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Research Article

The effect of atmospheric deposition on potassium accumulation in several tree species as a biomonitor

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ABSTRACT

Minimizing air, water, and soil pollution are very important for a sustainable environment. Particularly, ensuring the continuity of soil fertility without deteriorating the soil structure is very important. This objective can be achieved only by determining the physical, biological, and chemical properties of atmospheric deposition and taking the required measures in agricultural lands. Trees and plants reflect the soil quality and especially they take both beneficial and harmful materials in their bodies owing to Saharan dust and using fossil fuel. Among them, nutrient elements have specific importance since it was determined that many factors including texture, irrigation method, organic matter, lime concentration, plant species and age, pH, and ion balance play effective roles in the growth or degradation of plants' productivity. Being one of the major nutrient elements taken by plants, potassium (K^+) is of vital importance for trees and plants. Its concentration, which varies depending on the species of plant, is influenced by the mutual interaction between tree development and environmental/genetic factors. The scope of this study was to evaluate and rank the contribution of atmospheric potassium (K^+) deposition flows to organs of *Robinia pseudoacacia* L., *Cupressus arizonica* G., and *Platanus orientalis* L. trees as biomonitors.

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INTRODUCTION

Rapidly increasing world population and consequent increase in urbanization, industrialization, and unawares use of agricultural lands resulted in deterioration of many forests and fertile agricultural lands [1–3]. Minimizing air, water, and soil pollution is very important for a sustainable environment [4]. Particularly, ensuring the continuity of the urban environment without deteriorating the air and soil structure is very important for a sustainable environment [5]. Although the quality of the soil belongs to the region where it is located, atmospheric precipitation plays a role in global cases [6]. This is dust transport, emissions from nearby inert sources, and acid rain, which is formed as a result of the reactions of pollutants released due to the use of fossil fuels and their effects on plants [7]. Atmospheric potassium deposition can affect the physical, biological, and chemical properties of soil and take the required measures in agricultural lands via wet, dry, and total deposition [8]. Thus, plants need fundamental

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nutrient elements from the soil to grow and to maintain their metabolic activities. The potassium (K^+) is one of the most abundant elements that represent the amount of potassium defined in a spatial and temporal [9]. It is a nutrient influencing many biochemical and physiological processes [10]. It founds in dust and rainfall that likely comes from terrestrial sources that can quickly be re-deposited or be transported for large distances [11].

The K^+ is a fundamental nutrient allowing plants to survive various biotic and abiotic stresses (diseases, insects, drought, salinity, cold, frost, and flood) [12]. It is important for developmental crops and activation enzymes [13]. It was stated in previous studies that each plant has various concentration values and different levels of need for K element that is the vital impact for enzyme activation, protein synthesis, photosynthesis, energy transfer, stoma movement, osmoregulation, phloem transfer, and cation-anion balance [14]. The most well-known source of K in the soil minerals such as feldspar and mica although it is found in dust and rainfall likely comes from terrestrial sources [15]. The effects of differences in presence of K in different plants on species' anatomy, morphology, and plant metabolism couldn't be explained yet and they are still debated [16]. It was shown that the presence of K allowed the trees to overcome the stress conditions. In previous studies, it was reported that trees and plants primarily need mineral nutrients to overcome biotic and abiotic stress conditions [17–19]. The presence of K in fertilizers used in herbal production increases the quality of fertilizer. It was determined in many studies that the second-most important nutrient for plant development is potassium, following nitrogen. Previous studies showed that plant fertilizer has a positive correlation with crop development and quality. However, potassium deficiency can also be seen in some cases. Potassium deficiency is observed especially in acidic soils with ample water and high salinity levels [20]. Several negativities are observed in the development of plants and trees in such soils. Intake of potassium by plants and trees occurs via roots and the intake levels vary [21]. On the contrary other soil nutrients, K is available in the soil as only a K^+, which supports the plant productivity and environmental services, depending on the deficiency and abundance of nutrients [22]. Besides that, the optimum benefit can be obtained from the fertilization process, which is performed by having accurate knowledge about the chemical and physical properties [23]. For this purpose, many studies were carried out to determine the productivity levels of different regions and soils, to foreknow the potential nutritional problems, and to increase the crop quality [24]. The K^+ is one of the elements used by the plants in the soil at a higher concentration in comparison to the others [25]. Although there are many studies about the accumulation, transport, and levels of The K^+ is one of the elements used by the plants in the soil at higher concentrations of potassium, they could not calculate the amount of potassium that passes from the atmosphere to the soil [26]. For the determination of the available potassium amount, inputs (atmospheric deposition, plant residue, and animal manures, commercial fertilizers, minerals, etc.) and outputs (removal of plant, leaching, erosion, fixation, etc.) of potassium sources should be well known as ecosystem services [27, 28].

