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Changes in heavy metal accumulation in some edible landscape plants depending on traffic density

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Abstract Food scarcity is one of global issues that our world faces today. A significant portion of the world's population has no access to adequate food, and it is stated that approximately 830 million people suffer from chronic famine. This predicament is estimated to grow even further. Many attempts have been made to solve the food problem. Some examples are using new resources which have not been used for dietary purposes up to this point, planting new areas to produce food products, and increasing the potential harvest per an area unit. One of the solution proposals, which has come up recently within this scope, is the term of "edible landscaping", which means the use of edible plants in the landscaping works, and thus maximizing the potential for food security. However, edible landscaping poses a considerable risk. Heavy metal accumulation in plants grown in urban centers can reach to high levels, and consuming these plants will allow these heavy metals a direct access into the human body and wreak havoc to the public health. But since this subject has not been sufficiently studied yet, the extent of such a risk is not accurately determined yet. This study aims to determine the changes of Ni, Co and Mn concentrations depending on traffic density in the leaves, branches, barks and fruits of cherry, plum, mulberry and apple trees growing in areas with dense traffic, low-density traffic and no-traffic zones in Kastamonu province. The results showed that the concentrations of Ni and Co elements increased in many organelles depending on traffic density, and that the heavy metal concentrations in fruits could be very high. This situation indicates that fruit and vegetables grown in industrial zones and urban centers, where heavy metal pollution may be high, can be harmful to the public health if consumed as crops.

Keywords Biomonitor · Fruit · Heavy metal · Traffic density

Introduction

One of the most important problems of today's world is generally the population growth its related problems. While the world population was only 717

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million in 1750, it exceeded 6 billion in 2000, and is estimated to exceed 8 billion by 2025 (Cetin 2015a, b, c, 2016a, b, c; Demir 2018; Cetin 2017; Bozdogan Sert et al. 2019; Cetin 2019). The increase can lead to many challenges, one of which is food shortage. Food supply, which has increased two folds in the last 35 years in order to meet the ever-increasing demand of the world's population, will likely increase twice as much within the next 15 years. This could lead to the fields devoted to crop production and animal husbandry gradually decreasing and losing their fertility (Dolekoglu and Yurdakul 2004; Nowak et al. 2005; Kaya 2009; Kaya et al. 2019).

Edible landscaping suggests that growing crop plants in parks, road refuges and roofs, and essentially wherever the plants can grow can help tackle food shortages effectively (Ozel 2019; Nowak et al. 2005; Kaya 2009; Kaya et al. 2019). However, urban centers generally exhibit high population and human activities, and thus present a high level of pollution factors. In these areas, many pollutants are emitted from exhaust gases, car wheels, vehicles and vehicle wear. Among those infamous pollutants are heavy metals. This is because heavy metals do not decompose and tend to remain in nature for very longs times. They also tend to bioaccumulate (Cetin 2017; Cetin et al. 2018a, b; Turkyilmaz et al. 2018a, b; Sevik et al. 2019a; Cetin et al. 2019a, b).

It is known that heavy metal pollution is quite high in areas with dense traffic such as urban centers (Sevik et al. 2019b; Cetin et al. 2018a, b; Turkyilmaz et al. 2018c; Cetin et al. 2019a, b; Bozdogan Sert et al. 2019; Cetin 2019). Therefore, the high levels are likely to be reflected in the accumulation in plants as well. A few studies suggested that there is a correlation between high metal levels in the air and higher accumulations in plants in those same areas. Nevertheless, the degree of accumulation differs based on plant organelles; higher levels of HMs mean higher health risks (Schreck et al. 2012; Mombo et al. 2015; Shahid et al. 2017). We have strived to determine the buildup of HMs in the different organelles in the different plants in the different traffic density scenarios as detailed in the following section.

Material and method

The study was conducted on the materials collected from the Kastamonu town centre (the coordinates of 41° 23′20 N and 33° 46′ 45″E). Kastamonu town centre was founded and built around a valley. That valley is where the traffic is the densest. The samples were collected from the town center area with dense traffic; from the areas with low-density traffic (namely suburbs), and from the areas with almost no traffic (areas with no roadway found within 50 m in the vicinity). In the town center there is a 4-lane highway across with 2 lanes on each directions. The areas with low-density traffic were selected from the routes with flowing traffic outside the center.

