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Evaluation of Chromium Toxicity on Different Growth and Biochemical Attributes of *Abrus precatorius* L.

Evaluación de la toxicidad del cromo en diferentes atributos bioquímicos y de crecimiento de *Abrus precatorius* L.

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ABSTRACT

The toxicity of trace metals on human health and the environment has attracted considerable attention in recent years. Plants are the main link in the transfer of heavy metals from the contaminated soil to humans. In the present study, effects of different concentrations of chromium (Cr, 50-250 mg/l) was analyzed in medicinal plant *Abrus precatorius* L. with respect to seed germination, shoot and root growth and their dry weights along with changes in biochemical contents like pigments, protein and total sugar. The study showed that the different concentrations of Cr had an adverse effect on percentage of germination and growth parameters. The results also suggested that at higher concentrations, roots were strongly affected as compared to shoots. Further, when biochemical analysis was carried out it was depicted that the biochemical contents like chlorophyll A and B, carotenoids, protein and total sugar also decreased sequentially as the Cr concentration was increased.
Keywords: *Abrus precatorius*, chromium, heavy metal, medicinal plant, soil contamination, toxicity.

RESUMEN

La toxicidad de los metales traza en la salud humana y el medio ambiente ha atraído una atención considerable en los últimos años. Las plantas son el eslabón principal en la transferencia de metales pesados del suelo contaminado a los humanos. En el presente estudio, se analizaron los efectos de diferentes concentraciones de cromo (Cr, 50-250 mg/l) en la planta medicinal *Abrus precatorius* L. con respecto a la germinación de semillas, crecimiento de brotes y raíces y sus pesos secos junto con cambios en los contenidos bioquímicos. como pigmentos, proteína y azúcar total. El

estudio mostró que las diferentes concentraciones de Cr tuvieron un efecto adverso sobre el porcentaje de germinación y los parámetros de crecimiento. Los resultados también sugirieron que a concentraciones más altas, las raíces se vieron fuertemente afectadas en comparación con los brotes. Además, cuando se llevó a cabo el análisis bioquímico, se describió que los contenidos bioquímicos como la clorofila A y B, los carotenoides, las proteínas y el azúcar total también disminuyeron secuencialmente a medida que aumentaba la concentración de Cr.
Palabras clave: *Abrus precatorius*, cromo, metal pesado, planta medicinal, contaminación del suelo, toxicidad.

INTRODUCTION

Heavy metals are normally considered as environmental pollutants and their excess amount affects the growth of useful plants as well as human health. One of the common heavy metal found naturally in rocks, soil, volcanic dust and gases is chromium (Cr, ATSDR 1998). It occurs naturally in two predominant valance viz. Cr^{+3} and Cr^{+6}, in which the later being more toxic than former (Ertani et al. 2017). Cr^{+6} is found in the effluent of cement plants, steel production, electroplating, dye and paint industries, leather and wood preservation, timber processing, paper industries etc. (Cervantes et al. 2001, Zayed and Terry 2003). The excessive concentrations of this metal ultimately destroy the crop and impart serious health hazards in human beings by entering through food chain if such polluted effluents are employed for irrigation without proper waste water treatment (Vernay et al. 2007). Previous studies documented that the toxic effects of chromium in humans, animals, plants and microorganisms (Cervantes et al. 2001, Sangwan et al. 2013). The heavy metal pollution is one of the causes for the hazard of use of medicinal plant as a botanical raw material for preparation of herbal drugs (Mironov 2013). If such plant based products are consumed by humans, the body can be suffer from cancer and other complicated diseases as a result of heavy metal consumption (Karbassi et al. 2018).

Abrus precatorius (L.) is one of the popular perennial climbing herb belonging to fabaceae family. The plant is traditionally utilized for its abortifacient, laxative, sedative and aphrodisiac properties (Solanki and Zaveri 2012). Seeds administrated in infections of nervous system and their paste is applied locally in stiffness of shoulder joints and paralysis (Ambasta 1986). Whereas the roots are having sweet taste and they are being used as substitute to liquorice (Oladimeji and Valan 2020). The plant is reported to be a rich source of various chemical constituents such as abrol, abrasine, precol and precasine from the roots (Verma 2016). Likewise its seeds are also a good source of several essential amino acids like serine, alanine, valine, choline and methyl ester (Rajaram and

Janardan 1992). *A. precatorius* is used to cure dysentery (Rao and Sreeramulu 1985), diarrhoea (Tandon 2008), wounds, sores, scratches and leucoderma (Attal et al. 2010). It also possess different pharmacological activities such as anti-diabetic (Dhawan, et al. 1977), neuroprotective (Premanand and Ganesh 2010), anti-depression and anti-inflammatory (Attal et al. 2010), anti-oxidative (Arora et al. 2011), anti-malarial (Saganuwan et al. 2011) and anti-cancer (Sofi et al. 2018). The plant is not only used for its medicinal purpose, but also used as a food source for tribals (Rajaram and Janardan 1992).