Plants and trees are great bioindicators of atmospheric metals deposition including trace and toxic metals due to their effective adsorption capacity of them [29, 30]. The main sources of potassium and other elements are atmospheric inputs as wet, dry, and total deposition [31]. There are also some studies on the atmospheric trace metals transport and deposition on plants from anthropogenic sources [32–35]. The amount of potassium is increased with acid rain and precipitation because trace metals and other pollutants oxides form chemical compounds on terrestrial ecosystems [36]. Biomonitoring with plants ensures inexpensive knowledge on the composition and quantity of the deposition of trace and toxic metals [37]. In this study, the atmospheric potassium deposition was examined in the organs of trees for years. The K^+ concentrations were inspected in the rings of 3 different trees growing in the Kocaeli industrial zone via years and organs. The organs of trees used for this purpose *Robinia pseudoacacia* L., *Cupressus arizonica* G., and *Platanus orientalis* L. were selected because they are widespread on the terrestrial ecosystem for resistance to air pollution. The concentrations of K^+ were analyzed in the outer bark, inner bark, and wood fractions of trees. It was aimed to determine how the K^+ concentration in the annual rings of trees changed over the years.

MATERIALS AND METHODS

Study Area and Sampling Site

The study area is located around the organized zone of Kocaeli city, Türkiye. Significant factors of air pollutants are released from many industrial activities and fuel combustion. Air pollutants may contain heavy metals and toxic elements including macronutrients. Organs (wood, inner bark, and outer bark) of four dominant tree species were used *Robinia pseudoacacia* L., *Cupressus arizonica* G., and *Platanus orientalis* L. in an industrial area and were collected no more than 4 km from the site of the organized zone. All samples were taken from the main trunk of trees. After sampling, wood, inner bark, and outer bark were urgently placed in a glass vessel and transferred to the lab for preparation of analysis.

Preparation of Tree Species Sampling

The tree rings were determined to be 30 years old (between 1991 and 2020) in three years. The species had an almost same trunk diameter and height around 1 m above the ground. All samples were rinsed with acetone (Merck, Ger-

Table 1. Change of K^+ concentrations (ppm) based on species

Organ	Species			F value
	Robinia pseudoacacia L.	*Cupressus arizonica* G.	*Platanus orientalis* L.	
Wood	776.7 Aa	472 Aa	1439.2 Ba	15.8*
Inner bark	1976 Ba	783.9 Aa	6187.1 Cb	48537.8*
Outer bark	3216.8 Bb	1909.8 Ab	6458 Cb	50096.1*
F value	12.2*	36.2*	160.2*	

*: Significant at p<0.001. Upper and lower letters differ significantly based on the Duncan test.

many) then they were divided into groups for the age ranges. All samples taken into glass vessels were kept at 50ºC for 7 days. The samples were taken as 0.5 g weighed and 6 mL of 65% nitric acid (HNO_3) and 2 mL of 30% hydrogen peroxide (H_2O_2) were added to glass vessels. According to USEPA 3052 Method, the combustion process was carried out in the microwave oven at 200ºC for 15 minutes [38]. The resulting samples were made up to 50 mL with ultrapure water and potassium analyzes were made in by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) with a plasma source device (SpectroBlue, Spectro). Analytical grade chemicals were used for the research.

Statistical Analyses

All measurements were repeated as in triplicate. Analysis of variance (ANOVA) and Duncan test was conducted to identify the significance of atmospheric potassium deposition in species by using the SPSS 22.0 statistical package program for Windows.

