IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 8, Issue 5 Ver. III (May. 2014), PP 79-82
www.iosrjournals.org

Accumulation of heavy metals (cadmium and hexavalent chromium) in accessions of *Hordeum Vulgare*

Neha Mittal[1], A.K. Srivastava[1], Bhupendra[2] and Kiran[3]
[1]Department of Botany, C.C.S. University, Meerut, India
[2]Department of Botany, Bundelkhand University, Jhansi, India
[3]Institute of Environment & Development Studies, Bundelkhand University, Jhansi, India

Abstract: *Five partially tolerant and five non tolerant accessions of barley for cadmium and hexavalent chromium were analyzed for the assessment of heavy metal in the plant. This study was designed to assess total contents of Cd and Cr^{6+} in the plant root and leaves. The accumulation of metals from roots to shoots was evaluated in terms of Translocation Factor (TF). Total metal concentrations of Cd and Cr^{6+} in root and leaves varied between 29.84 - 0.35 $\mu g/g^{-1}$.*
Keywords: *Heavy metals, Phytoremediation, Translocation factor, Barley.*

I. Introduction

Contamination of soil and water with heavy metals has become a potential threat. Phytoremediation is one of the promising methods for reclamation of soils contaminated with toxic metals by using hyper accumulator plants (Baker et al., 2000; Ghosh & Singh, 2005; La'zaro et al., 2006). Phytoremediation technologies using green plants to remove heavy metals from soil and water are now being identified as promising and non-destructive methods (Haferburg and Kothe 2010). More than 400 plant species belonging to 45 plant families have been identified and reported from temperate to tropical regions with the ability to tolerate and hyper accumulate trace elements (Baker & Brooks, 1989). Accumulation of selected metals varied greatly among plants species and uptake of an element by a plant is primarily dependent on the plant species, its inherent controls, and the soil quality (Chunilall et al., 2005). Plants can tolerate high heavy metals concentration from soil by two basic strategies (Baker, 1981). The first strategy is called accumulation strategy where metal can accumulate in plants at both high and low concentration from soil (McGrath et al., 2001). These plants are capable of rendering the metals in various ways, for instance by binding them to cell walls, compartmentalizing them in vacuoles or complexing them to certain organic acids or proteins (Reeves and Baker, 2000). The second strategy is called exclusion strategy, where transport of heavy metals in shoots and leaves is limited over a wide range of metal concentrations in soil. Cadmium is a widespread heavy metal released into the environment by heating systems, metal working industries, waste incineration and contaminant of phosphates fertilizers. Chromium (Cr) which has several roles in our daily life exists in various oxidation states of Cr^{6+} is highly toxic. However, a polluted area is contaminated with several heavy metals at a time. Therefore, the present experiment was designed for the evaluation of the accumulation of two heavy metals in agriculturally important crop barley.

II. Materials and methods

Cadmium chloride ($CdCl_2$) and sodium dichromate ($Na_2 Cr_2 O_7$) were used as sources of Cd^{2+} and Cr^{6+} respectively. Treatment with 10^{-3} M of Cd^{2+}+Cr^{6+} solution was given to partially tolerant and non tolerant* accessions of barley (Table 1).

Table 1. Partially tolerant and non tolerant* accessions of barley.

Partially-tolerant		Non-tolerant	
Lab Code	Accession	Lab Code	Accession
B-16	D.L.35	B-60	K-232
B-35	K-170	B-79	RD-915
B-95	IC.108128	B-93	IC.108124
B-131	IC.138925	B-115	IC.118664
B-166	K-125	B-143	IC.138950

For estimating the accumulation of cadmium and hexavalent chromium in barley, roots and mature leaves sample were collected from the plants, grown hydroponically in 10^{-3}M Cd+Cr solution. The samples were collected after eight days of culture. Oven dried 100 mg roots and leaves were digested in 5 ml of 1:1

concentrated HNO_3 and perchloric acid ($HClO_4$) till the whole material got digested and liquid content evaporated. The resultant digested matter was dissolved in 10 ml of double glass-distilled water. Hexavalent chromium and cadmium accumulation were worked out in mature root and leaf samples of five accessions each of partially tolerant (PT) and non-tolerant (NT), using Atomic Absorption Spectrometer (A7000, LAB INDIA). Ratio of shoot to root accumulation were calculated using following formula,

$$S/R = \frac{\text{Conc. of heavy metal in mature leaves}}{\text{Conc. of heavy metal in root}}$$

III. Results

Cadmium and hexavalent chromium accumulation were worked out in mature root and leaf samples of five accessions of partially tolerant (PT) and non-tolerant (NT) of barley, using atomic absorption spectrophotometer (AAS). The concentration of hexavalent chromium and cadmium in shoot and root of barley are shown in table 2 & 3 and figure 1 & 2.

