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Phytoremediation Potential of Tomato for Cd and Cr Removal from Polluted Soils

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Abstract**—**Cadmium and chromium are toxic to most organisms and different mechanisms have been developed for overcoming with the toxic effects of these heavy metals. We studied the uptake and distribution of cadmium and chromium in different organs of tomato (*Lycopersicon esculentum* L.) plants in nine heavy metal polluted soils in western Hormozgan province, Iran. The accumulation of chromium was in increasing pattern of fruit peel<edible pulp<shoots<roots. Cadmium was detected neither in the peel nor in the pulp of fruits. Shoots cadmium concentration was more than that of the roots. Determination of bio-concentration factor (BCF) and translocation factor (TF) revealed that tomato was suitable for phytoextraction of cadmium, but not chromium, in all examined soil. In addition, tomato showed no suitability for phytostabilization in the soils polluted with cadmium and chromium.

Keywords**—**Cadmium, chromium, phytoextraction, phytostabilization, tomato.

I. Introduction

HEAVY metals are defined as a group of metals and metalloids with atomic density higher than 5 g cm^{-3}, including chromium, arsenic, lead, cadmium, mercury, zinc, copper, iron, and so on. These metals are ubiquitous, highly persistent, and almost non-biodegradable [1]-[3]. Heavy metals are among the major contaminants of food supply and may be considered as the most serious problem to the environment [4]. Accumulation of heavy metals in the environment increases as a result of natural weathering of rocks, irrigation with contaminated waters, application of fertilizers and metal based pesticides, industrial emissions, transportation etc. Human activities in recent decades have increased the quantity and distribution of some heavy metals in the atmosphere, land and water bodies [5].

Tomato (*Lycopersicon esculentum* L.) is the second most widely consumed vegetable after the potato [6]. Tomato is an important source of micronutrients, minerals (notably potassium), carboxylic acids, and carotenoids in the human diet [7], [8].

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Human exposures to heavy metals may occur through inhalation of air and ingestion of food and water. Heavy metals concentration in the environment varies markedly depending on their concentrations in soil and vicinity to sources of emission [9]. Heavy metal accumulation in soil and plants is of increasing concern because of the potential human health risk. This food chain contamination is one of the most important pathways for the entry of these toxic elements into the human body. Heavy metals accumulation and distribution in plant strongly depend on the plant species, metals level in the soil and air, soil pH and CEC, vegetation period, and some other parameters [10].

Phytoremediation, also known as green technology, which consists of the use of plants including trees, grasses, herbs and aquatic plants to extract, sequester, and detoxify heavy metals, is a novel approach that has shown considerable promise as a cost-effective and an environmentally friendly technology and has received much attention in recent years [11], [12]. In this technique, the natural capacity of plants is used to extract some elements and compounds from soil and translocate them between fruits, flowers, leaves, stems, and roots relating to the biological stage in which the elements and compounds are involved [11]. Phytoremediation of heavy metals is divided into three categories: phytoextraction, which shows the ability of plants to extract heavy metals from soil by accumulating the metal in aerial parts of plant [13]; phytostabilization, which is the use of plants to stabilize the soil surface by maintaining the metals in the roots [14]; and rhizofiltration, which is the use of plant roots to ab/adsorb metals from water and aqueous waste streams [15].

In the present study, we evaluated the uptake and distribution of cadmium and chromium in vegetative organs (roots and shoots) and fruits (pulp and peel) of tomato (*Lycopersicon esculentum* L.) plants in nine heavy metal polluted soils located in western fields of Hormozgan province, Islamic Republic of Iran.

