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PHYTOREMEDIATION OF CADMIUM IN SOIL AND HYDROPONICS BY *TRADESCANTIA FLUMINENSIS*

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Abstract: The purpose of this study is to examine the bioaccumulation of ecotoxic metal cadmium (Cd) from soil and waste water by *Tradescantia Fluminensis* as an ornamental plant. The plants grown in soil and hydroponic systems contaminated with Cd for this purpose (0-100 mg kg^{-1}). In this study, Cd accumulation and distribution in the *Tradescantia Fluminensis* were also investigated. Cd accumulation was the maximum in the root, followed by than the stem and leaves in pots and hydroponics. Translocation Factor (TF) and The Bioconcentration Factor (BCF) values were also calculated to appraise the efficacy of the plants being removed. The plant could well tolerate up to 100 mg kg^{-1} of Cd concentration level. Although the plant cannot be categorized as a hyperaccumulator, the plant has been very effective in Cd translocation from root to sprouting, as is evident from the data obtained from the BCF and TF values.

Keywords: *TradescantiaFluminensis,* Waste water, Soil, Cadmium, Phytoremediation.

1. INTRODUCTION

Environmental pollution, especially water pollution, is worrying both in developing and developed countries. The pollution from heavy metals in water and soil is one of the most critical environmental problems in the world because of the fast improvement of intense industry and agriculture. Persistence in the environment is a group of inorganic pollutants that attract scientific and public interest for toxicity and bioaccumulation to living beings. Due to toxic and unwanted impacts, most of the heavy metals can cause serious environmental and health problems even at very low concentrations (Arora et al., 2008; Memon & Schroder 2009; Shahbaz et al., 2013).

Cadmium (Cd) is an extremely toxic non-essential element and is a special part for human health as it may harm the liver, kidneys and other organs, often not be reversible and even at low concentrations (Kirkham 2006, Sampanpanish & Pinpa 2018). It mainly enters through anthropogenic activities such as soil and water mining, industrial wastewater and phosphorus fertilizer applications (Ali & Hadi 2015; Kirkham 2006). Varied methods (both chemical and physical) have been used for decontamination of metal contaminated water and soil, but these methods are often pricey and troublesome and have negative effects on the ecosystem. Green plants, which are generally thought to be food, fiber and fuel sources, can also be used for purifying of metal contaminated water and soil. As it is known collectively, plant-based technologies are called as phytoremediation. One of the plant improvement techniques known as plant extraction utilizes plants for the removal and accumulation of contaminants in the harvestable parts and the harvested parts are then removed (Khan et al., 2014; Ahmad et al., 2016; Kumar et al., 1995; Radovanović et al., 2017; Damian et al., 2018).

The plant species used for phytomining should probably be native and have the ability to accumulate rapid growth rate, comprehensive root system, high biomass yield, various habitat adaptation, high tolerance and pollutants on the ground. However, not much information is present about the capability of ornamental plants to heal polluted soils. These plants offer plenty advantages such as many plant species, enthusiastic stamina, rapid growth and at the same time make the environment beautiful. More significantly, most of the food is not about our chain. For this reason, phytochemistry seems to be a promising election by ornament plants (Miao & Yan 2013;Kurt 2018). Use of ornamental plants such as *Lonicera japonica* Thunb, *Salvia virgata* Jacq., *Althaea rosea* Cavan, *Dahlia hybrida* (Cay et al., 2016), *Salvia splendens, Tageteserecta*, *Abelmoschus manihot* (Wang & Zhou 2005), *Impatiens balsamina, Althaea rosea, Calendula officinalis* (Liu et al., 2008), *Chlorophytumcomosum* (Wang et al., 2012), *Quamolitpennata*, *Antirrhinum majus*L. and *Celosia critata pyramidalis* (Cui et al., 2013), *Amaranthus caudatus*(Cay 2016), *Limoniastrum monopetalum* (L.) (Manousaki et al., 2014) and *Euphorbia milli* (Ramana et al., 2015) were reported in previous studies.