Table 2. Accumulation (μg g^{-1} dry weight) of hexavalent chromium in roots and mature leaves of barley after (Cd+Cr) treatment.

	Hexavalent Chromium				
	Roots		Mature Leaves		
Acc.	Con.(μg/gm)	%RSD	Con.(μg/gm)	%RSD	S/R
B-16(PT)	7.60	22.44	4.26	6.89	0.56
B-35(PT)	12.54	6.89	13.69	11.74	1.09
B-95(PT)	11.39	2.13	6.56	4.78	0.58
B-131(PT)	4.37	25.07	6.10	20.00	1.39
B-166(PT)	15.19	9.12	4.49	HIGH	0.30
B-60(NT)	10.47	15.93	3.37	23.30	0.32
B-79(NT)	0.35	30.83	-0.58	-128.85	-1.67
B-93(NT)	14.27	13.81	4.26	6.89	0.30
B-115(NT)	15.08	11.89	14.85	30.34	0.98
B-143(NT)	13.81	16.91	2.88	HIGH	0.21

PT= Partially tolerant; NT= Non-tolerant; Con. = Concentration; RSD= Relative Standard Deviation; S/R=Ratio of Shoot and root.

Table 3. Accumulation (μg g^{-1} dry weight) of cadmium in roots and mature leaves of barley after (Cd+Cr) treatment.

	Cadmium				
	Roots		Mature Leaves		
Acc.	Con.(μg/gm)	%RSD	Con.(μg/gm)	%RSD	S/R
B-16(PT)	16.831	3.5435	9.381	7.1924	0.56
B-35(PT)	27.364	2.5312	19.844	0.5783	0.73
B-95(PT)	14.302	5.8712	11.246	18.0034	0.79
B-131(PT)	19.734	9.1205	14.42	7.0028	0.73
B-166(PT)	25.629	16.0052	19.204	4.3007	0.75
B-60(NT)	9.82	2.8361	16.781	8.9372	1.71
B-79(NT)	30.081	12.6731	23.752	5.6931	0.79
B-93(NT)	34.551	17.8191	29.836	7.5381	0.86
B-115(NT)	23.169	15.6314	12.407	1.5612	0.54
B-143(NT)	17.452	20.2112	24.031	14.3291	1.38

PT= Partially tolerant; NT= Non-tolerant; Con. = Concentration; RSD= Relative Standard Deviation; S/R=Ratio of shoot and root.

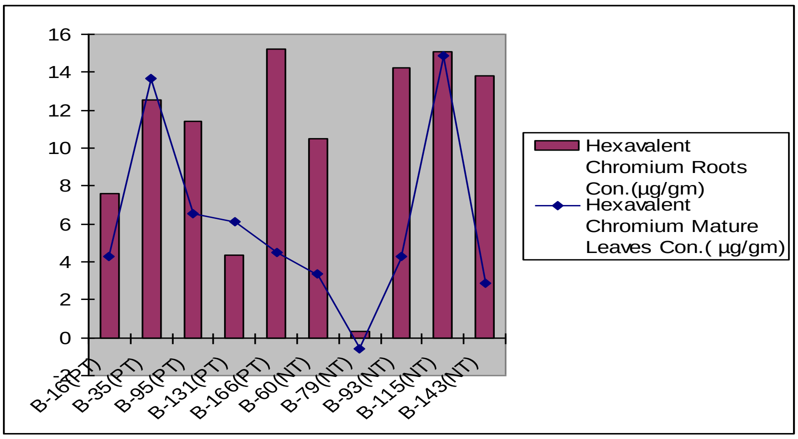

Fig.1 Concentration (µg/g^{-1} dry weight) of hexavalent chromium in roots and mature leaves of barley.

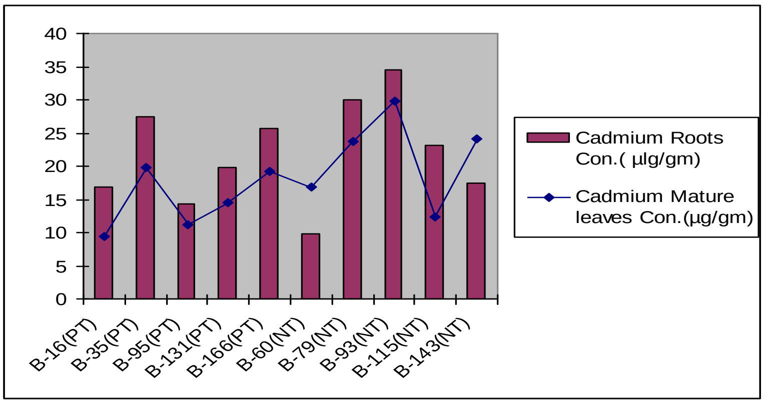

Fig. 2 Concentration (µg/g^{-1} dry weight) of cadmium in roots and mature leaves of barley.

