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The Potential of Corn *(Zea mays)* for Phytoremediation of Soil Contaminated with Cadmium and Lead

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ABSRACT

A study was carried out to investigate the potential of *Corn* (*Zea mays*) for phytoremediation of soil contaminated with Cadmium and Lead. Soil samplings of 0-20 cm depth were taken from the Chaharmahal Bakhtiari province in the western of Iran. *Corn* plantlets were planted in pots containing 3 kg of these soils. The experiment consisted of 9 treatments including soil without cadmium and Lead (T1), soil contaminated with 2 mg/kg concentration of cadmium (T2), soil contaminated with 4 mg/kg concentration of cadmium (T3), soil contaminated with 8 mg/kg concentration of cadmium (T4), soil contaminated with 16 mg/kg concentration of cadmium (T5), soil contaminated with 6 mg/kg concentration of Pb (T6), soil contaminated with 12 mg/kg concentration of Pb (T7), soil contaminated with 18 mg/kg concentration of Pb (T8) and soil contaminated with 24 mg/kg concentration of Pb (T9). Samples were taken for testing, after 60 days. Physical and chemical characteristics of soil such as soil texture, cation exchange capacity, pH, electrical conductivity, organic matter and extractable cadmium and lead were measured before and after the test. The evidences provided by this experiment indicated that *Corn* is an effective accumulator plant for phytoremediation of cadmium and lead polluted soils.

Key Words: Cadmium, *Corn*, Lead, Phytoremediation, Soil

INTRODUCTION

Heavy use of sewage sludge, compost, mining waste, chemical fertilizers and industrial development without control outputs, resulting accumulation of heavy metals in agricultural lands has been for many years remain in the soil (Alloway *et al.* 1991).

The increasing use of wide variety of heavy metals in industries and agriculture has caused a serious concern of environmental pollution (Sinhal *et al.* 2010).

Remediation of heavy metals polluted soil could be carried out using physico-chemicals processes such as ion-exchange, precipitation, reverse osmosis, evaporationand chemical reduction; however, the measures required external man-made resources and costly (Mangkoedihardjo and Surahmaida 2008). Phytoremediation is a viable, relatively low-cost approach to removing heavy metals from soil and groundwater (January 2006).

Phytoremediation is a developing technology that can potentially address the problems of contaminated agricultural land or more intensely polluted areas affected by urban or industrial activities. Three main strategies currently exist to phytoextract inorganic substances from soils using plants:(1) use of natural hyper accumulators; (2) enhancement of element uptake of high biomass species by chemical additions to soil and plants; and (3) phytovolatilization of elements, which often involves alteration of their chemical form within the plant prior to volatilization to the atmosphere (McGrath *et al.* 2002).

Phytoremediation is a promising new method that uses green plants to assimilate or detoxify metals and organic chemicals. The phytoremediation of metal-contaminated soils offers a low cost method for soil remediation and some extracted metals may be recycled for value (Chaney *et al.* 1997). Plants that accumulate metals to high concentrations are sometimes referred to as ‘‘hyperaccumulators’’ (Visoottiviseth *et al.* 2002).

Large areas of land contaminated with Cd were caused by anthropogenic activities such as mining and mineral processing of metallic ores, waste disposal, phosphate fertilizer application and wastewater irrigation. Soil Cd contamination is a great threat to human health since Cd is easily extracted by plants from the environment compared with other non-essential elements, and transferred to human food chain from the soils (Xiao *et al.* 2008). Cadmium is a ubiquitous non-essential element that possesses high toxicity and is easily accumulated from the environment by organisms (Rahimi and Nejatkhan 2010). Restoration of soils contaminated with potentially toxic metals and metalloids is of major global concern (Shelmerdine *et al.* 2009).

As public awareness of Pb contamination increases, so have the questions concerning the safety of areas such as playgrounds, homes, and gardens. The greatest human concern regarding the toxicity or accumulation of heavy metals is directed towards small children. Their bodies and central nervous systems are developing

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rapidly and any exposure to Pb, even blood levels as low as 10 µg/dL (0.1 ppm), can cause long-term health problems within many organ systems and mental and physical impairment (Succuro 2010).

Khodaverdi and Homai (2008) investigated modeling of phytoremediation of soil contaminated with Cadmium and Lead. Their results showed that the increasing soil contamination with Pb increased phytoremediation of Pb from soil by *Barbarea verna* and *Spinacia Oleracea* L. but increasing soil contamination with Cd did not change phytoremediation of cadmium from soil by *Barbarea verna* and *Spinacia Oleracea* L.

Cho-Ruk *et al.* (2006) investigated perennial plants in the phytoremediation of Lead-contaminated soils. Their results showed that *A.philaxeroides* had the ability to extract an approximately 1.3-1.8 times greater amount than *P. grandiflora* and *S. procumbens*.

In this study the potential of *Corn* (*Zea mays)* for phytoremediation of soil contaminated with Cadmium and Lead has been investigated.