Spiderwort (*Tradescantia fluminensis*) is a monocotyledonous plant with soft fleshy leaves and a fleshy body belonging to the Commelinaceae family, native to southwestern Brazil and Northern Argentina. To date, spiderwort is also presented in Portugal, Italy, New Zealand, Russia, Japan, and south – eastern regions of Australia and USA, growing in damp and shaded places not like the bulk areas of forests but such as banks, parks, gardens, streamsides, and forest edges (Liu 2016). In this study, the ability of *Tradescantia fluminensis* to tolerate and extract of Cd from polluted soil and water was investigated.

2. MATERIALS AND METHODS

2.1 Pot culture experiment

The experiment was conducted in a laboratory at the Giresun University, Giresun, Turkey. For the experiment, the soil was gathered from 0 to 20 cm depth in the garden. After drying underground shadow, the soil was drained and passed through a 2 mm mesh sieve, it was transferred to 4 kg plastic containers at a diameter of 20.0 cm and a depth of 15.0 cm and then transferred to four Cd concentrations (0, 25, 50, and 100 mg kg^{-1}) the analytical grade $CdCl_2 \cdot 2H_2O$ (Merck-Germany) is made ready in deionized water and mixed well to the soil. The soil was then subjected to cycles of wetting and drying for one month to ensure soil balance with Cd and to analyze pH, EC, extractable Cd, and organic carbon and calcium carbonate. Soil pH and EC were measured on 1:1 extract (Soil:Water). Heavy metal content and main analytical properties of soils were determined. For this purpose, 1.0 gram of sample soil was moistened at 30˚C with 20 mL nitric acid (HNO_3). Then, 50 mL perchloric acid ($HClO_4$) was added to the sample, and a complete digestion was heated strongly until observation. After cooling, the aqueous phase was separated from the remaining soil by centrifugation and diluted with distilled deionized water. Heavy metals in the sample were determined by a Burker (820-MS) Inductively Coupled Plasma Mass Spectrometer (ICP-MS). Calcium carbonateand organic carbon were determined by Walkley & Black (1934) and rapid titration (Jackson 1973) methods, respectively. Table 1 lists the physicochemical properties of the soil used for pot experiments.

Table 1. Physicochemical properties of the soil used for pot experiments

Property	Soil
pH	6.7
Organic matter (%)	1.47
Available P (g kg^{-1})	3.46
Available K (g kg^{-1})	112.24
$CaCO_3$ (%)	4.82
EC (dS m^{-1})	125
Cd* (mg kg^{-1})	<LOD (LOD=0.031)

*extractable metal concentrations ± SD (LOD: Limit of Detection)

After equilibration, five similar *Tradescantia fluminensis* seedlings were transported into the containers. After seven days, the number of seedlings was reduced to three per pot. All treatments were repeated three times in separate containers to minimize test errors. Plants were watered when needed. Fertilizers not applied. The plants were grown for four months.

2.2. Hydroponics experiment

Tradescantia fluminensis seedling was used for study. When the seedlings reached 10 cm in length and reached about 15 cm in length with mature roots, fidelities of similar shape and size were selected and washed three times with tap water to remove adhering particles. These plants were then used for phytoremediation experiments and separated into the beaker containing 100 ml of the nutrient solution for 2 days preculture. The feed medium was a modified half-strength Hoagland nutrient solution (pH 5.5) made with the following salts. (Liu & Schnoor 2008): 5 mM $Ca(NO_3)_2$, 5 mM KNO_3, 1 mM KH_2PO_4, 50 µM H_3BO_3, 1 mM $MgSO_4$, 4.5 µM $MnCl_2$, 3.8 µM $ZnSO_4$, 0.3 µM $CuSO_4$, 0.1 µM $(NH_4)_6MO_7O_{24}$ and 10 µM Fe–EDTA (Xia et al. 2009).Three rebuilds for each treatment with two *Tradescantia fluminensis* seedling in each beaker. The four treatments were set as follows: Cd concentrations (0, 25, 50, and 100 mg kg^{-1}). The plants were harvested after being grown for 15 days. Plant samples were carefully washed, dried, separated and weighed into roots, stems and leaves.

