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Interaction Between Cadmium and Lead and the Effects of These on the Concentration of Zinc and Manganese in Sunflower

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ABSTRACT: The pollution of soil by heavy metals is considered to be quite a big problem in many areas of the world. To limit the accumulation of lead and cadmium from soil in the products, a correct understanding of the characteristics and specifications of the translocation of cadmium and lead is necessary. In order to evaluate the effects of cadmium and lead interaction on zinc and manganese concentration, three levels of cadmium (0, 100 and 200 mg/kg), and three levels of lead (0, 200 and 400mg/kg) were tested on a sunflower cultivar SHF81-85 in a factorial experimental design with three replications. The results showed that cadmium has increased the cadmium and lead concentration in the shoot and root, while the effects of lead, were only significant on the concentration of lead in the shoot, and the concentration of both cadmium and lead in the root ($p<0.05$). Cadmium and lead revealed a preventing effect on zinc and manganese concentration in the root and shoot of the plant. More investigations at field conditions are recommended.

Key word: Cadmium, Lead, Soil pollution, Manganese, Sunflower

INTRODUCTION

Cadmium and lead are considered as environmental hazards, as they are toxic for human being and other organisms (Wang *et al.*, 2006; Ekmekyapar *et al.*, 2012; Ghaderi *et al.*, 2012). Although, cadmium and lead aren't necessary elements for plant, the plants absorb these elements from soil and concentrate them on different edible organs. These elements are not only toxic for human, but their concentration and absorption in plant organs also causes toxicity (Florijn and Van-Beusichem, 1993; Li *et al.*, 1995). Controlling of the input of heavy metals to the plant, especially plant's edible organs, is very important in order to make sure of the food's health. A study of several researches in the field of the effects of heavy metals on the absorption of toxic and nutrient elements in plants shows that many researches have been done in this field. But, in comparison to one-element researches, fewer investigations have been performed in field of the interaction of heavy metals in plant (Wong *et al.*, 1986; An *et al.*, 2004). Mostly, chemical pollutions are found in the form of combinations and mixtures of some contaminants in the environment and in between soil pollution is a multi-elements problem in many areas, which are caused by heavy metals (An *et al.*, 2004). Some studies about heavy metals interaction effects are performed at some species of plants. Joint effects of cadmium, copper, nickel and zinc in alfalfa, increase of lead and zinc toxicity associated with each other at mangrove plant and joint effects of cadmium, copper, lead and zinc have been reported (Luo and Rimmer, 1995; Macfarlan and Murchett, 2002; Peralta-Videa *et al.*, 2002). At lands of industries area, many soils have polluted as a result of high concentration of heavy metals, that, this case has prevented the performance of agricultural natural operations (Nasrabadi *et al.*, 2009; Divis *et al.*, 2012; Okuku and Peter, 2012). One of important problem is the interaction of these elements on each other. The meaning of interaction between cadmium and lead is that, at presence of both elements at soil, lead and cadmium may increase the absorption of other element or other metals by plant, therefore, in this condition danger of metal toxicity for animals and human increases (Madyiwa *et al.*, 2004). Many researchers have reported that, increase in concentration of cadmium and lead at soil or culture medium can decrease the plant's yield (Lieten and Rober, 19997; Zheljazkov and Nielsen, 1996; Zheljazkov and Warman, 2004a,b). Effect of each metal of cadmium and lead on other's absorption by plants is reported, when there are a lot of both at soil and if this effect, decreases metal absorption by plant, these plants could accumulates heavy metals. Accumulation's ability, with kind of plant's species, concentration and kind of heavy