Leaves, branches and fruit samples were collected in the second half of August in 2018, and were brought to the lab after being packed and labeled. The samples brought to the lab were firstly separated into organelles, then labeled and laid on cardboard plates to dry them. The wood and fruit samples were crushed and dried in glass settle plates to enable them to dry more easily. The samples, which were ventilated at least once a week for a period of two months, became air dried at the end of two months, and then further dried out in a drying-oven at 50 °C for a month after being taken in glass settle plates. Afterwards, the samples were sent to the lab for analysis after being hermetically packed to avoid humidity.

HMs analyses of the samples were performed in the Central Research Laboratory of Kastamonu University. The samples were pulverized using a steel blender in the laboratory. 2 g of powdered samples were kept waiting in 10 ml of concentrated HNO_3 at room temperature for 1 day inside a fume cupboard, and then boiled at 180 °C for 1 h. 20 ml of distilled water were added onto the prepared solutions, and the solution was filtered through filter paper of 45 μm. The solutions were then made ready for analysis by numbering in order to avoid intermixing. In the solutions obtained from the filtrate, the Ni, Co and Mn HM analyses were performed using GBC Integra XL –SDS-270 ICP-OES device.

The data obtained was organized and then was subjected to variance analysis with the help of SPSS program. Homogeneous groups were obtained by applying

Duncan test to the values with statistical differences at a minimum of 95% confidence level. The data obtained were interpreted after being simplified and tabulated.

Results

Changes of Ni concentration based on the species and organelle depending on traffic density

Changes of Ni concentration in the leaves, branches, bark and fruit of each species depending on traffic density were evaluated separately, and the F value acquired as a result of variance analysis applied to the data obtained, significance level, mean values and the groupings formed as a result of the Duncan test were summarized and given in Table 1.

When the changes of Ni concentrations depending on the traffic density on the basis of organelle are examined, it is observed that the changes in Ni concentration are statistically significant at a 95% confidence level in all organelles of all species. This change is significant at a 99% confidence level in plum branches, while it is at a 99.9% in all other organelles. When the mean values and the Duncan test results are examined, it is seen that Ni concentration in cherry leaves increases in direct proportion to traffic density, while it decreases in inverse proportion to traffic density in bark and fruit. The highest values in the bark were obtained in the areas with dense traffic, and the lowest value in the areas with low-density traffic.

When the table values are examined, it is noticeable that Ni concentration increases depending on traffic density in all organelles other than the fruit of mulberries and fruit and leaves of apples. Especially in plums, it is noteworthy that Ni concentration increases in direct proportion to traffic density in all organelles. In mulberry fruit, while the highest Ni concentration was obtained in the areas with dense traffic, the lowest Ni concentration was obtained in the areas with low-density traffic. In apple leaves and fruits, the highest Ni concentration was obtained in the areas with no traffic.

Table 1 Changes of Ni concentration on the species and organelle basis depending on traffic density

Species	Organelle	Traffic density			*F* value
		No traffic	Low-density traffic	Dense traffic	
Cherry	Leaves	771.67 a	962.33 b	1254.00 c	255.994***
	Branches	749.00 b	463.33 a	980.00 c	896.678***
	Bark	2386.33 c	1131.67 b	752.67 a	1833.903***
	Fruit	1377.67 c	488.00 b	432.00 a	1606.124***
Plum	Leaves	1110.33 a	1166.00 b	1369.33 c	624.980***
	Branches	872.33 a	1052.00 a	1289.67 b	13.655**
	Bark	753.00 a	1534.33 b	2355.00 c	5020.779***
	Fruit	1302.00 a	1761.00 b	2289.33 c	419.322***
Mulberry	Leaves	2157.67 a	2316.67 b	3335.33 c	5889.090***
	Branches	1668.00 a	2321.67 b	3129.33 c	1401.255***
	Bark	762.33 a	1459.00 b	2387.33 c	6933.916***
	Berries	1676.67 b	1363.00 a	2988.00 c	10,694.953***
Apple	Leaves	2842.33 c	1912.00 b	1401.33 a	2654.728***
	Branches	544.33 a	585.67 b	895.33 c	1860.699***
	Bark	1424.67 a	2726.67 b	8539.33 c	4480.060***
	Fruit	531.67 b	412.33 a	419.00 a	69.933***

