IN VITRO GERMINATION AND GROWTH RESPONSE OF PARTHENIUM WEED TO CHROMIUM (VI) STRESS

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ABSTRACT
Parthenium (*Parthenium hysterophorus* L.) is an exotic weed that has spread in different parts of Punjab, Khyber Pakhtunkhwa, and Kashmir to an alarming extent and is now threatening natural vegetation and ecosystems. In the present study, laboratory bioassays were carried out to evaluate the effect of heavy metal ion Cr(VI) on germination and root/shoot growth of parthenium. Five concentrations of the metal ion *viz.* 10, 20, 40, 80, and 160 ppm were used in the experiment. A gradual decline in germination and growth of seedlings was recorded with the increase in metallic ion concentration. Lower concentrations *viz.* 10, 20, and 40 ppm reduced seed germination by 11, 15, and 37% over control, respectively. Likewise, 10, 20, and 40 ppm metal solution reduced shoot length by 35, 67, and 93%, root length by 69, 93, and 95%, and plant dry biomass by 47, 69, and 97% over control, respectively. An 80 ppm solution of Cr(VI) completely arrested the germination. This study concludes that parthenium is highly susceptible to Cr(VI) stress, where an 80 ppm solution of these metallic ions can completely stop the germination of parthenium seeds.

Keywords: Abiotic stress, Chromium, Germination, Heavy metal, Noxious weed; *Parthenium hysterophorus*.

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INTRODUCTION

Parthenium is an American native weed species that has been spread in more than 50 countries in Asia, Africa, and Australia and has become a threat to both natural and agroecosystems (Al Ruheili *et al.,* 2022; Javaid *et al.,* 2022). It is known for its negative effects on the production of pastures and crops (Riaz and Javaid, 2011) and ill effects on human health (Kaur *et al.*, 2014). Characteristics such as abundant seed and allelochemicals production, high competitiveness against other plant species, fast-spreading capability, unsuitability as a grazing weed, and absence of natural enemies in new environments have made this weed a global threat to biodiversity and economy (Javaid and Anjum, 2005; Chetty *et al.,* 2022). In Pakistan, it has vastly spread to different parts of Punjab, Kashmir, and Khyber Pakhtunkhwa (Javaid and Riaz, 2012). Parthenium is mostly found along roadsides, in grazing pastures, on waste and undisturbed lands, and in some crops, especially in vegetables where plants are planted at a certain distance (Javaid and Anjum, 2005). The weed is known to cause allergic problems in almost all the countries where it has been established (Allen *et al.,* 2018).

Human activities directly or indirectly contaminate the soil through various pollutants, including heavy metals. Contamination of agricultural lands results

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in less yield and production of various crops, along with hazardous effects on both human and animal health. Heavy metals are a big source of soil contamination (Nagajyoti *et al.,* 2010; Liu *et al.,* 2022). Micro-elements participate in many physiological processes, and they are essential for the proper growth of plants (He *et al.,* 2005). However, they could be toxic when they cross optimal doses and inhibit plant growth-related processes. Chromium is toxic even at a very low concentration (Marschner, 2011). Chromium is present in two oxidative forms *viz.* Cr(III) and Cr(VI) (Andrade *et al.,* 2022). The latter is the hazardous form of chromium and may inflict serious health problems such as allergies, including skin rashes, nose irritations, nosebleeds, weakened defense systems, ulcers, genomic alteration, and liver and kidney damage (Teklay, 2016). The main reasons of chromium contamination in the soil are leather processing units, landfill leachate, industrial wastes, human activities, metal plating, automobile exhausts, improper incineration, excessive use of pesticides and fertilizers, cement manufacturing factories, metallization, metal finishing, tobacco emissions, acid manufacturing plants and paper producing industries (Kaur *et al.,* 2011). Chromium-based compounds are extremely toxic for plant growth. Although some crop plants are not affected by traces of Cr (Huffman and Allaway, 1973), most plants are affected by Cr even at 100 µM kg^{-1} concentration (Davies *et al.,* 2002). The plants having metal stress by various reduction reactions show detrimental growth that leads to low water potential and an imbalance of nutrients (Prasad *et al.,* 2005). Studies have confirmed that under chromium stress, plants synthesize less viable chlorophylls and carotenoids (Farid *et al.,* 2017). The present study was carried out to assess the effect of Cr(VI) on germination and early seedling growth of parthenium under *in vitro* environment.

