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Phytoremediation of cadmium from effected soil using maize plant (*Zea mays* L.)

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Abstract

In present study, the soil and water were analyzed for cadmium metal. Its concentration in soil and water was 0.21 ml/kg and 0.001 mg/l respectively. For phytoextraction experiment pots were arranged in different groups such as Group A, B, C, D, E and F. To the soil of group A pots no metal was added and concentration of 100,200,300,400 and 500 ppm cadmium was added to the soil of group B, C, D, E and F respectively. The seeds of maize were sown in pots and observed its germination. Seed germination in group A was 5 while in group B, C, D, E and F was 5, 4.66, 4.33, 3.66, and 2.33 respectively. Cadmium metal decreased the rate of germination. The fresh and dry weigh of the plants were decreased with increase of cadmium concentration in the soil. The cadmium content in the root of group A was 5.263 mg/kg while that of group B, C, D, E and F was 19.47, 36.75, 42.36, 50.96 and 62.32mg/kg respectively. The concentration of cadmium metal found in the stem of group A plants was 1.64 mg/kg while in the stem group B, C, D, E and F was 4.4, 3.01, 1.66, 1.05 and 0.08 mg/kg respectively. The concentration of cadmium in the leaves of group A was 2.86 mg/kg while in group B, C, D, E and F was 7.08, 6.96, 5, 3.36, and 2.44 mg/kg respectively. Calculated bioconcentration and translocation factors of all groups showed that both of them of the plant for cadmium metal decreased due to increasing cadmium concentration in the soil.

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Introduction

Cadmium is a heavy metal which spread in agricultural and natural land mainly through human actions like municipal wastes incinerators, mining, cleansing and fossil fuel ignition source (Wagner, 1993) in addition to natural rock mineralization process (Sanita de toppi and Gabrielli, 1999). Chief inputs of cadmium into forming soil are due to the use of phosphate fertilizer (Williams and David, 1976), soil amendment with urban sewage sledges and atmospheric deposition (Wagner, 1993).Several epidemiological studies of workers found that exposure to various cadmium compounds increase the risk of death from lung cancer (IARC, 1993). It disturb activities of the enzymes, reduce the transformation of DNA in microbes, influence mineral nutrition (Siedlecka *et al.,* 1997) causing impairment of respiration, protein denaturation (Das *et al*., 1997), disruption of cell transport process (Williams *et al.,* 2000), damaging the photosynthetic apparatus (Siedlecka *et al*., 1997), decreases seed germination and plant growth (Gardea Torresdey *et al*., 2005).cadmium metal was found to be one of the most phytotoxic heavy metal (pilon-smith., 2005). Soil cadmium contamination is a big risk to human fitness (Xiao *et al*., 2008). Cadmium is an ever-present unnecessary element that is highly poisonous and is simply accumulate from the surroundings by living organisms (Rahimi and Nejatkhan., 2010).

"Phytoremediation basically refers to the use of plants and related soil microorganisms to decrease the concentrations or poisonous effects of contaminants in the environments" (Greipsson, 2011). It can be used for removal of organic pollutants (such as, polychlorinated biphenyls, polynuclear aromatic hydrocarbons and pesticides), radionuclides as well as for heavy metals. It is a novel, efficient, cost effective, environment- and eco-friendly, in situ applicable and solar-driven remediation strategy (Singh and Prasad, 2011; Vithanage *et al.,* 2012). Plants generally handle the contaminants without affecting topsoil, thus conserving its effectiveness and fertility. They may increase fertility of the soil with inputs of organic matter (Mench *et al*., 2009). Phytoextraction is the key and generally useful phytoremediation technique for the removal of metalloids and heavy metals from contaminated soils, water or sediments (Milic *et al*., 2012). It is the most promising for commercial application (Sun *et al*., 2011). The efficiency of phytoextraction depends on many factors like soil properties, bioavailability of the heavy metals in soil, speciation of the heavy metals and plant species concerned (Ali *et al*., 2013).

This research work will provide a baseline for the different factors which effects the cadmium accumulation by the plants. to determine the amount of cadmium present in soil also effects their accumulation in plants are the main objective of this work. The present work is unique in its nature for the said research area, and will open new ways in this field for the young scientists of the area.

Methods and materials

Experimental plants

In this study *Zea mays* was used for the phytoextraction experiment of nickel metal. Seeds of *Zea mays* were collected from the local market and sowed in pots in the green house of Islamia college university Peshawar.