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metal was different. In this study, cd_{20}+ pb $_{200}$ treatment has tested and the effect of prevention at cd or pb accumulation was considered, when different species were uses. Researcher reported that, by highest rate of concentration which is used, maximum heavy metal concentration at plant tissues are viewed which this result was comparable with the report of others (Zhi-Xin *et al.,* 2007; Lu and He, 2005). These researchers mentioned that at soils containing 10-40 mg/kg cadmium in soil, *Ricinus communis* L. can accumulate cadmium in its tissues (Lu and He, 2005). Growth of this plant at higher concentration more than 40 mg/kg cadmium in soil decreased and the highest level of accumulation (4460.3 mg/kg) at concentration of 360 mg/kg happened not in 400 mg/kg, it means high concentration of cadmium has affected on metabolism of *Ricinus communis* L. So has decreased accumulation ability. In one experiment, the presence of one ion could reduce the absorption of another ion in a hydroponics culture medium (Zhi-Xin *et al.,* 2007). This result was comparable with the report of (Mohan and Hosetti, 1997). These researchers found that cadmium toxic ion had a preventing effect on absorption of other heavy metals (Pb and Cu) by root in greenhouse experiment; otherwise, researchers reported that at wheat cultivation 5 mg/kg of cadmium in soil, caused lead accumulation increase (Lin *et al*., 2000). At a study, different numbers ability of water- Spinach (*Ipomoea aquatica* Fork.) in absorption and translocation of cadmium and lead at seven soil treatments was evaluated, which contained different lead and cadmium (Xin *et al*., 2010). Existence effects of interaction between these elements caused their accumulation at shoots plant. In condition of cadmium and lead treatments with average concentration (Pb_{DTPA}= 27.6, Cd_{DTPA}= 0.32 mg/kg), lead treatment caused more, cadmium accumulation. Although, at treatment containing more lead (Pb_{DTPA}= 83.6 mg/kg-) accumulation of both cadmium and lead were limited. Translocation Factors (TF) of cadmium equal 202-474 were from lead which shows translocation of lead from soil to shoots of spinach is so low. The same result was reported by Liu *et al* (2003), that existence of lead at soil caused an increase at cadmium absorption of rice.

Totally, because we face the existence of some metal together in nature which a positive and negative interaction on absorption of foodstuffs and Plant's growth, So, this research with goals of (1) study of lead and cadmium heavy metals effect on availability of these elements in soil and (2) effect of relations between cadmium and lead to their absorption and translocation and micronutrients zinc and manganese in sunflower plant at greenhouse conditions, performed.

MATERIALS & METHODS

In order to do this research, first, suitable soil without pollution, provided from Campus of Agriculture and Natural Research, University of Tehran Located in Karaj. After, soil preparation for physical and chemical analysis, it's physical and chemical characteristics were defined based on current procedures and Lab. Standards (Table 1). To determine soil materials from hydrometric method (Bouyoucos, 1962), total nitrogen by kjeltek method (Bremner, 1996), available phosphorus by Olsen method (Kuo, 1996), available Potassium by normal ammonium acetate (Hemke and Sparks, 1996), cation exchange capacity by Bower method (Sumner and Milker, 1996), pH at saturated extract (Thomas, 1996), Electrical conductivity by Rhodes method (Rhodes, 1996), organic carbon percentage by Walkly and Black method (Nelson and Sommers, 1982), concentration of heavy metals such as cadmium, lead, zinc and manganese were measured through DTPA extraction by Atomic Absorption Spectrometry (Lindsay and Norvell, 1978). Treatments contains: three levels of cadmium from cadmium nitrate $Cd(NO_3)_2$, $4H_2O$: control (Cd_0), Cd_{100} and Cd_{200} mg/kg and three levels of lead from lead nitrate $Pb(NO_3)_2$, control (Pb_0), Pb_{200}, Pb_{400} mg/kg associated with interaction effects of lead and cadmium in form of factorial experiment with a Randomized Complete Block Design (RCBD) in three replications in greenhouse conditions.