Reports suggested that Cr does not have any known role in plant physiology (Reale et al. 2016), but it has well documented that its excessive levels in plants provokes several morpho-physiological and biochemical processes (UdDin et al. 2015; Kamran et al. 2017). The heavy metal like Cr can be accumulated in *A. precatorius* and if such plants can be consumed, it cause adverse gastrointestinal effects such as abdominal pain, vomiting, ulceration, haemorrhage and bloody diarrhoea (Guertin 2004). Many recent studies suggested that Cr affected different growth and biochemical parameters in *Cicer arietinum* (Singh et al. 2020), *Hibiscus* spp. (Sultana et al. 2020), *Macrotyloma uniflorum* (Dhali et al. 2020) and *Moringa oleifera* (Pehlivan et al. 2021). Similarly earlier report on *A. precatorius* suggested that heavy metal affected the seedling growth and its biochemical contents (Vyas 2017), however the effect of another common heavy metal pollutant Cr has not been studied yet. Thus, keeping this in mind, the present study aimed to assess the effects of chromium on seedlings growth and biochemical contents in *A. precatorius*.

MATERIALS AND METHODS

Collection of plant material: Seeds were collected from widely grown plants in the campus of V. N. South Gujarat University, Surat, Gujarat, India. They were washed with running tap water and healthy seeds were selected which were further sterilized with 0.2% $HgCl_2$.

Experimental procedure: Ten seeds were placed in petri-dishes containing filter paper in which chromium solution was added at different concentrations (50, 100, 150, 200 and 250 mg/l). The germination percentage, seedling growth, dry matter yield and biochemical contents were studied ten days after sowing. Seeds germinated in presence of distilled water were used as control for the study.

For determination of dry weight, shoots and roots were harvested, cut into small pieces and placed separately in brown bags after weighing and kept in oven for drying at 80 ºC for 8 days. The biochemical estimation of total sugar was done according to the methodology of Nelson (1944), in which the amount of sugar was calculated from O.D. obtained by spectrophotometer. Similarly, the protein content was determined from O.D.

using the procedure of Lowery et al. (1951). For the pigment determination, acetone extract of fresh leaves was used and the amount of chlorophyll A, chlorophyll B and carotenoid were calculated by using the formula given by Maclachalam and Zalik (1963) and Duxbury and Yentsch (1956).

Statistical analysis: All the experiments were repeated three times and ten replicates were maintained for each experiment. The values are given as mean and standard error (SE) from ten replicates.

RESULTS AND DISCUSSION

Seed germination: The ability of a plant to tolerate Cr toxicity depends upon its capacity to sustain germination in Cr contaminated environment (Peralta et al. 2001). In fact, plants show a great variation in their tolerance to Cr in the environment and Cr toxicity depends upon the plant species and the source (Lopez-Luna et al. 2009). Previous studies have also reported that Cr inhibited germination in plants such as *Medicago sativa* (Peralta et al. 2001), *Casuarina equisetifolia* (Zhou and Li 2004), *Glycine max*, *Vigna radiata* and *V. angularis* (Jun et al. 2009), *Beta vulgaris*, *Raphanus sativus*, *Daucus carota*, *Solanum melongena* and *Lycopersicon esculentum* (Lakshmi and Sundaramoorthy 2010) and *Brassica oleracea* var. *acephala* (Ozdener et al. 2011). In the present study, decreased seed germination with increasing concentration of Cr was observed in our result (Fig 1). This is in accordance with earlier studies in *Cucumis melo* (Akinci and Akinci 2010) and *Triticum aestivum* (Datta et al. 2011). It has been noted that the accumulation of Cr in plants affects metabolic processes which in turn results into decreased germination (Rai et al. 2004, Panda and Choudhury 2005, Adrees et al. 2015).

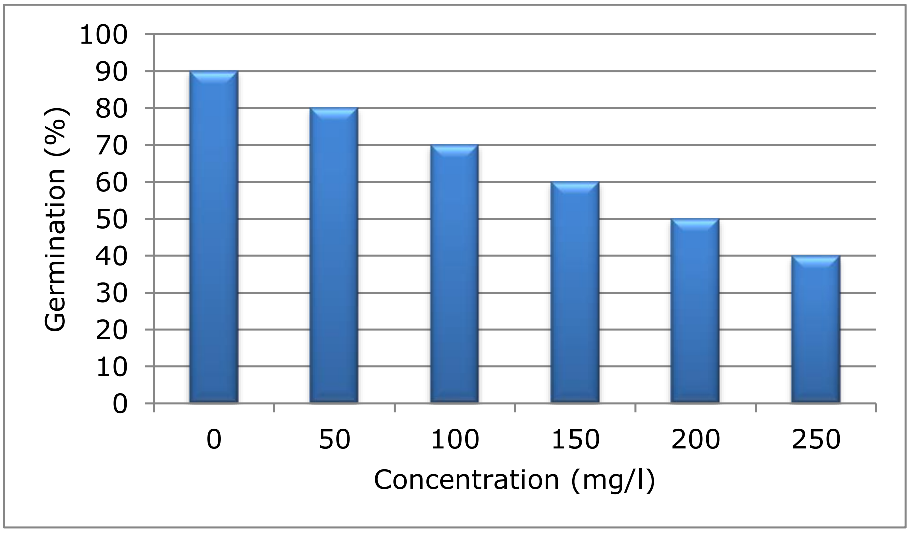

Fig. 1 Effect of Cr on seed germination of *A. precatorious*

Shoot and root length and their dry weights: Several studies have demonstrated the adverse effect of Cr on root and shoot growth and biomass (Singh et al. 2013).

