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DETERMINATION OF SOME HEAVY METALS AND MINERAL NUTRIENTS OF BAY TREE (*LAURUS NOBILIS* L.) IN BARTIN CITY, TURKEY

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Abstract

Concentrations of Al, Cd, Cu, Ni, and Pb in *Laurus nobilis* L. were examined for assessment of the impact of heavy metal exposure during winter periods, since these metals have the highest toxic potential. In this study, leaf (washed and unwashed), bark and branch samples of *L. nobilis* and soil samples were collected from 13 different localities, belonged to three stations. In conjunction with analyzing impact of the heavy metal exposure on the city using *L. nobilis* as a biomonitoring tool, the uptake and composition of mineral nutrients of *L. nobilis* were also investigated for determining the effects of heavy metals on mineral nutrition metabolism of the plant. The heavy metal and mineral nutrient concentrations of the collected samples were measured by using ICP-OES. The obtained data was analyzed with SPSS statistics program. As a result of measurements, the lowest and highest heavy metal accumulations and the amount of mineral nutrients measured in plants were as follows; Al (14.69-122.44 mg/kg d. wt), Cd (0.23-0.89 mg/kg d. wt), Cu (1.64-14.25 mg/kg d. wt.), Ni (0.001-0.45 mg/kg d. wt.), Pb (2.06-5.28 mg/kg d. wt.) and B (1.04-6.67 mg/kg d. wt.), Ca (1195.34-4919.03 mg/kg d. wt.), Fe (17.13-203.25 mg/kg d. wt.), K (538.99-3778.37 mg/kg d. wt.), Mg(48.1-268.5 mg/kg d. wt.), Na (24.91-77.43 mg/kg d. wt.) and Zn (4.75-15.74 mg/kg d. wt.). According to the experimental data, the volume of the air pollution was analyzed and found significant in the city. Also, it was noticed that the metabolism of mineral nutrients of *L. nobilis* was altered by heavy metals. Finally, it was proved that *L. nobilis* is a suitable organism to be used as a biomonitoring tool for conducting research on heavy metal pollution.

Introduction

The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet Earth. Air pollution can have serious consequences for the health of human beings, and also severely affects natural ecosystems (Badora, 2002; Maynard, 2004; Demir *et al*., 2010). High concentrations of suspended particulates adversely affect human health, provoking a wide range of respiratory diseases and exacerbating heart disease and other conditions (Goldberg *et al*., 2001; Iram *et al*., 2009; Bauer *et al*., 2010). The sources of air pollution are both natural and human-based. Air pollution is usually concentrated in densely populated metropolitan areas. The two main sources of pollutants in urban areas are transportation and fuel combustion in stationary sources, including residential, commercial, and industrial heating and cooling and coal-burning power plants (Qin & Chan, 1993; Bouhamra & Abdul-Wahab, 1999; Pirzada *et al*., 2009).

Bartin is a small city, which is located in the north-west part of Turkey (41° 53' N, 32° 45' E), on the Black Sea Coast. Bartin has approximately 2,143 km^2 land area and the altitude of the city center is 25 m. The city is divided into 4 administrative districts (Fig. 1) (Anon., 2011a). Bartin is a growing city and its population is 187,758 in total and 52,470 in the city center (Tuikapp, 2010).

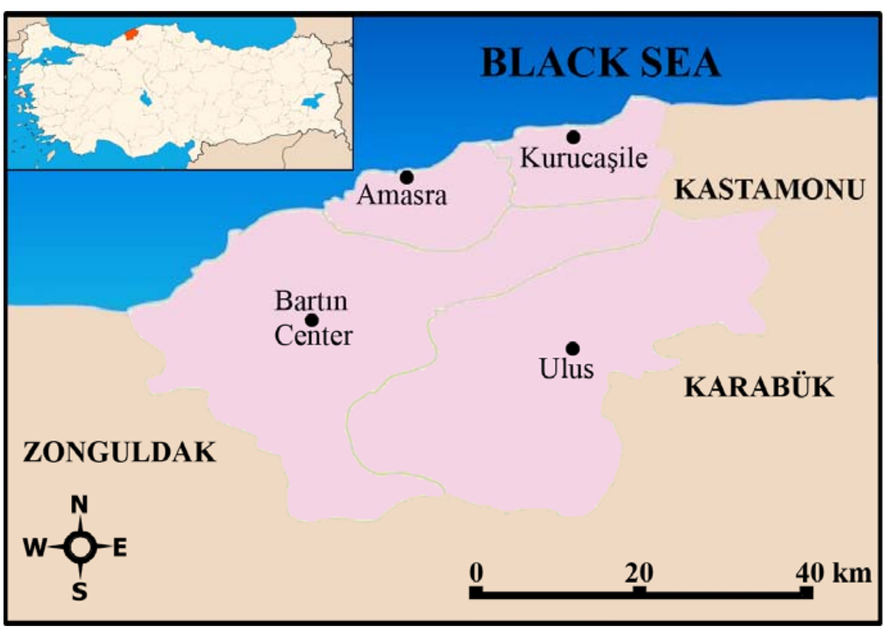


Fig. 1. Bartin Province, its administrative districts and location in Turkey.

