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Change of Several Plant Nutrient Elements by Plant Species and Organ

Ramazan Erdem[1,a,*]

[1]*Department of Forestry, Programs of Forestry and Forestry Products, Arac Rafet Vergili Vocational School Kastamonu University, 37150 Kastamonu, Turkey*
[*]*Corresponding author*

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A B S T R A C T

Nutrient elements, one of the major factors shaping plant development, are the major components of plants, and, after being taken from the soil, they are present in different organs of plant at different concentrations. The speciation of nutrient elements within plant body is vital importance for determining the contribution to plant development, knowing the transfer between organs within the body of organs, clearly understanding the factors influencing plant development, and shaping the plant development. In the present study, the change of the concentrations of K and Mg (macronutrient elements) and Cu (micronutrient elements) by species and organ in woody species *Prunus cerasifera, Platanus orientalis, Acer negundo, Fraxinus excelsior, Catalpa bignonioides, Aesculus hippocastanum,* and *Tilia platypyllos*. As a result, it was found that the changes of elements by species were statistically significant in all the organs, and, in general, the highest concentrations were observed in leaves. The study results revealed that the concentrations of these elements might significantly vary between the organs in the same species, which varies significantly by the species.

[a] *rerdem@kastamonu.edu.tr*   *https://orcid.org/0000-0002-5243-5685*

Introduction

Plants play a vital role for the organic life in the world, and the entire organic life is directly or indirectly dependent on the plants (Yigit et al., 2021). This character of plants arises from their photosynthesis capacity. In their habitat, plants use sunlight for photosynthesis, and they produce the nutrient required for organisms (Gur et al., 2021). Besides that, plants also fulfill many functions such as cleaning the air, preventing erosion, balancing the climate, providing shelter for wild animals, and serving recreational purposes (Elsunousi et al., 2021; Kalayci Onac et al., 2021; Ozturk et al. 2021). Moreover, they constitute one of the most important economic sources (Özel et al., 2021).

Plants' ability to fulfill these functions depends on their healthy growth and development. Plant development is the result of a very complex mechanism operating under the interaction between genetic structure (Güney et al., 2016; Hrivnak et al., 2017; Turkyilmaz et al., 2020) and environmental factors (Güney et al., 2012; Kulaç et al., 2013a,b). Understanding this mechanism is the only way to ensure optimum growth and development of plants, shaping this development in parallel with purposes and gaining the highest benefit.

Nutrient elements are among the major factors influencing plant development. Nutrients are the main constituents of plants and, after being taken from the soil, they exist in different organs of plants at different concentrations. In order to completely understand the factors influencing plant development, it is necessary to determine the speciation of nutrient elements within the body of plants, reveal the contribution to plant development, and know the transfer between organs. Hence, many studies have been carried out on the amounts of nutrient elements in organs of different plants grown in the same area (Sitters et al., 2020; Kumar et al., 2021; Cetin et al., 2021). Moreover, in some of these studies, the opportunities to use plants to determine the pollutant elements in air or soil (Cetin et al., 2021. But, as a result of these studies, it was stated that there is a lack of information about at which amounts the nutrient elements accumulate in plants depending on the amounts in soil or air, how the nutrient elements change by organ since the intake into the plant, how they are speciated within the plant, and the level of transition between the organs (Shahid et al., 2017).

The present study aimed to contribute to making up for the lack of knowledge in this field. Within this scope, it was aimed to compare the amounts of macro and micronutrient elements in different organs of different plants. In-plant nutrition, there are mainly 16 nutrient elements that are required, 9 of which are macronutrient elements (C, H, O, N, P, K, Ca, Mg, and S) and 7 of which are micronutrient elements (Fe, Zn, Mn, Cu, B, Mo, and Cl). Macronutrient elements are required for plant development, whereas micronutrient elements participate in various metabolic processes, including primary and secondary metabolisms, cell defense, signal transmission, gen regulation, energy metabolism, and hormone secretion. A deficit or toxicity causes severe disease symptoms in plants and, when not treated, they cause damage in the plant (Aygün et al., 2018; Koç, 2019).

