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Uptake of chromium in water hyacinth (*Eichhornia crassipes*) and its impact on biochemical structure

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Abstract

The present study was conducted to assess the accumulation of chromium in water hyacinth plant (*Eichhornia crassipes*) through its growing medium. The water hyacinth plant was collected from pond and treated with different concentration of $K_2Cr_2O_7$. The effect of chromium accumulation on growth and biochemical parameters of plant was observed. The results revealed that the heavy metal uptake by plant root was increased with increase in concentration of Cr in test solution while the translocation of absorbed Cr was very low to other part of plant in comparison to root. Relative growth rate, biomass productivity, total chlorophyll and carotenoid content were reduced with increased concentration of Cr in test solution. However, ascorbic acid concentration showed negative correlation with other parameters. It was found to be increased with increasing concentration of Cr in test solution. Proline content in plant showed a different trend. It initially increased with increase in Cr concentration in test solution and time and then followed a decreasing order.

Key Words*: B*ioconcentration factor*, B*iochemical parameters*, C*hromium*, T*ranslocation factor*, *Water hyacinth

Introduction

Soil and water in many parts of world are polluted by all kinds of chemical and toxic heavy metals because in several countries effluents are often disposed directly into the surface waters. A heavy metal is toxic when relatively it is dense metal or metalloid that is noted for its potential toxicity, especially in environmental context. Heavy metal toxicity means excess of required concentration or it is unwanted which were found naturally on the earth and becomes concentrated as a result of human caused activities (Asati *et al.*, 2016). Many industries such textile, metal producing, electroplating, battery and cable manufacturing, mining, tannery, steel and automotive textile release heavy metals such as chromium, cadmium, copper, nickel and lead in wastewaters. These heavy metals may be toxic to aquatic ecosystems and human health and they also accumulate in plants. The accumulation of these heavy metals in plants causes physiological and biochemical changes (Srinivas *et al.*, 2013).Chromium is known to be a toxic metal that can cause severe damage to plants and animals. Chromium induced oxidative stress involves induction of lipid peroxidation in plants that causes severe damage to cell membranes. Oxidative stress induced by chromium initiates the degradation of photosynthetic pigments causing decline in growth. High chromium concentration can disturb the chloroplast ultra structure there by disturbing the photosynthetic process (Peralta *et al.*, 2001). *Eichhornia crassipes*, commonly known as water hyacinth, is a flowering monocot and an aquatic weed species of family Pontederiaceae, originally native to tropical and subtropical South America. It has a cosmopolitan distribution but is found mostly in the warmer regions of the world. The plant has fast growth, large biomass and tolerance for many metals/metalloids (Das *et al.*, 2016). Thus keeping above things in mind, the present study was conducted to assess the effect of chromium on growth, biochemical parameters and its uptake in water hyacinth.

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Material and Methods

In order to assess the impact of chromium metal on growth and biochemical structure of water hyacinth, the healthy grown plants of water hyacinth excavated along with its root from pond and transferred into separate aquarium containing different concentration of potassium dichromate solution.

Plant material

Water hyacinth (*E. crassipes*) was randomly collected from a pond located in Roorkee, Uttarakhand. The collected plants were washed thoroughly with tap water to remove the residual particles, any epiphytes and insect larva grown on plants. The collected plants were placed in an aquarium filled with tape and pond water in the ratio of 1:1.

Experimental Setup

Potassium dichromate solution was prepared in three different concentrations i.e. 10 ppm, 25 ppm and 50 ppm. Five liter of each concentration solution was filled in separate aquarium of 6 liters capacity. Triplicate of each concentration was maintained. A separate aquarium for control study was also set up filled with tap water only. Water hyacinth collected from pond was placed in these aquariums. The study was conducted for 21 days. Water hyacinth samples were collected at 7^{th}, 14^{th} and 21^{st} days of experimental period.