RESULTS

The biomonitoring organ of plants was chosen outer bark, inner bark, and wood of a *Robinia pseudoacacia* L., *Cupressus arizonica* G., and *Platanus orientalis* L. which, due to its widely used and readily available in local terrestrial ecosystem. It has been proven that it can provide information on the presence of the K^+ element in Table 1.

According to the results of variance analysis (ANOVA) that the change in the concentration of K^+ element on an organ basis in all three species is statistically significant (p<0.001). Considering the Duncan test results, the lowest values are obtained in the wood and the highest values were obtained in the outer bark, the values obtained in the wood and inner bark of *Platanus orientalis* L. are in the same group, and in other species, each organ formed a separate group. Considering the Duncan test results, the inner bark and wood were in the same groups in *Robinia pseudoacacia* L. and *Cupressus arizonica* G. also, the inner bark and the outer bark of *Platanus orientalis* L. were in the same groups. It is noteworthy that the values obtained in the outer bark are many times higher than the values obtained in the inner bark and wood in all three species. The lowest value in the outer bark is obtained in *Cupressus arizonica* G. with 1909.8 ppm, the highest value is obtained in *Robinia pseudoacacia* L. with 3216.8 ppm, the highest value in the inner bark is obtained in *Platanus orientalis* L. with 6187.1 ppm, and the lowest value is obtained in *Cupressus arizonica* G. with 783.9 ppm. In the wood part, the lowest value is obtained in *Cupressus arizonica* G. with 472 ppm, and the highest value is obtained in *Platanus orientalis* L. with 1439.2 ppm. According to these results, it can be said that the lowest values are obtained in *Cupressus arizonica* G. and the highest values are obtained in *Platanus orientalis* L. The change in the K^+ concentration in woods depending on the age range and direction is given in Table 2.

When the values showing the change of K element according to the age range are examined, it is seen that the highest value in *Robinia pseudoacacia* L. is obtained with 3520.9 ppm in 2018–2020, the lowest value with 379.9 ppm in 1994–1996, the lowest value in *Cupressus arizonica* G. in 1997–1999 with 256.8 ppm, the highest value is obtained in the years 2015–2017 with 778.5 ppm, the highest value in *Platanus orientalis* L. with 3069.2 ppm in the years 2018–2020, and the lowest value with 982.1 ppm in the years 1997–1999. According to the analysis of variance results, it is determined that the variation of K concentration depending on the species is statistically significant at least 99.9% confidence level (p<0.001) in all age ranges. When the values are examined, it is very difficult to say that the K^+ concentration changes regularly based on species or year. This situation can be interpreted as the change of K^+ concentration in plants does not change primarily depending on the species or year, and other factors are more dominant.

DISCUSSION

In regions, where four seasons are observed, it was determined that the development of trees increased in parallel with several intakes of potassium (K) in their bodies [39]. Regarding this point, providing data about the nutrient accumulation in trees, tree rings and organs can give important information about the chronology of the atmospheric elements deposition in its ecosystem [40]. Although there are

Table 2. The K^+ concentration (ppm) age interval and species change of in wood

Years	Species			F value
	Robinia pseudoacacia L.	*Cupressus arizonica* G.	*Platanus orientalis* L.	
2018–2020	3520.9 Cg	762.4 Ag	3069.2 Bh	34256.8*
2015–2017	610.2 Af	778.5 Bh	2093.0 Cg	44693.2*
2012–2014	562.6 Ae	773.4 Bh	1688.0 Cf	11214.3*
2009–2011	404.4 Abc	637.2 Be	1160.8 Ce	8293.5*
2006–2008	487.2 Ad	722.8 Bf	1064.6 Cc	2267.6*
2003–2005	591.6 Bf	449.0 Ad	999.9 Cb	15820.5*
2000–2002	393.6 Bab	339.6 Ac	1100.3 Cd	4085.8*
1997–1999	396.1 Bab	256.8 Ab	982.1 Ca	7985.1*
1994–1996	379.9 Ba	123.6 Aa	1169.8 Ce	6713.1*
1991–1993	420.2 Bc	125.8 Aa	1064.2 Cc	28405.3*
F Value	22130.5*	8467.0*	12896.2*	

*: Significant at p<0.001. Upper and lower letters differ significantly based on the Duncan test.