Bartin has a typical Black Sea (oceanic) climate. Summers are warm and humid, and the average maximum temperature is around 23°C in July. Winters are cool and damp, and the lowest average minimum temperature is around 4.2°C in December. The total precipitation for Bartin averages 1,000 mm^3. The ratio of relative humidity is 80% in the city (Anon., 2011b).

Because of rapid urbanization and industrial development with growing population, Bartin has suffered serious problems related with pollution. The impact of the pollution on the city is getting worse day by day, especially during winter periods because of the utilization of low quality fuel and improper combustion techniques, industrial facilities and traffic. It is now apparent that the city struggles with air pollution.

An approximation of the damage done by the pollution may be discovered by using a biomonitoring technique. The term biomonitor is defined as an organism that provides quantitative information on the quality of the environment around it (Yilmaz et al., 2006; Yasar & Ozyigit, 2009). Therefore, *L. nobilis* was chosen as study material for biomonitoring approach in this study. Because this evergreen plant has some properties such as; being able to accumulate heavy metals and a widely distributed in the area. In conjunction with the estimation of pollution volume, the possible differences in the absorption, accumulation and utilization of mineral nutrients were also examined in *L. nobilis* for estimating of the impact of heavy exposure on mineral nutrition metabolism of *L. nobilis*.

Materials and Methods

I. Botanical characteristics of *Laurus nobilis* L.: Aromatic evergreen shrub or tree, 2-15 m; dioecious. Leaves 3-10 (11) x 2-4 (5) cm, narrowly oblong-lanceolate to broadly ovate, acute or acuminate, somewhat wavy-margined, coriaceous. Male flowers with 8-12 stamens, filaments with stipitate glands near base. Female flowers often with 4 staminodes. Fruit 10-12 (20) mm, globular to ellipsoid, black. Flowers March-May. Coastal macchie, dense bushes mixed with *Myrtus*, *Phillyrea* and *Erica arborea*, scattered as underwood in *Pinus brutia* forest, rocky slopes, damp gorges, ancient settlements; naturalized and cultivated for ornament, sea level-1200 m (Davis, 1982).

L. nobilis is distributed especially North, Central, South Anatolia and Islands in Turkey and S. Europe (mainly E.), N.W. Africa, Cyrenaica, W. Syria, Crimea; often subspontaneous in W. Mediterranean. Medit. element. Variable in shape and size of leaves and form of fruits. Specimens from N. Anatolia have oblonglanceolate leaves and globular fruits, while in S. Anatolia examples with broadly ovate leaves and ellipsoid fruits occur, mainly in humid and shady habitats. Leaf variants with conspicuously wavy margins have been recognized by some authors as var. undulata Reichb (Davis, 1982).

Lauraceae family member bay tree (*L. nobilis*) is widely cultivated as an ornamental plant in regions with Mediterranean climates. Evergreen plant *L. nobilis* is used as a medicinal and aromatic plant. It is commonly known as Bay, Sweet Bay, Laurel, Turkish Laurel and Roman Laurel, and called "defne" in Turkish (Kumar *et al*., 2004; Malti & Amorouch, 2009). Laurel leaves are used in the flavor and fragrance industry like spice and soap (Bruneton, 1995). The fruits and aromatic leaves of the bay tree are also used in perfumery and oil production (Kumar *et al*., 2004).

II. Methods: The plant and soil samples were collected from different parts of Bartin during 14th and 15th of January 2011 (Fig. 2). Bark samples were taken from main stem, about 1 m high from the soil. Soil samples also were collected from a deep of about 10 cm with a stainless steel shovel. In total, 13 plant and soil samples were labeled and packed into the polyethylene bags (Alam *et al.,* 2003).

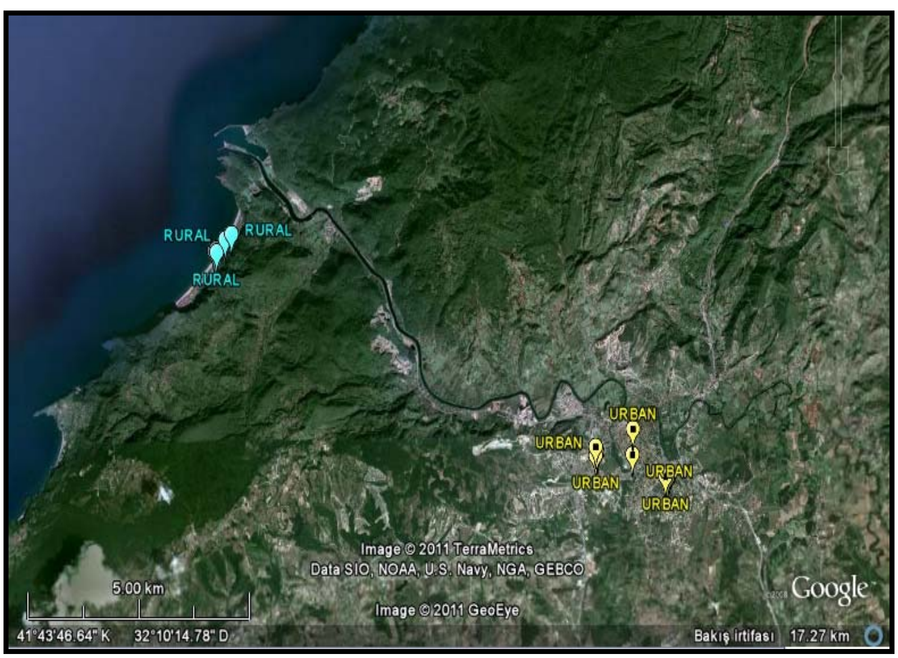


Fig. 2. The locations (Satellite image was taken by using the Google Earth Program).