Minimum accumulated concentration of hexavalent chromium was 0.35 µg g^{-1} in roots of B-78 (NT) and maximum was 15.19 µg/g^{-1} in roots of B-166 (PT) while in mature leaves minimum accumulated concentration was 0.00 µg/g^{-1} in B-79 and maximum concentration was 14.85 µg/g^{-1} in B-115 (NT). Ratio of accumulated hexavalent chromium in mature leave to root (Translocation factor) was >1 in B-35(PT), B-131(PT) since mature leaves accumulated higher amount of chromium in comparison to root, and <1 in B-16(PT), B-95(PT), B-166(PT) 60-(NT), B-79(NT), B-93(NT), B-115(NT) and B-131(PT) because of reverse situation. Minimum accumulated concentration of cadmium in roots was 9.82 µg/g^{-1} in B-60(NT) and maximum was 34.55 µg/g^{-1} in root of B-93(NT), while in mature leaves minimum accumulated concentration of cadmium was 9.38 µg/g^{-1} in B-16(PT) while maximum was 29.84 µg/g^{-1} in B-93(NT). In barley ratio of accumulated cadmium in mature leaves to root (Translocation factor) was >1 in B-60-(NT), B-143(NT) because of higher cadmium accumulation in leaves as compared to root and <1 in B-16(PT), B-35(PT), B-79(NT), B-93(NT), B-95(PT), B-115(NT), B-131(PT), and B-166(PT), reveals higher cadmium accumulation in root over those of leaves.

In general, cadmium could be accumulated in higher amount over that of hexavalent chromium in roots as well as mature leaves.

IV. Discussion

The concept of using plants to clean up contaminated environment is not new, about 300 years ago; plants were first proposed for use in the treatment of waste water (Hartman, 1975). At the end of 19th century, Thlaspi caerulescens and Viola calaminaria were the first plant species documented to accumulate high levels of metals in leaves (Baumann, 1885). Plants able to accumulate upto 1% nickel in shoots were reported by Minguzzi and Vergnano (1948) and Rascio (1977), reported high zinc accumulation in shoots of Thlaspi caerulescens. Brassica species now-a-days have received much attention for their metal accumulation capability. Studies carried with different varieties of B. juncea (Indian mustard) have shown that these plants were able to take up and concentrate toxic metal to a level up to several percent of their dried shoot biomass. Dushenkov et al. (1995) identified certain varieties of sunflower (Helianthus annuus) as being the most efficient plants for rhizofilteration.

Perusal of present set of data on cadmium and hexavalent chromium accumulation indicated that barley accessions could accumulate cadmium and hexavalent chromium in the roots as well as in mature leaves. In most accessions the concentration of both heavy metals was higher in the roots as compared to the mature leaves. The use of roots of terrestrial plants to remove organics or heavy metals from aqueous solutions may provide the foundation for a novel water treatment technology. The use of roots of terrestrial plants to remove organics or heavy metals from aqueous solutions may provide the foundation for a novel water treatment technology. Conceivably, this method may be applicable to the treatment of surface and ground water and industrial effluents to reduce the burden of contaminants. Plants that enhance organic degradation or accumulate toxic metals can be grown and harvested economically leaving the soil or water with a greatly reduced level of toxic chemical contamination.

Translocation Factor (TF) was described as ratio of heavy metals in plant shoot to that in plant root (Cui et al., 2007; Li et al., 2007). TF >1 had been used to evaluate the potential of plant species for phytoextraction and phytostabilization (Yoon et al., 2006; Li et al., 2007). Accumulation of cadmium and hexavalent chromium in mature leaves indicated that in some of the accessions, cadmium and hexavalent chromium could be translocated from roots to shoots.

Since, the accessions of barley differed from each other in their genotypes; these findings indicated that not only the accumulation of cadmium and hexavalent chromium but also its translocation from root to shoot was genotype dependent. Green plants can be compared with the ‘solar driven pumping and filtering systems’ that have ‘measurable loading, degrading and fouling’ capacity. Roots may similarly be described as ‘exploratory, liquid-phase extractor’ that can find, alter and/or translocate elements and compounds against large chemical gradients (Cunningham and Berti, 1993).