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When seeds of *A. precatorius* were treated with different concentrations of Cr, decrease in growth of both shoot and root was noted (Fig 2). Similarly several workers also studied the similar observations in *Medicago sativa* (Peralta et al. 2001), *Avena sativa* and *Sorghum vulgare* (Lopez-Luna et al. 2009), *Arachis hypogea* (Rajalakshmi et al. 2010), *Zea mays* (Mallick et al. 2010), *B. oleracea* (Ozdener et al. 2011), *Oryza sativa* (Sundaramoorthy et al. 2010, Ahmad et al. 2011) and *Hibiscus* spp. (Sultana et al. 2020). Present study also showed that root growth is more effected than shoot growth by Cr and similar results were documented by Gyawali and Lekhak (2006) in *O. sativa* where root growth was comparatively more inhibited than shoot. Recent study by Ahmed et al. (2021) also suggested that Cr was more accumulated in roots as compared to shoots. This might be the reason behind more growth retardation as compared to shoot as Cr affects the cell cycle and inhibits cell division followed by hindrance in root growth. The decreased root growth directly affects the water and nutrient absorption and their transportation to aerial plant parts, there by inhibiting shoot growth (Sundaramoorthy et al. 2010). Dotaniya et al. (2014) also suggested that the higher Cr concentration affected growth and in turn overall biomass of *Triticum aestivum*. Similarly in the present study, it was depicted that the Cr application also affected shoot and root dry weight significantly as compared to control (Fig 3). This is in corroboration with results of *Hibiscus esculentus* where decrease in dry weight of shoot and root was observed with an increase in Cr level (Amin et al. 2013).

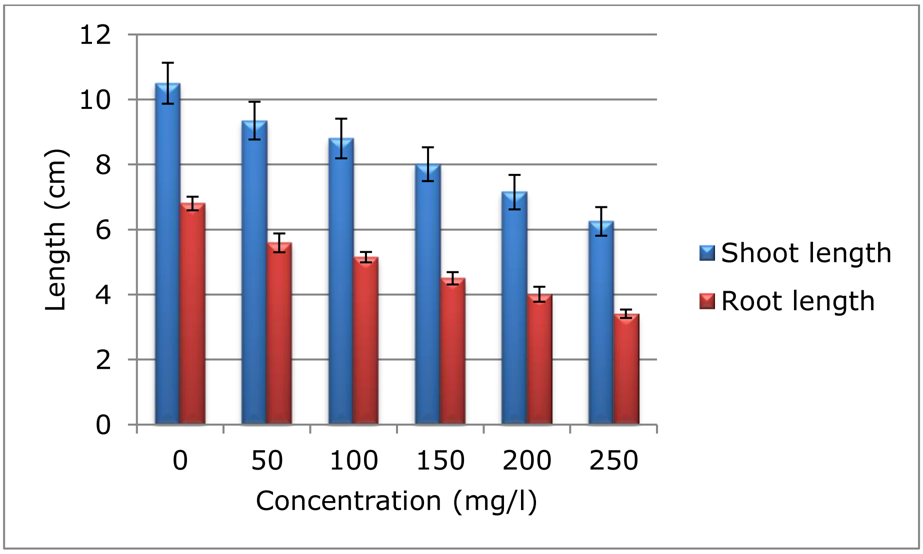

Fig 2. Effect of Cr on shoot and root length of *A. precatorious*. Each bar shows the mean values (n = 10) and error bar as standard error.

Chlorophyll A and B content: The photosynthetic pigments chlorophyll A and B of plant were decrease with increased chromium treatments (Fig 4). This is in line with recent report by Singh et al. (2020) in *Cicer arietinum* where similar trend for decline in chlorophyll A and B has been documented. Similar results were also observed in *H. esculentus* (Amin et al. 2013) and *Catharanthus roseus* plants (Rai et al. 2014). Some other studies have the same conclusion that the chlorophyll contents were decreased under different concentrations of Cr (Yang et al. 2001, Samantary and Deo 2004). The reduction in chlorophyll contents was may be due to the disruption of chlorophyll biosynthesis as the key regulatory enzyme i.e. δ-aminolevulinic acid dehydratase (ALAD) is inhibited by Cr due to the impairment in utilizing the δ-aminolevulinic acid and this has been well studied in plants under Cr stress (Shanker et al. 2005, Hayat et al. 2012).