The localities were categorized as follows: urban 1 (three localities), urban 2 (five localities-city center) and rural area (five localities) (Fig. 2). Urban 1 is a higher part of the city, which rises in the middle of the city center and has an elevation 97 m. Urban 2 is city center and the most urbanized part among our study areas with an elevation 25 m. The rural area (Inkumu) is relatively uncontamined and used as a baseline in this study- is a hidden bay in the northern part of Bartin, surrounded by wide forests. Plant samples were collected only 20-50 m away from the sea, from sea level to 10 m altitude, just in front of the mountains covered with untouched trees (Fig. 3).

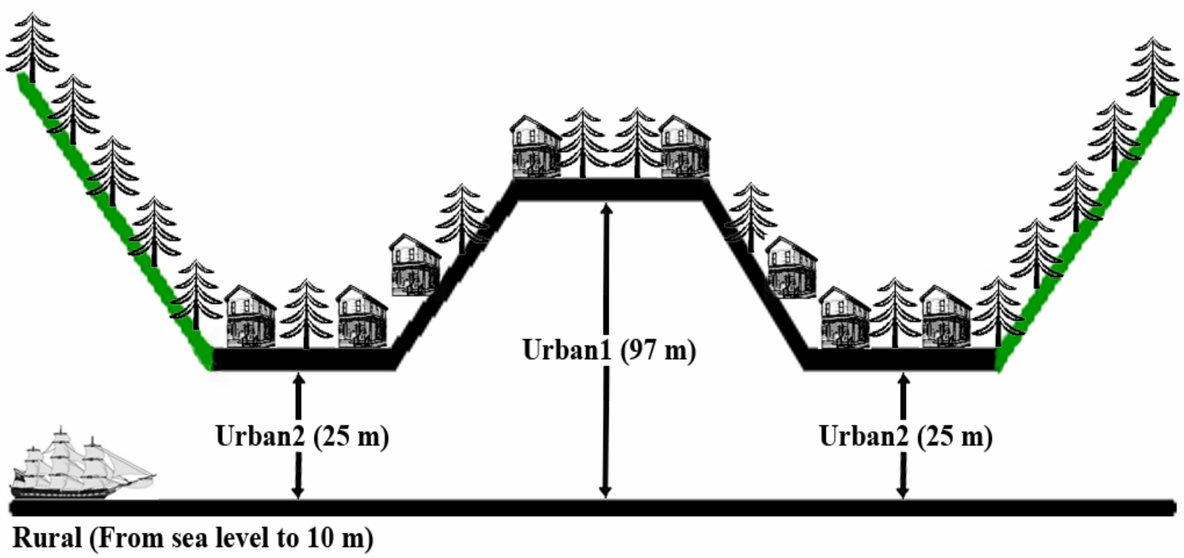


Fig. 3. General structure and altitudes of the stations that plant samples were collected from Bartin city.

The samples were specifically taken from the sides facing roads. Leaf samples were divided into two sub-samples; half of them were thoroughly washed with running deionized distilled water to remove dust particles in a standardized procedure and the remaining leaves samples were analyzed unwashed. The bark, branch, soil samples and rest of the leaf samples were untreated.

Plant parts (bark, branch and leaves) were isolated and oven-dried at 80°C for 24 h, milled in micro-hammer cutter and fed through a 1.5 mm sieve. Samples were weighed as 0.5 g and transferred into Teflon vessels and then 8 ml 65% HNO_3 was added. For soil samples, 9 ml 65% HNO_3, 3 ml 37% HCl and 2 ml 48% HF (Merck) were added. Samples were mineralized in microwave oven (Erghof - MWS2) as follows: in 14 5°C for 5 min., in 165°C for 5 min. and in 175°C for 20 min. After cooling, the samples were filtered by Whattman filters, and made up to 50 ml with ultra pure water in volumetric flasks and then stored in falcon tubes. Standard solutions were prepared by using multi element stock solutions-1000 ppm (Merck) and mineral element (B, Ca, Fe, K, Mg, Na and Zn) measurements were done by Inductively Coupled Plasma Optical Emission Spectroscopy (PerkinElmer-Optima 7000 DV).

The obtained data was analyzed with SPSS statistics program. The standard error values of the means were calculated to compare the site categories. A paired *t*-test was performed to determine the significance of washing of the leaves, comparing heavy metal contents of washed and unwashed plant samples for each type of site and *F*-test (ANOVA) was performed to compare different localities. According to the results of variance analysis and Tukey test, the mean difference is significant at $p<0.05$ level.

