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Original Article

The content of nickel, chromium and copper in some plants from polluted and control sites

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ABSTRACT
Heavy metals are some of the most pollutants in urban areas due to vehicle, industry, waste disposal and other human activities. The purpose of this study was to evaluate concentrations of nickel, chromium and copper in leaf and root of pine, cypress, plantain and ash from three sites (heavy traffic, moderate traffic and control) in Isfahan, Iran, differentially impacted by pollution. Heavy traffic (Azadi St) and control sites (Sabahi St) had the highest and lowest amount of nickel and copper concentrations, respectively in all studied species. Moderate traffic site (Ahmadabad St) had the highest concentrations of Cr in leaf and root. The highest correlation coefficients between traits were related to Cu in leaf vs. Ni in leaf and Cu in root vs. Ni in root indicating positive influence of leaf and root to absorb these metals from soil, water and air. The order of heavy metal concentration (mg/kg) in plants leaves and roots were found in as follows: Cu>Ni >Cr. The higher Cu, Ni and Cr contents in leaves rather than in roots in all studied sites illustrated a contribution of significant atmospheric deposition. The best accumulator plant species for Ni, Cr and Cu from polluted sites was *Pinus eldarica* Medw.

KEYWORDS: Air pollution; correlation coefficient; heavy metals.

INTRODUCTION

Pollution of the biosphere with toxic metals has accelerated significantly by industrial revolution (Swaminathan, 2003). Environmental pollution with heavy metals is belonged to human activities such as mining, smelting, electroplating, energy and fuel production, power transmission, intensive agriculture, sludge dumping and melting operations (Igwe and Abia, 2006). Heavy metals are mainly important due to their harmful effects on plants, especially those on vegetative and generative parts of the plants (Ekatarina and Jeliazkova, 2001). Traffic emissions on roads are the main cause of heavy metal accumulation in the surrounding environment and plant species (Scerbo et al., 2002). Recently, scientists have started to generate cost-effective technologies that include the use of biomass and live plants in the cleaning process of pollutants (Ebbs and Kochian, 1997; Dushenkov et al., 1997). Several studies have been conducted to investigate the effects of different heavy metals concentrations of live plants (Gajewska et al., 2006; Pandey and Sharma, 2002).
Cu, Cr, Ni and Zn may be toxic to plants at high concentration (McLaughlin et al., 1999). The concentration causing toxicity varies with the type of ion, plant, and conditions of growth (Hirschi et al., 2000). In one research, the metal uptake capacity of the root of *Quercus ilex* L. (holly oak) for different metals was found to be in the order: Ni>Cd>Pb>Cu>Cr and leaf Ni>Cd>Cu>Pb>Cr. The highest amount adsorbed was Ni (root>leaf). Cr exhibited the least adsorption values for all the three types of phytomass compared to other metals (Prasad and Freitas, 2000). In another research, Kord and Kord (2011) showed that the highest and lowest metal concentrations were found in the heavy traffic and control sites, respectively. The industrial part of the city was characterized by high Zn, Cr and Ni contents. Oklo and Asemave (2013) reported that the studied plants contain more of Fe and Pb, moderate amount of Zn, Co, Ni, and Cu and low concentration of Cd. Areas of higher population density appeared to have higher concentrations of the metals than the low population density area.
The aim of the present study was to determine the content of Ni, Cr and Cu in leaf and root of *Pinus eldarica* Medw., *Cupressus aruzonica*,

Platanus orientalis and *Fraxinus excelsior* species under various polluted sites in Isfahan city and to investigate relations between contents of these metals.

MATERIALS AND METHODS

Isfahan has an elevation of around 1570 m above sea level at latitude (32º 39′N) and longitude (51º 39′E). Minimum temperature is 3.7 ºC in January and maximum temperature is 28.9 ºC in August. The average annual precipitation in the investigated area is 120 mm/y. Relative humidity during daytime is relatively high ranging from 30% in July to 91% in December. Four plant species including pine (*Pinus Eldarica* Medw.), cypress (*Cupressus arizonica* Greene.), plantain (*Platanus orientalis*) and ash (*Fraxinus excelsior*) were chosen in polluted and control sites and Ni in leaf, Cr in leaf, Cu in leaf, Ni in root, Cr in root and Cu in root traits were studied in spring. The city suffered from high traffic density caused by vehicles. The average number of vehicle movements per hour in polluted sites (Azadi St and Ahmadabad St) and control site (Sabahi St) of the study area are 540, 338 and 128, respectively.

