World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Usability of *Robinia pseudoacacia* in monitoring changes and reducing airborne palladium pollution

Nazli AK TUTUNCU [1,*], Halil Baris OZEL [2], Hakan SEVIK [3] and Hatice COBANOGLU [4]

[1] *Department of Forest Engineering, Graduate School, Bartin University, Türkiye.*
[2] *Department of Forest Engineering, Faculty of Forestry, Bartin University, Türkiye.*
[3] *Department of Environmental Engineering, Faculty of Engineering and Architectu.re, Kastamonu University, Türkiye.*
[4] *Department of Forest Engineering, Graduate School, Düzce University, Türkiye.*

World Journal of Advanced Research and Reviews, 2024, 24(01), 2177–2184

Publication history: Received on 07 September 2024; revised on 15 October 2024; accepted on 17 October 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.1.3178

Abstract

Palladium (Pd), whose use has been increasing in recent years, is one of the heavy metals that pose a danger to the environment and human health, and it is known that heavy metals can be extremely harmful when inhaled from the air and taken into the human body. Therefore, monitoring and reducing the change of Pd pollution in the air is very important. This study aimed to determine the usability of *Robinia pseudoacacia*, which is grown intensively in urban areas where heavy metal pollution may be high, to monitor and reduce the change in Pd pollution in the air. Within the scope of the study, changes in Pd concentration in *Robinia pseudoacacia* stem sections grown in Düzce, among the 5 most polluted cities in Europe, depending on organ, direction, and age range in the last 60 years, were evaluated. As a result, it was determined that Pd pollution in the region may have been released into nature through agricultural activities or transported from much more distant sources. It was also determined that the species is not a suitable biomonitor that can be used to monitor the change in Pd pollution. Still, it is an accumulator species that is extremely suitable for reducing Pd pollution.

Keywords: Heavy metal; Palladium; Biomonitor; Accumulator; *Robinia pseudoacacia*

1. Introduction

The industrial revolution in the last century has caused significant changes worldwide. The most important of these changes are global climate change [1-2], which is now considered irreversible globally, and urbanization [3-8]. Another factor that is stated to be largely due to industrial activities and affects all living things and ecosystems on a global scale is pollution [9-12]. As a result of the extraction of various elements from mineral deposits to be used as raw materials in industrial activities and their release into nature, water [13], soil [14], and air [15-17] have become significantly polluted and started to threaten living life. The extent of air pollution is especially frightening. It was reported that 99% of the global population is subjected to low air quality; outdoor air pollution is estimated to have caused 4.2 million premature deaths and 6.7 million premature deaths annually [18-20].

Among air pollution components, heavy metals are the most dangerous and harmful. While some of them can be toxic, carcinogenic, and fatal to humans, even at low concentrations, it is stated that even those necessary for life can be harmful at high concentrations [21-23]. Moreover, if inhalation takes them from the air, their effects are much greater and harmful [24-26]. Therefore, it is critical to monitor changes and reduce the heavy metal pollution in the air [27-30].

* Corresponding author: Hakan SEVIK

Copyright © 2024 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution Liscense 4.0.

Due to the potential harms of heavy metal pollution, many studies have been conducted on the subject. Studies have shown that plants are the most effective arguments in monitoring the changes in heavy metal pollution in the air and reducing pollution [31,32]. Plants that can accumulate heavy metals, especially in the wood part, are the most suitable plants for this purpose. Because the wood part is the largest organ of the tree, heavy metals trapped in the wood part are not released into nature for tens or even hundreds of years [33]. However, suitable biomonitor or accumulator species must be determined separately for each heavy metal [34]. This study examined the accumulation levels of Pd elements in the trunk parts of Acacia (*Robinia pseudoacacia*) trees growing in urban areas with high heavy metal pollution.