2.3. Measurements and Analysis

After 3 months for pots and 15 days for hydroponics plants are harvested and divided into roots, stems and leaves. The separated pieces were then used to identify the accumulated Cd. Harvested plants were first washed with tap water and then washed with distilled water. The clean parts were dried in an oven at 70–80°C until constant weight was achieved. The dried plant samples were finely pulverized and their dry weights were measured. For the preparation of plant samples for analysis, microwave wet digestion technique was used. For this aim, a 0.1 g sample was weighed into a volumetric flask and 10 mL HNO_3 was added. The digestion schedule consisted of two steps: 25 minutes at 360 W and 5 minutes after 5 mL H_2O_2 at 360W. The cooled solution was transferred to a 100 mL calibrated flask and diluted with water to deionized water. Using filter paper in any step to separate adsorbent materials from final solutions causes significant systematic errors (fixed type error) on the final concentration of the analyzed solutions (Engin et al., 2010). Therefore, the aqueous phase was separated from the rest of the plant by centrifugation. The concentration of heavy metals in plant tissues was determined by a Burker. (820-MS) Inductive Coupled Plasma Mass Spectrometer (ICP-MS).

2.4 Data Analysis

In addition to the cumulative concentration, BCF (bioconcentration factor) and TF (translocation factor) were used to assess the Cd accumulation capacity of *Tradescantia fluminensis*. BCF is the ratio of metal concentration to soil or water in the plant collection site (root, stem or leaf) (Zayed et al., 1998). TF shows the ability to transport shoots defined as the ratio of the root of a plant to the concentration of metal in plant roots at plant roots. (Mattina et al., 2003).

BCF =Dry weight (dw) Cd concentration in plant tissue / The initial concentration of Cd in the medium

TF= Cd concentration in stem or leaf (dw)/Cd concentration in root (dw) (Chanu & Gupta 2016).

The standard reference material (CRM060 Lagorosiphon major, aquatic plant) was used to confirm the accuracy of the procedure. For this purpose, the standard reference material was analyzed in triplicate by the same procedure and compared with the specified value of the resulting reference material (student *t*-test). The calculated relative error was less than≈ 1%. The metal concentrations of water, sediment and plants were reported as mg kg^{-1} dry weight, and each result was the vehicle of three replicates. Analysis of Variance (ANOVA) was implemented with SPSS®16.0 statistical package Microsoft Excel® 2010 was used to draw the charts.

3. RESULTS AND DISCUSSION

3.1. Plant growth

Larger biomass production is a desirable parameter for plants used in plant extraction, so that these plants can extract more heavy metals than soil and water(Clemens et al., 2002). Cadmium is a non-essential trace element for plants and accumulation in plant tissues interferes with a variety of physiological processes such as plant-water associations, chlorophyll biosynthesis, mineral nutrition, transpiration rates, root growth and biomass production (Manousaki et al., 2014).

Table 2. Effects of Cd on *Tradescantia fluminensis* dry weight

Soil Systems		Hydroponic Systems	
Treatment	Dry weight (g pot^{-1})	Treatment	Dry weight (g pot^{-1})
Cd0	2.95±0.37[b]	Cd0	1.56±0.23[a]
Cd1	2.86±0.29[a]	Cd1	1.52±0.31[b]
Cd2	2.89±0.41[b]	Cd2	1.38±0.25[a]
Cd3	2.70±0.33[a]	Cd3	1.31±0.24[a]

Values within the same column and followed by the same letter are not different at $P < 0.05$ by an ANOVA-protected LSD test. **Cd0:** Control, **Cd1:** 25 mg kg^{-1} Cd, **Cd2:** 50 mg kg^{-1} Cd, **Cd3:** 100 mg kg^{-1} Cd.