studies on the usability of accumulation in the rings of trees, there are few studies on the transfer of elements between the organs of trees [41]. The changes in the concentration of K^+ in organs of 3 different trees grown in the intense industrial zone in Kocaeli province by organs. They were determined by making use of *Robinia pseudoacacia* L., *Cupressus arizonica* G., and *Platanus orientalis* L. in the present study. It was aimed to evaluate the level of atmospheric K^+ accumulation in the inner bark, outer bark, and wood segments of the tree and to interpret if the K^+ concentrations in rings and organs varied by year. In this study, the change of potassium concentration in barks and wood of three species was found to be 783.9 ppm of *Cupressus arizonica* G. but to be 6187.1 ppm in that of *Platanus orientalis* L. in the inner bark. Similarly, the K^+ concentration was found to be 472 ppm in *Cupressus arizonica* G. but 1439.2 ppm in *Platanus orientalis* L. in wood. Accordingly, it can be stated that K^+ concentration significantly varied between the species.

In previous studies carried out on this subject, it was determined that the concentrations of many elements significantly varied by the species [42]. The accumulation of elements within the bodies of plants is closely related to the plant habitus and development [43]. Plant development is shaped by the mutual interaction between genetic structure and environmental conditions [44]. Hence, the factors influencing the genetic structure of plants directly influence the intake and accumulation of elements in plants and, since different species have different genetic structures, it is normal for species to have different levels of element accumulation [45]. Another important result achieved in this study is that the concentration of potassium significantly varied by organs in all the species. Examining all three species, the highest values were found in the outer bark and the lowest values in the inner bark.

Many studies reported that the element accumulations differed between the organs of the same plant [46]. Moreover, it was also determined that the differences between the organs could reach very high levels [47]. In previous studies, the lowest concentrations were generally found in wood and the highest ones in outer bark [48]. The reason for higher element concentration in outer barks when compared to other organs was reported to mainly be the structure of the organ, particle matters, and the contamination of these particles by elements. It was determined in studies carried out before, it was determined that the elements in air adhered to the surface of particles and enriched them in elements, and these elements adhered to the plant organs and increased the element concentrations in these organs. The rough surface of the outer bark makes it easier for particles to hold on these surfaces [49].

The atmospheric potassium deposition significantly varied between the woods forming in subsequent years and the difference can reach very high levels. For instance, the potassium concentration in the woods of *Robinia pseudoacacia* L. forming from 2015 to 2017 was found to be 610.2 ppm, whereas it was 3520.9 ppm for the woods forming from 2018 to 2020. This finding suggests that the transfer of the K element in wood can be very limited. Among the species examined in this study, the lowest proportion of change was observed in *Platanus orientalis* L. and the highest one in *Robinia pseudoacacia* L. on atmospheric potassium deposition. It suggests that, among these species, the species that is most suitable for monitoring the change of potassium concentration is *Robinia pseudoacacia* L. in an industrial area. The knowledge about the transfer of elements between the organs is, however, very limited in plants.

CONCLUSIONS

Plants are the main indicator of urban environmental pollution and they fulfill many ecologic, economic, and social functions in ecosystem services. Development and phenotypic characters of plants are shaped by the genetic structure and edaphic factors such as soil's structure and nutrient content and soil, as well as climatic factors such as light, temperature, and atmospheric deposition-precipitation. Hence, to understand regional pollution which spatial distribution information links to existing or future policy with regards to sustainable environmental pollution including air and soil. Atmospheric deposition influences plant development, it is necessary to determine the intake and accumulation of elements directly from the surrounding environment. Atmospheric deposition contains quantities of K^+ which can significantly affect the structure and development of plants. Biomonitoring the deposition of atmospheric K^+ concentration is the crucial method to present levels of other metals and toxic metals in the territorial environment. The result of this study provides biomonitoring of atmospheric metals deposition on plants that tell the level of their accumulation. Future research on atmospheric other metals deposition for the suitability of some commonly found species for biomonitoring should be investigated the spatial and temporal variation of industrial and high traffic areas.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] G.S. Cumming, A. Buerkert, E.M Hoffmann, E. Schlecht, S. von Cramon-Taubadel and T. Tscharntke, "Implications of agricultural transitions and urbanization for ecosystem services," Nature, Vol. 515, pp. 50–57, 2014. [CrossRef]

