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Change of Calcium Concentrations in Forest Soils by Plant Species and Soil Depth

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Abstract: One of the most important factors playing role in plant development is the nutrient element content of the soil. Being one of the fundamentally necessary macronutrients for plant nourishment, calcium (Ca) plays an important role in the growth and development of a plant. Thus, even though many studies have been carried out on the change of Ca concentration in agricultural soils, the number of studies examining this subject for forest soils is very limited. In the present study, it was aimed to compare the concentrations of Ca in soil and plant organs for the soils, where different forest trees are grown. Within this scope, leaf, bark, wood, cone, and root samples were collected from Turkish fir, black pine, Scotch pine, and Oriental beech species and soil samples were taken from the surface, mid-deep, and deep soil levels. Then, the Ca concentrations were compared. As a result, it was determined that Ca concentrations statistically significantly vary between leaves, roots, and woods of plants and between mid-deep and deep soils by species ($p<0.05$).

Keywords: Soil, Forest, Nutrient Element, Ca

Öz: Bitki gelişiminde rol oynayan en önemli faktörlerden biri toprağın besin element içeriğidir. Bitki beslenmesi için temel olarak gerekli makro besinlerden biri olan kalsiyum (Ca), bitkinin büyüme ve gelişmesinde önemli bir rol oynar. Bu nedenle tarım topraklarında Ca konsantrasyonunun değişimi ile ilgili birçok çalışma yapılmış olmasına rağmen orman toprakları için bu konuyu inceleyen çalışma sayısı oldukça sınırlıdır. Bu çalışmada, farklı orman ağaçlarının yetiştirildiği topraklar için toprak ve bitki organlarındaki Ca konsantrasyonlarının karşılaştırılması amaçlanmıştır. Bu kapsamda köknar, karaçam, sarıçam ve doğu kayını türlerinden yaprak, ağaç kabuğu, odun, koni ve kök örnekleri toplanmış ve yüzey, orta-derin ve derin toprak seviyelerinden toprak örnekleri alınmıştır. Daha sonra Ca konsantrasyonları karşılaştırıldı. Sonuç olarak, Ca konsantrasyonlarının bitkilerin yaprak, kök ve odunları arasında ve türlere göre orta-derin ve derin topraklar arasında istatistiksel olarak anlamlı farklılık gösterdiği belirlenmiştir ($p<0.05$).

Anahtar Kelimeler: Toprak, Orman, Besin Elementi, Ca

1. Introduction

Plants are grown and perform on the soil where they photosynthesis by using the sunlight and produce the nutrients that are required by other organisms [1, 2]. Thus, the entire organic life is directly or indirectly dependent upon the plants [3]. For the plants, offering the benefits they are supposed to offer depends on their healthy growth and development [4-6]. Plant development depends mainly on climatic [7-9] and edaphic factors [10-12] and nutrient elements are among the factors influencing the plant development the most [13-14].

In plant nourishment, there are 16 fundamental nutrient elements that are required and, being one of these elements, calcium (Ca) is among the elements that are required for plant growth and development [15]. Ca plays an important role in growth and development of cells, in arranging the membrane permeability, in stabilization of tissues, and also in quality of plants. Moreover, it has also important effects on the chemical characteristics of the soil. Thus, it is of an inevitable importance for fauna, microflora, plant, and soil. In case of Ca deficiency, besides a decrease in plant yield, also the quality decreases generally [15-17].

Ca is also a heavy metal. Some of the heavy metals (such as Pb, Cr, Ni, and Hg) are toxic, carcinogenic, and harmful for organisms even when at low concentrations [18-21] and the ones that are necessary as plant nutrient elements can be harmful for organisms when at high concentrations [22-24]. Hence, it is very important to monitor the concentrations of heavy metals in air, soil, and water [25-27]. In the present study, in order to understand the interaction of Ca in soil and plant organs, the change of Ca concentrations in soil and plant organs was examined in soils, where different forest trees are grown.