Material and Method

Within the scope of this study, it was aimed to determine the change of nutrient elements by species and organ in organs of woody plants in an area where the edaphic and climatic factors are as homogeneous as possible. In this parallel, the plants grown at the city center of Ankara province were used. Within the scope of this study, leaf and branch samples were taken from the last year's offshoots of *Prunus cerasifera, Platanus orientalis, Acer negundo, Fraxinus excelsior*, *Catalpa bignonioides, Aesculus hippocastanum,* and *Tilia platypyllos* species that are widely used in landscaping works in city centers. The branch samples taken to the laboratory were separated into bark and wood parts. Thus, leaf, bark, and wood samples were obtained.

The samples were kept under laboratory conditions until day-dried, and then they were dried in a drying oven at 45°C for 2 weeks. Then, 0.5g of dried samples were added with 6ml 65% HNO_3 and 2 ml 30% H_2O_2 and placed into the microwave oven. The microwave was programmed to increase the temperature to 200°C in 15 minutes and then stay at 200°C for 15 minutes. The samples were combusted in Milostone Ethos one model microwave. Then, the solutions prepared using these samples were taken into balloons and, after completing to 50ml with ultrapure water, the GBC Integra XL-SDS-270 ICP-OES device was used to analyze K and Mg (macronutrient elements) and Cu (micronutrient element). This method is one of the most widely used methods utilized in determining the elements in plants (Sevik et al., 2020a,b). During this study, all the measurements were triplicated.

The data obtained were analyzed using variance analysis in SPSS 22.0 package software. Duncan test was conducted for the factors found to have statistically significant differences at the confidence level of 95% (minimum) (P<0.05), and homogeneous groups were obtained. The data obtained were interpreted after simplification and tabularization.

Results

The values regarding the change of the concentration of the K, one of the macronutrient elements examined in the present study, by species and organ are presented in Table 1.

Table 1. Change of K concentration by species and organ

Species	Organ		
	Leaf	Bark	Wood
P. cerasifera	15076.6^{a}	14629.7^{g}	3370.2^{c}
P. orientalis	15735.0^{ab}	4212.7^{a}	12156.7^{f}
A. negundo	15547.4^{ab}	8126.7^{c}	3950.7^{d}
F. excelsior	16006.6^{ab}	8731.3^{d}	2333.0^{a}
C. bignonioides	17954.6^{c}	9784.0^{e}	17543.4^{g}
A. hippocastanum	17716.6^{ab}	11377.5^{f}	3266.1^{b}
T. platypyllos	21107.3^{c}	5897.7^{b}	4718.3^{e}
F Value	6.578**	21038.154***	123538.157***

** significance at 0.01. *** significance at 0.001 level

Table 2. Change of Mg concentration by species and organ

Species	Organ		
	Leaf	Bark	Wood
P. cerasifera	771.6^{a}	857.8^{f}	326.6^{c}
P. orientalis	2168.1^{c}	764.0^{d}	1163.1^{e}
A. negundo	2222.9^{c}	1495.5^{g}	382.8^{d}
F. excelsior	2725.3^{d}	804.6^{e}	32.9^{a}
C. bignonioides	4131.3^{e}	189.8^{c}	2199.0^{f}
A. hippocastanum	1530.2^{b}	82.1^{a}	101.6^{b}
T. platypyllos	2138.4^{c}	174.9^{b}	104.8^{b}
F Value	90.090***	27378.608***	54029.718***