[2] D. Yılmaz and Ö. Işınkaralar, "Climate action plans under climate-resilient urban policies", Kastamonu University Journal of Engineering and Sciences, Vol. 7, pp. 140–147, 2021

[3] D. Yılmaz and Ö. Işınkaralar, "How Can Natural Environment Scoring Tool (Nest) be Adapted for Urban Parks?" Kastamonu University Journal of Engineering and Sciences, Vol. 7, pp. 127–139, 2021

[4] G. M. Barinova, D. V. Gaeva, and E. V. Krasnov, "Hazardous chemicals and air, water, and soil pollution and contamination," Good Health and Well-Being, pp. 255-266, 2020. [CrossRef]

[5] D. Hou, D. O'Connor, A.D. Igalavithana, D.S. Alessi, J. Luo, D.C. Tsang, D.L. Sparks, Y. Yamauchi, J. Rinklebe, and Y. S. Ok. "Metal contamination and bioremediation of agricultural soils for food safety and sustainability.," Nature Reviews Earth & Environment, Vol. 1(7), pp. 366–381, 2020. [CrossRef]

[6] X. Zhong, S. Joimel, C. Schwartz, and T. Sterckeman, "Assessing the future trends of soil trace metal contents in French urban gardens," Environmental Science and Pollution Research, Vol. 29, pp. 3900–3917, 2021. [CrossRef]

[7] A.R. Baker, M. Kanakidou, A. Nenes, S. Myriokefalitakis, P.L. Croot, R.A. Duce, Y. Gao, C. Guieu, A. Ito, T.D. Jickells, N.M. Mahowald, R. Middag, M.M.G. Perron, M.M. Sarin, R. Shelley, and D. Turner, R. "Changing atmospheric acidity as a modulator of nutrient deposition and ocean biogeochemistry," Science Advances, Vol. 7(28), pp. eabd8800, 2021. [CrossRef]

[8] E.A. Mikhailova, G.C. Post, M.P. Cope, C.J. Post, M.A. Schlautman, and L. Zhang, "Quantifying and mapping atmospheric potassium deposition for soil ecosystem services assessment in the United States," Frontiers in Environmental Science, Vol. 7, pp. 74, 2019. [CrossRef]

[9] C. Hafsi, A. Debez, and C. Abdelly, "Potassium deficiency in plants: effects and signaling cascades," Acta Physiologiae Plantarum, Vol. 36(5), pp. 1055-1070, 2014. [CrossRef]

[10] D. T. Britto, and H. J. Kronzucker, "Cellular mechanisms of potassium transport in plants," Physiologia Plantarum, Vol. 133(4), pp. 637–650, 2008. [CrossRef]

[11] M. Nieves-Cordones, R. Ródenas, A. Lara, V. Martínez, and F. Rubio, "The combination of K^+ deficiency with other environmental stresses: what is the outcome?" Physiologia Plantarum, Vol. 165(2), pp. 264–276, 2019. [CrossRef]

[12] S. Shabala, and I. Pottosin, "Regulation of potassium transport in plants under hostile conditions: implications for abiotic and biotic stress tolerance," Physiologia Plantarum, Vol. 151, pp. 257–279, 2014. [CrossRef]

[13] V. Römheld, and E.A. Kirkby, "Research on potassium in agriculture: needs and prospects," Plant and Soil, Vol. 335(1), 155–180, 2010. [CrossRef]

[14] J. Sardans, and J. Peñuelas, "Potassium: a neglected nutrient in global change," Global Ecology and Biogeography, Vol. 24(3), pp. 261–275, 2015. [CrossRef]

[15] E. Mikhailova, M. Cope, G. Groshans, C. Post, M. Schlautman, and L. Zhang, "Contribution of atmospheric deposition to soil provisioning ecosystem services in the contiguous United States: Part 1 Calcium," ProScience, Vol. 5, pp. 58–68, 2018.