2. Material and methods

The study was carried out on Acacia (*Robinia pseudoacacia*) growing in Düzce, one of Europe's 5 most polluted cities, according to the World Air Pollution Report 2021 [24]. The samples were taken in late 2022, off the growth period, by determining the north direction. It was determined that the log sample, whose surface was smoothed after being brought to the laboratory, was 60 years old, and samples were taken from the wood (WD) part, grouped into five-yearly groups, and from the inner bark (IB) and outer bark (OB), with the help of a steel drill. The samples were then dried in a 45 °C oven and pre-burned in a microwave oven specially designed for this process. The samples whose pre-combustion process was completed were analyzed with the ICP-OES device, and Pd concentrations were determined. This method has been widely used in previous studies in this field [35-38].

The data obtained was analyzed using the SPSS package program, and variance analysis was applied to the data. The Duncan test was also applied for factors showing statistically significant differences at the minimum 95% confidence level ($p < 0.05$). Considering the Duncan test results, the data were presented in tables, and interpretations were made.

3. Results

Average values and statistical analysis results regarding the change of Pd concentration in Acacia based on organ and direction are given in Table 1. It can be seen that the Pd concentration change in Acacia is statistically significant in all organs on a directional basis and in the east direction on an organ basis (Table 1). The highest value in the east direction was obtained in the inner crust. When we look at the directions according to the average values, the highest value is seen in the south direction, while the lowest is in the west direction. Pd concentration changes in all organs towards the north remained below detectable limits.

Table 1 Change of Pd concentration in Acacia tree based on organ and direction

Organ	East	South	West	F-value	Average
OB	99648.8 aC	104396.8 B	93600.4 A	7.4*	99215.3
IB	106381.9 bC	101797.9 B	97202.2 A	5.4*	101794.0
WD	99065.3 aB	102803.3 C	95262.0 A	44.9***	99043.5
F-value	6.7**	0.5 ns	0.7 ns		1.4 ns
Average	99629.6 B	102845.3 C	95281.9 A	49.2***	

The change of Pd concentration in Acacia based on period and direction is given in Table 2. Pd concentration in Acacia remained below detectable limits in all samples in the northern direction. According to the results of variance analysis, it was determined that the change in Pd concentration in Acacia was statistically meaningful on a direction basis and a western direction basis in all periods except the 1983-1987, 2003-2007, 2008-2012, 2013-2017, 2018-2022 periods. The highest value in the western direction was obtained in 2003-2007, 2013-2017 and 2018-2022. According to the average values, the highest value was obtained in the south direction and the lowest in the west direction. Therefore, when the north direction is included in the evaluation, it can be said that the Pd concentration is south>east>west>north.

Table 2 Change of Pd concentration in the wood of *Acacia* tree based on period and direction

Age group	East	South	West	F-value	Average
2018-2022	101839.2	103179.5	99386.1 c	1.1 ns	101468.2
2013-2017	97179.9	102780.0	100464.9 c	1.8 ns	100141.6
2008-2012	98548.2	102860.8	97637.8 bc	1.8 ns	99682.3
2003-2007	99123.4	104504.0	100363.8 c	4.1 ns	101330.4
1998-2002	97569.7 B	103213.7 C	93892.8 abA	6.9*	98225.4
1993-1997	100770.7 B	103866.3 C	93251.1 abA	9.5*	99296.0
1988-1992	96213.9B	101845.5 C	93420.8 abA	8.9*	97160.1
1983-1987	98893.2	101785.2	94021.3 ab	3.8 ns	98233.2
1978-1982	98893.6 B	103396.9 C	94425.6 abA	5.7*	98905.4
1973-1977	98807.7 B	102153.2 C	93264.7 abA	6.6*	98075.2
1968-1972	99708.2 B	100446.4 C	91256.5 a A	5.4*	97137.0
1963-1967	101235.6 B	103607.7 C	91758.5 aA	19.4**	98867.3
F-value	0.6 ns	0.3 ns	5.3***		0.8 ns
Average	99065.3 B	102803.3 C	95262.0 A	44.9***	