II. Materials and Methods

In this research, we studied three major tomato-growing areas (Tazian, Kahurestan, and Parsian) located in western parts of the Hormozgan province, Iran. Three farms were selected in each area, differing in field management and distance from roads, industries, cities and other pollution sources. Farming management practices including rate, type and method of fertilization, irrigation depth and interval, application of pesticides and harvesting time, which were recorded precisely. One composite soil sample was collected from each site (0-30 cm) before planting, oven-dried, ground and sieved through 2 mm sieve and the DTPA extractable Cd and Cr were determined by atomic absorption spectrophotometer method as given by Lindsay and Norvell [16]. Sampling of fruits, shoots, and roots was simultaneously accomplished three times during the plant growth period. After each sampling event, the fruit peel was separated from the edible pulp. All harvested organs including fruits, shoots and roots were rinsed with distilled water, oven-dried at 70 °C for 48 hours, weighed, ground, and dry-ashed at 500 °C. Concentrations of cadmium and chromium in fruit peel, fruit pulp, shoots, and roots were measured by atomic absorption spectrometric method [17] using atomic absorption spectrophotometer model SpectrAA-220 made in Varian company of Australia. BCF and TF show the capability of plants for tolerating and accumulating heavy metals. These indices were determined using the ratio of metal content in the aerial parts of plant to the soil (BCF) and the ratio of metal content in the aerial parts to the roots (TF) [18], [19]. Obtained raw data were statistically analyzed. Means comparison was performed by Duncan's Multiple Range Test, using MSTATC software. Figures were drawn by Microsoft-Excel software.

III. Results and Discussions

The suitability of using a plant for removal of heavy metals from a contaminated soil depends on uptake, accumulation and distribution of metals in different organs of plant [20]. Figs. 1, 2 show the pattern of distribution of two heavy metals Cd and Cr in fruit peel, edible pulp, shoots and roots of tomato in the nine studied regions. According to Fig. 1, neither peel nor edible pulp of tomato fruits showed cadmium in their tissues; however, some amounts of this heavy metal were measured in shoots and roots. Calculating the average ratio of shoots Cd concentration to roots Cd content for all studied regions revealed that more than 90% of the cadmium uptaken by tomato plants was found in the shoots. Cadmium accumulation in shoots could be reckoned as a possible strategy for removal of this metal from contaminated soils. The results presented in Table I show the BCFs and TFs for Cd and Cr. These indices are important values that estimate the potential of a plant for phytoextraction and phytostabilization. Plants showing a shoot BCF>1 may be a phytoextractant, and plants having a root BCF>1 and TF<1 are suitable for phytostabilization [18], [19]. Therefore, tomato could be considered as a phytoremediant in cadmium polluted soils in the studied regions. It has been proved that plants are able to take up elements electively. They may uptake heavy metals by their roots, stems, and leaves and accumulate them in their organs. Plants are employed for decontaminating heavy metals from soils and waters and have demonstrated high performances in treating these polluted resources. Several parameters including plant species, element species, pH, exposure duration, and temperature can affect the purification capacity of heavy metals by plants [21]. Cadmium is one of the mobile elements that could be easily absorbed by roots and transmitted into the shoots [20]. Its uptake from soil is completely dependent on the cadmium concentration in the soil [22]. Its distribution is based on the mobilization of the protective mechanisms of plants which inhibit the transport to tissues and organs [20]. Other researchers also reported tomato as a phytoremediant for removing the heavy metal cadmium from the contaminated soils [23], [24].

