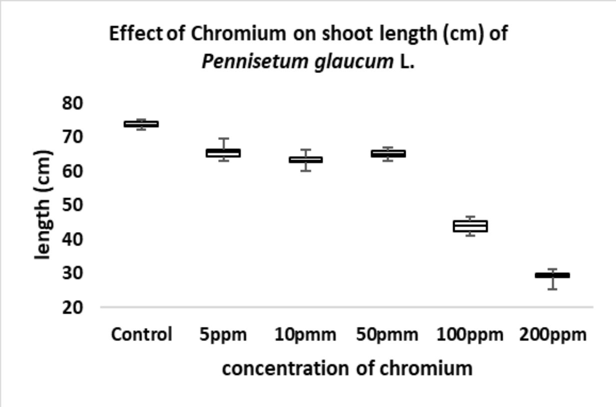
*significant at p < .01 ** not significant at p < .05
#significant at p < .05 values are average of 20 samples

***Pennisetum glaucum* L.:** The control value of length of shoot was 73.82 cm, highest value for plants treated with fly ash was 65.56 cm was recorded at 5ppm, followed by a gradual decrease with the lowest noted length of 29 cm at 100ppm. (Table 7, Fig 8)

***Pennisetum glaucum* L.:** The lowest values of fresh weight were recorded in *Pennisetum glaucum* L. plants. A maximum fresh weight of 8.02g for control followed by 7.81g was noted at

5ppm, and 3.20g was the lowest average fresh weight at 200pppm. (Table 9, Fig. 10)

Figure 8. Effect of Chromium on shoot length (cm) of *Pennisetum glaucum* L.



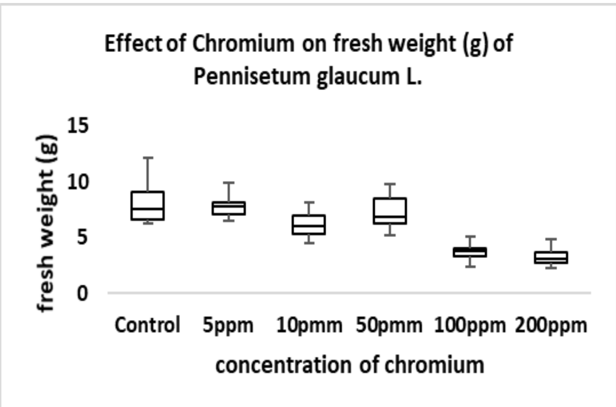
Effect of Chromium on Fresh weight

Table 9. Effect of Chromium on fresh weight (g) of selected plants

Concentration	*Pennisetum glaucum* L.
Control	8.02±1.79
5 ppm	7.81±1.11**
10 ppm	6.12±1.05*
50 ppm	7.31±1.50**
100 ppm	3.74±0.78*
200 ppm	3.20±0.71*

*significant at p < .01 ** not significant at p < .05 #significant at p < .05 values are average of 20 samples

Figure 10. Effect of Chromium on fresh weight (g) of *Pennisetum glaucum* L.



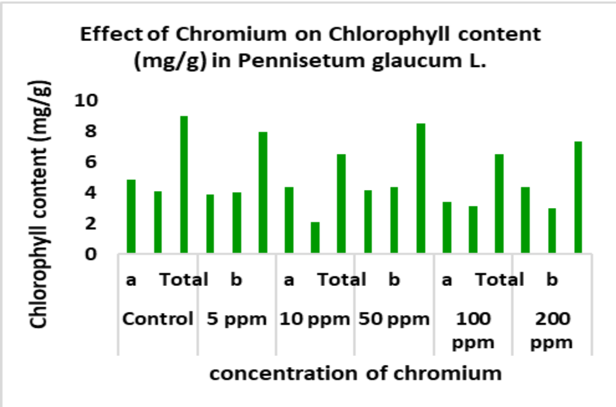
Effect of Chromium on Chlorophyll content

***Pennisetum glaucum* L.:** The plants irrigated with varying chromium solution concentrations showed a lower total chlorophyll content than the control. The control value was 8.98mg/g. The highest total chlorophyll content upon treatment with chromium was 8.55mg/g at 50ppm. The lowest calculated value of total chlorophyll was 6.51 mg/g at 100ppm. (Table 10, Fig. 11)

Table 10. Effect of Chromium on Chlorophyll content (mg/g)

Concentration	*Pennisetum glaucum* L.		
	Chl. a	Chl. b	Total Chl.
Control	4.86	4.12	8.98
5 ppm	3.89	4.04	7.93
10 ppm	4.40	2.12	6.52
50 ppm	4.19	4.35	8.55
100 ppm	3.39	3.11	6.51
200 ppm	4.38	2.98	7.37

Figure 11. Effect of Chromium on Chlorophyll content (mg/g) of *Pennisetum glaucum* L.