*** significance at 0.001 level

Table 3. Change of Cu (ppm) concentration by species and organ

Species	Organ		
	Leaf	Bark	Wood
P. cerasifera	367.4^{a}	408.5^{e}	155.5^{b}
P. orientalis	584.4^{c}	1186.2^{f}	553.8^{c}
A. negundo	1058.5^{e}	363.8^{c}	182.3^{b}
F. excelsior	1297.8^{f}	383.1^{d}	831.6^{d}
C. bignonioides	1967.3^{g}	90.4^{b}	1047.1^{e}
A. hippocastanum	462.4^{b}	39.1^{a}	48.4^{a}
T. platypyllos	659.5^{d}	83.3^{b}	49.9^{a}
F Value	3078.203***	8633.564***	601.014***

*** significance at 0.001 level

As a result of the variance analysis, it was determined that the change of K element was statistically significant (P<0.01). When examining the mean values, it was determined that the highest mean values were obtained in *C. bignonioides* and *T. platypyllos* for leaves, *P. cerasifera* and *A. hippocastanum* for barks, and *C. bignonioides* and *P. orientalis* for woods. Moreover, the highest values were achieved in leaves in all the species. Another interesting point is that there might be very high levels of difference between the organs. The values and groups obtained as a result of the statistical analyses on the change of the concentration of Mg, another macronutrient element examined here, by species and organ are presented in Table 2.

It was determined that the change of Mg concentration by species was statistically significant in all the organs (P<0.001). The highest values were found in leaves in *C. bignonioides* and *F. excelsior*, in *A. negundo* and *P.*

cerasifera in barks, and in *C. bignonioides* and *P. orientalis* in woods. It is attention-grabbing that the highest values obtained in woods were found in the same species with K values. It can be seen that the highest Mg concentrations were generally obtained from leaves, and there might be remarkable differences between organs. The values and groups obtained as a result of the statistical analyses on the change of the concentration of Cu, another macronutrient element examined here, by species and organ are presented in Table 3.

As in the other elements, the change of Cu concentration by species was found to be statistically significant in all the organs ($P<0.001$). Examining the mean values, the highest values were in *C. bignonioides* and *F. excelsior* for leaves, *P. orientalis* and *P. cerasifera* for barks, and *C. bignonioides* and *F. Excelsior* for woods. Moreover, the highest values were obtained in leaves in all the species, except for *P. orientalis* and *P. cerasifera*. Again, as in the other elements, there were very remarkable differences between the organs.

Discussion and Conclusion

It was determined that the change of the concentrations of K, Mg, and Cu elements, which were examined within the scope of this study, by species were found to be statistically significant in all the organs. The elements examined here are essential for plant development. K, which is one of the elements that plants need most, plays a vital role in stoma space, plant growth, and cell growth. Moreover, it is also necessary to convey the carbohydrates produced as a result of photosynthesis; to the fruit or roots through the phloem. K playing an important role in conveying the anions in xylem and phloem is critical in adaptation to various stress conditions and plant-water relationships (Denizhan et al., 2021).

Mg, another element examined here, is a white mineral that exists in the soil in various compounds, is very light, and can burn with a white flame in the air. Mg is one of the very important, maybe the most important, among 11 vital minerals. The amount of magnesium in the human body is approx. 20-28 g, and 60% of this amount is found in bones and teeth and 40% in muscles. When compared to the previous years, individuals take this mineral at lower amounts. Mg is a vital mineral and is difficultly absorbed in bowels. Magnesium is necessary at any point where energy is needed. Since the body cannot produce this mineral on its own, magnesium should be taken via nutrients. It is found in chlorophyll in plants, and it retains the energy photons coming from the sun (Işık et al., 2004; Boğa, 2007). The magnesium in the soil is used by the plants, and it can be called the ferrous of the plant kingdom (Işık et al., 2004). Mg is the central atom of chlorophyll and has vital importance in photosynthesis. For this reason, in the case of Mg deficiency, the amount of chlorophyll decreases and photosynthesis reduces; as a result, the growth decelerates, and yield losses occur (Mossi, 2018).