The letters a, b, c, etc. means according to Duncan test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

*significant at 0.05 level

**significant at 0.01 level

***significant at 0.001 level

Changes of Co concentration on the species and organelle basis depending on traffic density

Changes of Co concentration in the leaves, branches, bark, and fruit of each species depending on traffic density were evaluated, and the *F* value acquired as a result of variance analysis applied to the data obtained, significance level, mean values, and the groupings formed as a result of the Duncan test were summarized and given in Table 2.

When the table values are examined, it is seen that the changes in Co concentration depending on the traffic density is significant at a 95% confidence level in plum branches, whereas it is a 99% in cherry leaves, mulberry fruit, and apple leaves and fruit, and at a 99.9% in all other organelles. When the mean values and the Duncan test results are examined, it is seen that the values obtained in the areas with no traffic in all organelles other than cherry bark and fruit as well as apple leaves and fruit are included in the first homogeneous group.

According to the mean values, Co concentration increases correlatively with the traffic density in cherry leaves, in apple branches and barks, in all organelles of plum, and in all organelles of mulberry except its fruit.

Changes of Mn concentration on the species and organelle basis depending on traffic density

Changes of Mn concentration in the leaves, branches, barks, and fruits of each species depending on traffic density were evaluated, and the *F* value acquired as a result of variance analysis applied to the data obtained, significance level, mean values, and the groupings formed as a result of the Duncan test were summarized and given in Table 3.

According to the table values, the changes in Mn concentration depending on the traffic density are found to be significant at a 99% confidence level only in plum branches, while it is significant at a 99.9% confidence level in all other organelles. When the mean values and the Duncan test results are examined, no direct

Table 2 Changes of Co concentration on the species and organelle basis depending on traffic density

Species	Organelle	Traffic density			*F* value
		No traffic	Low-density traffic	Dense traffic	
Cherry	Leaves	313.67 a	352.00 b	371.67 b	14.117**
	Branches	310.00 a	819.67 c	373.67 b	1364.537***
	Bark	1433.33 c	894.67 b	221.33 a	8338.506***
	Fruit	615.33 c	494.00 b	389.67 a	598.951***
Plum	Leaves	337.33 a	399.00 b	460.00 c	137.441***
	Branches	518.33 a	582.00 ab	626.67 b	6.862*
	Bark	271.33 a	810.00 b	1348.33 c	3756.968***
	Fruit	303.67 a	394.67 b	477.33 c	321.859***
Mulberry	Leaves	401.00 a	467.00 b	544.67 c	331.656***
	Branches	169.33 a	838.00 b	1242.67 c	4593.582***
	Bark	166.00 a	267.33 b	1364.33 c	70,138.594***
	Berries	474.33 a	510.67 b	464.33 a	12.501**
Apple	Leaves	426.67 b	389.33 a	440.00 b	30.185**
	Branches	142.67 a	238.33 b	417.33 c	409.724***
	Bark	1007.67 a	1623.67 a	13,357.67 b	1090.651***
	Fruit	458.67 b	404.67 a	438.33 b	14.335**

The letters a, b, c, etc. means according to Duncan test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

*significant at 0.05 level

**significant at 0.01 level

***significant at 0.001 level

Table 3 Changes of Mn concentration on the species and organelle basis depending on traffic density

Species	Organelle	Traffic density			*F* value
		No traffic	Low-density traffic	Dense traffic	
Cherry	Leaves	56.62 c	14.93 b	12.35 a	75,533.514***
	Branches	12.54 c	2.23 a	3.63 b	128,647.935***
	Bark	158.78 c	21.96 a	39.40 b	247,425.247***
	Fruit	15.17 c	1.98 a	4.59 b	791,189.908***
Plum	Leaves	62.96 c	38.00 a	50.66 b	3661.811***
	Branches	3.37 a	6.50 b	11.87 c	24.707**
	Bark	65.81 c	13.07 a	39.33 b	15,424.773***
	Fruit	3.48 a	5.00 b	16.37 c	60,988.093***
Mulberry	Leaves	30.81 c	18.64 a	27.61 b	38,266.100***
	Branches	4.48 a	9.13 c	5.03 b	23,960.693***
	Bark	11.66 a	15.19 b	17.82 c	29,289.063***
	Berries	13.06 b	13.91 c	11.98 a	209.949***
Apple	Leaves	13.03 a	16.00 b	23.18 c	13,952.311***
	Branches	3.72 c	3.00 a	3.28 b	5295.200***
	Bark	15.61 a	20.00 b	30.66 c	1616.820***
	Fruit	3.20 c	2.00 a	2.12 b	1495.006***