When soil and hydroponic systems are exposed to Cd stress, plant growth, expressed as the dry weight of plants, is prevented in a negative way.In general, Cd administration resulted in reduced growth of plants compared to control. (Table 2). However, the differences betweencontrol, 25 mg Cd Kg^{-1} soil and 50 mg Cd Kg^{-1} soil werenot significant.A significant reduction in dry weight only 100 mg of Cd Kg^{-1} soil treatment was observed.Compared with the control, the dry weights of *Tradescantia fluminensis* decreased to 16 and 11% under hydroponics, respectively, for Cd2 and Cd3 treatments. There was no important difference in Cd1 treatment.

3.2. Cd accumulation of Plant

The concentrations of Cd in different tissues of

*Tradescantia fluminensis*at the end of the 3 months for pots and 15 days for hyroponics exposure are shown in Figure 1. It was observed that the accumulation of Cd was significantly higher at all Cd exposure concentrations in root than at stem and leaf. Different parts of plants (root, stem and leaf) showed different percentages of Cd accumulation by applying different treatments. Because the root system plays an interactive role between environmental pollutants and plants, most of the heavy metals entering the plant are first retained in stem cells, which provide a large margin for organ displacement and protect leaf tissue from heavy metal damage. All treatments showed a significant increase in cadmium deposition of *Tradescantia fluminensis* with increased Cd. For most plants, toxicity occurs when the Cd concentration is greater than 5-10 mg kg^{-1} dry matter. However, in this study, we found that even at concentrations of 100 mg kg^{-1} Cd, there was no significant toxic symptom in *Tradescantia fluminensis.*

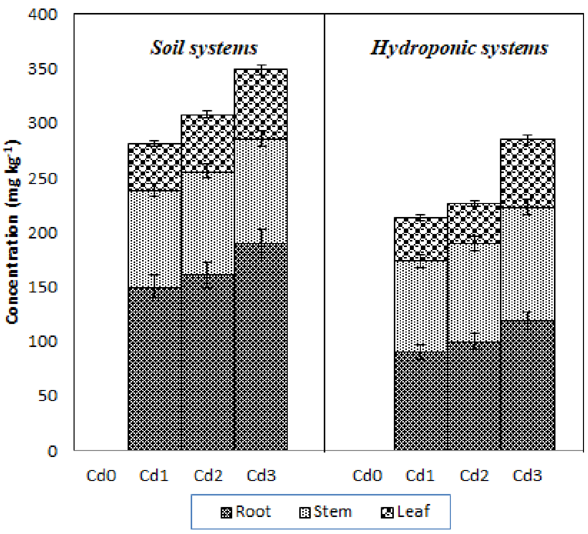

Figure 1. Concentration Cd in root, stem and leaf of *TradescantiaFluminensis*. (**Cd0:** Control, **Cd1:** 25 mg kg^{-1}Cd, **Cd2:** 50 mg kg^{-1}Cd, **Cd3:** 100 mg kg^{-1}Cd**)** Error bars represent ±SD of triplicates (n = 3).

3.3. Enrichment Coefficient (Bioconcentration factor) and Translocation Factor

Bioconcentration factor (BCF) is a measurement of the metal deposition efficiency of plants with high metal accumulation potential of the plant (Chanu & Gupta 2016).Root tissue BCF was several times higher than stem and leaf.The highest BCF value was observed in Cd1 treated plants with soil system Cd (see Table 3). The translocation factors (TFs) of different treatments ranged from 0.83 to 0.91 between soil concentrations of 0-100 mg kg^{-1} Cd. However, TF values calculated in for different treatments for hydroponics were always higher than in soil in the same conditions. Higher TF values reflect the mobilization of Cd in the body, particularly in the affected lower parts of the Cd exposure (see Table 3).