Results

The results of measurement show the concentrations of heavy metals in *L. nobilis* are quite variable such as Al (14.69-122.44 mg/kg d. wt.), Cd (0.23-0.89 mg/kg d. wt.), Cu (1.64-14.25 mg/kg d. wt.), Ni (0.001-0.45 mg/kg d. wt.), Pb (2.06-5.28 mg/kg d. wt.). The plant samples were collected on 14-15 January 2011 and during this period, the particles (PM_{10}) in the air reached the highest (172-190 µg/m^3) values of the month (Fig. 4) (Anon., 2011c). EPA's health-based national air quality standard for PM_{10} is 50 µg/m^3 (measured as an annual mean) and 150 µg/m^3 (measured as a daily concentration) (Anon., 2011d). The dark colored particles on leaf surfaces of *L. nobilis* were observed in both urban areas and these leaves were collected and analyzed. However similar situations were not observed in leaves, which were collected from rural areas. The washing procedure reduced many heavy metal values related to airborne pollution sources and other factors in range of 1.5% to 87.5% in different station types (Table 1). A strong correlation between heavy metal and mineral element levels of unwashed-washed leaf samples and soil-unwashed leaf samples was observed. Table 2 reveals correlation coefficient (*r*) for each element and these are all highly significant at $p<0.05$.

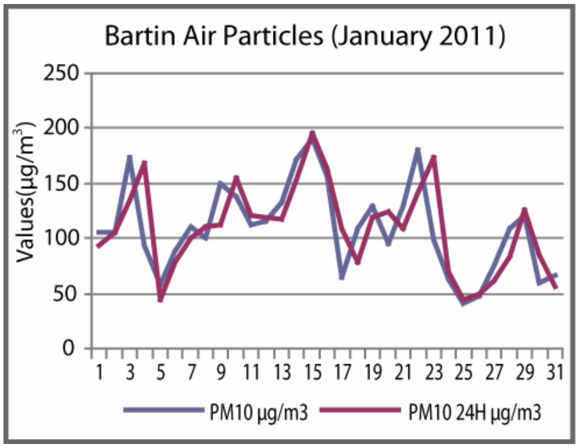


Fig. 4. Bartin Air Particle (PM_{10}) Values in January 2011 (Data obtained from Republic of Turkey Ministry of Environment and Forestry Air Quality Monitoring Network Web Site) (Anon., 2011c).

Table 1. Total percentage of heavy metals and mineral nutrients removed from the leaf samples of *Laurus nobilis* L. through washing procedure in three different stations. Significance of comparison means by ANOVA (*F*-test) are indicated (* *p*<0.05 significant).

Elements % removal	Station type (location)			*F*-test
	Rural	Urban1	Urban2	
Al	43.9	25.0	22.1	*
B	13.8	30.2	30.7	*
Ca	19.2	9.0	1.5	*
Cd	14.4	13.6	3.7	*
Cu	16.4	10.9	4.3	*
Fe	40.1	21.9	38.1	*
K	14.0	16.9	13.8	*
Mg	22.1	19.0	23.1	*
Na	17.4	15.5	21.3	*
Ni	87.5	76.9	6.5	*
Pb	20.1	8.4	5.9	*
Zn	10.1	9.8	12.2	*

Table 2. Relationship between heavy metal and mineral element concentrations in unwashed leaf-washed leaf, unwashed leaf-soil for *Laurus nobilis* L. (Correlation coefficient (*r*); * *p*<0.05 significant).

Elements	Unwashed leaf-washed leaf (*r*)*	Unwashed leaf-soil (*r*)*
Al	0.97	0.94
B	0.95	0.98
Ca	0.99	-0.92
Cd	0.98	0.96
Cu	0.99	0.85
Fe	0.87	0.84
K	0.99	0.97
Mg	0.99	0.99
Na	0.99	-0.92
Ni	0.99	0.66
Pb	0.99	0.89
Zn	0.99	0.99