Analytical Method

The collected water hyacinth plant samples were separated into root and shoot. The relative growth of plant was measured by the method used by (Lu *et al.*, 2004). Biomass productivity was analysed by (Chorom *et al.*, 2012). Chlorophyll content of plant was measured by method followed by (Arnon, 1949); carotenoid by (Kirk and Allen, 1965), ascorbic acid (Sadashivam and Balasubramanium, 1987). While moisture content and proline content were analysed by method used by Bates *et al.* (1973). The chromium concentration accumulated in plants was measured by AAS. Physico chemical properties and chromium concentration of water used in present study was analysed by referring standard method (APHA, 2005).

Results and Discussion

Chromium uptake and translocation by water hyacinth plant

Chromium can be absorbed by plants both as Cr (III) or Cr (VI), but there is no specific mechanism for Cr uptake. However, it is taken up by other non specific carriers along with the uptake of essential elements and water (Shanker*et al.*, 2005b). The uptake of Cr from aqueous media depends upon the pH, oxidative state of Cr and its concentration, salinity and the presence of dissolved salts (Babula *et al.*, 2008). In present study the chromium uptake by roots of water hyacinth plant placed in 10 ppm solution of Cr was found as 6.83±1.21 ppm while in 25 ppm solution of Cr, uptake was 16.02±1.29 ppm. However, plant roots placed in 50 ppm solution absorbed Cr concentration as 34.35±6.62 ppm. The absorption of chromium by water hyacinth plant was found to be increasing with increase in time period and concentration of Cr in aquarium water (Table 1). The chromium concentration translocated from root to shoot was found as 0.33±0.04 ppm in the condition when plant was placed in solution containing 10 ppm of Cr. While the plants placed in Cr solution of 25 ppm, translocated concentration of chromium was 0.89±0.05 ppm and in case of 50 ppm Cr solution, translocation of chromium was found as 1.65±0.29 ppm. Translocation of chromium observed to be slightly increased with time and concentration of Cr in aqueous media in aquarium (Table 1).

Bioconcentration and translocation factor

Bioconcentration factor (BCF) refers to the chemical concentration of a substance in an organism's tissue, divided by its equilibrium concentration in water expressed in equivalent units (Alexander, 1999). Bioconcentration factor in water hyacinth plant placed in aqueous media containing 10 ppm of Cr was found to be 0.68±0.12. Plants placed in aqueous solution having chromium concentration of 25 ppm showed the bioconcentration factor of 0.64±0.05 while plants exhibited bioconcentration factor as 0.68±0.13 placed in aqueous solution having chromium concentration of 50 ppm. Bioconcentration factors found to be increased with time period but there was no trend observed with increasing concentration (Table 2).The ability of plant to translocate metals from the roots to shoots is measured by calculating translocation factor which is defined as the ratio of metal level in the shoots to that in the roots (Mganga, 2014). Translocation factor (TF) of chromium from root to shoot in water hyacinth plant placed in aqueous solution having 10 ppm of Cr concentration, observed in the range of 0.047±0.004. While TF of plant placed in aqueous solution of 25 ppm Cr was 0.055±0.001 and in water hyacinth plants placed in 50 ppm Cr solution TF was 0.047±0.002 (Table 2). The mobility of Cr from root to shoot was found in very low

Table 1. Chromium uptake by water hyacinth (*E. crassipes*) plant and its impact on biochemical parameters