Analysis of cadmium metal in the used soil and water

The soil and water used in the experiment were analyzed for the concentration of cadmium metal. Cadmium in the soil was determined according to sharidah (1999). 5 g sample of the soil was taken in a 100 mL beaker. 3 mL of 30 % H_2O_2 was added to it. This was left undisturbed for 1 hour until the vigorous reaction ceased. Then 75 mL of 0.5 M HCl solution was added to it and heated on hot plate for 2 hours. The digest was then filtered through a Whatman filter paper. The filtrate was used for the determination of cadmium metal (Cd) by atomic absorption spectrometry (AAS).Water was passed through filter paper and the concentration of cadmium was determined in them by AAS. The analysis was conducted in triplicate. Results are shown as mean.

Experimental design

Experiment was conducted in 18 pots. These pots were arranged in six groups. The first group (group A), which was control group to which no metal was added. Different concentration of Cadmium metal was added to the rest of 5 groups in the form of $3CdSO_4.\ 8H_2O$. Concentration of 100ppm, 200ppm, 300ppm, 400ppm and 500ppm cadmium metal was added to group B, C, D, E and F respectively.

Analysis of Accumulated Heavy Metals in Plant Samples

For this purpose, each plant part was thoroughly washed with tape water and then with distilled water in order to remove dusts and soil particles. The clean plant parts were dried in an oven at 105ºC for 24 hours. Then the samples were digested according to Awofolu (2005): 0.5 g sample of the plant part was taken into a 100 mL beaker. 5 mL concentrated (65%) HNO_3 and 2 mL $HClO_4$ were added to it and heated on hot plate until the digest became clear. The digest was allowed to cool and then filtered through a Whatman filter paper. The filtrate was collected in a 50 mL volumetric (measuring) flask and diluted to the mark with distilled water. The filtrate was used for the analysis of heavy metal (Cd) by AAS (AAS-700, Perkin-Elmer, USA) using acetylene/air as gas mixture. The lamp wavelength (λ) for Cd was 213.9 nm. As mentioned previously, each experiment was run in triplicate. Results are shown as mean.

Bioconcentration and Translocation factor of Zea mays for cadmium

Bioconcentration factor (BCF) refers to the capacity of a plant in up-taking cadmium metals from soil and accumulating them into its tissues. "It is a ratio of the heavy metal concentration in the plant tissue (root, stem or leaves) to that in soil." It is calculated as follows (Zhuang *et al.*, 2007).

$$BCF = C\ \textit{harvested tissue} \div C\ \textit{soil}$$

where C *harvested tissue* is the concentration of cadmium metal in the plant harvested tissue (roots, stem or leaves) and C *soil* is the concentration of the same metal in soil.

Translocation factor (TF) shows the efficiency of the plant in translocating the accumulated heavy metals from roots to shoots. "It is a ratio of the concentration of the heavy metal in shoots (stem or leaves) to that in its roots." It can be calculated as follows (Padmavathiamma and Li, 2007; Adesodun *et al.*, 2010).

$$TF = C\ \textit{shoots} \div C\ \textit{roots}$$

Where as *C shoots* is the concentration of cadmium metal in shoots (Stem and leaves) and *C roots* is the concentration of the same metal in Roots.

Bioconcentration and translocation factors of *Zea mays* for cadmium metal were calculated according to the mentioned formulas. From these calculations feasibility of *Zea mays* for the phytoextraction of cadmium metal was analyzed.

Effects of Cadmium on Zea mays

Seed germination of Zea mays was observed in group A soil and cadmium contaminated groups (B, C, D, E and F). Germination of the seeds of Zea mays of group A soil (Control group) was compared with the germination of the seeds of Zea mays of cadmium contaminated groups (B, C, D, E and F). After maturity the plans were uprooted and their fresh weight and dry weight was calculated with the help of digital balance. The fresh weight and dry weight of the plants of group A plants were compared with the fresh weight and dry weight of the plants grown in cadmium contaminated groups of soil (B, C, D, E and F). Results are shown as mean ± SD.

Results

Concentration of cadmium metal in used water and soil

Water used for the irrigation of plants was found to have 0.001 mg/l cadmium metal. Group A represents the control pots of soil to which no metal was added. The concentration of cadmium metal in the soil of group A (control) was 0.21 mg/kg. Different concentration of cadmium i.e. 100, 200, 300, 400, 500 ppm was added to the soil of group B, C, D, E and F. The total concentration of cadmium metal in each group of soil is shown in table 2.1.

Table 2.1. Concentration of cadmium metal in used soil.