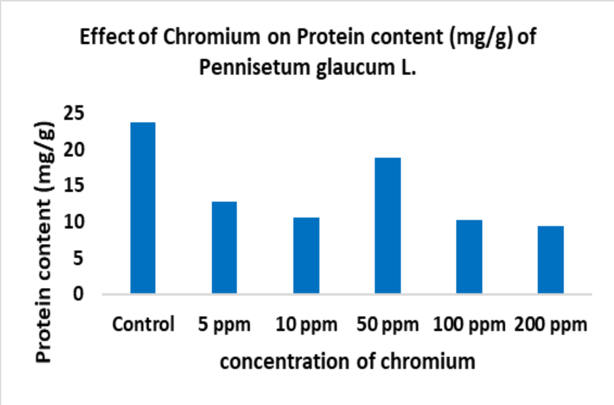
Effect of Chromium on Protein content

Table 11. Effect of Chromium on Total Protein content (mg/g)

Concentration	*Pennisetum glaucum* L.
Control	23.7
5 ppm	12.7
10 ppm	10.6
50 ppm	18.9
100 ppm	10.3
200 ppm	9.4

***Pennisetum glaucum* L.:** The protein content for the control plants was 23.7mg/g. An increase in the protein content was measured at 50ppm of 18.9mg/g and a minimum of 9.4mg/g at 200ppm. (Table 11, Fig. 12)

Figure 12. Effect of Chromium on Protein content (mg/g) of *Pennisetum glaucum* L.



Uptake of Chromium by selected plants

Compared to other toxic metals like cadmium, lead, mercury, Chromium does not have a elucidated pathway of uptake in plants. There is a specific mechanism for its uptake and is dependent on metal speciation. The chromium ions have an oxidation state of VI in potassium dichromate. Hexavalent chromium is more soluble than trivalent chromium, forming stable complexes in the soil, thus increasing its bioavailability. (Lopez-Luna J. *et al.*, 2009). The pathway of Cr^{6+} transport is an active mechanism; it depends on metabolic energy and is performed by carriers of essential ions. (Cervantes, *et al.* 2001). The readings for chromium uptake by selected plants have been expressed in ppm in the following table 12.

Table 12. Uptake of Chromium by selected plants in ppm

Concentration	*Pennisetum glaucum* L.	
	Root	**Shoot**
Control	ND	ND
5 ppm	870.3	994.5
10 ppm	241.4	484.0
50 ppm	1076.2	2487.9
100 ppm	918.3	1333.0
200 ppm	1054.8	1347.7

***Pennisetum glaucum* L.:** In the root samples, chromium uptake was highest at 50ppm (1076 ppm). The lowest amount was recorded at 10ppm (241 ppm), and chromium was not detected in the control samples. Whereas in the shoot samples of *Pennisetum glaucum* the lowest amount was recorded at 5ppm (994 ppm) and the maximum accumulation was measured at 50ppm (2487 ppm) (Table 12, Fig. 13, Fig. 14)