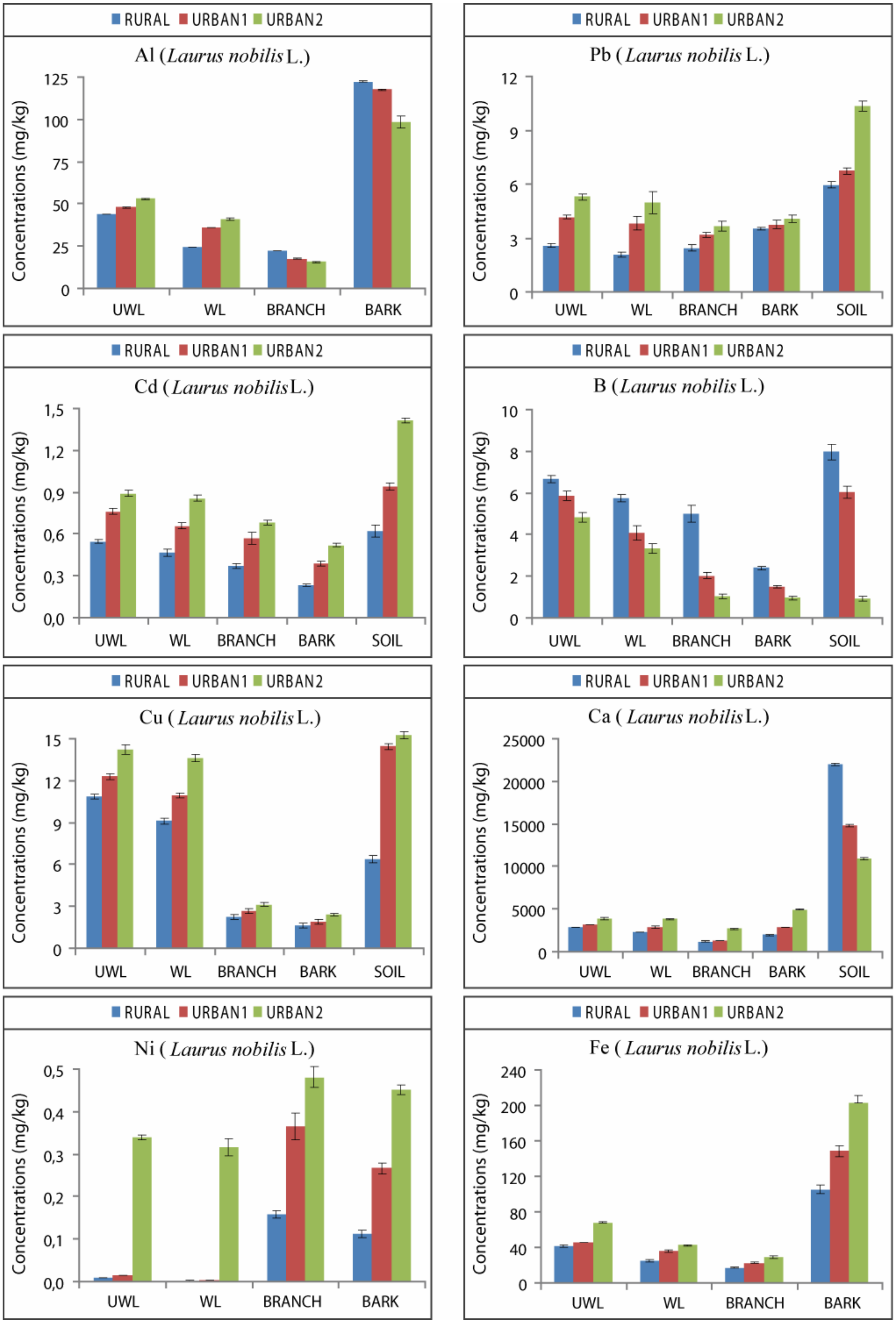
The mean Al concentration in plants collected from different station types is shown in Fig. 5. Because of the high Al level in the soil, it isn't shown in the figure. As a result of the measurements, the average highest value of Al accumulation was gained in bark samples collected from rural area (122.44 ± 0.26 mg/kg d. wt.) and the lowest value was detected as 14.68 ± 0.58 mg/kg d. wt. with branch samples collected from urban 2. On the other hand, the average highest soil Al level was found in urban2 (8853.89 ± 208.95 µg/g d. wt.) while the lowest in rural area with 4414.56 ± 84.81 µg/g d. wt. (Fig. 5).

It is accepted that the normal limits of Cd concentration in plants is between 0.2-0.8 mg/kg d. wt. and between 5-30 mg/kg d. wt. is accepted as toxic values (Ross 1994; Kabata-Pendias & Pendias, 2001). In our study, the average highest Cd value was found in the unwashed leaf samples collected from urban 2 (0.89 ± 0.2 mg/kg d. wt.) and the average lowest value was detected as 0.23 ± 0.01 mg/kg d. wt. with bark samples. Similar to the plant samples, the average highest soil Cd level was found in urban2 (1.41 ± 0.02 mg/kg d. wt.) while the lowest in rural area with 0.62 ± 0.4 mg/kg d. wt. According to these values, the Cd concentrations in this study were within normal limits (Fig. 5).

The mean Cu concentration in plants collected from different station types is shown in Fig. 5. According to the literature, the normal limits of Cu in plant tissues are in range of 4-15 mg/kg d. wt. and between 20-100 mg/kg d. wt. are accepted toxic levels (Allaway, 1968; Bowen, 1979; Kabata-Pendias & Pendias, 2001). In this study, the average highest Cu value was observed in the unwashed leaf samples collected from urban 2 (14.24 ± 0.25 mg/kg d. wt.) and the average lowest value was detected as 1.63 ± 0.15 mg/kg d. wt. with bark samples collected from rural area. The average highest soil Cu level was found in urban 2 (15.27 ± 0.23 mg/kg d. wt.) while the lowest in rural area with 6.35 ± 0.27 mg/kg d. wt.

Ni concentration of three different samples (unwashed-washed leaves, barks and branches) of *L. nobilis* is shown in Fig. 5. The average highest level of Ni was in urban 2 area (barks) while the lowest was determined in the rural area (washed leaves). The values were 0.45 ± 0.01 mg/kg d. wt. and 0.001 ± 0.000 mg/kg d. wt., respectively. The average highest soil Ni values were measured in urban 2 area with 13.75 ± 0.55 mg/kg d. wt. while the lowest were measured in rural area with 1.33 ± 0.02 mg/kg d. wt. The normal accepted Ni values in plant tissues are between 0.5-5 mg/kg d. wt. (Allen, 1989). Ni is readily taken by plants from soil and the normal Ni values in soil are between 5-150 mg/kg dw (Kabata-Pendias & Pendias, 2001). According to the results of this study, our plant and soil values are within normal limits.