Soil groups	Concentration of Cd (mg/kg)
Group (A)	0.21
Group (B)	100.21
Group (C)	200.21
Group (D)	300.21
Group (E)	400.21
Group (F)	500.21

Comparison of group A plants with group B, C, D, E and F plants

Plants of *zea mays* grown in control pots (group A) and experimental pots (B, C, D, E and F) were compared for the uptake of cadmium metal. The uptake of cadmium metal by different parts (Root, Stem and Leaves) of the plants are shown in figs. given below

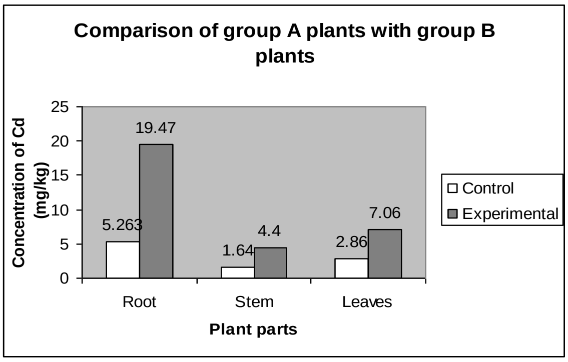

Fig. 2.1 (a). Comparison of group A plant with group B.

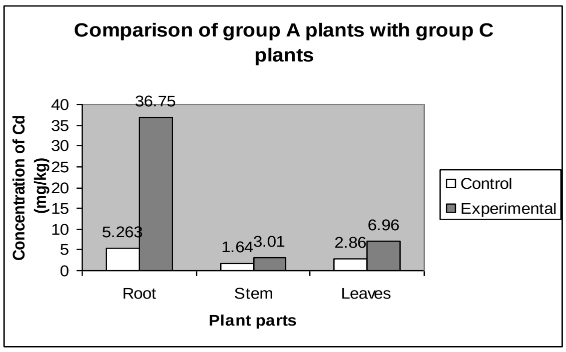

Fig. 2.1 (b). Comparison of group A plant with group C.

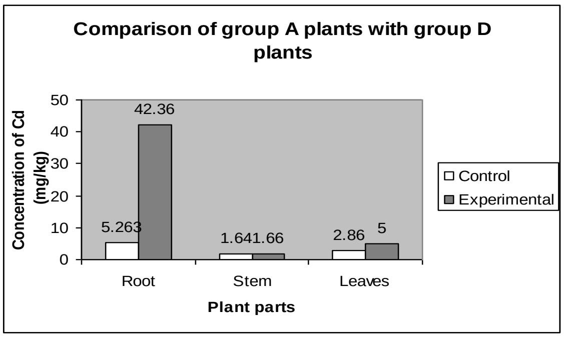

Fig. 2.1 (c). Comparison of group A plant with group D.

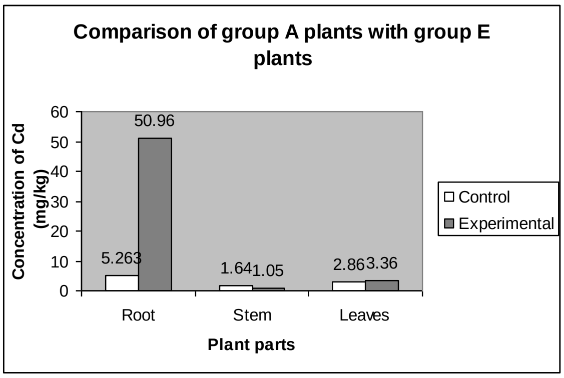

Fig. 2.1 (d). Comparison of group A plant with group E.

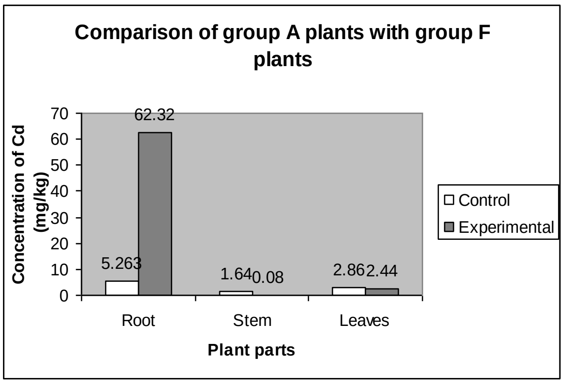

Fig. 2.1 (e). Comparison of group A plant with group F.

Bioconcentration factor (BCF) and translocation factor (TF)

Bioconcentration as well as translocation factor was calculated for the plant grown in control soil (Group A) and cadmium contaminated soil (Group B, C, D, E and F). There bioconcentration factor and translocation factor for cadmium metal is shown in table 2.3.

Table 2.3. Bioconcentration factor (BCF) and translocation factor (TF) of *zea mays* grown in different groups of soil.