Figure 13. Uptake of Chromium (ppm) by the root of selected plants

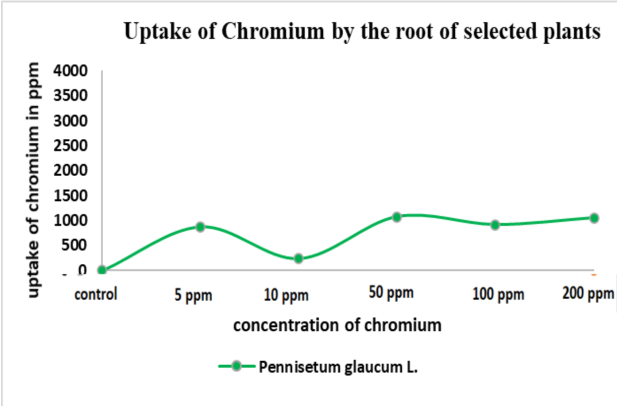
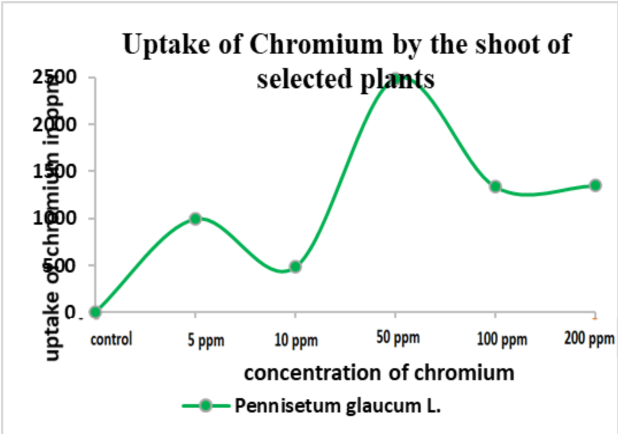


Figure 14. Uptake of Chromium (ppm) by the shoot of selected plants



Conclusion

Based on the values recorded, 5 ppm and 10 ppm of chromium indicate a favorable increase in root growth than the control, whereas at higher concentrations, an inhibitory effect was seen. Maximum inhibition of root was observed at 200 ppm chromium for all the selected plants. According to a study, 200ppm concentrations of chromium decreased paddy growth, i.e. *Oryza sativa* L. (Sundaramoorthy *et al.* 2010). The detrimental effect of chromium on roots can be explained by inhibition of the cell division correlating with the mitotic index noted by Zou J. H. *et al.* 2006. Breakdown of root tissue and reduction in root surface caused by chromium stress may contribute to plants' decreased growth. (Oliveira H., 2012). These results have been following other researchers showing stimulation of root growth at low chromium concentrations. (Zou J.H., *et al.* 2006). Peralta J.R. *et al.* 2001 demonstrated that 5ppm showed that Cr(VI) increased root growth compared to the control, and at higher doses, there was an inhibitory effect.

Saplings of *Pennisetum glaucum* L. showed a sudden decrease in height on exposure to 100 ppm of chromium. Shoot length gradually decreased with the increase in chromium concentrations with a pronounced effect seen at 200 ppm. Overall, shoot growth was affected due to chromium's presence with a reduction in the number and size of leaves due to wilting and necrosis. This decrease in plant length and shoot growth could be correlated to reduced root growth, resulting in lesser nutrient transport and water transport to the plant's aerial parts. These results are consistent with the results reported in *Zea mays* L. (Mallick S., 2010)

Plant weight is dependent on the length and number of roots, shoots, and leaves, as chromium has negatively affected most aspects of growth, fresh weight of the transplants has decreased. The fresh weight of the plants reduced by 54.85% at 200 ppm. Poor development of lateral roots and root number was affected by exposure to chromium resulting in shorter and fewer roots hairs. (Samantary S., 2002)

A general decrease in chlorophyll content at higher chromium concentrations suggests that chlorophyll synthesis is being affected. Our results revealed a significant decrease in chlorophyll b compared to chlorophyll an as it greatly sensitive to salt stress. This decrease in chlorophyll levels in salt-stressed plants has been considered a typical symptom of oxidative stress (Smirnoff N., 1996), resulting in chlorophyll's suppressed biosynthesis with its degradation by the enzyme chlorophyllase (Santos C.V., 2004). Vazques M.D. *et al.* 1987 reported that chromium-induced inhibition of photosynthesis is due to disorganization of chloroplasts ultrastructure.

Similarly, the protein content also decreased with the increase in chromium concentrations. A concentration-dependent decrease in soluble protein content over the control was observed in the shoot of *Albizia lebbek* (Tripathi A.K. and Tripathi S., 1999). Since plants' nitrogen content was reduced by metal stress relatively, plants' amino acids and protein content also got reduced (Crooke W.M. and Inkson R.H.E., 1955; Mayz D.M.J. and Cartwright P.M. 1984). The decrease in protein level is caused either by a reduced biosynthesis or an increased disintegration of proteins to amino acids (Todd G.W. and Arnold W.M., 1961). The decrease in protein content can also be attributed to oxidative damage caused by ROS generated under abiotic stress conditions. Proteins play an imminent role in plant stress response since they are involved in mobilizing their energy reserves, energy reserves consumption, and an enhanced protein degradation under stress.