The plants were dug from the earth as a whole, so as not to damage the root system and in this form transported to the laboratory where the roots were separated from the leaves. Both roots and leaves of plants were thoroughly washed in deionized water with a small addition of non-ionic detergent, then rinsed several times (also with deionized water) to the disappearance of foam. Washed plants were placed on sheets of blotting paper for pre-drying and placed in an oven at 70 °C for 48 h. The samples (1 g) were digested with concentrated HNO3 in a microwave system. Heavy metal concentrations were measured by the flame atomic absorption spectrophotometer, Perkin-Elmer AAS analysis 300 model, with three replicates. Used metal standards were provided from Merck, Germany.

Data were tested for skewness, kurtosis and normality by Minitab (1998) statistical software. Then, analysis of variance in a factorial experiment based on CRD and comparison of the traits means based on Duncan’s Multiple Range Test (DMRT) were performed in SAS (2001) and MSTAT-C (1990) softwares. Excel 2007 software was used for drawing of figures. For simple correlation analysis, a matrix of simple correlation coefficients among the traits were computed (Snedecor and Cochran, 1981).

RESULT AND DISCUSSION

Analysis of variance of the studied traits showed that there were high significant differences ($p<0.01$) among the species (Table 1) indicating the presence of high genetic variability for the traits.

Table 1. Analysis of variance (ANOVA) of the traits in studied species

		Mean square (MS)					
SOV	df	Ni in leaf	Ni in root	Cr in leaf	Cr in root	Cu in leaf	Cu in root
Species	3	4.81 **	0.26 **	0.29 **	0.04 **	7.79 **	2.50 **
Site	2	4.77 **	0.44 **	0.16 **	0.04 **	4.31 **	1.80 **
Species×Site	6	0.09 *	0.03 **	0.007 *	0.005 **	0.13 *	0.07 *
Error	60	0.04	0.01	0.003	0.001	0.05	0.03
CV%		14.39	10.44	15.42	21.09	11.52	15.66

ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively.
SOV: Source of variation, df: degree of freedom, Ni: Nickel, Cr: Cromium, Cu: Copper.

Results of means comparison showed that *Pinus Eldarica* Medw. species had the highest concentrations of Ni, Cr and Cu in leaf (1.91, 0.46 and 2.62 ppm, respectively) and *Fraxinus excelsior* species had the lowest concentrations of Ni, Cr and Cu in leaf (0.69, 0.16 and 1.06 ppm, respectively) (Fig. 1, 3 and 5, respectively). On the other hand, the highest concentrations of Ni, Cr and Cu in root were belonged to *Fraxinus excelsior* species (0.95, 0.22 and 1.45 ppm, respectively) and the lowest concentrations of Ni, Cr and Cu in root were related to *Cupressus arizonica* Greene. species (0.71, 0.12 and 0.7 ppm, respectively) (Fig. 2, 4 and 6, respectively).