4. CONCLUSIONS

Phytoextraction is a green and low-cost healing technology that uses plants to clean polluted environment. Unfortunately, the use of most metal hyperacumulator plants is limited to low biomass and slow growth rate. This study demonstrates the ability to store excess Cd in the soil and hydroponics and to store excess Cd in the stem and lower stem at high Cd exposure. The plant could well tolerate up to 100 mg kg^{-1}Cd concentration levels, no visual symptom of necrosis was observed in *Tradescantia fluminensis*. Thus, the high biomass, cannot be classified as a hyperaccumulator, perennial herb and ornamental plant specious of *Tradescantia fluminensis* could have a great potential in phytoremediation in Cd contaminated soil and water.

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REFERENCES

Ahmad A., Hadi F., Ali N. & Jan A.U., 2016. *Enhanced phytoremediation of cadmium polluted water through two aquatic plants Veronica anagallis-aquatica and Epilobium laxum* Environ Sci Pollut R 23:17715-17729 doi:10.1007/s11356-016-6960-2

Ali N. & Hadi F., 2015. *Phytoremediation of cadmium improved with the high production of endogenous*

Table 3. Enrichment Coefficients (Bio Concentration factor) and Translocation Factors under different treatments

Soil Systems			Hydroponic Systems		
Treatment	**BCF**	**TF**	**Treatment**	**BCF**	**TF**
Cd0	-	-	Cd0	-	-
Cd1	11.24	0.87	Cd1	8.52	1.37
Cd2	6.16	0.91	Cd2	4.52	1.26
Cd3	3.49	0.83	Cd3	2.85	1.39

Cd0: Control, **Cd1:** 25 mg kg^{-1} Cd, **Cd2:** 50 mg kg^{-1} Cd, **Cd3:** 100 mg kg^{-1} Cd.

phenolics and free proline contents in Parthenium hysterophorus plant treated exogenously with plant growth regulator and chelating agent Environ Sci Pollut R 22:13305-13318 doi:10.1007/s11356-015-4595-3

Arora M., Kiran B., Rani S., Rani A., Kaur B. & Mittal N., 2008. *Heavy metal accumulation in vegetables irrigated with water from different sources* Food Chem 111:811-815 doi:10.1016/j.foodchem.2008.04.049

Cay S., 2016. *Enhancement of cadmium uptake by Amaranthus caudatus, an ornamental plant, using tea saponin* Environ Monit Assess 188

Cay S., Uyanik A. & Engin M.S., 2016. *EDTA Supported Phytoextraction of Cd from Contaminated Soil by Four Different Ornamental Plant Species* Soil Sediment Contam 25:346-355

Chanu L.B. & Gupta A., 2016. *Phytoremediation of lead using Ipomoea aquatica Forsk. in hydroponic solution* Chemosphere 156:407-411

Clemens S., Palmgren M.G. & Kramer U., 2002. *A long way ahead: understanding and engineering plant metal accumulation* Trends Plant Sci 7:309-315

Cui S., Zhang T.G., Zhao S.L., Li P., Zhou Q.X., Zhang Q.R. & Han Q., 2013. *Evaluation of Three Ornamental Plants for Phytoremediation of Pb-Contamined Soil* Int J Phytoremediat 15:299-306

Damian G., Andráš P., Damian F., Turisová I. & Iepure G., 2018. *The role of organo-zeolitic material in supporting phytoremediation of a copper mining waste dump* Int J Phytoremediat20:1307-1316doi: 10.1080/15226514.2018.1474440

Engin M.S., Uyanik A., Cay S. & Icbudak H., 2010. *Effect of the adsorptive character of filter papers on the concentrations determined in studies involving heavy metal ions* Adsorpt Sci Technol 28:837–846

Jackson, M. L., 1973. *Soil Chemical Analysis***,** Prentice Hall of India, New Delhi

Khan I.U.,Khan N.U.,Khan M.Q.,Khan M.J., Khan, M.J. & Rahman H.U., 2014. *Phyto-extraction of municipal wastewater's and applied solution of copper, lead and zinc, using high bio-mass crops, zea mays and brassica napus* Carpathian Journal of Earth and Environmental Sciences 9:(1), 107-116

Kirkham M.B., 2006. *Cadmium in plants on polluted soils: Effects of soil factors, hyperaccumulation, and amendments* Geoderma 137:19-32 doi:10.1016/j.geoderma.2006.08.024