Uptake and accumulation of chromium was mainly in the roots, with little translocation to the shoots. A maximum concentration of chromium was seen at 50 ppm in the root as well as shoot. Chromium is immobilized in the root cells' vacuoles could be a reason for higher accumulation in roots. (Shanker A.K. *et al.* 2004). Another study with temperate trees confirmed that chromium was poorly taken up into the aerial tissues but predominantly in the root. (Pulford I.D. *et al.* 2001). Bishnoi N.R. et al, 1993 reported that chromium toxicity had a detrimental effect on seed germination, seedling growth, chlorophyll, and crop plants' nutrient content.

Plant yield is dependent on the plant's all-around development, including a number of roots, length of the shoot, and leaf growth as chromium affects physiological processes and the morphology in plants, productivity decreases. The present study indicated that accumulation is high in the roots compared with the shoot, thereby holding the metal firmly in the ground away from the reach of other interactions of the shoot. In this plant, chromium at low concentrations (5ppm) was found to promote growth and increase yield. However, it is not an essential element for plants, whereas increasing metals' concentration severely inhibited the growth in terms of various morphological and physiological parameters. Since it is an edible crop, despite showing a good potential for phytoremediation techniques, it can't be used to hyper accumulate this metal to remove it from the soil as *Pennisetum glaucum* L. showed more accumulation of the heavy metal in the shoot than the root.

References

1. Hawkes JS (1997). Heavy Metals, J. Chem. Educ. 74(11): 1374Mildvan A.S. (1970). Metals in enzyme catalysis. In: The enzymes, Vol. " (Ed: D.D. Boyer). Academic Press, London. pp. 445-536.
2. Blaylock M.J., and Huang J.W. (1999). Phytoextraction of metals. In Phytoremediation of Toxic Metals: Using Plants to Clean Up the Environment, eds. Wintz H. *et al.* 2002
3. Fryzova R., Pohanka M., Martinkova P., Cihlarova H., Brtnicky M., Hladky J. and Kynicky J. (2017). Oxidative Stress and Heavy Metals in Plants. 10.1007/398_2017_7.
4. Baker A.J.M. and Brooks R.R. (1989). "Terrestrial higher plants which hyper accumulate metallic elements: a review of their distribution, ecology, and phytochemistry," Bio recovery, vol. 1, pp. 81–126.
5. Tiller K.G. (1986). Essential and toxic heavy metals in waters and their ecological relevance. Trans. XIII Congr. Intern. Soc. Water Sci. 1, 29-44.
6. Imam Khasim D., Nandakumar N.V., Hussain R.C., Bhagyalakshmi K., and Naidu D.M. (1994). Chromium translocation from farm water contaminated with chromate industrial effluents into plants. Po/ln. Res. 13:303-316.
7. Jasuja K., Parwana H.K., and Rao A.L.J. (1997). Removal of Cr (VI) from wastewater by *Ablemoschus esculentus*. Indian J. Environ. Hlth. 39:103-108.
8. Purohit S., Varghese T.M., and Kumari M. (2003). Effect of Cr on morphological features of tomato and bringal. Indian J. Environ. Bioi. 8, 17-22.
9. Mertz W. (1993). Chromium in human nutrition: a review. The Journal of Nutrition, 123: 626 633.
10. Sundaramoorthy P., Chidambaram A., Sankar G., Kaliyaperumal, Unnikannan P., and Baskaran L. (2010). Chromium stress in paddy: (i) Nutrient status of paddy under chromium stress; (ii) Phytoremediation of chromium by aquatic and terrestrial weeds. Comptes rendus biologies. 333. 597-607.
11. Shanker A.K., Cervantes C., Loza-Tavera H. and Avudainayagam S. (2005). Chromium toxicity in plants. Environ. Int., 31, 739.