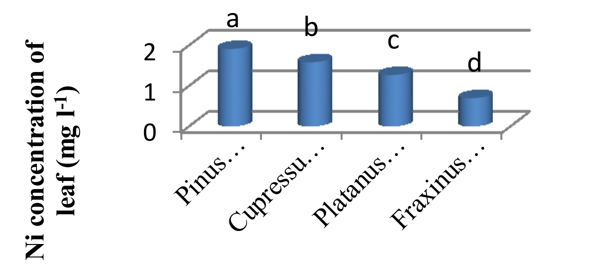

Fig. 1. Ni concentrations of leaf in the studied species

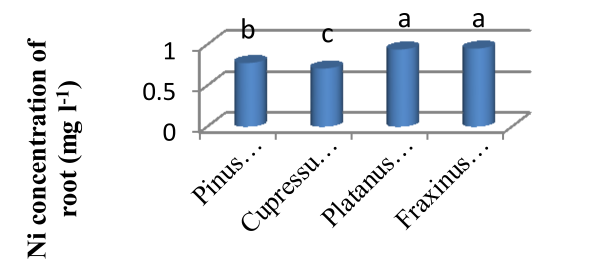

Fig. 2. Ni concentrations of root in the studied species

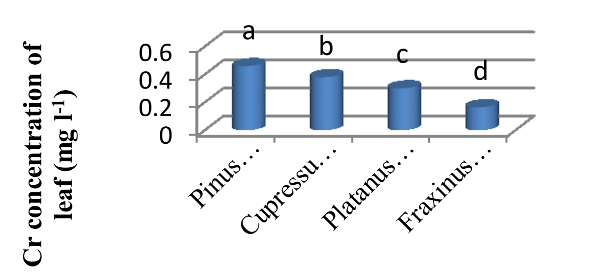

Fig. 3. Cr concentrations of leaf in the studied species

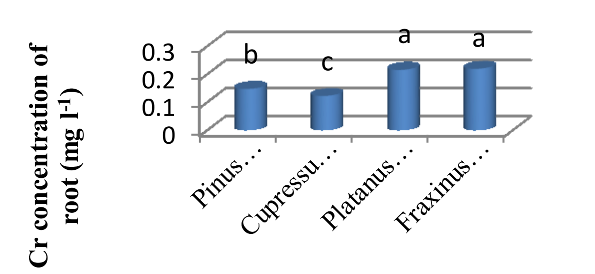

Fig. 4. Cr concentrations of root in the studied species

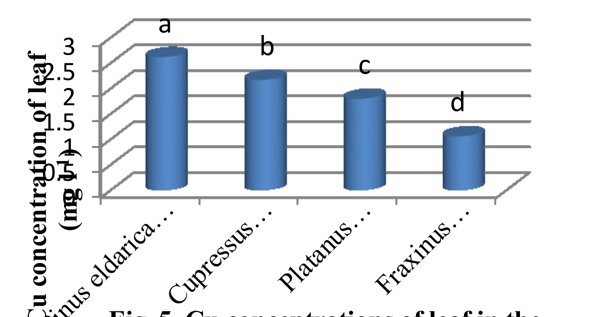

Fig. 5. Cu concentrations of leaf in the studied species

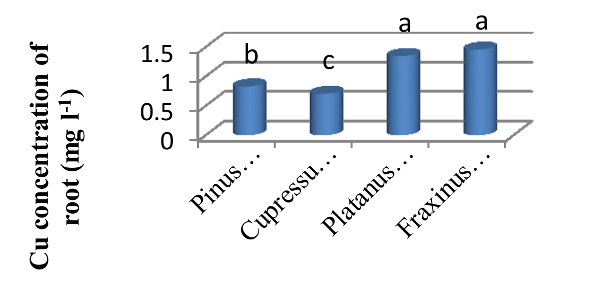

Fig. 6. Cu concentrations of root in the studied species

There were significant differences between sites for the studied traits, indicating presence of different concentration (mg l^{-1}) of heavy metals in various sites (Table 1). Heavy traffic site (Azadi St) had the highest concentrations of Ni and Cu in leaf (1.84 and 2.40 ppm, respectively) and root (0.98 and 1.39 ppm, respectively), whereas moderate traffic site (Ahmadabad St) had the highest concentrations of Cr in leaf and root (0.42 and 0.22 ppm, respectively) (Table 2). On the other hand, the lowest concentrations of Ni in leaf and root were related to control site (Sabahi St) and the lowest concentrations of Cr in leaf and root were belonged to heavy traffic site (0.27 and 0.15 ppm, respectively) (Table 2). The mean metal concentration values were arranged in the following order: Cu > Ni > Cr. Analysis of trees roots and leaves could be used for differentiating between atmospheric pollutants and soil contaminants. The results indicated that concentrations of Ni, Cr and Cu were usually high in the leaves as compared with roots which may be due to high concentration of heavy metals in air than in soil. The same results were found by Zhanyuan et al., (2012) and Ligocki et al., (2011) for Ni, Cr and Cu.