2. Material and Method

The main objective of the present study is to investigate the variance in Ca concentration by the plant species grown in soils forming on the same bedrock. Thus, an area, where different forest trees are grown but the environmental factors are similar, was chosen as the study material. The study area, which is a plain field, is in the Araç district of Kastamonu province and the environmental factors other than the plant species are similar. Thus, it was accepted that the main factor altering the soil structure was the plant species.

Within the scope of this study, leaf, bark, wood, cone, and root samples were collected from Turkish fir (*Abies nordmanniana* subsp. bornmülleriana Mattf), black pine, (*Pinus nigra* Arnold.), Scotch pine, (*Pinus sylvestris* L.), and Oriental beech (*Fagus orientalis* Libsky.) species grown in places, which were close to each other, whereas the soil samples were taken from surface (0-5 cm), mid-depth (20-30 cm), and deep (50-60 cm) levels under each trees. Ca analyses were performed using the ICP-OES device. This method is one of the most widely used methods preferred in many studies in recent years [28-31]. The data obtained were analyzed using Variance analysis and Duncan's test by making use of SPSS package software. The data were interpreted after simplifying and tabularizing them.

3. Result and Discussion

The data and statistical analysis results regarding the change of Ca concentration in plant organs are presented in Table 1.

Table 1. Change of Ca concentration between plant organs

Species	Organ					F Values	Average
	Leaf	Bark	Cone	Wood	Root		
Tf	8164.4 Db	5901.4 C	3803.6 B	1614.8 Aa	7881.9 CDb	14.4***	5473.2
Bp	6624.7 Ca	5574.8 B	1458.3 A	4517.4 Bb	3695.7 Ba	7.97***	4374.2
Sp	6880.2 Ba	8047.9 B	1773.0 A	1547.1 Aa	7146.3 Bb	63.89***	5078.9
Ob	8205.6 Cb	4999.7 A	-	3907.9 Ab	6599.1 Bb	14.90***	5928.1
F Values	9.36***	2.20 ns	2.80 ns	12.59***	15.85***		2.19 ns
Average	7468.7 C	6130.9 B	2344.9 A	2896.8 A	6330.8 B	37.59***	

Variance analysis results showed that the change of Ca concentration by organ was statistically significant in all the species at the confidence level of 99.9%. Given the data, it can be seen that the lowest values were obtained from the woods and cones, whereas the highest values were obtained from the leaves. Examining by the species, the change of Ca concentration was not statistically significant in barks and cones ($p>0.05$). Considering the leaves, the lowest values were obtained from the pine varieties, whereas the highest ones were obtained from beech and fir species. The changes of Ca concentration in soil samples are presented in Table 2.

Table 2. Change of Ca concentration in soils

Species	Soil depth			F Values	Average
	Upper	Medium	Lower		
Tf	8855.75	8695.33 b	8993.38 bc	0.08 ns	8848.15 b
Bp	8858.86 A	10105.41 Bc	7673.16 Ab	4.34*	8879.14 b
Sp	9209.50	9606.77 bc	9594.08 c	0.42 ns	9470.12 b
Ob	8770.61 B	5014.27 Aa	5635.52 Aa	17.65***	6473.47 a
F Values	0.12 ns	48.19***	10.55***		16.14***
Average	8923.68	8355.45	7974.04	1.99 ns	

As can be seen in Table 2, the change of Ca concentration by the soil depth was statistically significant for only soils, where Bp and Ob were grown ($p>0.05$). Besides that, the change of Ca concentration was not statistically significant for the surface level but statistically significant for mid-depth and deep levels. In mid-depth level, the lowest value was obtained from the soils where Ob was grown, whereas the highest values were obtained from the soils where pine varieties were grown. Considering the deep level, the lowest values were obtained from the soils where Ob was grown, whereas the highest values were obtained from the soils where Tf and Sp were grown.