After, disinfection and germination of sunflower seed Var.SHF 81-85, the number of 4 seeds in each pot planted, which at 4 leaves Phase reduced to two bushes in each pot. Pots watering, during growth period was done by distilled water and nutrient elements which were necessary for plant were provided by use of urea fertilizer and potassium sulfate according to the results of soil test. After 70 days at beginning of reproductive period, shoot and root of sunflower cut and concentration of heavy metals, were measured at plant's extract. Data variance analysis by SAS and a comparison of means was done with Sigma plat software.

RESULTS & DISCUSSION

According to provided results at Table 2 & 3, cadmium use showed a significant effect on cadmium concentration in root and shoot of sunflower. Also, use of lead at soil, had a significant effect on concentration of lead in sunflower's shoot ($P<0.01$). Lead treatment on concentration of zinc showed a significant effect but cadmium treatment didn't show significant effect (Table 2 and 3).

Table 1. Physical and chemical properties of the soil used in greenhouse study

Characteristics	Value	Characteristics	Value
Clay	26.00	CEC ($Cmol_{(c)}/kg$)	11.70
Silt	35.00	Total N (%)	0.082
Sand	39.00	Available P (mg/kg)	17.30
Soil texture	Loam	Available K (mg/kg)	167/00
pH	8.20	Fe (mg/kg) *	4.81
EC(dS/m)	1.45	Cu(mg/kg)*	1.43
%T.N.V	7.90	Mn(mg/kg)*	12.22
%OC	0.73	Zn(mg/kg)*	1.14
SP	37.50	Pb(mg/kg)*	1.12
HCO_3^-(meq/l)	5.80	Cd(mg/kg)*	0.12

* DTPA Extractable

Table 2. Results of ANOVA for effects of experimental treatments on root properties

		Cd		Pb		Zn		Mn	
Source of variation	DF	MS	F	MS	F	MS	F	MS	F
Cadmium	2	858598.93**	195.41	1357.57 ns	0.22	338.19 ns	1.83	1357.57 ns	0.22
Lead	2	4160.78 ns	0.95	4695.19 ns	0.76	956.23*	5.19	4695.19 ns	0.76
Cadmium×Lead	4	19949.44*	4.54	22275.87**	3.62	417.05 ns	2.26	22275.87**	3.62
Error	18	4393.82		6157.51		184.35		6157.51	

**, * and ns are significant at 1% and 5% levels and non significant, respectively.

Table 3. Results of ANOVA for effects of experimental treatments on shoot properties

		Cd		Pb		Zn		Mn	
Source of variation	DF	MS	F	MS	F	MS	F	MS	F
Cadmium	2	11401.87**	92.87	204.09 ns	2.06	369.32**	32.24	2892.06**	6.57
Lead	2	227.37 ns	1.85	3703.92**	37.35	20.67 ns	1.80	1251.77 ns	2.84
Cadmium×Lead	4	146.04 ns	1.19	58.48 ns	0.59	144.47**	12.61	408.49 ns	0.93
Error	18	122.78		99.17		11.46		440.13	

**, * and ns are significant at 1% and 5% levels and non significant, respectively.

Lead and cadmium interaction on manganese concentration in root and shoot was also significant. Evaluation of results for each different level of lead and cadmium on concentration of this element in root and shoot are provided at Table 4. So, the highest level of cadmium of root and shoot was seen in treatments accompanied by use of cadmium and lead, together. Although, the highest level of lead concentration in root was reported in treatments: Cd100Pb200 and Cd0Pb400, respectively with rate Cd 389.33 and 388.33 mg lead in kilogram of dry mater of plant. Also, the highest level of lead concentration in shoot was seen in treatment with use of lead and cadmium together (Table 4). These results show that, there are differences in lead and cadmium absorption and their translocation to shoot. In one hand, so much level of cadmium than lead are accumulated in plant's root, which specifies the high absorption and ability of dissolution of cadmium in equal concentration by plant. On the other hand, considerable rates of cadmium were moved to the shoot (Table 4; Fig. 1). Although, mostly lead accumulated in plant's root, but it's translocation to shoot was done too (Table 4; Fig. 2). The results of this research are comparable with, other foundlings

