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Analyzing Populous Seedling Resistance towards Heavy Metal Contamination

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Abstract

Cadmium is an unnecessary and toxic element for plants which enters the soil through different human activities. Heavy elements such as cadmium produced by urban, industrial and agricultural main activities lead to the contamination of water resources. On the other hand, given the increasing need for afforestation in Iran, it is necessary to conduct a comprehensive research on fast-growing Populous species and the role of these plants in absorbing heavy metals, including cadmium. For this reason, using Populous seedlings in two control and contaminated areas, the accumulation rate of cadmium metal in the air and ground areas was tested. After the data collection, results were calculated using ANOVA test. The cadmium metal accumulation rate in the contaminated areas of the leave, stem and root is 86 mg/kg, 94 mg/kg and 67 mg/kg, respectively and also the amount of cadmium metal in soil in the depths of 0-10 cm and 10-20 cm is 43 mg/kg and 28 mg/kg, respectively. Based on the results obtained from the research, Populous is a species relatively suitable for the accumulation of cadmium in the contaminated soils.

Keywords: Populous; Heavy metals; Cadmium; Phytoremediation

Introduction

Currently, one of the basic challenges in the area of environment is the gradual increase in the concentration of heavy metals in the soil due to their non-decomposition by microorganisms. Due to having cytotoxic, carcinogenic and mutagenic potential effects, these types of metals impose serious risks on the health of humans and other living creatures (1). Cadmium is one of the heavy metals which naturally exists in the soil (2). The significance of cadmium among other toxic elements is because this element can be accumulated greatly in the plant organs, which is toxic for humans and animals, but there is no sign of toxicity present in the plant (3). The average biological half-life of cadmium is 18 years (4). Cadmium is absorbed through the root and leaf and is transferred to the livestock or humans, leading to the incidence of metabolic disorders. Cadmium has a severe synthetic desire to sulfhydryl and hydroxyl groups and ligands containing nitrogen. Thus, these elements deactivate many significant enzymes, leading to the disruption of photosynthesis, respiration and other metabolic processes in the plant (5). Although cadmium is not a necessary nutrient, it is easily absorbed through the plant roots and accumulated in the plant with concentrations which are dangerous for the food chain. The accumulation of cadmium in plant tissues at the cellular level can also be toxic and lead to the decrease in growth. Therefore, preventing the cadmium accumulation by plant roots can be an important strategy in minimizing the biological side effects of this element (6). Phytoremediation is one of the bioremediation methods in soils, which has been under the attention in recent decades. In this method, resistant plants are used for the purification of soils contaminated with organic and inorganic compounds. The advantages of this method compared to other methods include simplicity, low price and the possibility of widespread application. In this method, the plant selection is of particular importance. The plant selection depends on the climatic conditions and the contamination rate (7). The Populous tree can have a height up to 30 m and due to having white hairy leaves at the ground level and shiny bark, it is called Sepidar or Sefidar in Farsi (spruce or Populous). It is one of the native plants in Iran. The tree trunk bark is silvery and its branch bark is grayish or greenish white (8). In the study of changes in the metabolism of carbohydrates in *Populous nigra* L roots, Stobrawa and Plucinska concluded that heavy metals existing in the soil affected the metabolism of tree roots' carbohydrates. They suggested that there was a significant difference between the amount of glucose and fructose in the tree roots in the contaminated and uncontaminated areas. In addition, results show that when the amount of heavy metals in the soils increases, the concentration of galactose in the root will also increase (7). In their researches, they concluded that although cadmium was not a nutrient, it was easily absorbed through plant roots and accumulated in the plant with concentrations dangerous for the food chain. The accumulation of cadmium in the plant tissues at the cellular level can also be toxic and lead to the decrease in growth. Therefore, preventing the absorption of cadmium by plant roots can be an important strategy in minimizing the biological side effects of this element.

Materials and Methods

In this research, first, a group including 50 homogeneous Populous seedlings was selected from the margin of a metal manufacturing factory and 50 homogeneous Populous seedlings were also selected from the factory environment as the control group. In three stations of the factory environment, soil samples were collected from depths of 0-10 cm and 10-20 cm. The soil samples were dried under the air, crushed by a plastic hammer and passed through a 2-mm sieve. The soil collected from the sieve was used for chemical analyses. Some samples of the stem, leaf and root of the Populous species were collected. Then, they were dried in the oven under the temperature of 70˚C and were passed through a 2-mm sieve for analysis. After the samples digestion by the Atomic Absorption Spectrometer through the

dry digestion method, the amount of cadmium in the plant samples was checked. Data collected from the plant experiment were organized in SPSS software. For the data analysis, first, ANOVA test was administered to determine the metal accumulation rate in the plant's shoot and root.