4. Discussion and Conclusion

The results obtained here showed that Ca concentration in plant organs and in soils, where the species examined here are grown, might change depending on the plant species. It suggests that Ca nutrient element in soils is used at different levels by different plants. Therefore, plants significantly alter the nutrient element content in the soils, where they are grown. The nutrient element content of the soil is one of the most important factors influencing the root development of plants

[32-34]. As with all other organisms, the phenotypical characteristics and development of plants are shaped under the effects of plants' genetic structures [35-37] and environmental factors [38-41].

Among the environmental factors, one of the main factors influencing the plant development is the soil structure. Many factors such as nutrient content of soil, soil depth, enzymatic activities, microorganism status, soil structure, and soil texture influence the plant development [13, 42]. In fact, although the main factors influencing the plant development are the climatic [43-46] and edaphic [47-49] factors, previous studies showed that microclimatic and microedaphic factors affected the development and phenotypical characteristics of plants more than macro factors did [50-51] because plants get stressed due to various factors such as temperature, water deficiency, frost, UV-B, diseases and pests, and air pollution and it significantly affects plant development and phenotypical characteristics [52-61]. Among these factors, one of the ones influencing the plant development the most is the soil composition, which indicates the nutrient content of the soil [13,32].

Plants utilize the nutrient elements, which are necessary for their development, by taking them from the soil through their roots. As a result, the amount of nutrient content in the soil decreases and it affects the plant development. In agricultural soils, the deficiency of nutrient elements in the soil can be compensated through fertilization. However, since no fertilization can be performed in forest soils and it is necessary to carefully select the tree species to be grown by considering the nutrient content in the soil. But the number of studies examining to what extent the forest trees utilize which nutrient elements to what extent is very limited.

To date, many studies were carried out examining the concentrations of various nutrient elements in plant organs [62-64] and the soils [33-34]. However, the intake of nutrient elements into plants occurs through roots and aboveground roots. The knowledge of which sources the nutrient elements in plant organs are taken into plant body from is very limited [65]. Similarly, the information about the transfer of nutrient elements within the plant after the intake from soil or air is also limited [66-68]. Thus, to provide important information, it is necessary to determine the amounts of nutrient elements in soil and to perform comparative evaluations. Hence, it is recommended to carry out and diversify the studies examining this subject.

Competing Interest / Conflict of Interest

The authors declare that they have no competing interests.

Author Contribution

We declare that all Authors equally contribute.

5. References

[1] Yigit, N., Cetin, M., Ozturk, A., Sevik, H., & Cetin, S. (2019). Varitation of stomatal characteristics in broad leaved species based on habitat. Applied Ecology and Environmental Research, 17(6),12859-12868.

[2] Ozel, H. B., Donduran, B., Cakmakli, E., & Sevik, H. (2020). Factors affecting success in natural regeneration works of cedar (*Cedrus libani* A. Rich.) In Kas region of Antalya. World Journal of Advanced Research and Reviews, 6(2), 054-059.

[3] Cesur, A., Zeren Cetin, I., Abo Aisha, A. E. S., Alrabiti, O. B. M., Aljama, A. M. O., Jawed, A. A., Cetin, M., Sevik, H., Ozel, H. B. (2021). The usability of *Cupressus arizonica* annual rings in monitoring the changes in heavy metal concentration in air. Environmental Science and Pollution Research, 8(27), 35642-35648.

[4] Aricak, B., Cetin, M., Erdem, R., Sevik, H., & Cometen, H. (2019). The change of some heavy metal concentrations in Scotch pine (*Pinus sylvestris*) depending on traffic density, organelle and washing. Applied Ecology and Environmental Research, 17(3), 6723-6734.

[5] Sevik, H., Cetin, M., Kapucu, O., Aricak, B., & Canturk, U. (2017). Effects of light on morphologic and stomatal characteristics of Turkish Fir needles (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.). Fresenius Environmental Bulletin, 26(11), 6579-6587.