	Concentration of $K_2Cr_2O_7$ (ppm)	10 day	14 day	21 day	Average
Chromium uptake by root (ppm)	10	5.49	7.17	7.84	6.83±1.21
	25	14.68	16.13	17.25	16.02±1.29
	50	28.95	32.37	41.73	34.35±6.62
Chromium uptake by shoot(ppm)	10	0.28	0.31	0.37	0.33±0.04
	25	0.84	0.89	0.94	0.89±0.05
	50	1.37	1.65	1.94	1.65±0.29
Relative Growth	Control	1.208	1.308	1.5	1.34±0.15
	10	1.167	1.283	1.417	1.29±0.13
	25	1.125	1.108	1.208	1.15±0.05
	50	1.125	1.092	1.167	1.13±0.04
Biomass Productivity (gm/day)	Control	3.57	2.64	2.8	3.00±0.50
	10	2.85	2.42	2.38	2.55±0.26
	25	2.14	0.93	1.19	1.42±0.64
	50	2.14	0.79	0.95	1.29±0.74
Total Chlorophyll (mg/100 gm)	Control	88.4	88.77	83.98	87.05±2.67
	10	81.25	74.55	71.78	75.86±4.87
	25	77.42	72.55	69.43	73.13±4.03
	50	72.82	70.1	64.13	69.02±4.45
Carotenoid Content (mg/100gm)	Control	11.61	11.37	11.35	11.44±0.14
	10	14.74	15.33	14.09	14.72±0.62
	25	14.51	12.42	13.38	13.44±1.05
	50	12.03	11.55	11.64	11.74±0.26
Ascorbic Acid (mg/100gm)	Control	62.67	62.42	63.15	62.75±0.37
	10	93.1	95.4	102.67	97.06±5.00
	25	118.35	103.72	110.58	110.88±7.32
	50	127.49	140.05	155.46	141.0±14.01
Proline (µmol/gm FW)	Control	0.95	1.12	1.2	1.09±0.13
	10	3.12	3.33	2.8	3.08±0.27
	25	2.45	3.01	2.28	2.58±0.38
	50	2.28	2.49	1.58	2.12±0.48

concentration. The translocation of Cr from root to shoot is restricted (Mishra *et al.*, 2009). The maximum amount of Cr accumulates in the roots followed by shoots, leaves and fruits (Ramachandran *et al.*, 1980). Roots in general, accumulate 100-fold higher Cr than the shoots (Zayed *et al.*, 1998b). It is probably due to poor translocation of this element because of the formation of insoluble Cr compounds (Singh *et al.*, 2013).

Table 2.Bioconcentration factor and Translocation factor of chromium in water hyacinth (*E. crassipes*) plant

Bioconcentration Factor (BCF)			
10 day	14 day	21 day	Average
0.55	0.72	0.78	0.68±0.12
0.59	0.65	0.69	0.64±0.05
0.58	0.65	0.83	0.69±0.13
Translocation Factor (TF)			
10 day	14 day	21 day	Average
0.052	0.044	0.047	0.048±0.004
0.057	0.055	0.054	0.055±0.002
0.047	0.050	0.046	0.048±0.002

Effect of Cr uptake on growth and biochemical structure of water hyacinth

Relative plant growth

Relative plant growth of water hyacinth placed in tap water aquarium was observed as 1.34±0.15. Water hyacinth plants placed in aquarium filled with 10 ppm of Cr solution showed growth rate of 1.29±0.13. However, plants placed in 25 ppm and 50 ppm of Cr solution showed a relative growth of 1.15±0.05 and 1.13±0.04 respectively. Perusal data summerised in Table 1 relative growth of plant was found to be reduced with increased concentration of Cr accumulated in plant. Chromium accumulation in plants causes high toxicity in terms of reduction in growth and biomass accumulation (Singh *et al.*, 2013).

Biomass Productivity

Biomass productivity of water hyacinth plant placed in tap water aquarium was observed as 3.00±0.50 gm/day. Water hyacinth plants placed in aquarium filled with 10 ppm of Cr solution showed biomass productivity as 2.55±0.26 gm/day. However, plants placed in 25 ppm and 50 ppm of Cr solution showed biomass productivity as 1.42±0.64 gm/day and 1.29±0.74 gm/day respectively. According to the values depicted in Table 1, the biomass productivity of water hyacinth plant was found to be decreased with increasing concentration of Cr accumulated in plant. It has been reported that the accumulation of Cr results in decrease in total biomass production in aquatic plants (Sridhar *et al.*, 2011).