[16] A.N.M. Roseli, T.F. Ying, and N. Osman, "Changes in leaf thickness, chlorophyll content, and gas exchange of a landscape tree, Xanthostemon Chrysanthus, treated with paclobutrazol and potassium nitrate," Arboriculture & Urban Forestry, Vol. 47(2), 2021. [CrossRef]

[17] M. Wang, Q. Zheng, Q. Shen, and S. Guo, "The critical role of potassium in plant stress response," International Journal of Molecular Sciences, Vol. 14(4), pp. 7370–7390, 2013. [CrossRef]

[18] P. Shults, P. Nzokou, and I. Koc, "Nitrogen contributions of alley cropped Trifolium pratense may sustain short rotation woody crop yields on marginal lands," Nutrient Cycling in Agroecosystems, Vol. 117(2), pp. 261–272, 2020. [CrossRef]

[19] I. Koc, "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, pp. 1-7, 2021.

[20] J. Guo, Y. Jia, H. Chen, L. Zhang, J. Yang, J. Zhang, and Y. Zhou, "Growth, photosynthesis, and nutrient uptake in wheat are affected by differences in nitrogen levels and forms and potassium supply," Scientific Reports, Vol. 9(1), pp. 1–12, 2019. [CrossRef]

[21] D.K. Jaiswal, J.P. Verma, S Prakash, V.S. Meena, and R.S. Meena, "Potassium as an important plant nutrient in sustainable agriculture: a state of the art," Potassium Solubilizing Microorganisms for Sustainable Agriculture, pp. 21-29, 2016. [CrossRef]

[22] A. Wakeel, M. Farooq, M. Qadir, and S. Schubert, Potassium substitution by sodium in plants. Critical reviews in plant sciences, Vol. 30(4), pp: 401-413, 2011. [CrossRef]

[23] Y. Xing, J. Bubier, T. Moore, M. Murphy, N. Basiliko, S. Wendel, and C. Blodau, "The fate of 15 N-nitrate in a northern peatland impacted by long term experimental nitrogen, phosphorus and potassium fertilization," Biogeochemistry, Vol. 103(1), pp. 281–296, 2011. [CrossRef]

[24] C. Zörb, M. Senbayram, and E. Peiter, "Potassium in agriculture–status and perspectives," Journal of Plant Physiology, Vol. 171(9), pp. 656–669, 2014. [CrossRef]

[25] D.W. Dibb, and W.R. Thompson Jr, "Interaction of potassium with other nutrients," Potassium in Agriculture, pp. 515–533, 1985. [CrossRef]

[26] D.A. Manning, "Mineral sources of potassium for plant nutrition. A review," Agronomy for Sustainable Development, Vol. 30(2), pp. 281–294, 2010. [CrossRef]

[27] N. C Brady, and R.R. Weil, "The nature and properties of soils," 13th ed., Pearson Education, London, 2002.

[28] F. Bilias, and N. Barbayiannis, "Potassium availability: an approach using thermodynamic parameters derived from quantity-intensity relationships," Geoderma, Vol. 338, pp. 355–364, 2019. [CrossRef]

[29] I.E. Bruteig, "The epiphytic lichen Hypogymnia physodes as a biomonitor of atmospheric nitrogen and sulphur deposition in Norway," Environmental Monitoring and Assessment, Vol. 26(1), pp. 27–47, 1993. [CrossRef]

[30] H. Schulz, P. Popp, G. Huhn, H.J. Stärk, and G. Schüürmann, "Biomonitoring of airborne inorganic and organic pollutants by means of pine tree barks. I. Temporal and spatial variations," Science of the Total Environment, Vol. 232, 49–58, 1999. [CrossRef]

[31] L., Morselli, E., Bernardi, I., Vassura, F., Passarini, and E. Tesini, "Chemical composition of wet and dry atmospheric depositions in an urban environment: local, regional and long-range influences," Journal of Atmospheric Chemistry, Vol. 59(3), pp. 151–170, 2008. [CrossRef]

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

[33] W.E.O Ghoma, H. Sevik, and K. Isinkaralar, "Using indoor plants as biomonitors for detection of toxic metals by tobacco smoke," Air Quality, Atmosphere & Health, 2022. [CrossRef]

[34] K. Işınkaralar and R. Erdem, "Changes of calcium content on some trees in Kocaeli", Kastamonu University Journal of Engineering and Sciences, vol. 7, pp. 148–154, 2021

[35] M. Çetin, H. Şevik, A. Türkyılmaz and K. Işınkaralar, "Using abies's needles as biomonitors of recent heavy metal accumulation," Kastamonu University Journal of Engineering and Sciences, Vol. 7, pp. 1–6, 2021.