[6] Yucedag, C., Ozel, H. B., Cetin, M., & Sevik, H. (2019). Variability in morphological traits of seedlings from five *Euonymus japonicus* cultivars. Environmental Monitoring and Assessment, 191(5), 1-4.

[7] Koç, İ. (2021). Changes that may occur in temperature, rain, and climate types due to global climate change: the example of Düzce. Turkish Journal of Agriculture-Food Science and Technology, 9(8), 1545-1554.

[8] Koç, İ. (2022). Determining the biocomfort zones in near future under global climate change scenarios in Antalya. Kastamonu University Journal of Engineering and Sciences, 8(1), 6-17.

[9] Zeren Cetin, I., Varol, T., Ozel, H. B. & Sevik H. (2022). The effects of climate on land use/cover: a case study in Turkey by using remote sensing data. Environmental Science and Pollution Research, 1-12.

[10] Varol, T., Ozel, H. B., Ertugrul, M., Emir, T., Tunay, M., Cetin, M., & Sevik, H. (2021). Prediction of soil-bearing capacity on forest roads by statistical approaches. Environmental Monitoring and Assessment, 193(8), 527.

[11] Sevik, H., Cetin, M., Ozel, H. B., & Pinar, B. (2019). Determining toxic metal concentration changes in landscaping plants based on some factors. Air Quality, Atmosphere & Health, 12(8), 983-991.

[12] Shults, P., Nzokou, P., & Koc, I. (2020). Nitrogen contributions of alley cropped Trifolium pratense may sustain short rotation woody crop yields on marginal lands. Nutrient Cycling in Agroecosystems, 117(2), 261-272.

[13] Kravkaz Kuscu, I. S., Cetin, M., Yigit, N., Savaci, G., & Sevik, H. (2018). Relationship between enzyme activity (Urease-Catalase) and nutrient element in soil use. Polish Journal of Environmental Studies, 27(5), 2107-2112.

[14] Erdem, R. (2021). Change of Several Plant Nutrient Elements by Plant Species and Organ. Turkish Journal of Agriculture-Food Science and Technology, 9(12), 2319-2324.

[15] Tuna, L. A. & Özer, Ö. (2005). Effect of different calcium compounds on the fruit yield, nutrition and some quality properties of watermelon (*Citrullus lanatus*) plant. Journal of Ege University Faculty of Agriculture, 42(1), 203-212.

[16] Mossi, M. M. M. (2018). Determination of heavy metal accumulation ın some shrub formed landscape plants. Kastamonu University, Institute of Science Department of Forest Engineering, PhD. Thesis. 141 pages.

[17] Cetin, M., Sevik, H., & Cobanoglu, O. (2020). Ca, Cu, and Li in washed and unwashed specimens of needles, bark, and branches of the blue spruce (Picea pungens) in the city of Ankara. Environmental Science and Pollution Research, 27(17), 21816-21825.

[18] Isinkaralar K. (2022). Some atmospheric trace metals deposition in selected trees as a possible biomonitor. Romanian Biotechnological Letters, 27(1), 3227-3236.

[19] Kuzmina, N., Menshchikov, S., Mohnachev, P., Zavyalov, K., Petrova, I., Ozel, H.B., Aricak, B., Onat, S. M., & Sevik, H. (2022). Change of aluminum concentrations in specific plants by species, organ, washing, and traffic density. BioResources, (InPress)

[20] Isinkaralar, K. (2022). Atmospheric deposition of Pb and Cd in the *Cedrus atlantica* for environmental biomonitoring. Landscape and Ecological Engineering, 1-10.

[21] Sevik, H., Cetin, M., Ozturk, A., Ozel, H. B., & Pinar, B. (2019). Changes in Pb, Cr and Cu concentrations in some bioindicators depending on traffic density on the basis of species and organs. Applied Ecology and Environmental Research, 17(6),12843-12857.