(Zhi-Xin *et al.*, 2007). This researcher reported that, the highest used concentration caused maximum accumulation of heavy metal in plant's matter. Also, the results of this section were in harmony with (Xin *et al.*, 2010; Liu *et al.*, 2003; Zheljazkov *et al.*, 2006). In recent research, it was reported that, mostly lead accumulated in root and its translocation to shoot become limited. In treatments with use of cadmium and lead, resulted toxicity at plant and its absorption of elements increased in a significant manner. In such a way that maximum accumulation contained two elements and a kind of positive interaction or synergistic effects in relation with these two heavy metals was seen. In order to confirm results of this research, we can rely on the other reports (Wong *et al.*, 1986; Lu and He, 2005; Lin *et al.*, 2000). According to provided results in fig. 3 and 4, use of cadmium and lead treatments, to some extent manganese concentration in root, shoot is an indicator of king of negative interaction between zinc and cadmium and also lead and zinc, including that in high toxicities of both elements, accumulation of zinc is considered in root, which can be received as defensive mechanism, so, its translocation from root to shoot became limited (Fig. 5 & 6).

Table 4. The mean of Cd and Pb in root and shoot in different treatments of cadmium and lead

		Root		Shoot	
Cadmium Treatments(mg/kg)	Lead Treatments(mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
0	0	0.10 [c]	0.50 [d]	0.10 [c]	0.50 [b]
0	200	0.10 [c]	218.00 [bc]	0.10 [c]	34.67 [a]
0	400	0.10 [c]	388.33 [a]	0.10 [c]	39.83 [a]
100	0	375.67 [b]	0.50 [d]	36.67 [b]	0.50 [b]
100	200	537.00 [a]	135.67 [cd]	53.00 [ab]	21.30 [ab]
100	400	367.33 [b]	389.33 [a]	36.33 [b]	32.57 [a]
200	0	681.00 [a]	0.47 [d]	78.00 [a]	0.47 [b]
200	200	534.33 [a]	182.00 [bc]	74.00 [a]	37.00 [a]
200	400	585.67 [a]	327.00 [ab]	60.67 [ab]	44.33 [a]
LSD		155.8	154.9	26.04	23.40

* Means followed by the same letter do not differ significantly from one another (p = 0.01)