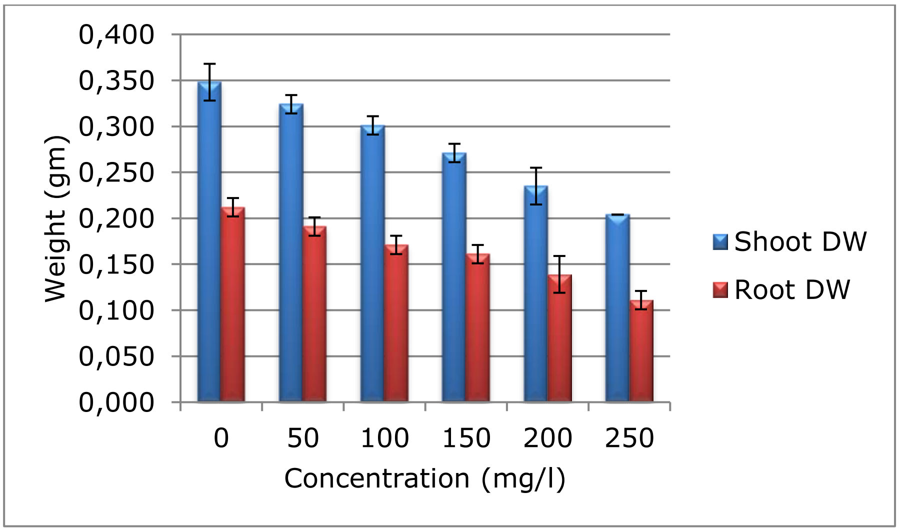

Fig 3. Effect of Cr on shoot and root dry weights of *A. precatorious*. Each bar shows the mean values (n = 10) and error bar as standard error.

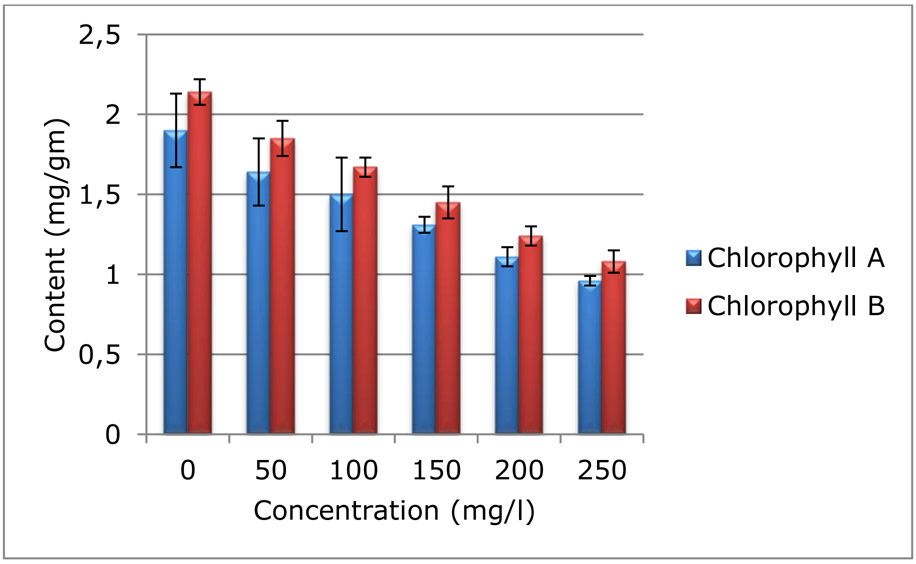

Fig 4. Effect of Cr on chlorophyll A and B content in *A. precatorious*. Each bar shows the mean values (n = 10) and error bar as standard error

Carotenoids content: Our result for carotenoids content showed reducing trend in leaves of *A. precatorious* against different concentrations levels of metal (Fig 5). Similarly, carotenoids contents also decreased in leaves of Cluster-Bean plants treated with Cr as reported by Sangwan et al. (2013). Other studies on *Ocimum tenuiflorum*, lettuce and soybean also documented decreased carotenoids after Cr treatment (Rai et al. 2004, Ganesh et al. 2008). Whereas contrary results were reported in plants like *Capsicum annuum* (Oliveira 2012) and *C. roseus* (Rai et al. 2014) where the carotenoid level has been increased after Cr treatment.

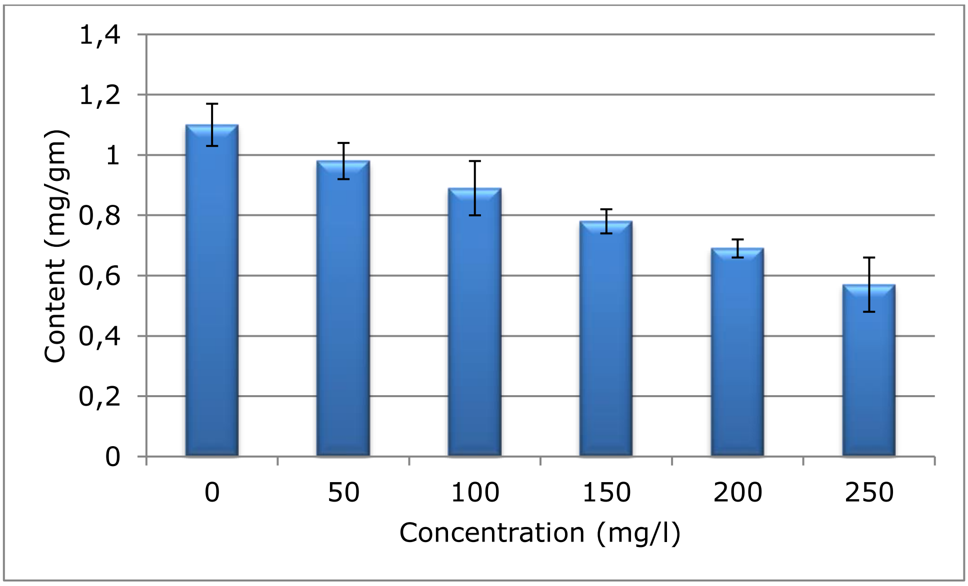

Fig 5. Effect of Cr on carotenoid content in *A. precatorious*. Each bar shows the mean values (n = 10) and error bar as standard error