MATERIALS AND METHODS

Preparation of Cr(VI) solutions

A stock solution of 100 mL of 160 ppm Cr(VI) was prepared by dissolving potassium dichromate in distilled water. It was serially double diluted to prepare 80, 40, 20, and 10 ppm solutions.

Laboratory bioassays

Mature, dark brown fruits of parthenium were picked in February 2022 and sun-dried to separate the husks from the seeds. Healthy seeds of uniform size were separated to be used in the laboratory bioassay. In sterilized Petri plates, a layer of filter paper was set, and 25 parthenium seeds were uniformly distributed on it. Thereafter, 2.5 mL solutions of five concentrations (10, 20, 40, 80, and 160 ppm) were added to each respective plate. There were four replicates of each concentration of Cr(VI). The experiment was carried out at room temperature for 10 days. On the last day, germinated seeds in each Petri plate were counted, and the data were transformed into percentage germination in each Petri plate. Lengths of the shoot and root of each seedling were recorded with the help of a scale, and the data of each plate were averaged for each studied parameter. Seedlings in each Petri plate were collectively dried, and their composite weight was recorded (Javaid *et al.,* 2020).

STATISTICAL ANALYSIS

All the data about germination and shoot and root growth were analyzed by one-way ANOVA. Thereafter, the LSD test was applied using Statistix 8.1 software to calculate the difference among the treatments at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect of Cr(VI) on germination of parthenium

Germination of parthenium seeds was adversely affected by the solution. Germination gradually declined to zero with the increase in the concentration of Cr(VI) in the solution. In general, all five applied Cr(VI) concentrations exhibited significant ($P \leq 0.05$) adverse effects on germination. In the three lower concentrations, *viz.* 10, 20, and 40 ppm, the germination was 89, 85, and 63%, which was 11, 15, and 37% lower than the control, respectively. An 80 ppm solution of Cr(VI) completely arrested the germination of parthenium seeds (Fig. 1 and 2A). Previously, a 120 µM solution of Cr(VI) reduced the germination of mungbean seeds by 45% (Singh *et al.,* 2021). Similar adverse effects of chromium have also been reported on the germination of six leguminous plants (Jun *et al.,* 2009), *Hibiscus esculentus* (Amin *et al.,* 2013), and tomato (Brasili *et al.,* 2020). The poor germination under Cr-stress could be due to inhibited amylase activity or activation of proteases by Cr following a decline in the transport of carbohydrates to the germ (Shah *et al.,* 2010).

Cr(VI) concentration (ppm)

Figure 1. Effect of different concentrations of Cr(VI) on germination and seedling growth of parthenium in laboratory bioassays.

Effect of Cr(VI) on the growth of parthenium

Shoot length was the highest in the control (2.16 cm). Application of different concentrations of Cr(VI) solution gradually and significantly reduced shoot length to 1.4, 0.72, and 0.16 cm under the effect of Cr(VI) concentrations of 10, 20, and 40 ppm, that was 35, 67 and 93% lower than the control, respectively. There was no growth beyond 40 ppm concentration (Fig. 1 and 2B). The effect of Cr(VI) on root length was more severe than the effect of corresponding concentrations on shoot length. Maximum root length was recorded in control (2.14 cm) that was reduced to 0.66, 0.16, and 0.10 cm due to 10, 20, and 40 ppm solution of Cr(VI). In terms of percentage decrease, 10, 20, and 40 ppm solutions of Cr(VI) reduced root length by 69, 93 and 95% over control, respectively (Fig. 2C). Since roots were the first part of the plant that absorbs Cr(VI) solution from the surrounding solution, therefore, they were affected more severely than the shoot. In many previous studies, similar effects of allelopathic plant's extracts (Javaid *et al.,* 2011) and fungal metabolites (Javaid *et al.,* 2021; Khan *et al.,* 2022) have also been reported on root growth of parthenium. The reduction in root length under Cr stress could be attributed to Cr buildup in root cells and the damaging of cells at the root tip (Singh *et al.,* 2021). Roots generally accumulate 10–100 times additional Cr than aerial parts (Zayed *et al.,* 1998).