The mean Pb concentrations in plants collected from different station types are shown in Fig. 5. According to the literature, the normal limits of Pb in plant tissues are between 0.1-10 mg/kg d. wt. and between 30-300 mg/kg d. wt. are accepted toxic levels (Kabata-Pendias & Pendias, 2001). In our study, the average highest Pb value was observed in the unwashed leaf samples collected from urban 2 (5.28 ± 0.65 mg/kg d. wt.) and the average lowest value was detected as 2.06 ± 0.12 mg/kg d. wt. with unwashed leaf samples collected from rural area. Similar to the plant samples, the average highest soil Pb level was found in urban 2 (10.36 ± 0.26 mg/kg d. wt.) while the lowest in rural area with 5.94 ± 0.17 mg/kg d. wt. According to these values, the Pb concentrations in this study were within normal limits.


RURAL URBAN1 URBAN2
Al (Laurus nobilis L.)
Concentrations (mg/kg)
0
25
50
75
100
125
UWL WL BRANCH BARK
RURAL URBAN1 URBAN2
Pb (Laurus nobilis L.)
Concentrations (mg/kg)
0
3
6
9
12
UWL WL BRANCH BARK SOIL
RURAL URBAN1 URBAN2
Cd (Laurus nobilis L.)
Concentrations (mg/kg)
0,0
0,3
0,6
0,9
1,2
1,5
UWL WL BRANCH BARK SOIL
RURAL URBAN1 URBAN2
B (Laurus nobilis L.)
Concentrations (mg/kg)
0
2
4
6
8
10
UWL WL BRANCH BARK SOIL
RURAL URBAN1 URBAN2
Cu (Laurus nobilis L.)
Concentrations (mg/kg)
0
3
6
9
12
15
UWL WL BRANCH BARK SOIL
RURAL URBAN1 URBAN2
Ca (Laurus nobilis L.)
Concentrations (mg/kg)
0
5000
10000
15000
20000
25000
UWL WL BRANCH BARK SOIL
RURAL URBAN1 URBAN2
Ni (Laurus nobilis L.)
Concentrations (mg/kg)
0,0
0,1
0,2
0,3
0,4
0,5
UWL WL BRANCH BARK
RURAL URBAN1 URBAN2
Fe (Laurus nobilis L.)
Concentrations (mg/kg)
0
40
80
120
160
200
240
UWL WL BRANCH BARK