Total chlorophyll content

Total chlorophyll content in water hyacinth plant placed in tap water aquarium was observed as 87.05±2.67 mg/100 gm. Plants placed in aquarium filled with 10 ppm of Cr solution exhibited chlorophyll content as 75.86±4.87 mg/100gm. However, plants placed in 25 ppm and 50 ppm of Cr solution showed total chlorophyll content as 73.13±4.03 mg/100gm and 69.02±4.45 mg/100gm respectively. The data summarized in Table 1 revealed that chlorophyll content of water hyacinth was decreased with increasing the accumulation of Cr in plant. Cr (III, VI) has been reported to alter structures of chloroplast and nuclei and membrane ultra structure in plants (Bassi *et al.*, 1990). Electron microscopic studies have demonstrated that Cr exposure damage membrane systems of thylakoids, chloroplast envelope, plasmalemma, tonoplast and mitochondria (Appenroth *et al.*, 2003).

Carotenoid

Carotenoid content in water hyacinth plant placed in tap water aquarium was observed as 11.44±0.14 mg/100gm. Water hyacinth plants placed in aquarium filled with 10 ppm of Cr solution showed carotenoid content as 14.72±0.62 mg/100gm. However, plants placed in 25 ppm and 50 ppm of Cr solution showed carotenoid content as 13.44±1.05 mg/100gm and 11.74±0.26 mg/100gm respectively. As per the data summerised in Table 1 carotenoid content of water hyacinth plants revealed gradual decrease with increase in concentration of Cr solution with respect to increase in uptake of Cr by plants. Inhibition of carotenoid in plants treated with metallic solution was previously reported by (Phukan*et al.*, 2015).

Ascorbic Acid

Ascorbic acid concentration in water hyacinth plants placed in tap water aquarium was observed as 62.75±0.37 mg/100gm. Water hyacinth plants placed in aquarium filled with 10 ppm of Cr solution showed ascorbic acid concentration as 97.06±5.00 mg/100gm. However, plants placed in 25 ppm and 50 ppm of Cr solution showed ascorbic acid concentration as 110.88±7.32 mg/100gm and 141.00±14.01 mg/100gm respectively. The values depicted in Table 1 revealed that the ascorbic acid concentration in water hyacinth plant was found to be increased with increasing the Cr concentration in test solution. It has been reported the increased production of ascorbic acid as a direct response to Cr stress to plants (Shanker *et al.*, 2005).

Proline

Proline content in water hyacinth plants placed in tap water aquarium was observed as 1.09±0.13 µmol/gm of fresh weight. Water hyacinth plants placed in aquarium filled with 10 ppm of Cr solution showed proline content as 3.08±0.27 µmol/gm of fresh weight. However, plants placed in 25 ppm and 50 ppm of Cr solution showed proline content as 2.58±0.38 µmol/gm and 2.12±0.48 µmol/gm of fresh weight (Table 1). In present study, proline content of water hyacinth was initially increased till treated with 10 ppm solution of Cr and further decreased on increasing the concentration of Cr in test solution. However, the rate of increase in proline content slowed down after 14 days. The obtained results are in agreement with (Bathla, 2016).

Conclusion

The present study revealed the significant increased accumulation of chromium in plant root of water hyacinth with increased concentration of Cr in test solution. Although the plant root showed the ability to restrict the movement of Cr from root to shoot as translocation factor was found to be very low in comparison to bioconcentration factor. The study indicated that Cr is a toxic metal that induces toxicity in plant by inducing the production of ascorbic acid and reducing the growth rate of plant, biomass productivity and other biochemical parameters. Cr interferes with various metabolic processes that are vital for plant growth and development.

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References

Alexander, 1999. Bioaccumulation, bioconcentration, biomagnifications. ***Environmental Geology***, DOI. 10.1007/1-4020-4494-1_31, 43-44.

APHA, 2005. Standard methods for examination of water and waste water, 21st ed., Washington.

Appenroth, K-J, Keresztes, A., Sarvari, E., Jaglarz, A. and Fischer, W., 2003. Multiple effects of chromate on *Spirodela polyrhiza*: electron microscopy and biochemical investigations. ***Plant Biology***, 5: 315-323.

Arnon, D.I., 1949. Copper enzyme in isolated chloroplast: Polyphenyl oxidase in *Beta vulgaris* plant. ***Plant Physiology***, 24: 1-15.

Asati, A., Pichhode, M. and Kumar, N., 2016. Effect of heavy metals on plants: An overview. *International Journal of* ***Application or Innovation in Engineering and Management***, 5(3): 56-66.

