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The effects of manganese on the remediation of the heavy metal contaminated soil by using the dock (*Rumex patientia* L.) plant

Sevinç Adiloğlu

Namık Kemal University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Tekirdağ, Turkey, Tel. +90 2822501108, Fax +90 2822509929, email: sadiloglu@hotmail.com

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ABSTRACT

The heavy metal contamination has emerged as a critical pollution problem in agricultural soils in recent years. The studies on heavy metal contamination in soil have been conducted mainly on the sources and behaviors of the contaminants, their effects on public health, decontamination and analysis, improvement management and techniques, and the risk analysis. In recent studies, plants like *Vaccinium myrtillus Aesculus hippocastanum* L., *Silene vulgaris, Rumex patientia* L, *Thlaspi caerulescens, Althaea rosea, Solanum nigrum* L, *Hypericum amblysepalum*, and *Plantago lanceolata* have been identified to accumulate toxic heavy metals in their structure and to possess the ability of phytoremedation. The relationship between Cr, Cd, Pb and Mn in Dock (*Rumex patientia* L.) plant was investigated by using the phytoremediation method in heavy metal pollution soils. In a DTPA soil test, the Dock (*Rumex patientia* L.) plant by using some heavy metals was investigated with regard to the effects of manganese interactions with Ethylenediamine tetraacetic acid (EDTA) chelate. Some 100 mg / kg Cr, Cd, Pb were applied as heavy metals $Cr(NO_3)_3$, $Cd(NO_3)_3$ and $Pb(NO_3)_2$ were given in this formula to each pot. Four increasing EDTA doses (0, 5, 10, and 15 mmol/kg) were applied to the pots at the beginning of flowering of the Dock plant. The plants were harvested after a two-month development period. Variance analyses were done on heavy metals and Mn concentration in plant parts (root and shoot).

Keywords: Dock plant; Phytoremediation; Manganese; Heavy metal; Soil pollution

1. Introduction

The modern technology, being in a constant and continuous change and advancement, influences directly the agricultural activities. Some heavy metals, accumulated by aromatic and medical plants, do not have a negative effect on the amount and content of the secondary metabolites [1,2]. Many applications such as the excess of chemical and inorganic fertilizers, some hormones, soil regulators, pesticides, and the use of treatment sludge and waste water in irrigation are preferred in order to gain maximum yield from per unit area in agriculture. The increase in the amount of toxic heavy metal as a result of advancing industry and urbanization has become a threat to the ecosystem. In many industries, a great amount of various heavy metals such as uranium, cadmium, lead, chrome, cobalt, nickel, mercury, and copper is released. While investigating the soil pollution, it should never be forgotten that the soil cannot be reproduced and its replacement is impossible [3,4].

Many of the physico-chemical technologies that are used in soil treatment are completely destroying the biological activities in soil and are turning soil into a habitat impossible for the plant growth, whereas the phytoremediation method protects the biological characteristics of the soil and its physical structure [5].

The aim of this study is to identify the applicability of the Phytoextraction method in the region as one of the solutions to the pollution problem by using field experiment, which is one of the cheapest and the most efficient biological formulas to eliminate heavy metal pollution which affects the agricultural fields in the country in general and in Trakya region in particular. In this research, the increasing doses of EDTA and the Cd, Cr, Pb applications on uptake of Mn by the Dock (*Rumex patientia* L.) plant were investigated.

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2. Materials and methods

The experiment was done at Namık Kemal University under the research greenhouse conditions of the Faculty of Agriculture, by using "Completely Randomized Block" design with three replicates. The Dock (*Rumex patientia* L.) plant with some heavy metals was applied to investigate the effects of manganese interactions on the increasing Ethylenediamine tetraacetic acid (EDTA) chelate. In this respect, some 100 mg/kg Cd, Cr, Pb were applied as heavy metals $Cd(NO_3)_3$, $Cr(NO_3)_3$ and $Pb(NO_3)_2$ were given in this formula to each pot and then incubated for one month in the experimental pots. Afterwards, four increasing EDTA doses (0, 5, 10 and 15 mmol/kg) were applied to the pots at the beginning of flowering of the Dock plant. Plants were harvested after two months of the growing period. Variance analyses were done between heavy metals and Mn concentration in the root and shoot parts of the plant. The pots are shown in Fig. 1.

The dock (*Rumex patientia* L.) plant samples were harvested and then dried for 48 h at 68°C, [6]. The plant samples were digested by microwave own and Mn and heavy metal analysis was made by using ICP-OES (Inductively coupled plasma optical emission spectroscopy) instrument.

The pH value of the soil sample was determined according to [7], $CaCO_3$ content by using Scheibler calcimeter [8], and the organic matter amount was determined by Walkey-Black method [9]. The available phosphorus amount was determined according to Olsen method [10], the exchangeable K content analysis was conducted according to 1 N ammonium acetate (pH: 7) method [11], and the extractable Mn content analysis was made according to DTPA (diethylene triamine pentaacetic acid) method [12]. The texture of the soil sample was made according to Bouyoucos hydrometer method [13].

3. Results and discussion

The results of the experiment and the statistical relations between Mn and heavy metal of Dock plant are given in Tables 2–4. What have been determined are the increasing of EDTA doses and Cd, Cr and Pb contents of Dock (*Rumex patientia* L.) plant, and the interaction between these heavy metals and Mn contents of Dock (*Rumex patientia* L.) plant at the pot experiment. Some physical and chemical properties of the experimental area soil are given in Table 1.