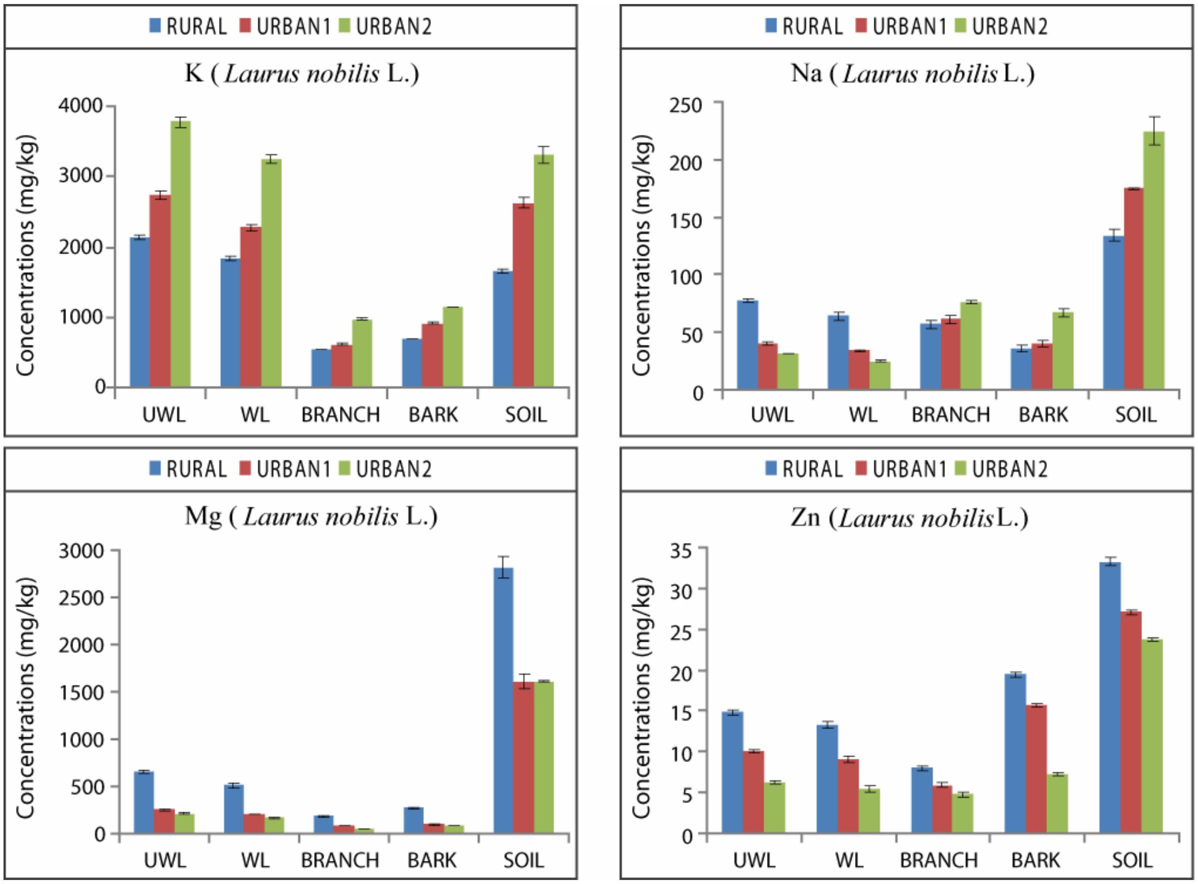


Fig. 5. Mean Al, Cd, Cu, Ni, Pb and B, Ca, Fe, K, Mg, Na, Zn concentration (mg/kg d. wt.) in barks, branches, unwashed-washed leaves and (soil) together with S.E. bars. UL: Unwashed leaves. WL: Washed leaves significances of differences between washed and unwashed plants by Tukey test are indicated ($p< 0.05$ significant).

Meanwhile, the microelements (B, Ca, Fe, K, Mg, Na, and Zn) measured in *L. nobilis* (unwashed and washed leaf, bark and branch samples) were determined to assess the effects of heavy metals on mineral nutrient uptake. The result indicates that the levels of mineral nutrient uptake and composition in *L. nobilis* samples showed fluctuations such as B (1.04-6.67 mg/kg d. wt.), Ca (1195.34-4919.03 mg/kg d. wt.), Fe (17.13-203.25 mg/kg d. wt.), K (538.99-3778.37 mg/kg d. wt.), Mg(48.1-268.5 mg/kg d. wt.), Na (24.91-77.43 mg/kg d. wt.) and Zn (4.75-15.74 mg/kg d. wt.) among the three study sites. The concentrations of mineral nutrients in *L. nobilis* collected at three sampling sites in Bartin are shown in Fig. 5. Experimental data obtained for estimation of heavy metal impact on mineral nutrients uptake and composition of *L. nobilis* addressed that mineral nutrient metabolism of *L. nobilis* was adversely affected by heavy metals.

Discussion

Heavy metal concentrations of Al, Cd, Pb, Ni, and Cu in *L. nobilis* were investigated to provide information on pollution of Bartin City. Meanwhile, the effects of heavy metals on mineral nutrient uptake were analyzed in *L. nobilis*. As regards geographical variation in the accumulation of heavy metals in Bartin City, the bay tree (*L. nobilis*) data showed up variation between three stations for Al, Cd, Cu, Ni and Pb. Although there was low variability from plant to plant, the highest concentrations of Al, Cd, Cu, Ni, and Pb were consistently found in the city center (Fig. 5).

Heavy metals have become one of the main abiotic stress agents for living organisms. It is known that the release of certain heavy metals as a result of human activity including increasing use in the developing fields of industry, agriculture, mining, combustion of fossil fuels and traffic have a strong impact on the stability of ecosystems (Tyler *et al.*, 1989) and because of deposition of heavy metals in surface soil and atmosphere, the biota growing under such conditions accumulate high amounts of heavy metals.

According to EPA, because of PM_{10}'s ability to reach respiratory tract, particles are likely in charge of adverse health effects like damage to lung tissue, cancer, asthma, premature death and influenza (Anon., 2011d). In this work, the heavy metal particle values found to be higher than the EPA's standards. Therefore, it is likely that people who live in Bartin may suffer from several diseases in coming years.

A number of heavy metals such as Co, Fe, Mn, Mo, Ni, Zn, Cu are essential micronutrients and required for normal plant growth and development since they are constituents of many enzymes and other proteins in plants. Heavy metals considered nonessential such as Pb, Cd, Cr, Hg are potentially toxic for plants (Devi *et al.,* 1998; Rai *et al.,* 2004; Sebastiani *et al.,* 2004). Elevated concentrations of both essential and nonessential heavy metals can lead to toxicity symptoms and the inhibition of growth, decrease in biomass and death of the plant (Zenk, 1996). There are three different molecular mechanisms of heavy metal toxicity: production of reactive oxygen species, blocking of essential functional groups in biomolecules and displacements of essential metal ions from biomolecules (Schutzendubel & Polle, 2002) resulting in inhibition and/or alteration of physiological processes such as respiration, photosynthesis, cell elongation, plant-water relationship, N-metabolism and mineral nutrition (Zornoza *et al.,* 2002). For example, a decrease in the mitotic index was observed in the case of Pb (Wierzbicka, 1999) and Hg (Patra *et al.,* 2004). Cd (Poschenrieder *et al.,* 1989) or Cu (Maksymiec *et al.,* 1995) inhibits leaf elongation as the result of induced preferential decrease of cell wall elasticity. Decreased K leaf uptake and inhibition of photosynthesis via sugar accumulation could be the reason of Cu inhibition of cell expansion in cucumber plants (Alaoui-Sosse *et al.,* 2004). Excessive Pb leads to decrease in seed germination, root elongation and biomass, inhibition of chlorophyll biosynthesis (Balsberg-Pahlsson, 1989; Kumar *et al.,* 1991; Fargasova, 1994; Xiong, 1997).