The effect of the application of Cr(VI) on fresh and dry biomass of parthenium seedlings is presented in Fig. 2 C and D. Fresh weight in control was 270 mg which was reduced to 133, 75, and 12 mg when 10, 20, and 40 ppm Cr(VI) solutions were applied resulting in 51, 72 and 96% decrease over control, respectively. Likewise, the dry weight of seedlings in control was 72 mg which was diminished to 38, 22, and 2.32 mg due to the application of 10, 20, and 40 ppm Cr^{+6} solutions resulting in 47, 69, and 97% reduction over control. There was no biomass production in 80 and 160 ppm Cr(VI) solutions. Negative effects of chromium stress have also been reported on root and shoot length and plant biomass of mungbean (Singh *et al.,* 2021), rice (Chen *et al.,* 2017), and chickpea (Singh *et al.,* 2020). Cr accumulation influences different metabolic processes inside the plant body that cause various physiological and morphological defects in plants (Shah *et al.,* 2010; Adrees *et al.,* 2015). Suppression in the growth of plants due to Cr stress may be attributed to a reduction in chlorophyll formation, embarrassment of electron transport, liberation of Mg^{+2} from chlorophyll molecules (Panda and Choudhury, 2005; Shah *et al.,* 2010), and modifications in nitrogen metabolism such as negative effects on nitrogenase, glutamate dehydrogenase nitrite, and nitrate reductases, and glutamine synthetase (Sangwan *et al.,* 2014).

CONCLUSION

Parthenium germination and early growth were found highly susceptible to Cr(VI) stress. A concentration of 10 ppm can significantly suppress germination and shoot/root growth of parthenium. An 80 ppm concentration of Cr(VI) can completely control the germination of this weed.