The letters a, b, c, etc. means according to Duncan test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

*significant at 0.05 level

**significant at 0.01 level

***significant at 0.001 level

relationship is found between traffic density and Mn concentration. While the highest Mn concentration in all organelles of cherry is found in the areas with no traffic, the lowest values in the organelles of cherry except its leaves are found in the areas with low-density traffic. While the lowest values in plum branches and fruit are found in the areas with no traffic, the highest values in plum leaves and bark are found in areas with no traffic. Similar data emerge in other species as well. Therefore, it is quite difficult to surmise that Mn concentration has a direct relation to traffic density.

Discussions

Ni is used in coal, oil, steel, and alloy production as well as galvanization and the electronics industry and is a carcinogenic element to mammals and other animals (Aricak et al. 2019). Co is an element that may cause damage and dysfunction to the lungs and heart; an increase in blood sugar, cholesterol, and fat levels; and cancer, miscarriage; and infertility. It is also an element that may cause lung and liver fibrosis and may lead to gastrointestinal tract problems (Batır 2019) when taken orally. On the other hand, when Mn enters the human body through food chain, the main symptoms of toxicity are observed in the respiratory system and brain; and it is an element that may cause hallucinations, fatigue, insomnia, weakness, dysmnesia, and nerve damages as well as Parkinson disease, lung embolism, and bronchitis (Çetin and Çobanoğlu 2019).

The study results indicate that the concentrations of elements vary significantly between species and between different organelles of the same species. For instance, the Ni concentration, which is one of the most hazardous heavy metals to human health, had a value of 419 ppb in the apple fruit, while it was 2988 ppb in the mulberry fruit and 8539 ppb in the apple bark. Similar results were obtained in the other elements. Therefore, it is a plausible supposition that HM concentrations vary significantly both on the basis of species in the same organelles and on the basis of organelles in the same species.

This result generally complies with the results obtained in the previous studies. In the studies conducted to date, it is found that the most significant differences in the changes of heavy metal concentrations occur on the basis of species. There are many studies stating that different heavy metals are held by different plants more intensely (Turkyilmaz et al. 2018d; Erdem 2018; Sevik et al. 2019a). Similarly, there are many studies conducted regarding the fact that heavy metals are held more intensely by different organelles of the same plants (Pinar 2019; Mossi 2018; Saleh 2018; Akarsu 2019). In fact, the studies carried out on this subject show that there are differences even between the different-aged organelles of the same plants (Cobanoğlu 2019).

The HM accumulation potential of plants is closely related to the anatomical structure of the plant and thus to the plant species. Changes in heavy metal concentration in plant organelles may vary depending on many other factors such as the organelle structure; interactivity of organelles with physio-chemical properties of metals, morphology, surface area, and surface texture; and size of the organelles, plant habitus, heavy metal exposure time and humidity (Xu and Zhou 2008; Xiong et al. 2014; Shahid et al. 2017; Turkyilmaz et al. 2019; Ozel 2019).

One of the most important outcomes of this study is the determination of the fact that the fruits of most of the species contain high levels of heavy metals. For example, the highest Ni concentration in plum plant was obtained in its fruit. The concentrations obtained in the fruit of other elements were also quite high. Over the last 20 to 30 years, many studies have focused on the health risks associated with consuming contaminated vegetables (Mombo et al. 2015; Xiong et al. 2016; Yang et al. 2016). It is reported that metal contents found in edible parts of plants may exceed the maximum permissible limits (MPL) and cause serious public health conditions (Shaheen et al. 2016).