[22] Elajail, I. S. I., Sevik, H., Ozel, H. B., & Isik, B. (2022). Examining the chemical compositions of mineral concrete agents in terms of their environmental effects, Feb-Fresenius Environmental Bulletin. (InPress).

[23] Ghoma, W., Sevik, H. & Isinkaralar, K. (2022). Using indoor plants as biomonitors for detection of toxic metals by tobacco smoke. Air Quality, Atmosphere & Health, 15, 415-424.

[24] Isinkaralar, K., Erdem, R. (2021), Landscape plants as biomonitors for magnesium concentration in some species. International Journal of Progressive Sciences and Technologies, 29(2), 468-473.

[25] Isinkaralar, K., Koc, I., Erdem, R., Sevik, H. (2022). Atmospheric Cd, Cr, and Zn deposition in several landscape plants in Mersin, Türkiye. Water, Air, & Soil Pollution, 233(4), 1-10.

[26] Koç, İ. (2021). Using *Cedrus atlantica*'s annual rings as a biomonitor in observing the changes of Ni and Co concentrations in the atmosphere. Environmental Science and Pollution Research, 28(27), 35880–35886.

[27] Ucun Ozel, H., Ozel, H. B., Cetin, M., Sevik, H., Gemici, B. T., & Varol, T. (2019). Base alteration of some heavy metal concentrations on local and seasonal in Bartin River. Environmental Monitoring and Assessment, 191(9), 594.

[28] Sevik, H., Ozel, H. B., Cetin, M., Özel, H. U., & Erdem, T. (2019). Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants. Air Quality, Atmosphere & Health, 12(2), 189-195.

[29] Sulhan, O.F., Sevik, H. & Isinkaralar, K. (2022). Assessment of Cr and Zn deposition on *Picea pungens* Engelm. in urban air of Ankara, Türkiye. Environment, Development and Sustainability, 1-20.

[30] Isinkaralar, K. (2022). Temporal variability of trace metal evidence in Cupressus arizonica, Platanus orientalis, and Robinia pseudoacacia as pollution-resistant species at an industrial site. Water, Air, & Soil Pollution, 233(7), 1-12.

[31] Isinkaralar, K., Isinkaralar, O., Sevik, H. (2022). Usability of some landscape plants in biomonitoring technique: an anaysis with special regard to heavy metals. Kent Akademisi Dergisi, 15(3),1413-1421.

[32] Kravkaz-Kuscu, I. S., Sariyildiz, T., Cetin, M., Yigit, N., Sevik, H., & Savaci, G. (2018). Evaluation of the soil properties and primary forest tree species in Taskopru (Kastamonu) district. Fresenius Environmental Bulletin, 27 (3), 1613-1617.

[33] Isinkaralar, K. (2022). Theoretical removal study of gas form BTEX onto activated carbon produced from Digitalis purpurea L. biomass. Biomass Conversion and Biorefinery, 1-11.

[34] Cetin, M., Aljama, A. M. O., Alrabiti, O. B. M. Adiguzel, F., Sevik, H., & Zeren Cetin, I. (2022). Using topsoil analysis to determine and map changes in Ni, Co pollution. Water, Air and Soil Pollution, 233, 293.

[35] Sevik, H., Yahyaoglu, Z., & Turna, I. (2012). Determination of genetic variation between populations of *Abies nordmanniana* subsp. *bornmulleriana* Mattf according to some seed characteristics, genetic diversity in plants. Chapter, 12, 231-248.

[36] Kurz, M., Koelz, A., Gorges, J., Carmona, B. P., Brang, P., Vitasse, Y., ... & Csillery, K. (2022). Tracing the origin of Oriental beech stands across Western Europe and reporting hybridization with European beech-implications for assisted gene flow. bioRxiv.