MATERIALS AND METHODS

Site description, Sample preparation

The experiment was carried out at green house. Soil samplings of 0-20 cm depth were taken from Chaharmahal Bakhtiari province in the western of Iran. Soil samples were allowed to air dry in a green house at a temperature between 25ºC and 30ºC and were then ground to pass a 2-mm mesh sieve for prepared of soil samples (Makoi and Verplancke 2010) and *Corn* plantlets were planted in pots containing 3 kg of these soils. The experiment consisted of 9 treatments including soil without cadmium and Lead (T1), soil contaminated with 2 mg/kg concentration of cadmium (T2), soil contaminated with 4 mg/kg concentration of cadmium (T3), soil contaminated with 8 mg/kg concentration of cadmium (T4), soil contaminated with 16 mg/kg concentration of cadmium (T5), soil contaminated with 6 mg/kg concentration of Pb (T6), soil contaminated with 12 mg/kg concentration of Pb (T7), soil contaminated with 18 mg/kg concentration of Pb (T8) and soil contaminated with 24 mg/kg concentration of Pb (T9). Samples were taken for testing, after 60 days.

Laboratory determinations

Physical and chemical characteristics of soil such as soil texture, cation exchange capacity (CEC), soil reaction (pH), electrical conductivity (EC), organic matter (OM), extractable Cadmium and Lead were measured before and after the test. Soil texture was determined by the Bouyoucos hydrometer method (Gee and Bauder 1986). Soil pH and EC were measured on 1:1 extract (Soil:Water). Extractable Cadmium and Lead (Pb) in soil samples were carried out by DTPA in accordance the Standard Methods (APHA 1998). Soil OM was determined as in Walkley and Black and CEC was determined (ASA 1982).

Statistical analysis

Data will be analyzed using SPSS software. Comparison between the average levels treatments will be performed by Duncan's test.

RESULTS AND DISCUSSION

Soil properties before experiment, comparing the means of Cadmium treatments in soil, comparing the means of Cadmium treatments in *Corn*, comparing the means of Lead treatments in soil and comparing the means of Lead treatments in *Corn* are shown in Tables 1, 2, 3, 4 and 5, respectively.

Table 1. Soil properties before experiment

pH	EC (dSm^{-})	CEC (me/100g)	OM (%)	Clay (%)	Sand (%)	Silt (%)	Fe (ppm)	Cd (ppm)	Pb (ppm)
				Main Soil					
6.99	1.11	9.5	0.70	10.00	60.90	29.10	2.50	0	0

Phytoremediation of Cadmium

As known, the exchangeable form Cd is easily absorbed by plant. In the presence of vegetation, the exchangeable form Cd was partly removed by plant uptake that accompanied with the intake of nutrition (Zhang *et al.* 2009).

Cd-hyperaccumulating plant species, are almost the only ones that can grow in soil solutions containing Cd concentrations as high as 35 µmol/L (3.9 mg/L) (Brown et al., 1994; Xiao et al., 2008).

A possible explanation could be the exchangeable form Cd in planted soil was the predominant species for Cd uptake by plant (Zhang *et al.* 2009). Zhang *et al.* (2009) expressed: as the phytoextraction of Cd by maize, the percentage of exchangeable form Cd decreased in the planted soil. Besides, plant root exudates and rhizosphere microorganisms accelerated the stability process of added Cd in soils, which might make the exchangeable form transform to other relatively stable forms such as organic form and residual form and might help reduce the harm of Cd to soil and water environment.

Table 2. Comparing the means of Cd treatments in soil after 60 days

Parameter	**Treatments**				
	T1	T2	T3	T4	T5
Cd (ppm)	0.00a+	0.700b	1.857c	3.415d	14.25e

+ Row means followed by the same letter are not significantly different at 0.05 probability level

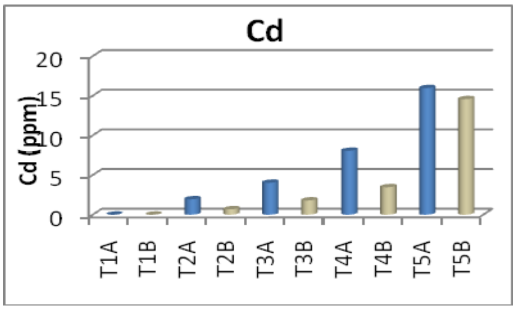

Figure 1. Changes of Cadmium in soil
T1, T2, T3, T4 and T5 are treatments 1, 2, 3, 4 and 5, respectively
A and B are soils before 60 days and after 60 days, respectively

Table 3. Comparing the means of Cd treatments in corn

Cd (ppm)	**Corn**	
	Root	**Shoot**
0 (T1)	0a+	0f
2 (T2)	5.1913b	1.3305g
4 (T3)	8.6906c	2.7917h
8 (T4)	15.4127d	3.5126i
16 (T5)	9.7215e	5.5304j

+ Row means followed by the same letter are not significantly different at 0.05 probability level