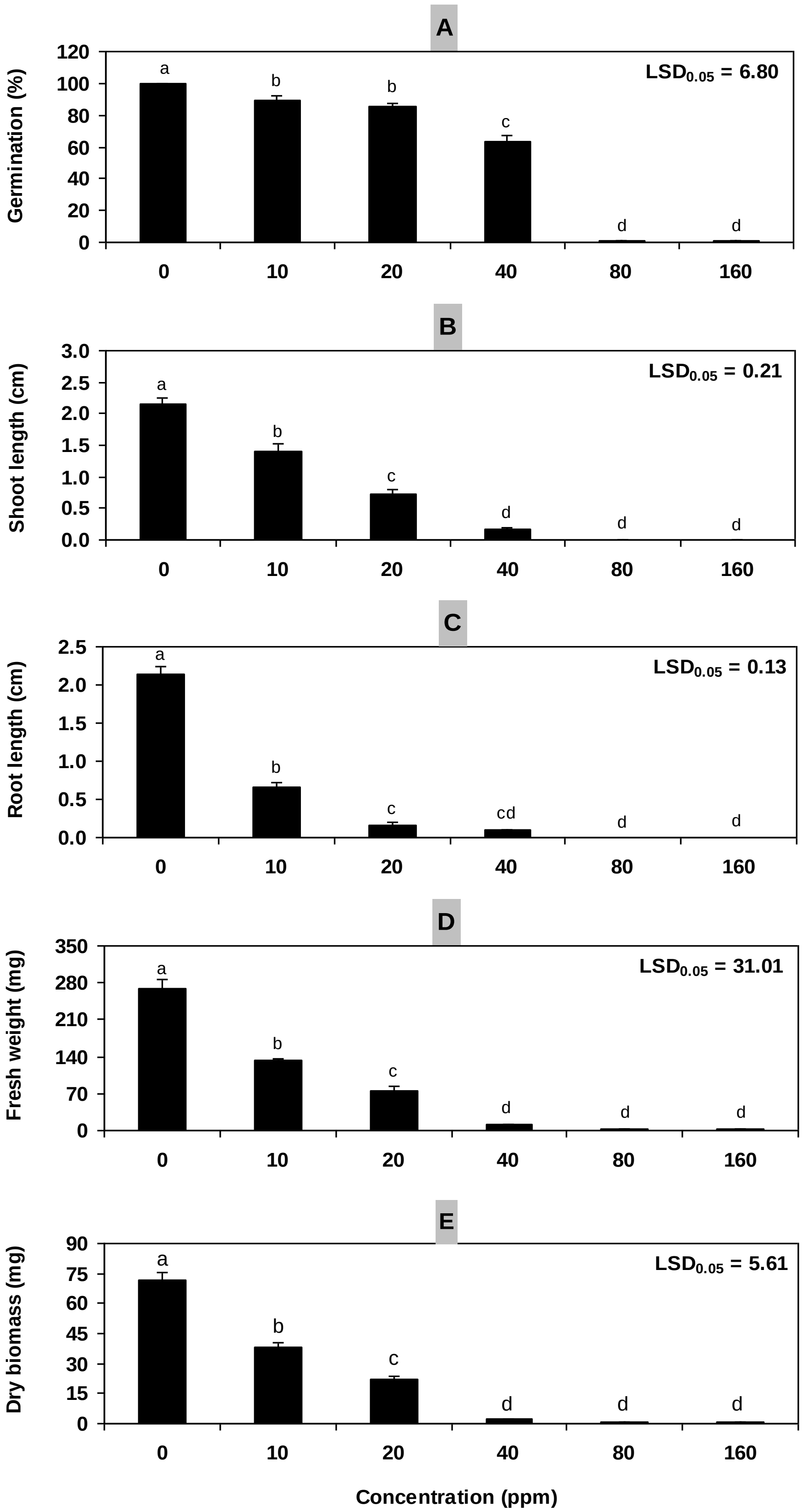

Figure 2. Effect of different concentrations of Cr(VI) on germination and seedling growth of parthenium in laboratory bioassays. Vertical bars show standard errors of means of five replicates. Values with different letters at their top show significant difference (P≤0.05) as determined by LSD Test.

REFERENCES CITED

Adrees, M., S. Ali and M. Iqbal. 2015. Mannitol alleviates chromium toxicity in wheat plants in relation to growth, yield, stimulation of anti-oxidative enzymes, oxidative stress and Cr uptake in sand and soil media. Ecotoxicol. Environ. Saf., 122: 1-8.

Allan, S., B. Shi and S.W. Adkins, 2018. Impact of parthenium weed on human and animal health, parthenium weed: Biology, ecology and management, vol. 7, CABI, Oxfordshire, UK, pp. 105-128.

Al Ruheili, A.M., T. Al Sariri, A.M. Al Subhi. 2022. Predicting the potential habitat distribution of parthenium weed (*Parthenium hysterophorus*) globally and in Oman under projected climate change. J. Saudi Soc. Agric. Sci., 21: 469-478.

Amin, H., B.A. Arain, F. Amin and M.A. Surhio. 2013. Phytotoxicity of chromium on germination, growth and biochemical attributes of *Hibiscus esculentus* L. Am. J. Plant Sci., 4: 720-726.

Andrade, D.C., M.B. Dolic, C.A. Martinez-Huitle, E.V. dos Santos, T.F.C.V. SIlva and V.J.P. Vilar. 2022. Coupling electrokinetic with a cork-based permeable reactive barrier to prevent groundwater pollution: A case study on hexavalent chromium-contaminated soil. Electrochem. Acta, 429: Article 140936.

Brasili, E., I. Bavasso, V. Petruccelli, G. Vilardi, A. Valletta and C. Dal Bosco. 2020. Remediation of hexavalent chromium contaminated water through zero-valent iron nanoparticles and effects on tomato plant growth performance. Sci. Rep., 10: 1-11.

Chen, Q., X. Zhang, Y. Liu, J. Wei, W. Shen and Z. Shen. 2017. Hemin-mediated alleviation of zinc, lead and chromium toxicity is associated with elevated photosynthesis, antioxidative capacity; suppressed metal uptake and oxidative stress in rice seedlings. Plant Growth Regul., 81: 253-264.

Chetty, S., O. Mutanga and R. Lottering. 2022. Detecting and mapping invasive *Parthenium hysterophorus* L. along the northern coastal belt of KwaZulu-Natal, South Africa using image texture. Sci. Afr., 13: Article e00966.

Davies, J.F.T., J.D. Puryear, R. J. Newton, J.N. Egilla and J.A.S. Grossi. 2002. Mycorrhizal fungi increase chromium uptake by sunflower plants: influence on tissue mineral concentration, growth, and gas exchange. J. Plant Nutr., 25(11): 2389-2407.

Farid, M., S. Ali, N.A. Akram, M. Rizwan, F. Abbas, S.A.H. Bukhari, R. Saeed. 2017. Phyto-management of Cr-contaminated soils by sunflower hybrids: physiological and biochemical response and metal extractability under Cr stress. Environ. Sci. Poll. Res., 24: 16845-16859.

He, Z.L., X.E. Yang and P.J. Stoffella. 2005. Trace elements in agroecosystems and impacts on the environment. J. Trace Elem. Med. Biol., 19: 125-140.

Javaid, A. and T. Anjum. 2005. *Parthenium hysterophorus* L. – A noxious alien weed. Pak. J. Weed Sci. Res., 11(3-4): 171-177.

Javaid, A., S. Shafique and S. Shafique. 2011. Management of *Parthenium hysterophorus* (Asteraceae) by *Withania somnifera* (Solanaceae). Nat. Prod. Res., 25 (4): 407-416.