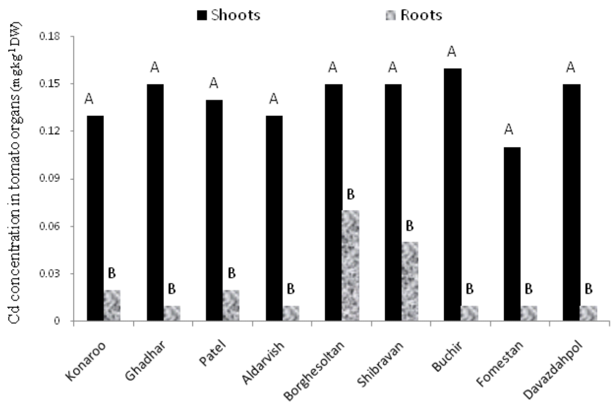

Fig. 1 Cadmium distribution in different tomato organs

TABLE I
BCF and TF for Cd and Cr in Tomato

Heavy metal	Region	Harvestable parts BCF	Roots BCF	TF
Cd	Konaroo	1.38	0.21	6.50
	Ghadhar	1.03	0.07	15.00
	Patel	1.04	0.15	7.00
	Aldarvish	1.01	0.08	12.63
	Borghesoltan	1.29	0.60	2.15
	Shibravan	1.10	0.37	3.00
	Buchir	1.10	0.07	16.00
	Fomestan	1.01	0.08	12.63
	Davazdahpol	1.15	0.08	15.00
Cr	Konaroo	0.06	0.04	1.52
	Ghadhar	0.09	0.06	1.50
	Patel	0.08	0.05	1.50
	Aldarvish	0.07	0.05	1.47
	Borghesoltan	0.07	0.04	1.52
	Shibravan	0.07	0.04	1.59
	Buchir	0.09	0.06	1.57
	Fomestan	0.06	0.04	1.59
	Davazdahpol	0.09	0.06	1.59

All parts of tomato plants had significantly different concentrations of chromium and increased in the order of fruit peel<edible pulp<shoots<roots (Fig. 2). The highest and lowest Cr contents were recorded in the roots and fruit peel with 6.62 and 1.77 mg kg^{-1} dry weight, respectively. The average concentration of chromium in tomato fruits (4.74 mg kg^{-1} dry weight) was about twice the maximum allowed level (2.30 mg kg^{-1} dry weight) suggested by WHO/FAO [25]. It is necessary to mention that 40% of fruit Cr content was accumulated in the peel (Fig. 2), and therefore, separating the peel from the tomato fruits can be a good strategy for decreasing daily intake of chromium in our daily diet. BCF and TF values were too small to introduce tomato as a phytoremediant in soils contaminated with the heavy metal chromium (Table I). The high concentration of Cr in soil and

plant could be attributed to the high levels of industrial activities, metal works, overuse of phosphorus fertilizers, vehicular emissions, small scale tanning operations, etc. [26]. Other researchers have also reported the potential of tomato plants for uptake of the heavy metal chromium from contaminated soils [26]-[28].

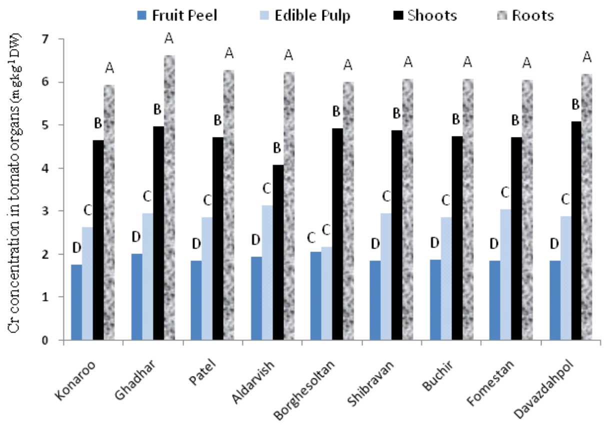

Fig. 2 Chromium distribution in different tomato organs

IV. Conclusions

The elemental distribution of the heavy metal Cr in different parts of tomato was in increasing pattern of fruit peel<edible pulp<shoots<roots. However, the average concentration of chromium in the fruits was about twice the maximum allowed level suggested by WHO/FAO [25]. The results showed that 40% of fruit Cr content was present in the peel, and therefore, removing the peel from the tomato fruits can be a good tactic to decrease daily intake of this heavy metal in our daily diet. The high concentration of Cr in soil and plant could be associated to the factors such as industrial activities, metal works, overuse of phosphorus fertilizers, vehicular emissions, small scale tanning operations, etc. Cadmium was observed neither in the peel nor in the pulp of tomato fruits. Furthermore, cadmium accumulation in the shoots was higher than in the roots. In general, Cd was accumulated in the vegetative parts and not in the fruits of tomato, making it safe for public consumption. This shows a selectivity for metal compartmentation in the plant. BCF and TF values for chromium were too small to introduce tomato as a phytoremediant in soils contaminated with these three heavy metals. On the other hand, the high BCF and TF values for cadmium (>1) along with the high biomass production of tomato could result in making tomato as a good choice for phytoremediation of cadmium polluted soils.