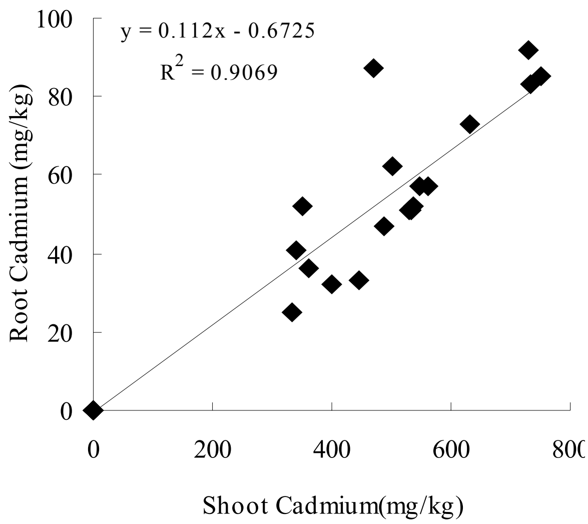

Fig. 1. Correlation between root and shoot cadmium

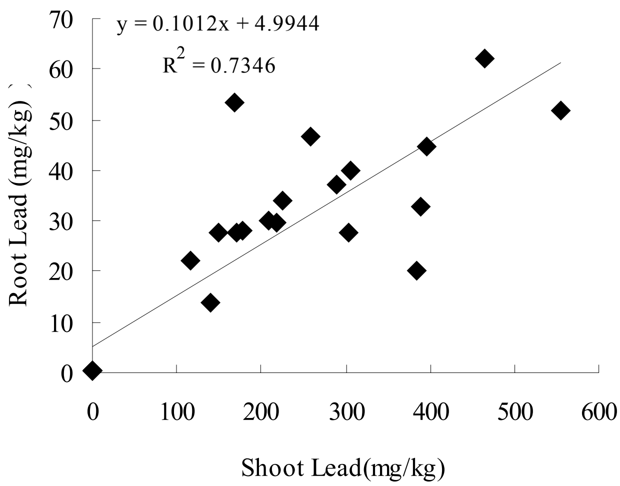

Fig. 2. Correlation between root and shoot Lead

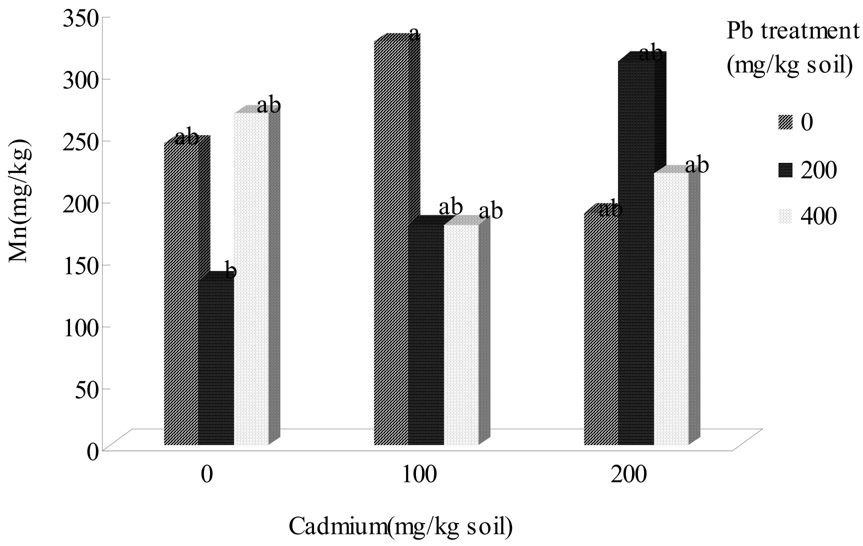

Fig. 3. Mn Concentration in root under different treatments

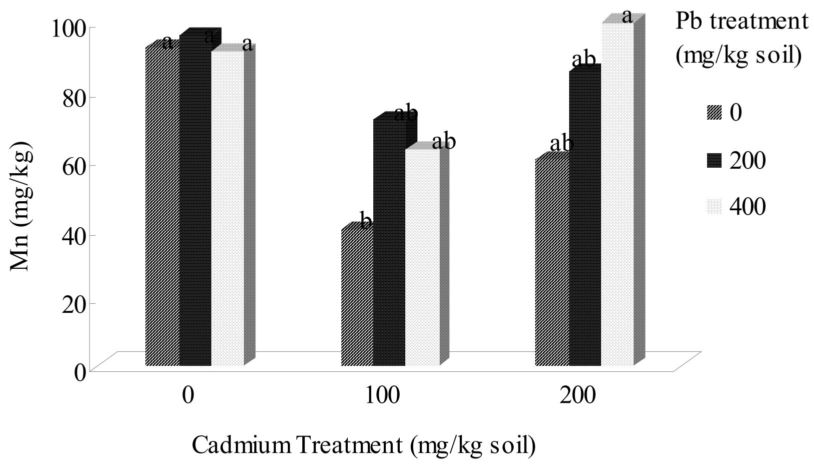

Fig. 4. Mn Concentration in shoot under different treatments

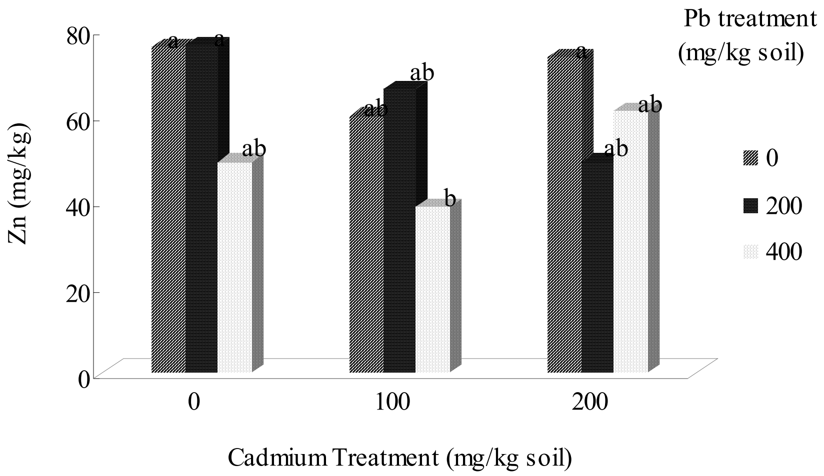

Fig. 5. Zn Concentration in root under different treatments

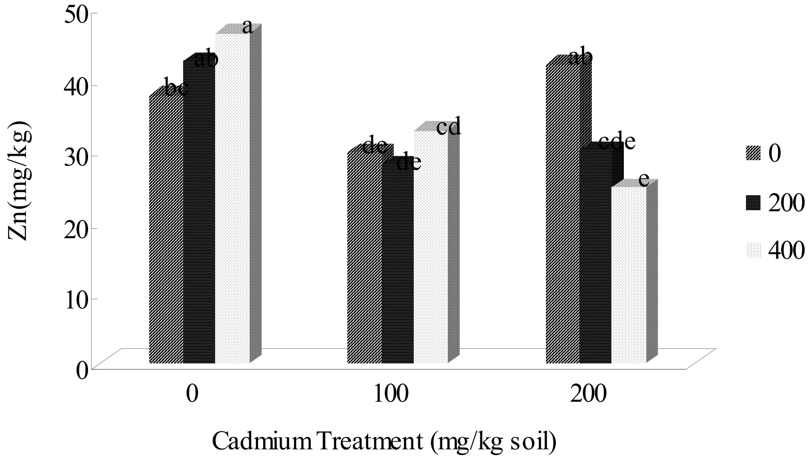

Fig. 6. Zn Concentration in shoot under different treatments

Researchers have reported that at cotton seed, interaction between zinc and cadmium at the same concentrations could prevail on cadmium toxicity (Chakravarty and Srivastava, 1997). Researchers by research of cadmium absorption and its interaction with nutrient element of manganese in lettuce reported that number of this plant has high ability to absorb and transfer cadmium to the edible organ even without confession of toxicity signs of cadmium (Ramos *et al.,* 2002). In this research, increase of manganese concentration in shoot was observed, after apply of cadmium treatment, but concentration of other micronutrients, such as iron, copper and zinc decreased, greatly.

In a study announced that, by evaluation of effects of lead, cadmium and copper interaction to absorb metals and growth of plant *Brassica chinensis*, among treatments which are used: (Pb+Cd) (Pb+Cu), and (Cd+Cu), combining treatment (Cd+Cu) showed the highest toxicity for the plant (Wong *et al*., 1986). Effects of positive interaction between lead and cadmium were reported. Also, there weren't any interaction effect between lead and copper.

CONCLUSION

Generally, the results of this research have shown the presence of synergistic effects between cadmium and lead at greenhouse conditions that were studied. Including the importance of this interaction was considered according to the usage point of view at land's remediate and also, from agriculture point of view and its toxicity for plant and translocation to the food chain. Specially, the effect of these elements on absorption and/or lack of absorption of nutrient's elements are an important subject. To know more about mechanisms and relations between toxic elements with each other and also with micronutrients needs researches development in this section and at soil and regional different conditions. Researches' in perpetuity numbers of each plant's species in this field are suggested.

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