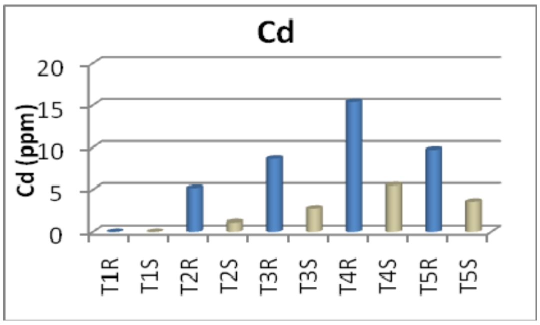

Figure 2. Changes of Cadmium in Corn
T1, T2, T3, T4 and T5 are treatments 1, 2, 3, 4 and 5, respectively
R and S are Root and Shoot, respectively

According to Tables 2, It was clear that the concentration of Cd significantly decreased in the planted soil after 60 days culture. Accumulation of cadmium in root is higher than in shoot, this showed that root of Corn is more active than shoot to phytoremediation of cadmium. This is in line with finding of Zhang *et al.* (2009) and Xiao *et al.* (2008).

Increasing soil contamination to 8 (ppm) increased phytoremediation of cadmium from soil by *Corn* but increasing soil contamination to 16 (ppm) decreased phytoremediation of cadmium from soil by *Corn*.

Phytoremediation of Lead

Water soluble and exchangeable lead are the only fractions readily available for uptake by plants. Oxyhydroxides, organic, carbonate, and precipitated forms of lead are the most strongly bound to the soil. The capacity of the soil to adsorb lead increases with increasing pH, cation exchange capacity (CEC), organic carbon content, soil/water Eh (redox potential) and phosphate levels. In the natural setting, lead hyperaccumulation has not been documented. However, certain plants have been identified which have the potential to uptake lead (Henry 2000).

Table 4. Comparing the means of Pb treatments in soil after 60 days

Parameter	**Treatments**				
	T1	T6	T7	T8	T9
Pb (ppm)	0.00a+	3.64b	7.23c	10.80d	14.17e

\+ Row means followed by the same letter are not significantly different at 0.05 probability level

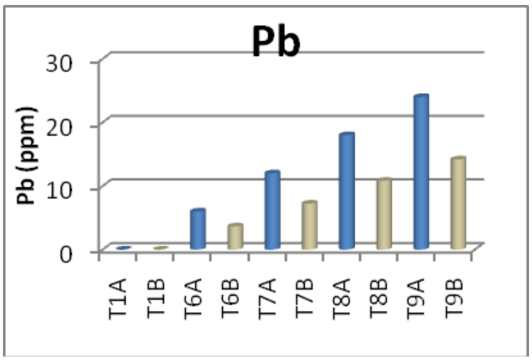

Figure 3. Changes of Lead in soil
T1, T2, T3, T4 and T5 are treatments 1, 6, 7, 8 and 9, respectively
A and B are soils before 60 days and after 60 days, respectively

Table 5. Comparing the means of Pb treatments in corn

Pb (ppm)	Corn	
	Root	**Shoot**
0 (T1)	0a+	0f
6 (T6)	4.9845b	1.3005g
12 (T7)	11.6056c	3.0317h
18 (T8)	16.3127d	5.4006i
24 (T9)	19.4015e	6.3124j

+ Row means followed by the same letter are not significantly different at 0.05 probability level

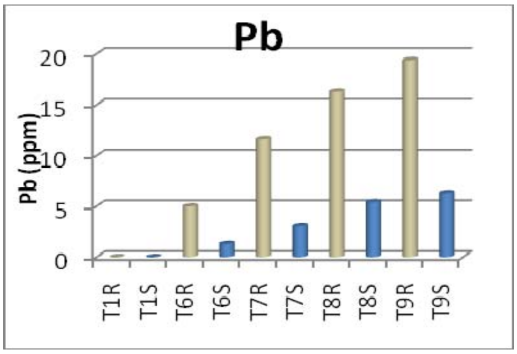

Figure 4. Changes of Lead in Corn
T1, T2, T3, T4 and T5 are treatments 1, 6, 7, 8 and 9, respectively
R and S are Root and Shoot, respectively

According to Tables 4, It was clear that the concentration of extractable Pb significantly decreased in the planted soil after 60 days culture. It was clear that the concentration of extractable Lead in soil under all treatments dercreased between 39.2-40.9%.

Accumulation of Pb in root is higher than in shoot, this showed that root of *Corn* is more active than shoot to phytoremediation of Lead. This is in line with findings of Parsadoost *et al.* (2008) and Cho-Ruk (2006).

CONCLUSIONS

The increasing use of wide variety of heavy metals in industries and agriculture has caused a serious concern of environmental pollution. Phytoremediation is a developing technology that can potentially address the problems of contaminated agricultural land or more intensely polluted areas affected by urban or industrial activities. *Corn* is an effective accumulator plant for phytoremediation of cadmium and lead polluted soils.

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