Further research is necessary in order to find the potential transformation mechanisms for heavy metals tolerance of tomato and to assess the effects of each heavy metal as well as the interactions of different levels on soil quality and relative uptake to the edible plant species.

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References

[1] J. L. Torresdey, J. R. P. Videa, G. D. Rosa, and J. Parsons, “Phytoremediatoin of heavy metals and study of the metal coordination by X- ray absorption spectroscopy,”*Coordin. Chem. Rev*., vol. 249, pp. 1797- 1810, Jul. 2005.

[2] J. O. Duruibe, M. C. Ogwuegbu, and J. N. Egwurugwu, “Heavy metal pollution and human biotoxic effects,”*Int. J. Phys. Sci.*, vol. 2, no. 5, pp. 112-118, Apr. 2007.

[3] S. Doumett, L. Lamperi, L. Checchini, E. Azzarello, S. Mugnai, and S. Mancuso, “Heavy metal distribution between contaminated soil and Paulownia tomentosa, in a pilot-scale assisted phytoremediation study: influence of different complexing agents,” *Chemosphere*, vol. 72, pp. 1481–1490, Jul. 2008.

[4] M. I. Zaidi, A. Asrar, A. Mansoor, and M. A. Farooqui, “The heavy metal concentrations along roadside trees of Quetta and its effects on public health,” *J. Appl. Sci*., vol. 5, pp. 708–711, Oct. 2005.

[5] M. S. Abdullahi, A. Uzairu, and O. J. Okunola, “Quantitative determination of heavy metal concentration in onion leaves,”*Int. J. Environ. Res*., vol. 3, no. 2, pp. 271-274, Oct. 2009.

[6] A. Lugasi, L. Biro, J. Hovarie, K. V. Sagi, S. Brandt, and E. Barna, “Lycopene content of foods and lycopene intake in two groups of the Hungarian population,”*Nutr. Res*., vol. 23, pp. 1035-1044, Jul. 2003.

[7] M. Caputo, M. G. Sommella, G. Graciani, I. Giordano, V. Fogliano, R. Porta, and L. Mariniello, “Antioxidant profiles of corbara small tomatoes during ripening and effects of aqueous extracts on j-774 cell antioxidant enzymes,”*J. Food Biochem*., vol. 28, pp. 1-20, Apr. 2004.

[8] M. Hernandez-Suarez, E. M. Rodryguez Rodryguez, and C. Dyaz-Romero, “Mineral and trace element concentrations in cultivars of tomatoes,” *Food Chem*., vol. 104, pp. 489-499, Apr. 2007.

[9] B. Kenneth, and P. S. Harvey, “Health Implication of Trace Metal in the Environment,” in *Ultra Trace Metal Analysis in Biological Sciences and Environment*, T. H. Risby, Ed. Washinton DC: Advances in Chemistry Society, 1979, pp: 27-32.

[10] R. K. Rattan, S. P. Dattan, P. K. Chhonkar, K. Suribabu, and A. K. Singh, “Long-term impact of irrigation with sewage effluent on the heavy metal content in soil, crops and ground water. A case study,”*Agric. Ecosyst. Environ*., vol. 109, pp. 310-322, Apr. 2005.

[11] P. Ximenez-Embum, B. Rodriguez-Sanz, Y. Madrid-Albarran, and C. Camara, “Uptake of heavy metals by lupin plants in artificially contaminated sand: Preliminary Results,” Int. J. Environ. An. Ch., vol. 82, no. 11-12, pp. 805-813, Apr. 2001.

[12] Q. Wang, Y. Cui, X. Lin, Y. Dong, and P. Christie, “Soil contamination and plant uptake of heavy metals at polluted sites in China,”*J. Environ. Sci. Health*, vol. 38, no. 5, pp. 823-838, Jul. 2003.