[37] Koç, İ (2021). Examination of gas exchange parameters of *Abies balsamea* (L.) Mill. and Abies concolor saplings, grown under various water regime, exposed to extreme drought stress at the end of the growing season. Turkish Journal of Forest Science, 5(2), 592-605.

[38] Bayraktar, E. P., Isinkaralar, O., & Isinkaralar, K. (2022). Usability of several species for monitoring and reducing the heavy metal pollution threatening the public health in urban environment of Ankara. World Journal of Advanced Research and Reviews, 14(3), 276-283.

[39] Isinkaralar, O., & Varol, C. (2023). A cellular automata-based approach for spatio-temporal modeling of the city center as a complex system: The case of Kastamonu, Türkiye. Cities, 132, 104073.

[40] Koç, İ. (2022). Determining the near-future biocomfort zones in Samsun province by the global climate change scenarios. Kastamonu University Journal of Forestry Faculty, 22(2), 181-192.

[41] Sevik, H., Cetin, M., & Kapucu, O. (2016). Effect of light on young structures of Turkish fir (*Abies nordmanniana* subsp. *bornmulleriana*). Oxidation Communications, 39(1), 485-492.

[42] Koç, İ., Nzokou, P., Cregg B. (2021). Biomass allocation and nutrient use efficiency in response to water stress: Insight from experimental manipulation of balsam fir, concolor fir and white pine transplants. New Forests, 53(5), 915-933.

[43] Isinkaralar, O., Varol, C., & Yilmaz, D. (2022). Digital mapping and predicting the urban growth: integrating scenarios into cellular automata—Markov chain modeling. Applied Geomatics, 1-11.

[44] Koç, İ. (2021). Examining seed germination rate and seedlings gas exchange performances of some Turkish Red pine provenances under water stress. Düzce University Journal of Science & Technology, 9(3), 48-60.

[45] Zeren Cetin, I. & Sevik, H. (2020). Investigation of the relationship between bioclimatic comfort and land use by using GIS and RS techniques in Trabzon. Environmental Monitoring and Assessment, 192 (2), 71.

[46] Tekin, O., Cetin, M., Varol, T., Ozel, H. B., Sevik, H., Zeren Cetin, I. (2022). Altitudinal migration of species of Fir (Abies spp.) in adaptation to climate change. Water, Air, & Soil Pollution, 233, 385 (2022).

[47] Varol, T., Emir, T., Akgul, M., Ozel, H. B., Acar, H. H., & Cetin, M. (2020). Impacts of small-scale mechanized logging equipment on soil compaction in forests. Journal of Soil Science and Plant Nutrition, 1-11.

[48] Işınkaralar, K. & Erdem, R. (2022). The effect of atmospheric deposition on potassium accumulation in several tree species as a biomonitor. Environmental Research and Technology, 5(1), 94-100.

[49] Karacocuk, T., Sevik, H., Isinkaralar, K. Turkyilmaz, A., Cetin, M. (2022). The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density. Landscape and Ecological Engineering, 18, 75-83.

[50] Yigit, N., Mutevelli, Z., Sevik, H., Onat, S. M., Ozel, H. B., Cetin, M., Olgun, C. (2021). Identification of some fiber characteristics in Rosa sp. and Nerium oleander L. wood grown under different ecological conditions. BioResources, 16(3), 5862-5874.

[51] Sevik, H., Cetin, M., Ozel, H. B., Erbek, A., & Cetin, I. Z. (2021). The effect of climate on leaf micromorphological characteristics in some broad-leaved species. Environment, Development and Sustainability, 23(4), 6395-6407.

[52] Ozel, H. B., Cetin, M., Sevik, H., Varol, T., Isik, B., Yaman, B. (2021). The effects of base station as an electromagnetic radiation source on flower and cone yield and germination percentage in Pinus brutia Ten. Biologia Futura. https://doi.org/10.1007/s42977-021-00085-1

[53] Yigit, N., Cetin, M., & Sevik, H. (2018). The of *Prunus laurocerasus* L. species by their habitat. Turkish Journal of Agriculture-Food Science and Technology, 6 (11), 1517-1521.