Table 2. Heavy metal contents of four various species collected from different sites in Isfahan city

Treatment		Ni in leaf (mg l^{-1})	Ni in root (mg l^{-1})	Cr in leaf (mg l^{-1})	Cr in root (mg l^{-1})	Cu in leaf (mg l^{-1})	Cu in root (mg l^{-1})
	S_1	1.84 a	0.98 a	0.27 b	0.15 b	2.40 a	1.39 a
Site	S_2	1.27 b	0.84 b	0.42 a	0.22 a	1.64 b	0.87 c
	S_3	0.97 c	0.70 c	0.29 b	0.16 b	1.70 b	0.98 b
	$Sp_1 \times S_1$	2.51 a	0.85 cd	0.37 c	0.12 de	3.30 a	1.07 cd
	$Sp_1 \times S_2$	1.74 c	0.75 def	0.57 a	0.17 bc	2.23 c	0.66 f
	$Sp_1 \times S_3$	1.47 d	0.72 efg	0.44 b	0.16 cd	2.33 c	0.75 ef
	$Sp_2 \times S_1$	2.08 b	0.82 de	0.30 d	0.01 e	2.73 b	0.88 de

species×site interaction	$Sp_2 \times S_2$	1.44 de	0.68 fg	0.47 b	0.15 cd	1.84 de	0.60 f
	$Sp_2 \times S_3$	1.22 ef	0.62 g	0.37 c	0.12 de	1.93 d	0.62 f
	$Sp_3 \times S_1$	1.81 c	1.1 a	0.25 de	0.19 bc	2.22 c	1.72 a
	$Sp_3 \times S_2$	1.17 fg	0.95 bc	0.41 bc	0.28 a	1.61 ef	1.09 c
	$Sp_3 \times S_3$	0.81 hi	0.75 def	0.24 de	0.18 bc	1.57 f	1.22 bc
	$Sp_4 \times S_1$	0.98 gh	1.12 a	0.15 f	0.21 b	1.36 f	1.89 a
	$Sp_4 \times S_2$	0.72 i	0.99 b	0.23 e	0.29 a	0.88 g	1.13 bc
	$Sp_4 \times S_3$	0.38 j	0.72 efg	0.11 f	0.16 cd	0.96 g	1.33 b

Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's Multiple Range Test.

S_1: Azadi St (heavy traffic), S_2: Ahmadabad St (Moderate traffic), S_3: Sabahi St (Control), Sp_1: *Pinus Eldarica* Medw., Sp_2: *Cupressus arizonica* Greene., Sp_3: *Platanus orientalis*, Sp_4: *Fraxinus excelsior*.

Interaction effects of species×site on all studied traits were significant, indicating the presence of significant differences in Ni, Cr and Cu concentrations of leaf and root in all the species samples collected from different sites (Table 1). *Pinus eldarica* Medw. species in Azadi St had the highest concentrations of Ni and Cu in leaf (2.51 and 3.30 ppm, respectively) and *Fraxinus excelsior* species in Sabahi St and Ahmadabad St had the lowest concentrations of Ni and Cu in leaf (0.38 and 0.88 ppm, respectively) (Table 2). The highest concentrations of Cr in leaf were belonged to *Pinus eldarica* Medw. species in Ahmadabad St and the lowest concentrations of Cr in leaf were related to *Fraxinus excelsior* species in Sabahi St and Azadi St (0.11 and 0.15 ppm, respectively) (Fig. 2).

Fraxinus excelsior and *Platanus orientalis* species in Azadi St had the highest concentrations of Ni in root (1.12 and 1.1 ppm, respectively) and Cu in root (1.89 and 1.72 ppm, respectively) and *Cupressus aruzonica* species in Sabahi St had the lowest concentrations of Ni in root (0.62 ppm) (Table 2). *Cupressus aruzonica* species in Ahmadabad St and Sabahi St and *Pinus eldarica* Medw. species in Ahmadabad St had the lowest concentrations of Cu in root (0.60, 0.62 and 0.66 ppm, respectively) (Table 2). The highest concentrations of Cr in root were belonged to *Fraxinus excelsior* and *Platanus orientalis* species in Ahmadabad St (0.29 and 0.28 ppm, respectively) and the lowest concentrations of Cr in root were related to *Cupressus arizonica* Greene. species in Azadi St (0.01 ppm) (Table 2). So, *Pinus eldarica* Medw. species can be used to decrease air pollution in Isfahan city.