[13] L. Sebastini, F. Scebba, and R. Tognetti, “Heavy metal accumulation and growth responses in poplar clones Eridano (Populus deltoids×maximowiczii) and I-214 (P.×euramericana) exposed to industrial waste,”*Environ. Exp. Bot*., vol. 52, pp. 79- 88, Oct. 2004.

[14] A. Marques, H. Moreira, A. Rangel, and P. Castro, “Arsenic, lead and nickel accumulation in Rubus ulmifolis growing in contaminated soil in Portugal,”*J. Hazard. Mater*., vol. 165, pp. 174-179, Apr. 2008.

[15] A. Erakhrumen, and A. Agbontalor, “Phytoremediation: an environmentally sound technology for pollution prevention, control and remediation in developing countries,”*Educ. Res. Rev*., vol. 2, no. 7, pp. 151-156, Apr. 2007.

[16] W. L. Lindsay, and W. A. Norvell, “Development of a DTPA test for zinc, iron, manganese and copper,”*Soil Sci. Soc. Am. J*., vol. 42, pp. 421-428, Apr. 1978.

[17] J. Ryan, G. Stefan, and A. Rashid, *Soil and Plant Analysis Laboratory Manual*. Syria, ICARDA: Aleppo,2001, p. 172.

[18] S. Saraswet, and J. P. N. Rai, "Phytoextraction potential of six plant species grown in multimetal contaminated soil,"*Chem. Ecol*., vol. 5, no. 1, pp. 1-11, Jan. 2009.
[19] M. Zacchini, F. Pietrini, G. Mugnozza, and V. Lori, "Metal tolerance, accumulation and translocation in poplar and willow clones treated with cadmium in hydroponics," *Water Air Soil Poll*., vol. 197, pp. 23- 34, Apr. 2008.
[20] A. Sekara, M. Poniedzialek, J. Ciura, and E.Jedrszczyk, "Cadmium and lead accumulation and distribution in the organs of nine crops: Implications for phytoremediation," *Pol. J. Environ. Stud.*, vol. 14, no. 4, pp. 509-516, Oct. 2005.
[21] S. Cheng, "Heavy metals in plants and phytoremediation," *Environ. Sci. Pollut. R.*, vol. 10, no. 5, pp. 335-340, Jul. 2003.
[22] M. Greger, "Metal availability, uptake, transport and accumulation in plants," in *Heavy metal stress in plants: From biomolecules to ecosystems*, 2nd ed., M. N. V. Prasad, Ed. Berlin: Springer, 2004, pp. 1–27.
[23] M. Cheraghi, M. Sohrabi, and K. Shayesteh, "Determination of copper and cadmium concentration in greenhouse tomatoes produced in Hamadan province during 2012" (in Persian). *J. Food Hyg*., vol. 3, no. 12, pp. 31-41.Jan. 2014.
[24] F. A. Andal, "Assessment of the possible utilization of tomato as a phytoremediant in soils artificially contaminated with heavy metals,"*Int. J. Appl. Environ. Sci*., vol. 11, no. 1, pp. 193-209, Oct. 2016.
[25] WHO/FAO, "Joint FAO/WHO Food Standard Programme" Codex Alimentarius Commission, 13 Session. Report of the thirty eight session of the codes committee on food hygiene. Houston, USA, 2007.
[26] J. O. Jacob, and S. E. Kakulu, "Assessment of heavy metal bioaccumulation in spinach, jute mallow and tomato in farms within Kaduna Metropolis, Nigeria,"*Am. J. Chem*., vol. 2, no. 1, pp. 13-16, Jul. 2012.
[27] L. E. Hellen, and O. C. Othman, "Levels of selected heavy metals in soil, tomatoes and selected vegetables from Lushoto district-Tanzania,"*Int. J. Environ. Monit. Anal*., vol. 2, no. 6, pp. 313-319, Oct. 2014.
[28] Z. S. Ilić, N. Kapoulas, L. Šunić, D. Beković, and N. Mirecki, "Heavy metals and nitrate content in tomato fruit grown in organic and conventional production systems,"*Pol. J. Environ. Stud.*, vol. 23, no. 6, pp. 2027-2032, Apr. 2014.

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