Javaid, A. and T. Riaz. 2012. *Parthenium hysterophorus* L., an alien invasive weed threatening natural vegetations in Punjab, Pakistan. Pak. J. Bot., 44(S1): 123-126.

Javaid, A, I.H. Khan, S. Ahmad, M.F.H. Ferdosi and S.F. Naqvi. 2021. Metabolites of *Penicillium citrinum* as potent herbicides against parthenium weed. Pak. J. Phytopathol., 33(1): 109-115.

Javaid, N., M.H. Shah, I.H. Khan, A. Javaid and S.M. Waleed. 2020. Herbicidal activity of *Ageratum conyzoides* against parthenium. Pak. J. Weed Sci. Res., 26(2): 137-146.

Javaid, A., T. Jabeen, I.H. Khan, K. Jabeen and M. Akbar. 2022. Herbicidal potential of *Alternaria citri* Ellis and Pierce metabolites against *Parthenium hysterophorus* L. Allelopathy J., 55(1): 25-34.

Jun, R., T. Ling and Z. Guanghua. 2009. Effects of chromium on seed germination, root elongation and coleoptile growth in six pulses. Int. J. Environ. Sci. Technol., 6: 571-578.

Kaur, S., M.R. Kamli and A. Ali. 2011. Role of arsenic and its resistance in nature. Can. J. Microbiol., 57: 769-774.

Kaur, M., N.K. Aggarwal, V. Kumar and R. Dhiman. 2014. Effects and management of *Parthenium hysterophorus*: a weed of global significance. Int. Sch. Res. Notices, 2014: 12.

Khan, I.H., A. Javaid and S. Ahmad. 2022. Potential of *Penicillium crustosum* metabolites in controlling parthenium weed. Pak. J. Weed Sci. Res., 28(1): 77-85.

Liu, J., H. Kang, W. Tao, H. Li, D. He, L. Ma, H. Tang, K. Yang and X. Li. 2022. A spatial distribution – Principal component analysis (SD-PCA) model to assess pollution of heavy metals in soil. Sci. Total Environ., 859: Article 160112.

Marschner, H. 2011. Marschner's mineral nutrition of higher plants. Academic Press.

Nagajyoti, P.C., K.D. Lee and T.V.M. Sreekanth. 2010. Heavy metals, occurrence and toxicity for plants: a review. Environ. Chem. Lett., 8(3): 199-216.y

Panda, S.K. and S. Choudhury. 2005. Chromium stress in plants. Braz. J. Plant Physiol., 17: 95-102.

Prasad, S.M., R. Dwivedi and M. Zeeshan. 2005. Growth, photosynthetic electron transport, and antioxidant responses of young soybean seedlings to simultaneous exposure of nickel and UV-B stress. Photosynthetica, 43(2): 177-185.

Riaz, T. and A. Javaid. 2011. Prevalence of alien weed *Parthenium hysterophorus* L. in grazing and wastelands of district Attock. Pakistan. J. Anim. Plant Sci., 21(3): 542-545.

Sangwan, P., V. Kumar and U.N. Joshi. 2014. Effect of chromium(VI) toxicity on enzymes of nitrogen metabolism in clusterbean (*Cyamopsis tetragonoloba* L.). Enzyme Res., 2014: 784036.

Shah, F.U.R., N. Ahmad, K.R. Masood, J.R. Peralta-Videa and F.U.D. Ahmad.2010. Heavy metal toxicity in plants. In: *Plant Adaptation and Phytoremediation,* M. Ashraf, M. Ozturk, M.S.A. Ahmad (eds.), Springer. pp. 71-97.

Singh, D., N.L. Sharma, C.K. Singh, S.K. Sarkar, I. Singh and M.L. Dotaniya. 2020. Effect of chromium (VI) toxicity on morpho-physiological characteristics, yield, and yield components of two chickpea (*Cicer arietinum* L.) varieties. PLoS ONE, 15: e0243032.

Singh, I., N.L. Sharma, C.K. Singh, V. Yerramilli, R. Narayan, S.K. Sarkar and I. SIngh. 2021. Chromium (VI)-induced alterations in physio-chemical parameters, yield, and yield characteristics in two cultivars of mungbean (*Vigna radiata*). Front. Plant Sci., 735129.

Teklay, A. 2016. Physiological effect of chromium exposure: a review. Int. J. Food Sci. Nutr. Diet, 7: 1-11.

Zayed, A., C.M. Lytle, J.-H. Qian and N. Terry. 1998. Chromium accumulation, translocation and chemical speciation in vegetable crops. Planta, 206: 293-299.