High metal accumulation may be attributed to well develop detoxification mechanism based on sequestration of heavy metal ions in vacuoles, by binding them on appropriate ligands such as organic acids, proteins and peptides in the presence of enzymes that can function at high level of metalicions (Cui et al., 2007) and metal exclusion strategies of plant species (Ghosh & Singh, 2005). The elevated concentration of heavy metals in roots and low translocation in above ground parts (TF<1) indicated their suitability for phyto-stabilisation.

The author acknowledge to the DST for providing INSPIRE fellowship.

References

[1]. Baker A J M, 1981. Accumulators and excluders strategies in the response of plants to heavy metals [J]. J. Plant Nutr. 3(1-4): 643-654.

[2]. Baker A J M, Brooks R R, 1989. Terrestrial higher plants which hyperaccumulate metallic elements. A review of their distribution, ecology and phytochemistry [J]. Biorecovery, 1: 81-126.

[3]. Baker A J M, McGrath S P, Reeves R D et al., 2000. Metal hyperaccumulator plants: A review of ecology and physiology of a biological resource for phytoremediation of metal polluted soils [M]. In: “Phytoremediation of Contaminated Soil and Water”. N. Terry and others, Boca Raton (ed), 129-58.

[4]. Baumann A, 1885. Das Verhalten von Zinksatzen gegen Pflanzen und im Boden[M]. Landwirtsch. Vers.-Statn. 31: 1-53.

[5]. Chunilall V, Kindness A, Jonnalagadda S B, 2005. Heavy metal uptake by two edible Amaranthus herbs grown on soils contaminated with Lead, Mercury, Cadmium and Nickel [J]. J. Environ. Sci. Health, 40: 375-384.

[6]. Cui S, Zhou Q, Chao L, 2007. Potential hyper-accumulation of Pb, Zn, Cu and Cd in endurant plants distributed in an old smeltery, northeast China [J]. Environmental Geology, 51: 1043-1048.

[7]. Cunningham S D, Berti W R, 1993. Remediation of contaminated soils with green plants, an overview[J] . In Vitro Cell. Dev. Biol, 29: 207-212.

[8]. Dushenkov V, Nanda Kumar P B A, Motto H et al., 1995. Rhizofiltration: The use of plants to remove heavy metals from aqueous streams [J]. Environ. Sci. Technol, 29: l239-1244.

[9]. Ghosh M, Singh S P, 2005. A review on phytoremediation of heavy metals and utilization of its byproducts [J]. Applied Ecology and Environmental Research, 3: 1-18.

[10]. Haferburg G, Kothe E, 2010. Metallomics: lesssons for mettalliferous soil remediation[J] . Appl. Microbiol. Biotechnol, 87: 1271-1280.

[11]. Hartman W J J, 1975. An evaluation of land treatment of municipal wastewater and physical silting of facility installations [M]. Washington DC, US, Department of Army.

[12]. La´zaro, D J, Kiddb P S, Martý´neza C M T, 2006. A phytogeochemical study of the Tra´s-os- Montes region (NE Portugal): Possible species for plant-based soil remediation technologies [J]. Science of the Total Environment, 354: 265- 277.

[13]. Li M S, Luo Y P, ZY Su, 2007. Heavy metal concentrations in soils and plant accumulation in a restored manganese mineland in Guangxi, South China [J]. Environmental Pollution , 147: 168-175.

[14]. McGrath S W, Zhao F J, Lombi E, 2001. Plant and rhizosphere processes involved in phtoremediation of metalcontaminated soils [J]. Plant and Soil, 232(1-2): 207-214.

[15]. Minguzzi C, Vergnano O, 1948. II contento di nichel nelli ceneri di Alyssum bertlonii Desv[J] . Atti delia Societa Toscana di Science Naturali, Mem Ser A, 55: 49-77.

[16]. Rascio W, 1977. Metal accumulation by some plants growing on Zn mine deposits [J]. Oikos ,29: 250-253.

[17]. Reeves R D, Baker A J M, 2000. Metal accumulating plants. In: “Phytoremediation of Toxic Metals: using Plants to clean up the Environment”, I. Raskin and B.D. Ensley, John Wiley and Sons, (ed) Inc, Toronto, Canada, 303.

[18]. Yoon J, Cao X, Zhou Q, Ma L Q, 2006. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site [J]. Science of the Total Environment, 368: 456-464.