Some heavy metals can be quite harmful to humans, even when exposed at low levels. This is due to lack of effective tolerance or excretion mechanism in heavy metals. Consuming plants contaminated with heavy metals is reported to be more or less harmful for human health. While HMs' harms can display simple symptoms such as nausea, vomiting, and asthenia, they may also cause severe health conditions such as dysfunction of organelles, cancer and even death (Jarup 2003; Shahid et al. 2017; Aricak et al. 2019; Aricak et al. 2020; Ozel 2019; Batır 2019).

Unfortunately HMs can also be present in herbal products (oil, herbal medical nutrition, and nutrients) and can also pose some health risks. Previous studies show that some medicinal, aromatic, and herbal plants used in the preparation of various products utilized by humans can also accumulate a large amount of heavy metals (Zheljazkov and Warman 2003; Zheljazkov et al. 2008, 2006).

In a study conducted by Saleh (2018), it was determined that the concentrations of Pb, Ca, Fe, Cr, Zn Cu, Ca, Ni, and Mn increased in eight plant species due to traffic density. Similar results were obtained by Mossi (2018) for Ni, Fe, and Mg elements; by Erdem (2018) for Ni, Pb, Cd, and Cu elements; by Elfantazi et al. (2018a) for Cr and Pb elements; and by Elfantazi et al. (2018b) for Ni, Cd, Fe, Mn, and Zn elements. Similar results were obtained in many other studies as well (Ozel et al. 2015; Turkyilmaz et al. 2018a, b; Aricak et al. 2019, 2020).

Although the atmospheric heavy metal pollution is caused by different sources, heavy metal emissions from industrial- and traffic-related activities are among the most important sources of atmospheric pollution. (Martley et al. 2004; Uzu et al. 2011). Exhaust gases, car wheels, vehicles, and vehicle wear are an important pollution sources within the city (Zhuang et al. 2009; Schreck et al. 2011). Previous studies show that the diffusion of heavy metals in the atmosphere and their intake by the plant are very complex mechanisms (Shahid et al. 2017; Mossi 2018).

The HM accumulation in plant bodies is closely related to environmental conditions. HMs can be carried far away from their sources with the help of wind. Apart from this, environmental conditions directly affect plant metabolism and during this process, the entry of heavy metals into the plant also varies. A significant relationship is stated to exist between the entry of heavy metals into the plant body, air humidity, and precipitation in particular (Shahid et al. 2017; Mossi 2018; Ozel 2019).

It can also be expected to have different levels of heavy metal concentrations in the subspecies, forms, varieties, and origins of the plant. In fact, the studies conducted indicate that many phenological, morphological, and anatomical structures vary depending on these characteristics (Yucedag and Kaya 2016; Sevik et al. 2019c; Cetin et al. 2018a, b; Yigit et al. 2016; Yucedag et al. 2019). In this case, it is inevitable that the plant metabolism also changes, and this affects the absorption of heavy metals (Sevik et al. 2019a, b; Mossi 2018).

For many factors such as the stress level of the plant significantly affecting the plant metabolism (Sevik and Cetin 2015), plant origin (Sevik and Topacoglu 2015; Yigit et al. 2016), chlorophyll amount, hormone applications, and genetic structure (Hrivnák et al. 2017; Sevik et al. 2019a; Aricak et al. 2020), it is possible to affect the HM absorption and thus the HM concentration of plants. After all, the change in HM concentration in plants is the result of a complex mechanism depending on the joint interaction of many factors. However, this mechanism is not fully solved yet, and in particular, information on the intake of heavy metals by the above-ground organelles is very limited (Shahid et al. 2017; Mossi 2018).

Conclusions

Consuming heavy metal–contaminated food is extremely dangerous to the human health. Awareness campaigns should be promoted to the residents of urban areas to outline the risks of the consumption of plants grown in urban centers, where traffic is dense and pollution is high.

Four plant species were evaluated under the scope of this study. Yet, many vegetables and fruit are grown in urban centers and areas with high industrial pollution, and they are likely to be consumed as food. In fact, some agricultural activities are carried out on large lands near some industrial facilities. It is of great importance to identify the potential hazards of these plants by subjecting them to similar studies. Diversifying similar tests by using different plant species is highly recommended.

Author contributions All authors have equally contributed on this research.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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