Cu is an essential element since it plays an important role in enzyme activation and carbohydrate and lipid metabolisms (Asri and Sönmez, 2006). In previous studies, it was reported that copper plays critical roles in physiological processes, such as photosynthesis, respiration, carbohydrate degradation, use and storage of nitrogen, and cell membrane metabolism, that it regulates the xylem permeability, that it controls the DNA and RNA production, and that it plays an important role in the disease resistance mechanism. It was reported that plant reproduction stops in case of a copper deficiency (Okcu et al., 2009).

As a result, it was found that the concentrations of these elements by species remarkably varied between the organs of plants. In many studies carried out before, it was determined that the concentrations of many elements significantly varied between species (Turkyilmaz et al., 2018a,b). The accumulation of elements within the plant body is closely related to plant habitus and development (Savas et al., 2021). Plant development is shaped by the interaction between genetic structure (Güney et al., 2019a,b; Shults et al., 2020; Koç, 2021a,b) and environmental conditions (Koç, 2021c; Varol et al., 2021a,b; Canturk and Kulac, 2021). Thus, the environmental conditions and factors influencing the genetic structure affect the intake of elements into the body of plants both directly and indirectly (since it influences the plan development) (Mossi, 2018).

The intake of elements into the plant organism occurs mainly via roots and leaves. However, it is not easy to determine the origins of elements found in the plant because the intake pathways can operate synchronously with each other (Shahid et al., 2017). Thus, the factors influencing the soil and air composition also affect the element concentrations in plants (Cetin et al., 2020). For instance, air pollution in urban areas increases the concentrations of heavy metals, many of which act as micronutrient elements, in the air (Isinkaralar, 2020; Koç, 2021a; Savas et al., 2021). The air pollution and anthropogenic factors in urban areas can also cause soil pollution (Isinkaralar et al., 2017; Bayraktar et al., 2019a,b). Hence, the concentrations of these elements in plants grown in these areas are at very high levels (Cesur et al., 2021).

Since the accumulation of nutrient elements in various organs or plants is closely related the plant metabolism, many factors influence the plant metabolism, such as cultural activities, including pruning and shading (Wilson et al., 2013; Kulaç and Yıldız, 2016), stress level (Kulaç et al., 2012; Yildiz et al., 2014; Koc and Nzokou, 2018; Koç, 2021d; Ozel et al., 2021a,b) and genetic structure (Kulaç et al., 2011; Güney et al., 2015; Kulac and Nayır, 2021) or plant, hormone implementation (Turna et al., 2013; Güney et al., 2020; Yıldırım et al., 2020), and water quality (Mutlu et al., 2014, Mutlu and Kurnaz, 2017; Mutlu and Kutlu, 2017; Mutlu and Uncumusaoğlu, 2018; Mutlu, 2019; Mutlu and Emin Güzel, 2019; Sutan et al., 2020; Uncumusaoğlu and Mutlu, 2021, Mutlu et al., 2021; Mutlu, 2021, Tokatli et al., 2021) also affect the accumulation of elements in plants. Moreover, the environmental and soil structure altered by humans (Kravkaz Kuscu et al., 2018a,b) and also the human-created micro ecological factors (Cetin et al., 2018a,b) affect the change of element concentrations in plant organs. For instance, the previous studies showed that the particles, most of which also are micronutrient elements) in the air are contaminated by heavy metals, and that these particles increase the element concentrations in leaves by adhering onto the leaves (Karacocuk et al., 2021). Thus, the particles that can more easily adhere to the barks because of the rough surface structure can cause much higher element concentrations in barks when compared to the other organs (Koç, 2021a). Within the scope of this study, when compared to the other organs, much higher Cu concentrations are obtained from *P. orientalis* and *P. cerasifera* barks might be because of the particle matters.

In conclusion, the change of element concentrations in plant organs results from a complex mechanism that depends on the mutual interaction of many factors, and this mechanism could not be wholly revealed yet (Sevik, 2021). The studies on this subject have generally focused on the annual plants, and the number of studies carried out, especially on trees, is relatively limited. Thus, it is recommended to diversify and increase the studies on this subject and to carry out these studies in controlled environments if possible.

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