The decrease of biomass due to heavy metal toxicity could be an indirect consequence of its influence on the metabolism of macro- and micronutrients. In general, heavy metals have been shown to interfere with uptake, transport and the use of several elements such as Zn, Mn, Fe, Ca, Mg, P, resulting in nutrient imbalance (Clarkson & Luttge, 1989; Harrison *et al.,* 1994). Although the heavy metal levels of plant and soil samples in this study are within normal limits, we observed an accumulation in different levels and mineral element uptake decreased or increased with different types of physiological mechanisms related to this situation. A strong correlation was observed between heavy metal and mineral element levels of unwashed-washed leaf samples and soil-unwashed leaf samples. However, there was a negative correlation between Ca and Na levels of soil and unwashed leaf samples. Table 2 reveals correlation coefficient (r) for each element and these are all highly significant at $p<0.05$. In our study, the presence of Al, Cd, Ni, Pb and Cu strongly influenced the uptake and transport of other cations and in particular, that of Mg, Zn and B whose concentrations markedly decreased in *L. nobilis*. The competition for a common carrier could reduce the Zn and Mn uptake across the plasma membrane (Clarkson & Luttge, 1989). Zn deficiency has been reported to cause photo-oxidation of thylakoid constituents and impairment of detoxifying mechanisms (Cakmak & Marschner, 1993). Our result suggests an oxidative effect of Zn deficiency in *L. nobilis* due to heavy metal accumulation. It was often reported that heavy metals reduce content of Mg in tree seedlings (Gussarsson, 1994; Harrison *et al.,* 1994). In this work, it was found that heavy metals compete with Mg by blocking Mg transport. This is consistent with our result. Increased cytoplasmic Ca regulates hyperosmotic stress in plants (Knight *et al.,* 1997). One mechanism of Ca increase is based on activation of Ca channels in the plasma membrane (Blatt, 2000). Ca binds to the plasma membrane and by that it controls the permeability of the plasma membrane and prevents Ca efflux from the cells (Rengel, 1992). Our results showed that Ca was actively transported by the plant because of its role in membrane and stomatal functions, cellular stress recovery etc. (McLaughlin & Wimmer, 1999) and heavy metals did not seem to influence the Ca uptake, probably because other divalent cations did not compete for specific Ca channels. In the present study, high concentration of K and low concentration of Na were observed in leaves in *L. nobilis*. K is the major solute contributing to osmotic pressure and ionic strength. Most cells maintain relatively high K and low Na concentrations in the cytosol. This is achieved through coordinated regulation of transporters for H^+, K^+, and Na^+. Na is taken up into plant cells passively, presumably through K transport systems (Schroeder *et al.,* 1994). The results revealed that Na uptake by the roots was competitively inhibited or Na transport from roots to shoots was restricted by heavy metals. Meanwhile, our data suggests that for restoring osmotic pressure and ionic strength disturbed by heavy metals, K was actively transported from roots to shoots as a response to heavy metal stress by the plant. Heavy metal induced changes in water relations of plants have been reviewed recently (Shah & Dube, 1997; Poschenrieder & Barcelo, 1999). Increase in stomatal resistance or decrease stomatal conductance has been reported in plants exposed to excess supply of Cd (Kirkham, 1978; Poschenrieder *et al.,* 1989; Costa & Spitz, 1997), and Ni (Carlson *et al.,* 1975; Alia & Saradhi, 1991). Experimental data showed that heavy metals did not seem to influence the Fe uptake in *L. nobilis*. The results related to the uptake of Al in this study suggest that roots of *L. nobilis* are barriers to Al translocation to the above ground parts. Within the cortex heavy metals are transported in the apoplastic space according to their concentration gradient and also accumulate in the cell walls (Arduini *et al.,* 1996). First, toxic effects of heavy metals are observed at plasma membrane and then within the cell. By active and passive transport systems, heavy metals are transported into the cells. A common transmembrane transporter was found for Cd, Cu, and Ni. Also, the uptake of heavy metals was competitively inhibited by K, Ca, and Mg (Clarkson & Luttge, 1989). In the plant *L. nobilis*, toxic effects of heavy metals could be modified by essential elements like Zn, Ca, Fe, and Mn. Also, physical and chemical properties of similar elements act antagonistically to each other biologically. Elements of similar type are to compete for the same transport and storage sites in the cell. For example, Cd may inhibit Cu toxicity (Hewitt, 1966). Scientists have been using many different living organisms as biomonitors to estimate contamination levels of pollutants for a long time. Overall, heavy metals are transported and stored within *L. nobilis* and for estimation of heavy metal accumulation; *L. nobilis* could be used as a model organism. Also, our results showed that nutrient uptake is sensitive to heavy metals; therefore, air and soil contamination of these elements could imbalance the mineral nutrition of *L. nobilis*.

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