Kumar P.B.A.N., Dushenkov V., Motto H. & Raskin I., 1995. P*hytoextraction - the use of plants to remove heavy-metals from soils* Environ Sci Technol 29:1232-1238 doi:Doi 10.1021/Es00005a014

Kurt M.A., 2018. *Comparison Of Trace Element And Heavy Metal Concentrations Of Top And Bottom Soils In A Complex Land Use Area*, Carpathian Journal of Earth and Environmental Sciences, 13:47 – 56; DOI:10.26471/cjees/2018/013/005.

Liu J.N., Zho Q.X., Sun T., Ma L.Q. & Wang S., 2008. *Growth responses of three ornamental plants to Cd and Cd-Pb stress and their metal accumulation characteristics* J Hazard Mater 151:261-267

Liu J.Y. & Schnoor J.L., 2008. *Uptake and translocation of lesser-chlorinated polychlorinated biphenyls (PCBs) in whole hybrid poplar plants after hydroponic exposure* Chemosphere 73:1608-1616

Liu R.Y., 2016. *Variation in the phenotypic features and transcripts of thermo-sensitive leaf-color mutant induced by carbon ion beam in Green wandering jew (Tradescantia fluminensis)* Sci Hortic-Amsterdam 213:303-313

Manousaki E., Galanaki K., Papadimitriou L. & Kalogerakis N., 2014. *Metal Phytoremediation by the Halophyte Limoniastrum Monopetalum (L.) Boiss: Two Contrasting Ecotypes* Int J Phytoremediat 16:755-769

Mattina M.I., Lannucci-Berger W., Musante C. & White J.C., 2003. *Concurrent plant uptake of heavy metals and persistent organic pollutants from soil* Environ Pollut 124:375-378

Memon A.R. & Schroder P., 2009. *Implications of metal accumulation mechanisms to phytoremediation* Environ Sci Pollut R 16:162-175 doi:10.1007/s11356-008-0079-z

Miao Q. & Yan J.H., 2013. *Comparison of three ornamental plants for phytoextraction potential of chromium removal from tannery sludge* J Mater Cycles Waste 15:98-105

Ramana S., Biswas A.K., Singh A.B., Ajay, Ahirwar N.K. & Rao A.S., 2015. *Tolerance of Ornamental Succulent Plant Crown of Thorns (Euphorbia milli) to Chromium and its Remediation* Int J Phytoremediat 17:363-368

Radovanović V., Životić L., Žarković B. & Đorđević A., 2017. *Soil-to-plant bio-accumulation factor as indicator of trace metal implementation into the food chain,*Carpathian Journal of Earth and Environmental Sciences 12:, 2, 457-464

Sampanpanish P. & Pinpa K., 2018. C*admium Removal from Contaminated Sediment Using EDTA and DTPA with Water Hyacinth*Int J Environ Res 12:543-551.

Shahbaz M., Hashmi M.Z., Malik R.N. & Yasmin A., 2013. *Relationship between heavy metals concentrations in egret species, their environment and food chain differences from two Headworks of Pakistan* Chemosphere 93:274-282

Walkley A. & Black, C.A.,1934. *An examination of Degtgareff method for determining soil organic matter and a proposed modification of the chromic acid titration method.* Soil Science 37:29-37.

Wang X.F. & Zhou Q.X., 2005. *Ecotoxicological effects of cadmium on three ornamental plants* Chemosphere 60:16-21

Wang Y.B., Yan A.L., Dai J., Wang N.N. & Wu D.,

2012. *Accumulation and tolerance characteristics of cadmium in Chlorophytum comosum: a popular ornamental plant and potential Cd hyperaccumulator* Environ Monit Assess 184:929-937

Xia H.L., Chi X.Y., Yan Z.J. & Cheng W.W., 2009. *Enhancing plant uptake of polychlorinated biphenyls and cadmium using tea saponin* Bioresource Technol 100:4649-4653

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

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