[36] N. M. Mahowald, R. Scanza, J. Brahney, C.L. Goodale, P.G. Hess, J.K. Moore, and Neff, J. "Aerosol deposition impacts on land and ocean carbon cycles," Current Climate Change Reports, Vol. 3(1), pp. 16–31, 2017. [CrossRef]

[37] B. Wolterbeek, "Biomonitoring of trace element air pollution: principles, possibilities and perspectives," Environmental Pollution, Vol. 120(1), pp. 11-21, 2002. [CrossRef]

[38] USEPA E (1996) Method 3052: Microwave assisted acid digestion of siliceous and organically based

matrices. United States Environmental Protection Agency, Washington, DC USA.

[39] B. Nemzer, F. Al-Taher, and N. Abshiru, “Phytochemical composition and nutritional value of different plant parts in two cultivated and wild purslane (Portulaca oleracea L.) genotypes,” Food Chemistry, Vol. 320, pp. 126621, 2020. [CrossRef]

[40] M. E. Conti, and G. Cecchetti, “Biological monitoring: lichens as bioindicators of air pollution assessment—a review,” Environmental Pollution, Vol. 114(3), pp. 471–492, 2001. [CrossRef]

[41] A. Turkyilmaz, H. Sevik, K. Isinkaralar and M. Cetin, “Using Acer platanoides annual rings to monitor the amount of heavy metals accumulated in air,” Environmental Monitoring and Assessment, Vol.190, pp. 578, 2018. [CrossRef]

[42] B. Aricak, M. Cetin, R. Erdem, H. Sevik and H. Cometen, “The change of some heavy metal concentrations in Scotch pine (Pinus sylvestris) depending on traffic density, organelle and washing,” Applied Ecology and Environmental Research, Vol. 17(3), pp. 6723–6734, 2019. [CrossRef]

[43] D. Güney, E. Seyis, F. Atar, A. Bayraktar and İ. Turna, “Effects of some nitrogen-fixing plants on seedling growth of scotch pine,” Turkish Journal of Forestry, Vol. 20(4), pp. 284-289, 2019. [CrossRef]

[44] D. Güney, Z. Yahyaoglu, A. Bayraktar, F. Atar and I. Turna, “Genetic diversity of Picea orientalis (L.) Link populations in Turkey,” Šumarski list, Vol. 143(11-12), pp. 539–547, 2019. [CrossRef]

[45] H. Sevik, M. Cetin, H.U. Ozel, H.B. Ozel, M.M.M. Mossi and I.Z. Cetin, “Determination of Pb and Mg accumulation in some of the landscape plants in shrub forms,” Environmental Science and Pollution Research, Vol. 27(2), pp. 2423–2431, 2020. [CrossRef]

[46] T. Karacocuk, H. Sevik, K. Isinkaralar, A. Turkyilmaz and M. Cetin, “The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density,” Landscape and Ecological Engineering, Vol. 18(1), pp. 75–83, 2022. [CrossRef]

[47] D.S. Savas, H. Sevik, K. Isinkaralar, A. Turkyilmaz and M. Cetin, “The potential of using Cedrus atlantica as a biomonitor in the concentrations of Cr and Mn,” Environmental Science and Pollution Research, Vol. 28, pp. 55446–55453, 2021. [CrossRef]

[48] A. Turkyilmaz, M. Cetin, H. Sevik, K. Isinkaralar and E.A.A. Saleh, “Variation of heavy metal accumulation in certain landscaping plants due to traffic density,” Environment, Development and Sustainability, Vol. 22(3), pp. 2385–2398, 2020. [CrossRef]

[49] H. Sevik, “The variation of chrome consantration in some landscape plants due to species, organ and traffic density,” Turkish Journal of Agriculture-Food Science and Technology, Vol. 9(3), pp. 595-600, 2021. [CrossRef]