Correlation analysis described interaction between the traits (Table 3). There are high significant correlation coefficients between most of the studied traits (Table 3). The highest correlation coefficients between traits were related to Cu in leaf vs. Ni in leaf and Cu in root vs. Ni in root ($r = 0.94$ and $r = 0.82$, respectively). This indicated that leaf and root had positive influence to absorb Cu and Ni from soil, water and air.

Table 3. Correlation coefficients of metal concentration in leaf and root of four various species

Trait	Ni in leaf	Ni in root	Cr in leaf	Cr in root	Cu in leaf	Cu in root
Ni in leaf	-					
Ni in root	0.12^{ns}	-				
Cr in leaf	0.55^{**}	-0.29^{*}	-			
Cr in root	-0.31^{**}	0.63^{**}	0.01^{ns}	-		
Cu in leaf	0.94^{**}	-0.07^{ns}	0.53^{**}	-0.43^{**}	-	
Cu in root	-0.15^{ns}	0.82^{**}	-0.59^{**}	0.46^{**}	-0.19^{ns}	-

ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively.

Nickel plays an essential role in metabolic processes of higher plants (Ahmad and Erum, 2010). However, Ni concentration is increasing in certain areas by human activities such as mining works, emission of smelters, burning of coal and oil, sewage, phosphate fertilizers and pesticides (Gimeno-Garcia et al., 1996). The values of nickel in the studied species were quite high as compared to national environmental quality standard range i.e. 1-5 mg/kg (Ahmad and Erum, 2010). In this study, the level of Nickel in all studied species decreases with decreased traffic density (Table 2).

Copper is an essential heavy metal for higher plants (Mahmood and Islam 2006; Chatterjee et al. 2006). Plants absorb Cu from the soil most often through the roots, but the intensive absorbtion also occurs through aerial parts of plants (Rossini Oliva and Mingorance, 2006). Cu is a main component of various proteins like plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron transport chain (Demirevska-kepova et al. 2004). But enhanced industrial activities have increased occurrence of Cu in ecosystems (Nagajyoti et al., 2010). Compared to toxic Cu concentrations (>20 mg/kg) for aerial parts of the plants (Rademacher, 2001; Nouri *et al.*, 2009), the obtained concentrations in leaves of all the species were much higher. The obtained copper concentrations in heavy traffic site were higher than in the other sites (Table 2).

Chromium is considered as a serious environmental pollutant, due to wide industrial use (Shanker et al., 2005). Chromium compounds are highly toxic to plants and are detrimental to their growth and development (Aslam et al., 2012). Cr does not play any role in plant metabolism (Dixit et al., 2002). The toxic range of Cr in plants is 0.5-2 mg/kg (Clemente et al., 2007). In this research, the control site had the moderate level of Chromium in leaf and root of all plant species indicating that vehicle traffic is a minor emission source for Chromium and it is possible to be another Chromium source around, such as industrial activities.

CONCLUSION

The results showed that heavy traffic and control sites had the highest and lowest nickel and copper concentrations, respectively. Cu in leaf vs. Ni in leaf and Cu in root vs. Ni in root had the highest correlation coefficient among traits indicating positive influence of leaf and root to absorb Cu and Ni from soil, water and air. According to our findings the order of heavy metals in plants leaves and roots were found in as follows: Cu > Ni > Cr, indicating high level of environmental pollution with Cu. For biomonitoring of environmental pollution with Cu, Ni and Cr, the studied species leaves were better bioindicators than roots which may be due to high concentration of heavy metals in air than in soil. Based on the results, the best accumulator plant species for Ni, Cr and Cu was *Pinus eldarica* Medw. We suggest this species, as an effective metal accumulator, for monitoring of heavy metals from polluted sites in Isfahan city.

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