Total sugar and protein content: From this investigation it was revealed that both total sugar (Fig 6) and protein (Fig 7) were also decreased gradually as the concentration of Cr increased. This is in line with earlier reports in paddy plant in which the content of both them were gradually decreased with the increase in chromium concentrations (Nagarajan and Sankar Ganesh 2014). Sugars are considered as important metabolites in plant metabolism not only because these are the first complex organic compounds formed in the plant as a result of photosynthesis but also because they provide a major source of respiratory energy (Solanki and Dhankhar 2011). It has been suggested that the Cr toxicity not only reduces the plant growth by inducing ultrastructural modifications of the cell membrane and chloroplast, persuading chlorosis in the leaves, damaging root cells; but it also reduces the contents of pigments by altering different enzymatic activities (Ali et al. 2015; Farooq et al. 2016; Reale et al. 2016).

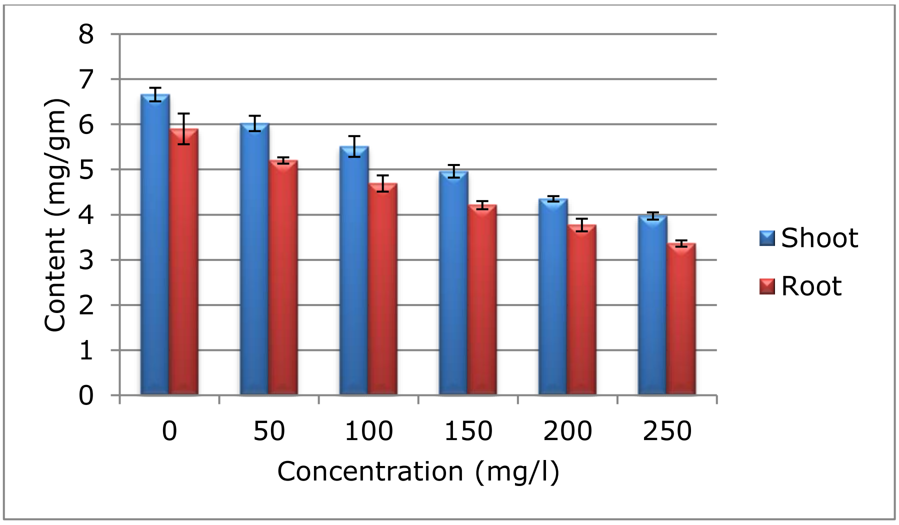

Fig 6. Effect of Cr on protein content in *A. precatorious*. Each bar shows the mean values (n = 10) and error bar as standard error.

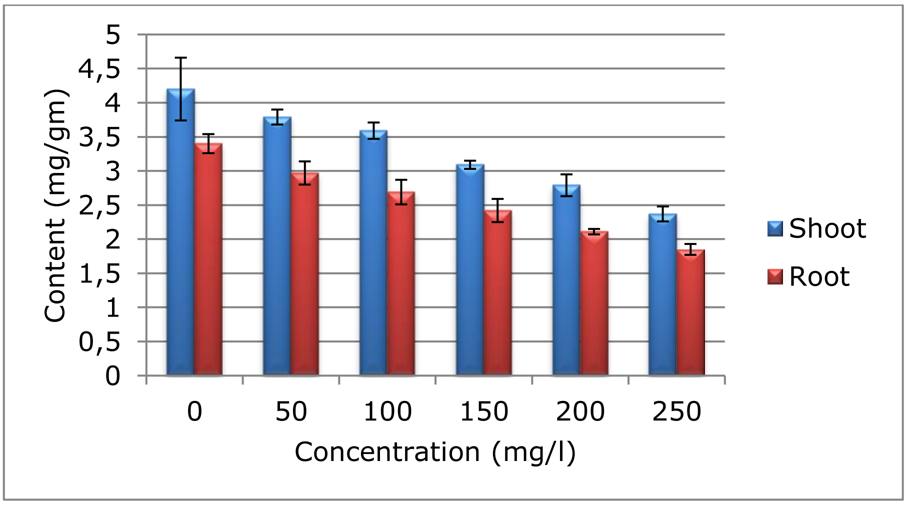

Fig 7. Effect of Cr on total sugar content in *A. precatorious*. Each bar shows the mean values (n = 10) and error bar as standard error

The present study has been carried out on effect of different concentrations of heavy metal Cr on different parameters like germination, growth, pigments and nutrients like proteins and total sugar in medicinal plant *A. precatorious*. The study showed that Cr is a non-essential element for plant and it induces toxicity in plants at different parameters such as growth and development, as well as on biochemical contents of plant. The extensive use of Cr in a large number of products and industrial process can cause detrimental effects on growth of plant along with severe environmental contamination. Thus, Cr contaminated water should be properly treated and then discharged into nearby water bodies in order to prevent water pollution. Further, the consumption of plants grown in such contaminated area also requires proper pre-treatment.