Babula, P., Adam, V., Opatrilova, R., Zehnalek, J., Havel, L. and Kizek, R., 2008. Uncommon heavy metals, metalloids and their plant toxicity: a review. ***Environmental Chemistry Letters***, 6: 189-213.

Bassi, M., Corradi, M.G. and Ricci, A., 1990. Effect of chromium (VI) on two fresh water plants, Lemna minor and Pistia stratiotes 2. Biochemical and physiological observations. ***Cytobios***, 62: 101-109.

Bates, L.S., Waldren, R.P. and Teare, I.D., 1973. Rapid determination of free prolin for water stress studies. ***Plant Soil***, 39: 205-207.

Bathla, P., 2016. Phytoremediation of metals contaminated distillery effluent using water hyacinth (*Eichhornia crassipes*). ***International Journal of Engineering Technology, Management and Applied Sciences***, 4(4): 283-290.

Chorom, M., Parnian, A. and Jaafarzadeh, N., 2012. Nickel removal by the aquatic plant (*Ceratophyllum demersum L.*). ***International Journal of Environmental Sciences and Development***, 3(4): 372-375.

Das, S., Goswami, S. and Das Talukdar, A., 2016. Physiological responses of water hyacinth, Eichhornia crassipes (Mart.) Solms, to cadmium and its phytoremediation potential. ***Turkish Journal of Biology***, 40: 84-94.

Kirk, J.O.T. and Allen, R. L., 1965. Dependence of salinity stress on the activity of glutamine synthatase and glutamate dehydrogenase in triticale seedling. ***Polish Journal of Environmental Studies*****,** 14: 523-530.

Lu, X., Kruatrache, M., Pokethitiyook and Homyok, K., 2004. Removal of cadmium and zinc by water hyacinth, *Eichhornia crasssipes*. ***Environmental Science Technology and Management Research*****,** 30: 93-103.

Mganga, N.D., 2014. The potential of bioaccumulation and translocation of heavy metals in plant species growing around the tailing dam in Tanzania**. *International Journal of Science and Technology*****,** 3(10): 690-697.

Mishra, K., Gupta, K. and Rai, U.N., 2009. Bioconcentration and phytotoxicity of chromium in *Eichhornia crassipes*. ***Journal of Environmental Biology*****,** 30(4): 521-526.

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

Phukan, P., Phukan, R. and Phukan, S.N., 2015. Heavy metal uptake capacity of Hydrilla verticillata: A commonly available aquatic plant. ***International Research Journal of Environment Sciences*****,** 4(3): 35-40.

Ramachandran, V., D' Souza, T.J. and Mistry, K.B., 1980. Uptake and transport of chromium in plants. ***Journal of Nuclear Agriculture and Biology*****,** 9: 126-128.

Sadashivam, S. and Balasubramanium, T., 1987. Practical manual in biochemistry. Tamilnadu Agricultural University, Coimbatore.

Shanker, A.K., Cervantes, C., Loza-Tavera, H. and Avudainayagam, S., 2005. **Chromium toxicity in plants. *Environment International*****,** 31: 739-753.

Shanker, A.K., Ravichandran, V. and Pathmanabhan, G., 2005b. Phytoaccumulation of chromium by some multipurpose tree seedlings. ***Agroforestry Systems*****, 64: 83-87.**

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: 229-254.

Sridhar, B.B.M., Han, F.X., Diehl, S.V., Monts, D.L. and Su, Y., 2011. Effect of phytoaccumulation of arsenic and chromium on structural and ultrastructural changes of brake fern (*Pteris vittata*). ***Brazilian Journal of Plant Physiology*****,** 23(4): 285-293.

Srinivas, J., Purushotham, A.V. and Murali Krishna, K.V.S.G., 2013. The effects of Heavy metals on seed germination and plant growth on Coccinia, Mentha and Trigonella plant seeds in Timmapuram, E.G. District, Andhra Pradesh, India. ***International Research Journal of Environmental Sciences***, 2(6): 20-24.

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