Plant Groups	BCF	TF
Group (A)	25.06	0.423
Group (B)	0.196	0.294
Group (C)	0.183	0.176
Group (D)	0.141	0.078
Group (E)	0.127	0.043
Group (F)	0.124	0.040

Effects of cadmium on the germination, fresh and dry weight of Zea mays

The effects of different concentration of cadmium metal on the germination, fresh weight and dry weight of *Zea mays* are given in table 2.4.

Table 2.4. Effects of different concentration of cadmium on the germination, fresh and dry weight of *Zea mays.*

Soil group	Germination	Fresh weight (g)	Dry weight (g)
(A)	5 ± 0.00	356.1± 47.3994	212.8± 22.655
(B)	5 ± 0.00	332.1± 46.6180	210.4± 79.791
(C)	4.66± 0.57735	327.8± 17.4696	176.7± 24.445
(D)	4.33± 0.5773	325.8± 188.751	175± 32.458
(E)	3.66± 1.5275	253.66± 73.7656	162.3± 28.969
(F)	2.33± 1.5275	175.3± 76.0233	98± 33.281

Discussion

Concentration of Cadmium in used water and soil

The used water for the irrigation of Zea mays was analyzed for cadmium metal. It was found that irrigated water was having 0.001 ppm cadmium metal. Friberg *et al.,* (1986) stated that in unpolluted natural water the concentration of cadmium is usually below 0.001 mg/L. The present data of 0.001 ppm is very close to the value of Friberg *et al.,* (1986).

Table 2.1 data shows the concentration of cadmium metal in control and experimental soil. Soil of group B, C, D, E and F was having 100.21, 200.21, 300.21, 400.21 and 500.21 mg/kg concentration of cadmium metal respectively. The concentration of cadmium metal found in control soil (Group A) is 0.21 mg/kg. Friberg *et al.,* (1986) stated that the average concentration of cadmium in uncontaminated soil is from 0.1-0.5 mg/kg. The present soil analysis for cadmium of the control soil (group A) is very close to the figs. of Friberg *et al.,* (1986).

Uptake potential of the plants grown in control and experimental soil

It is clear from figs. 2.1(a) _2.1 (e) that the uptake potential of cadmium by *Zea mays* grown in control soil (group A) and experimental soil is different. The comparison of the uptake of cadmium by the roots of the control (group A) and experimental plants (group B) indicates that the uptake potential of the roots of the control plant (5.263 ppm) is lesser than that of the roots of the experimental plants (19.47 ppm).The uptake of cadmium by the stem of the control plants 1.64 ppm while that of the experimental plant (group B) is 4.4 ppm. Incase of leaves the uptake potential of the experimental plants (group B) is 7.08 ppm which is higher than that of the control plants2.86 ppm.

Fig. 2.1 (b) shows the comparison of bioaccumulation of cadmium by different parts of Zea mays grown in control and experimental soil (group c).It is clear from this fig. that the uptake of the root of the experimental plants (group c), 36.75 ppm is higher than that of the plants grown in control soil (group A) which is 5.263 ppm. The comparison of the stem of the control and experimental plants shows the same pattern, in the stem of the control plants (1.64 ppm) the concentration of cadmium is lower than that of the experimental plants (3.01 ppm) while the uptake potential of the experimental leaves (6.96 ppm) is greater than that of the leaves of the control plants which is 2.86ppm.

Fig. 2.1 (c) indicates the comparison of the uptake potential of cadmium by different parts of *Zea mays* grown in control soil and experimental soil (group D).The accumulation of cadmium by the roots of the plants grown in experimental soil (group D) is 42.36ppm which is higher than that of the roots of the control soil (5.263ppm). Comparison of the stem of the control plants and experimental plants (group D) shows that the uptake potential of stem is lower in control (1.64) than that of the experimental plants (group D) which is 1.66 ppm. Incase of leaves the uptake potential of the plants grown in experimental soil (5ppm) is higher than that of the leaves of the control plants (2.86ppm).

Fig. 2.1(d) data shows that the bioaccumulation of cadmium by the roots of experimental plants (group E), 50.96 ppm is higher than that of the roots of control plants (5.263 ppm) while incase of stem the concentration of cadmium of the experimental plants (group D), 1.05 ppm is lower than that of the control plants (1.64 ppm).The comparison of the leaves of the experimental and control plants shows that the concentration of cadmium is higher in the leaves of experimental plants (3.36ppm) than the leaves of the control plants (2.86 ppm).