Results

Study of the effect of cadmium metal on the leaves of populous seedlings

According to results of the ANOVA test, data collected from the study of the effect of cadmium metal on the leaves of Populous seedlings show that in the leaf feature, the significance level is lower than 5%; therefore, it is concluded that there is probably a significant 95% difference in the concentration rate of cadmium metal (Table 1).

Sig.	F	Mean Square	df	Type III Sum of Squares	Source
0.001*	2170.035	18523.18	1	18523.18	Treatments
-	-	5.447	48	161.416	Error
-	-	-	49	18684.596	Total

Table 1: The results of ANOVA test on the leaves of Populous seedlings in two control and contaminated concentrations. *significance at 95% level, ns= non-significant.

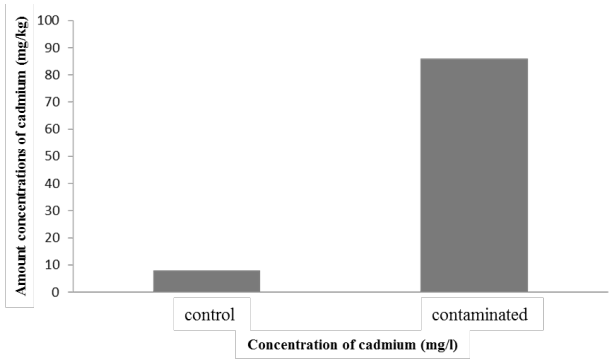

Figure 1: The accumulation rate of cadmium metal in leaves of Populous seedlings.

Study of the Effect of Cadmium Metal on the Stem of Populous seedlings

According to the results of the ANOVA test, data collected from the study of the effect of cadmium metal on the stem of Populous seedlings show that in the stem feature, the significance level is lower than 5%; therefore, it is concluded that there is probably a significant 95% difference in the concentration rate of cadmium metal (Table 2).

Sig.	F	Mean Square	df	Type III Sum of Squares	Source
0.000*	1935.043	16731.20	1	16731.20	Treatments
-	-	4.356	48	131.13	Error
-	-	-	49	16862.33	Total

Table 2: The results of ANOVA test on the stems of Populous seedlings in two control and contaminated concentrations. *significance at 95% level, ns=non-significant.

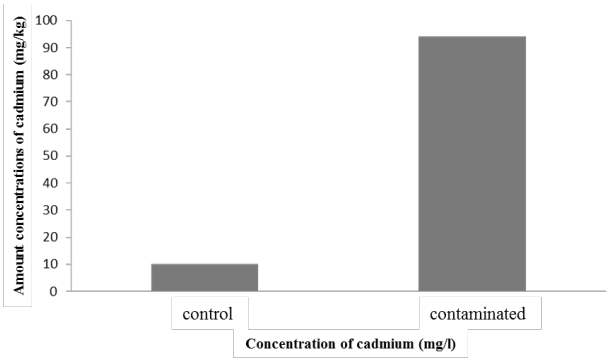

Figure 2: The accumulation rate of cadmium metal in stems of Populous seedlings.

Study of the effect of cadmium metal on the root of populous seedlings

According to the results of the ANOVA test, data collected from the study of the effect of cadmium metal on the root of Populous seedlings show that in the root feature, the significance level is lower than 5%; therefore, it is concluded that there is probably a significant 95% difference in the concentration rate of cadmium metal (Table 3).

Sig.	F	Mean Square	df	Type III Sum of Squares	Source
0.000*	1522.444	4975.903	1	4975.903	Treatments
		1.243	48	41.112	Error
			49	5017.015	Total

Table 3: The results of ANOVA test on the roots of Populous seedlings in two control and contaminated concentrations.

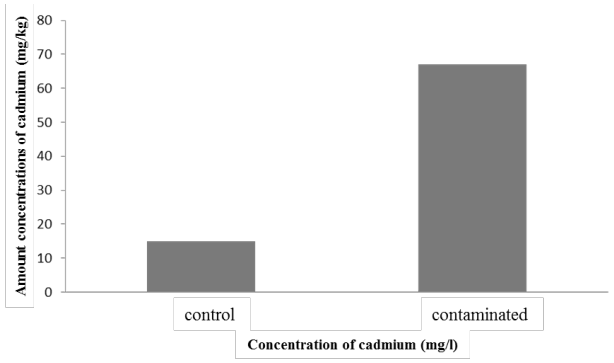

Figure 3: The accumulation rate of cadmium metal in of Populous seedlings.