REFERENCES

Adrees, M., Ali, S., Iqbal, M., Aslam Bharwana, S., Siddiqi, Z., Farid, M., Ali, Q., Saeed, R. and Rizwan, M. 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. *Ecotoxicology and Environmental Safety* 122:1-8.

Agency for Toxic Substances and Disease Registry (ATSDR). 1998. *Toxicological profile for chromium*. U.S. Department of health and human services, Atlanta, GA.

Ahmad, M., Wahid, A., Ahmad, S.S., Butt, Z.A. and Tariq, M. 2011. Ecophysiological responses of rice (*Oryza sativa* L.) to hexavalent chromium. *Pakistan Journal of Botany* 43(6):2853-2859.

Ahmed, F., Fakhruddin, A.N.M., Fardous, Z., Chowdhury, M.A.Z., Rahman, M.M. and Kabir, M.M. 2021. Accumulation and translocation of chromium (Cr) and lead (Pb) in chilli plants (*Capsicum annuum* L.) grown on artificially contaminated soil. *Nature Environment and Pollution Technology* 20(1):63-70.

Akinci, I.E. and Akinci, S. 2010. Effect of chromium toxicity on germination and early seedling growth in melon (*Cucumis melo* L.). *African Journal of Biotechnology* 9(29):4589-4594.

Ali, S., Bharwana, S.A., Rizwan, M., Farid, M., Kanwal, S., Ali, Q., Ibrahim, M., Gill, R. A. and Khan, M.D. 2015. Fulvic acid mediates chromium (Cr) tolerance in wheat (*Triticum aestivum* L.) through lowering of Cr uptake and improved antioxidant defense system. *Environmental Science and Pollution Research* 22:10601-10609.

Ambasta, S.P. 1986. The useful plants of India. National institute of science communication and information resources. CSIR, New Delhi, India.

Amin, H., Arain, B.A., Amin, F. and Surhio, M.A. 2013. Phytotoxicity of chromium on germination, growth and biochemical attributes of *Hibiscus esculentus* Linn. *American Journal of Plant Science* 4(12):2431-2439.

Arora, R., Gill, N.S., Kaur, S and Jain, A.D. 2011. Phytopharmacological evaluation of ethanolic extract of the seed of *Abrus precatorius* L. *Journal of Pharmacology and Toxicology* 6(6):580-588.

Attal, A.R., Otari, K.V., Shete, R.V., Upasani, C.D. and Nandgude, T.D. 2010. *Abrus precatorius* Linnaeus: a phytopharmacological review. *Journal of Pharmacy Research* 3(11):2585-2587.

Cervantes, C., Campos-García, J., Devars, S., Gutiérrez-Corona, F., Loza-Tavera, H., Torres-Guzmán, J.C. and Moreno-Sánchez, R. 2001. Interactions of chromium with microorganisms and plants. *FEMS Microbiology Reviews* 25(3):335-347.

Datta, J.K., Bandhyopadhyay, A., Banerjee, A. and Mondal, N.K. 2011. Phytotoxic effect of chromium on the germination, seedling growth of some wheat (*Triticum aestivum* L.) cultivars under laboratory condition. *Journal of Agricultural Technology* 7(2):395-402.

Dhali, S., Pradhan, M., Sahoo, R.K., Pradhan, C. and Mohanty, S. 2020. Growth and biochemical variations in *Macrotyloma uniflorum* var. Madhu under chromium stress. *Indian Journal of Agricultural Research* 54(1):95-100.

Dhawan, B.N., Patnaik, G.K., Rastogi, R.P., Singh, K.K. and Tandon, J.S. 1977. Screening of Indian plants for biological activity: part VI. *Indian Journal of Experimental Biology* 15(3):208-219.

Dotaniya, M.L., Das, H., Meena, V.D. 2014. Assessment of chromium efficacy on germination, root elongation, and coleoptile growth of wheat (*Triticum aestivum* L.) at different growth periods. *Environmental Monitoring Assessment* 186(5):2957-2963.

Duxbury, A.C. and Yentach, C.S. 1956. Plankton pigment monograph*. Sears Foundation: Journal of Marine Research* 15(1):92-101.

Ertani, A., Mietto, A., Borin, M. and Nardi, S. 2017. Chromium in agricultural soils and crops: A review. *Water, Air and Soil Pollution* 228:190.

Farooq, M., Ali, S., Hameed, A., Bharwana, S., Rizwan, M., Ishaque, W., Farid, M., Mahmood, K. and Iqbal, Z. 2016. Cadmium stress in cotton seedlings: Physiological, photosynthesis and oxidative damages alleviated by glycinebetaine. *South African Journal of Botany* 104:61-68.

Ganesh, K.S., Baskaran, L., Rajasekaran, S., Sumathi, K., Chidambaram, A.L.A. and Sundaramoorthy, P. 2008. Chromium stress induced alterations in biochemical and enzyme metabolism in aquatic and terrestrial plants. *Colloids and Surfaces B: Biointerfaces* 63(2):159-163.