Fig. 2.1 (e) shows the comparison of the uptake potential of cadmium by different parts of Zea mays grown in control soil and cadmium contaminated soil (group F).The uptake of cadmium by the roots of the experimental plants (group F) is 62.32 ppm which is higher than that of the roots of the control plants (5.263) while the concentration of cadmium of the stem of experimental plants (group F) is 0.08 ppm which is lower than that of the stem of the control plants (1.64 ppm). Incase of leaves the concentration of cadmium in control plants (2.86 ppm) is slightly greater than that of the experimental plants (group F) which 2.44 ppm is. Smical *et al.,* (2008), stated that different plant parts contain different quantities of heavy metals with the highest ones being contained in roots and leaves. This is because heavy metals are absorbed by roots from soil solution and later on translocated to leaves (through xylem vessels) where they are deposited in vacuoles. Our results agreed with the statement of Smical *et al.* (2008).

In both cases (control and experimental plants) the order of accumulation of cadmium by different parts of *zea mays* is in the order: Root > Leaves > Stem. Ali *et al.*, (2012) stated that this sequence is commonly observed for the accumulation of cadmium metals in plants.

Bioconcentration factor (BCF) and translocation factor (TF)

Table 2.3 data shows bioconcentration factor (BCF) and translocation factor (TF) of cadmium of *zea mays* grown in different groups of soil. Bioconcentration factor of *Zea mays* grown in control soil (0.21ppm) and cadmium contaminated soil, 100.21ppm (group B) , 200.21ppm(group C), 300.21ppm, (group D) 400.21ppm (group E) and 500.21ppm (group F) is 25.06, 0.196, 0.183, 0.141, 0.127 and 0.124 respectively, while their translocation factor is 0.423, 0.294, 0.176, 0.078, 0.043 and 0.040 respectively. Both BCF and TF of the plants decrease with increase in cadmium concentration. Plants grown in 0.21ppm contaminated soil showed bioconcentration factor greater than one, while translocation factor in all cases is less than one. (Sheoran *et al.*, 2011; Malik and Biswas, 2012: Ali *et al.*, (2013), stated that metal excluders accumulate heavy metals from substrate into their roots but limit their transport and entry into their shoots. Such plants have a low potential for metal extraction but may be efficient for phytostabilization purposes.

Effects of cadmium on the germination, fresh and dry weight of Zea mays

Table 2.4 shows the effects of different concentration of cadmium on the germination, fresh and dry weight of *Zea mays*. It is clear from this table that the mean valve of the germination of the seeds sown in control (group A) soil is 5 while the germination of the seeds in cadmium contaminated groups (B, C, D, E and F) of soil is 5, 4.66, 4.33, 3.66, and 2.33 respectively. Jadia *et al.*, (2008) stated that cadmium is the most toxic metal for seed germination. The present result shows that increase of cadmium concentration in soil decreases germination of the seeds of *Zea mays*. Our results are similar to the statement of Jadia *et al.*, (2008).

It is clear from table 2.4 that fresh and dry weight of the plants grown in control soil (group A) is 356.1 g and 212.8 g respectively while the fresh weight and dry weight of the plants grown in different concentration of cadmium contaminated groups (B, C, D, E and F) of soil is 332.1, 210.4; 327.8, 176.7; 325.8, 175; 253.66, 162.26 and 175.3, 98.3 g respectively. The comparison of the fresh weight and dry weight of the plants grown in control soil (group A) with the plants grown in different concentration of cadmium contaminated groups (B, C, D, E, and F) of soil shows that both fresh weight and dry weight of the plants decreases due to increase in the concentration of cadmium metal in the soil. Lozano-Rodriguez *et al.*, (1997) stated that the fresh and dry weight of *Zea mays* decreases with high concentration of cadmium in the soil. The present data shows similarity with the statement of Lozano-Rodriguez *et al.*, (1997).

Conclusion

It is concluded from the present research work that the concentration of cadmium metal in the used soil and water was 0.21 mg/kg and 0.001 mg/L respectively. When the seeds of Zea mays were sown in different concentration of cadmium contaminated soil, they highly effect seed germination of *Zea mays*. The accumulation of cadmium by the root of the plant grown in cadmium contaminated soil was higher than that of the plants grown in control soil while translocation of the accumulated metal from the root to the stem and leaves was found to decreases continuously due to increase in the concentration of cadmium in the soil. The fresh and dry weight as well as bioconcentration and translocation factor of *Zea mays* was found to decreases with an increase of cadmium concentration in the soil. *Zea mays* L. is a fast growing, deep rooted with high biomass producing plant species. Zea mays have a low potential for metal extraction but may be efficient for phytostabilization purposes because it can absorb sufficient amount of cadmium metal in their roots.

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