[54] Koç, İ. (2021). Examining of seed germination rate and seedlings gas exchange performances of Anatolian black pine under water stress. International Karabakh Applied Science Conference. Khazar Univeristy, June 17-19, 2021. (Conference paper).

[55] Işınkaralar, K. (2021). Changes in cadmium (Cd) concentrations in some plants depending on traffic density. New Trends and Issues Proceedings on Advances in Pure and Applied Sciences, (14), 63-70.

[56] Guney, K., Cetin, M., Sevik, H., Guney K. B. (2016). Influence of germination percentage and morphological properties of some hormones practice on *Lilium martagon* L. seeds. Oxidation Communications, 39(1-II), 466-474.

[57] Cesur, A., Zeren Cetin, I., Cetin, M., Sevik, H., Ozel, H. B. (2022). The use of *Cupressus arizonica* as a biomonitor of Li, Fe, and Cr pollution in Kastamonu. Water, Air and Soil Pollution, 233, 193.

[58] Koc, I., & Nzokou, P. (2018). Effects of water stress and cold treatments on the germination of two conifers (*Pinus nigr*a and *Pinus brutia*) species from Turkey. Hortscience, 53(9), 259-259.

[59] Sevik, H., & Erturk, N. (2015). Effects of drought stress on germination in fourteen provenances of *Pinus brutia* Ten. seeds in Turkey. Turkish Journal of Agriculture-Food Science and Technology, 3(5), 294-299.

[60] Sevik, H., & Karaca, U. (2016). Determining the resistances of some plant species to frost stress through ion leakage method. Feb-Fresenius Environmental Bulletin, 25(8), 2745-2750.

[61] Varol, T., Cetin, M., Ozel, H. B., Sevik, H., Zeren Cetin, I. (2022). The effects of climate change scenarios on *Carpinus betulus* and *Carpinus orientalis* in Europe. Water, Air and Soil Pollution, 233, 45.

[62] Savas, D.S., Sevik, H., Isinkaralar, K. Turkyilmaz, A. & Cetin, M. (2021). The potential of using *Cedrus atlantica* as a biomonitor in the concentrations of Cr and Mn. Environmental Science and Pollution Research, 28(39), 55446-55453.

[63] Turkyilmaz, A., Cetin, M., Sevik, H., Isinkaralar, K., & Saleh, E. A. A. (2020). Variation of heavy metal accumulation in certain landscaping plants due to traffic density. Environment, Development and Sustainability, 22(3), 2385-2398.

[64] Sevik, H., Cetin, M., Ozel, H. B., Ozel, S., & Cetin, I. Z. (2020). Changes in heavy metal accumulation in some edible landscape plants depending on traffic density. Environmental Monitoring and Assessment, 192(2), 78.

[65] Shahid, M., Dumat, C., Khalid, S., Schreck, E., Xiong, T., & Niazi, N. K. (2017). Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. Journal of Hazardous Materials, 325, 36-58.

[66] Key, K., & Kulaç, Ş. (2022). Proof of concept to characterize historical heavy metal concentrations from annual rings of *Corylus colurna*: determining the changes of Pb, Cr, and Zn concentrations in atmosphere in 180 years in North Turkey. Air Quality, Atmosphere & Health, 1-11.

[67] Turkyilmaz, A., Sevik H., Isinkaralar K, & Cetin M. (2019). Use of tree rings as a bioindicator to observe atmospheric heavy metal deposition, Environmental Science and Pollution Research, 26(5), 5122-5130.

[68] Yayla, E. E., Sevik, H., & Isinkaralar, K. (2022). Detection of landscape species as a low-cost biomonitoring study: Cr, Mn, and Zn pollution in an urban air quality. Environmental Monitoring and Assessment, 194(10), 1-10.