Guertin, J. 2004. Toxicity and health effects of chromium (All Oxidation States). Chromium VI Handbook. CRC Press, USA. 216-230 pp.

Gyawali, R. and Lekhak, H.D. 2006. Chromium tolerance of rice (*Oryza sativa* L.) cultivars from Kathmandu Valley, Nepal. *Scientific World* 4(4):102-108.

Hayat, S., Khalique, G., Irfan, M., Wani, A.S., Tripathi, B.N. and Ahmad, A. 2012. Physiological changes induced by chromium stress in plants: An overview. *Protoplasma* 249:599-611.

Jun, R., Ling, T. and Guanghua, Z. 2009. Effects of chromium on seed germination, root elongation and coleoptile growth in six pulses. *International Journal of Environmental Science and Technology* 6:571-578.

Kamran, M., Eqani, S., Katsoyiannis, A., Xu, R., Bibi, S., Benizri, E. and Chaudhary, H. 2017. Phytoextraction of chromium (Cr) and influence of *Pseudomonas putida* on *Eruca sativa* growth. *Journal of Geochemical Exploration* 182:269-274.

Karbassi, A., Tajziehchi, S. and Khoshgalb, H. 2018. Speciation of heavy metals in coastal water of Qeshm Island in the Persian Gulf. *Global Journal of Environmental Science and Management* 4(1):91-98.

Lakshmi, S. and Sundaramoorthy, P. 2010. Effect of chromium on germination and seedling growth of vegetable crops. *Asian Journal of Science and Technology* 1:28-31.

Lopez-Luna, J., Gonzalez-Chavez, M.C., Esparza-Garcia, F.J. and Rodriguez-Vazquez, R. 2009. Toxicity assessment of soil amended with tannery sludge, trivalent chromium and hexavalent chromium, using wheat, oat and sorghum plants. *Journal of Hazardous Materials* 163(2-3):829-834.

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. 1951. Protein measurement with the folin phenol reagent*. The Journal of Biological Chemistry* 193:265-275.

Maclachalam, S. and Zalik, S. 1963. Plastid structure, chlorophyll concentration and free amino acid composition of a chlorophyll mutant of barely. *Canadian Journal of Botany* 41(7):1053-1062.

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* 73:987-995.

Mironov, A.N. 2013. Modern approaches to the issue of standardization of medicinal plant raw materials. *Bulletin of the Scientific Centre of Expertise in Medicinal Products* 2:52-56.

Nagarajan, M. and Sankar Ganesh, K. 2014. Effect of chromium on growth, bio chemicals and nutrient accumulation of paddy (*Oryza sativa* L.). *International Letters of Natural Sciences* 23:63-71.

Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. *The Journal of Biological Chemistry* 153:375-380.

Oladimeji, A.V. and Valan, M.F. 2020. The potential therapeutic advantage of *Abrus precatorius* Linn. an alternative to *Glycyrrhiza glabra*: A review. *Journal of Pharmaceutical Research International* 32(40):79-94.

Oliveira, H. 2012. Chromium as an environmental pollutant: Insights on induced plant toxicity. *Journal of Botany* 2012:1-8.

Ozdener, Y., Aydin, B.K., Fatma Aygün, S. and Yürekli, F. 2011. Effect of hexavalent chromium on the growth and physiological and biochemical parameters on *Brassica oleracea* L. var. *acephala* DC. *Acta Biologica Hungarica* 62(4):463-476.

Panda, S.K. and Choudhury, S. 2005. Chromium stress in plants. *Brazilian Journal of Plant Physiology* 17(1):95-102.

Pehlivan, M. 2021. Chromium toxicity in *Moringa oleifera* Lam. *Indian Journal of Traditional Knowledge* 20(2):537-543.

Peralta, J.R., Gardea-Torresdey, J.L., Tiemann, K.J., Gomez, E., Arteaga, S., Rascon, E. and Parsons, J.G. 2001. Uptake and effects of five heavy metals on seed germination and plant growth in alfalfa (*Medicago sativa* L.). *Bulletin of Environmental Contamination and Toxicology* 66(6):727-734.

Premanand, R. and Ganesh, T. 2010. Neuroprotective effects of *Abrus precatorius* Linn. aerial extract on hypoxic neurotoxicity induced rats. *International Journal of Chemical and Pharmaceutical Sciences* 1(1):9-15.

Rai, V., Tandon, P.K. and Khatoon, S. 2014. Effect of chromium on antioxidant potential of *Catharanthus roseus* varieties and production of their anticancer alkaloids: Vincristine and vinblastine. *BioMed Research International* 2014:1-10.

Rai, V., Vajpayee, P., Singh, S.N. and Mehrotra, S. 2004. Effect of chromium accumulation on photosynthetic pigments, oxidative stress defense system, nitrate reduction, proline level and eugenol content of *Ocimum tenuiflorum* L. *Plant Science: An International Journal Experimental Plant Biology* 167(5):1159-1169.