According to the results of the pot experiment, Manganese contents of roots and shoots of plant increased with the increasing of EDTA application to the plants. These increases were found to be statistically significant at the level of 1 % (Tables 2–4). According to Table 2, in general, the highest Mn concentration was obtained in Cr application pots and the lowest Mn concentration was obtained in Pb application pots for shoot part of Dock plant.

According to Table 3, in general, the highest Mn concentration was obtained in Cr application pots and the lowest Mn concentration was obtained in Cd application pots for root part of the Dock plant.

Heavy metal concentration of Dock (*Rumex patientia* L.) plant increased with EDTA application. Chromium concen-

Table 1
Some physical and chemical properties of the experimental area soil

Soil properties	Value
pH	7.95
Electrical conductivity, mS/cm	0.01
Texture class	Clay
Organic matter content, %	0.14
$CaCO_3$ amount, %	6.03
P_2O_5 amount, kg/da	12.50
K_2O amount, kg/da	497.03
Mn content, mg/kg	15.39
Cr*, mg/kg	0.05
Cd*, mg/kg	0.02
Pb*, mg/kg	0.98
Cr** , mg/kg	26.56
Cd**, mg/kg	5.78
Pb**, mg/kg	37.98

*:initial, **:after contamination

Fig. 1. A view of the Dock (*Rumex patientia* L.) plant pot during the experiment.

Table 2
Mean values and interactions of the significance of EDTA applications on the Mn and Cr, Cd, Pb accumulation of the dock shoots (mg/kg) [a]

Heavy metal	EDTA, mmol /kg			
	0	5	10	15
Cr × Mn	806.747 f	850.813 c	946.310 c	824.593 a
Cd × Mn	654.907 e	674.033 ı	923.623 h	838.140 b
Pb × Mn	554.077 d	626.373 k	650.500 j	771.923 g
$LSD_{(P\leq 0.01)}$	Heavy metal: 1.812	EDTA: 2.832	Heavy metal × EDTA: 4.9049	

[a]The mean values of the three replications and of the root and shoot were evaluated individually.

Table 3
Mean values and interactions of the significance of EDTA applications on the Mn and Cr, Cd, Pb accumulation of the dock roots (mg/kg) [a]

Heavy metal	EDTA, mmol/kg			
	0	5	10	15
Cr × Mn	256.533 d	265.600 c	273.967 b	356.867 a
Cd × Mn	109.167 l	113.067 k	131.367 j	226.667 g
Pb × Mn	196.011 c	194.089 d	216.889 b	278.089 a
$LSD_{(P\leq 0.01)}$	Heavy metal: 2.500	EDTA:1.134	Heavy metal × EDTA:1.9633	

[a]The values mean of three replications and root and shoot were evaluated individually.

Table 4
Manganese (Mn) interactions with the results of analysis of variance

SV	d_f	Shoots			Roots		
		SS	MS	F Value	SS	MS	F Value
Heavy metal (A)	2	258414.69	129207.34	39286.08**	124528.14	62264.07	9944.13**
Eror-1	6	19.73	3.28		37.56	6.26	
EDTA (E)	3	168148.75	56049.58	6855.36**	41619.64	13873.21	10590.98**
A × E	6	92502.35	15417.05	1885.64**	9410.38	1568.39	1197.33**
Eror	18	147.16	8.17		23.57	1.31	
General	35	519232.70	14835.22		175619.31	5017.69	

**: Significant at 1%. SV: Source of variation, d_f: Degrees of freedom, SS: Sum of squares, MS: Mean of squares.

tration of plant (root + shoot) is of 38.38 and 318.12 mg/kg for 0 and 15 mmol/kg EDTA applications, respectively. Cadmium and lead concentrations in plant (root + shoot) are of 4.17, 84.64 mg/kg and 32.05, 220.58 mg/kg for 0 and 15 mmol/kg EDTA application, respectively. Similar results were earlier obtained by other researchers [14–16].

4. Conclusion

Trakya Region and Tekirdağ province have become migration receiving places in recent years with their geography, socio-economic condition and industrial establishments. The industrial and population density causes many problems, among which biological, physical, and chemical pollution in various environmental components such as soil, air, and water.

This aspect necessitates methods of removing heavy metals such as Pb, Cd and Cr which mix with soil as a result of natural and human activities and have a limited movement ability by using chelator (EDTA) and Dock (*Rumex patientia* L.) – a hiperacumulator plant – to increase their mobility.

This experiment result is predictable, because the application of chelates such as EDTA increases the dissolubility of some heavy metals in soil and their absorption by plants. Increasing heavy metal absorption hinders the use of some basic nutrient elements by which the dry matter yield of plants decreases dramatically. At the end of this experiment, the amounts of Cr, Cd and Pb heavy metals which are removed from soil by the plant increased with the increasing EDTA doses applications. On the other hand, Mn, Cd, Cr and Pb contents of root and shoot of plant increased with

EDTA application to the soils. Interactions between Mn and Cr, Cd, Pb contents of plant were found statistically significant at the level of 1%.

As a result, simple and cheap methods (such as the Phytoremediation method) which help to remove the Cr, Cd and Pb from soil by increasing their mobility are gaining more significance day by day with regard to the agricultural lands of Trakya Region.

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