Study of the effect of cadmium metal on the soil of populous seedlings

According to the results of the ANOVA test, data collected from the study of the effect of cadmium metal on the soil depth of 0-10 cm of Populous seedlings show that in the soil feature, the significance level is lower that 5%; therefore, it is concluded that there is probably a significant 95% difference in the concentration rate of cadmium metal (Table 4).

Sig.	F	Mean Square	df	Type III Sum of Squares	Source
0.002*	7563.320	997.860	1	997.860	Treatments
-	-	0.130	48	1.890	Error
-	-	-	49	999.75	Total

Table 4: The results of ANOVA test on the depth of soil 0-10 cm of Populous seedlings in two control and contaminated concentrations. *significance at 95% level, ns=non-significant.

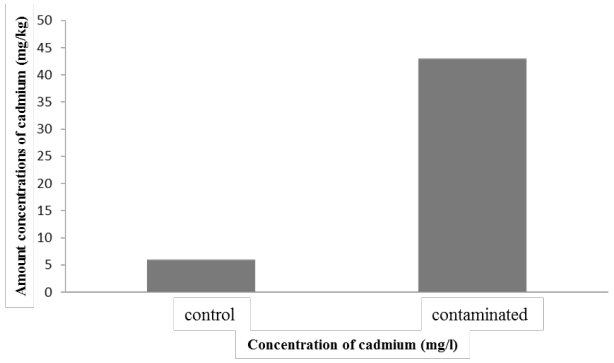

Figure 4: The accumulation rate of cadmium metal in Soil 0-10 cm of Populous seedlings.

According to the results of ANOVA test, data collected from the study of the effect of cadmium metal on the soil depth of 10-20 cm of Populous seedlings show that in the soil feature, the significance level is lower that 5%; therefore, it is concluded that there is probably a significant 95% difference in the concentration rate of cadmium metal (Table 5).

Sig.	F	Mean Square	df	Type III Sum of Squares	Source
0.011*	7321.560	974.650	1	974.650	Treatments
-	-	0.070	48	1.420	Error
-	-	-	49	976.07	Total

Table 5: The results of ANOVA test on the depth of soil 10-20 cm of Populous seedlings in two control and contaminated concentrations. *significance at 95% level, ns=non-significant.

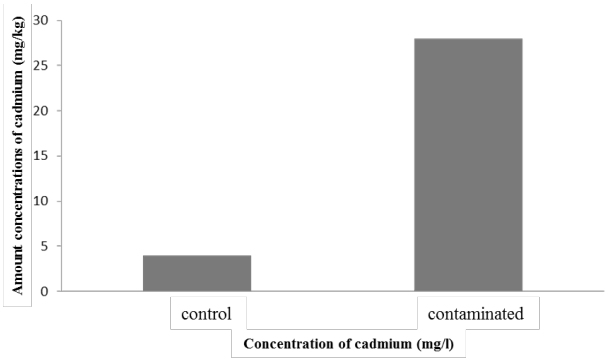

Figure 5: The accumulation rate of cadmium metal in Soil 10-20 cm of Populous seedlings.

Discussion and Conclusion

Results of the present research indicate that the leaves of Populous seedlings show a significant difference regarding the accumulation of cadmium metal in two treatment and control concentrations (Table 1). And with the increase of cadmium concentration in the soil, the accumulation rate of cadmium metal in the leaves of Populous seedlings will also increase (Figure 1). The results of the stem of Populous seedlings showed that with the accumulation of cadmium metal in two treatment and control concentrations, a significant difference was achieved (Table 2 and Figure 2). In his study under the title "The Effect of Cadmium on Some Physiological Parameters of Eucalyptus" and also by comparing the accumulation and transfer of cadmium in that study, Shariat (10) showed that the absorption of this metal in the root was more than that in the stem and leaf. Results of the study on the accumulation rate of cadmium metal in the root of Populous seedlings showed that in two treatment and control concentrations, the contamination was effective (Table 3 and Figure 3). In their researches, Kolelia et al. concluded that although cadmium was not a nutrient, it was easily absorbed through plant roots and accumulated in the plant with concentrations dangerous for the food chain. The cadmium accumulation in plant tissues at cellular level can also be toxic and lead to the decrease in growth. Thus, preventing the

cadmium accumulation by plant roots can be an important strategy in minimizing the biological side effects of this element. Results of the analysis of seedlings' soil in the depths of 0-10 cm and 10-20 cm showed that there was a significant difference (Figures 4 and 5). In this research, according to the results obtained, it can be concluded that Populous is a rather appropriate species for cadmium metal accumulation in the contaminated soils.

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