Rajalakshmi, K., Kumar, P., Saravanakumar, A., Aslam, A., Shahjahan, A. and Ravikumar, R. 2010. Arachis bioassay for soil contaminated with hexavalent chromium. *The Recent Research in Science and Technology* 2(6):110-115.

Rajaram, N. and Janardhanan, P. 1992. The chemical composition and nutritional potential of the tribal pulse, *Abrus precatorius* Linn*. Plant Foods Human Nutrition* 42(4):285-290.

Rao, K.P. and Sreeramulu, S.H. 1985. Ethnobotany of selected medicinal plants of Srikakulam district, Andhra Pradesh*. Ancient Science of Life* 4(4):238-244.

Reale, L., Ferranti, F., Mantilacci, S., Corboli, M., Aversa, S., Landucci, F., Baldisserotto, C., Ferroni, L., Pancaldi, S. and Venanzoni, R. 2016. Cyto-histological and morpho-physiological responses of common duckweed (*Lemna minor* L.) to chromium. *Chemosphere* 145:98-105.

Saganuwan, S.A., Onyeyili, P.A., Ameh, E.G. and Etuk, E.U. 2011. *In vivo* antiplasmodial activity by aqueous extract of *Abrus precatorius* in mice. *The Revista Latinoamericana de Química* 39(1-2):32-44.

Samantary, S. and Deo, B. 2004. Studies on chromium toxicity in mung bean (*Vigna radiata* L.). *Advances in Plant Sciences* 17:189-194.

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.

Sangwan, S., Kumar, V., Khatri, R.S. and Joshi, U.N. 2013. Chromium (VI) induced biochemical changes and gum content in cluster bean (*Cyamopsis tetragonoloba* L.) at different developmental stages. *Journal of Botany* 2013:1-8.

Shanker, A.K., Cervantes, C., Loza-Tavera, H. and Avudainayagam, S. 2005.

Chromium toxicity in plants. *Environment International* 31(5):739-753.

Singh, D., Sharma, N.L., Singh, C.K., Sarkar, S.K., Singh, I. and Dotaniya, M.L. 2020. Effect of chromium (VI) toxicity on morpho-physiological characteristics, yield, and yield components of two chickpea (*Cicer arietinum* L.) varieties. *PLoS One* 15(12): e0243032.

Singh, H.P., Mahajan, P., Kaur, S., Batish, D.R. and Kohli, R.K. 2013. Chromium toxicity and tolerance in plants. *Environmental Chemistry Letters* 11(3):229-254.

Sofi, M.S., Sateesh, M.K., Bashir, M., Ganie, M.A. and Nabi, S. 2018. Chemopreventive and anti-breast cancer activity of compounds isolated from leaves of *Abrus precatorius* L. *3 Biotech* 8(8):371.

Solanki, A. and Zaveri, M. 2012. Pharmacognosy, phytochemistry and pharmacology of *Abrus precatorius* leaf: A review. *International Journal of Pharmaceutical Sciences Review and Research* 13(2):71-76.

Solanki, R. and Dhankhar, R. 2011. Biochemical changes and adaptive strategies of plants under heavy metal stress. *Biologia* 66(2):195-204.

Sultana, R., Islam, S.M.N., Zaman, M.W. and Uddin, N. 2020. Phytotoxicity of lead and chromium on germination, seedling establishment and metal uptake by Kenaf and Mesta. *Pollution* 6(2):429-440.

Sundaramoorthy, P., Chidambaram, A., Ganesh, K.S., 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(8):597-607.

Tandon, N. 2008. Medicinal Plants and Preparations Used for the Management of Certain Water Borne Diseases. S.G. University, Surat, Gujarat, India. [Ph.D. Thesis].

Uddin, I., Bano, A. and Masood, S. 2015. Chromium toxicity tolerance of *Solanum nigrum* L. and *Parthenium hysterophorus* L. plants with reference to ion pattern, antioxidation activity and root exudation. *Ecotoxicology and Environmental Safety* 113:271-278.

Verma, S. 2016. Phytochemical and pharmacological study on *Abrus precatorius*. *Asian Journal of Plant Science and Research* 6(2):24-26.

Vernay, P., Gauthier-Moussard, C. and Hitmi, A. 2007. Interaction of bioaccumulation of heavy metal chromium with water relation, mineral nutrition and photosynthesis in developed leaves of *Lolium perenne* L. *Chemosphere* 68:1563-1575.

Vyas, M.K. 2017. Changes in seedling growth and bio-chemical contents in *Abrus precatorius* L. under nickel treatment. *UK Journal of Pharmaceutical and Biosciences* 5(3):14-18.

Yang, D.H., Andersson, B., Aro, E.M. and Ohad, I.T. 2001. The redox state of the plastoquinone pool controls the level of the light-harvesting chlorophyll a/b binding protein complex II (LHC II) during photoacclimation. *Photosynthesis Research* 68:163-174.

Zayed, A.M. and Terry, N. 2003. Chromium in the environment: factors affecting biological remediation. *Plant and Soil* 249:139-156.

Zhou, X.Q. and Li, Y.H. 2004. The physiological and ecological responses of the seed germination of *Casuarina equisetifolia* to chromic stress. *Chinese Journal of Eco-Agriculture* 12(1):53-55.

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