12. Sharma D. C., Chatterjee C., and Sharma C. P. (1995). Chromium accumulation by barley seedlings (Hordeum vulgare L.). Journal of experimental botany 25: 241-251.
13. Toxicological Profile for Chromium. (2000). Agency for Toxic Substances and Disease Registry, Health Administration Press, Atlanta, Ga, USA.
14. World Health Organization, Quality Control Methods for Medicinal Plant Materials, WHO, Geneva, Switzerland, 2005.
15. Arnon D. (1949) Copper Enzymes in Isolated Chloroplasts. Polyphenol oxidase in Beta vulgaris. Plant Physiology, 24, 1-15.
16. Lowry O.H., Rosebrough N.J., Fair A.L., and Randall R.J. (1951). Protein measurement with the Folin phenol reagent. J. Biol. Chem., 193: 265-275.
17. Sundaramoorthy P., Chidambaram A., Sankar G., Kaliyaperumal, Unnikannan P., and Baskaran L. (2010). Chromium stress in paddy: (i) Nutrient status of paddy under chromium stress; (ii) Phytoremediation of chromium by aquatic and terrestrial weeds. Comptes rendus biologies. 333. 597-607.
18. Zou J. H., Wang M., Jiang W. S. and Liu D. H. (2006). "Effects of hexavalent chromium (VI) on root growth and cell division in root tip cells of Amaranthus viridis L.," Pakistan Journal of Botany, vol. 38, no. 3, pp. 673–681.
19. Oliveira H. (2012). "Chromium as an environmental pollutant: insights on induced plant toxicity," Journal of Botany, vol. 2012, Article ID 375843.
20. Peralta J.R., Gardea Torresdey J.L., Tiemann K.J., Gomez E., Arteaga S., Rascon E., et al. (2001). Uptake and effects of five heavy metals on seed germination and plant growth in alfalfa (Medicago sativa) L. B Environ Contam Toxicol. 66(6):727 34.
21. Mallick S., Sinam G., Mishra R.K. and Sinha S. (2010). "Interactive effects of Cr and Fe treatments on plants growth, nutrition and oxidative status in Zea mays L.," Ecotoxicology and Environmental Safety, vol. 73, no. 5, pp. 987–995.
22. Samantary S. (2002). Biochemical responses of Cr-tolerant and Cr sensitive mung bean cultivars grown on varying levels of chromium, Chemosphere, 47 (10): 1065 1072.
23. Smirnoff N. (1996). The function and metabolism of ascorbic acid in plants. Annals of Botany 78: 661–669.
24. Santos C.V. (2004). Regulation of chlorophyll biosynthesis and degradation by salt stress in sunflower leaves Scientia Horticulturae, 103, pp. 93-99
25. Vazques M.D., Poschenrieder C. and Barcelo J. (1987). Chromium (VI) induced structural changes in bush bean plants. Ann Bot. 59: 427 38.
26. Tripathi A.K. and Tripathi S. (1998). Changes in some physiological and biochemical characters in Albizia lebbek as bio- indicators of heavy metal toxicity. J. Environ. Biol., 20(2), 93−98.
27. Crooke W.M. and Inkson R.H.E. (1955). Relation between nickel toxicity and major nutrient supply. Plant Water 6:1-15.
28. Mayz D.M.J. and Cartwright P.M. (1984). The effect of pH and aluminium toxicity on the growth and symbiotic development of cowpea (Vigna unguiculata). Plant Water 80; 423-430.
29. Todd G.W, and Arnold W.M. (1961). Evaluation of methods used to determine

injury to plant leaves to air pollution. Bot Gaz 1961; 123: 151-154

30. Shanker A.K., Djanaguiraman M., Sudhagar R., Chandrashekar C.N. and Pathmanabhan G. (2004). Differential antioxidative response of ascorbate glutathione pathway enzymes and metabolites to chromium speciation stress in green gram (Vigna radiata (L.) R. Wilczek, cv. CO 4) roots. Plant Sci., 2004a; 166: 1035 – 1043.
31. Pulford I.D., Watson C. and McGregor S.D. (2001). Uptake of chromium by trees: prospects for phytoremediation. Environ Geochem Health; 23: 307 – 11.
32. Bishnoi N. R., Dua A., Gupta V. K. and Sawhney S.K. (1993). Effects of chromium on seed germination, seedling growth and yield of, peas. Agri. Eco. Environ. 47,47-57.

Cite this article as:

Nitesh Joshi and Pallavi Menon. Effect of chromium on basic growth factors of *Pennisetum glaucum* L. *Annals of Plant Sciences.* 10.1 (2021) pp. 4105-4116.

http://dx.doi.org/10.21746/aps.2021.10.1

Subject Editor: Dr. Mannur Ismail Shaik, Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia

Source of support: Nil; **Conflict of interest:** Nil.