4. Discussion

In the study, it was determined that the acacia tree can accumulate significant amounts of the Pd element in its wood and bark parts. Since the importance of heavy metals for human health has been understood, many studies have been carried out on monitoring changes and reducing heavy metal pollution. However, these studies generally focus on more common and known elements such as Pb, Ni, Cr, Cu, and Mn [38-40]. However, due to its unique chemical and physical properties, Pd is widely used in many industrial sectors, such as the chemical and petroleum industries, automobile catalysts, electronic devices, dental applications, fine jewelry production, etc. The significant increase in the industrial use of Pd over the last 20 years has resulted in high levels of this metal in air, water, and soil. Exposure to Pd may cause acute toxicity or hypersensitivity with respiratory symptoms, urticaria, and contact dermatitis. Epidemiological studies have shown that Pd ions are one of the most frequently reacted sensitizers among metals. This effect on the immune system shows that Pd is a very risky and harmful element for humans [41]. Therefore, monitoring and reducing Pd pollution is extremely important.

The study determined that there was no statistically significant difference in Pd accumulation between bark and wood. In studies conducted to date, generally, high heavy metal concentrations have been obtained in the outer [30,38,41]. However, some studies also obtained the opposite results [42]. It is stated that the heavy metal concentration in the barks is largely related to the heavy metal content of the particulate matter adhering to the barks [26,40].

The current study determined that the highest Pd concentrations were obtained in the southern direction, while Pd concentrations in the northern direction remained below the detectable limits. This can be interpreted as Pd not accumulating in the study area due to traffic. Studies show that heavy metals are intensively released into nature because of mining [17], industry [21], traffic [28], and agricultural activities [22,41]. The study results also show that Pd may have been released into nature through agricultural activities or transported from much more distant sources. As a matter of fact, studies show that heavy metals can adhere to particulate matter and be transported far from their source with the help of wind [26,38].

In the current study, there was a statistically noteworthy difference between the periods only in the western direction, and there was no statistically meaningful difference between the periods in terms of other directions and average values. This result can be explained as Pd pollution in the study area has not changed remarkably from past to present or Pd can be transferred between tissues. The fact that the Pd concentration in the northern direction remains below

the detectable limits but is high in the other directions and remains in a narrow range can be interpreted as Pd being transported in the vertical direction but not in the horizontal direction. Studies show that some elements can be transferred within different types of wood tissue, while some elements are limited [24,30,39].

The study results show that *Acacia* accumulates Pd intensively in its bark and wood, which can exceed 100 ppm. As it is known, the phenotypic characters of all living things are shaped under the mutual interaction of genetic structure [43-49] and environmental factors [50-63]. Therefore, all factors affecting plant physiology also affect the entry and accumulation of heavy metals into the plant, which is shaped under the mutual interaction of many factors affecting each other, such as edaphic [64], climatic factors [65-70], and stress factors [71-78], in addition to genetic structure. Therefore, many of these factors, directly and indirectly, affect plants' heavy metal accumulation potential, and information about this complex mechanism is still limited [35,41].

5. Conclusion

In conclusion, while the study results show that Acacia is an extremely suitable species for reducing Pd pollution, satisfactory results have not been achieved regarding whether the species can be used to monitor the change in Pd pollution. The study results show that Pd can be transferred between the bark and wood of Acacia and within the wood. The study results can be interpreted as Pd can be transported in the vertical direction but cannot be transferred in the horizontal direction. However, there are almost no studies on the vertical or horizontal transport of heavy metals in wood. It is recommended that detailed studies be conducted on this subject.

Compliance with ethical standards

Acknowledgements

We thanks to Bartin University Faculty of Forestry, Düzce University Faculty of Forestry, and Kastamonu University Faculty of Architecture and Engineering.

Disclosure of conflict of interest

The authors declare that they no conflict of interest. The none of the authors have any competing interests in the manuscript.

References

[1] Işınkaralar, Ö., Işınkaralar, K., Şevik, H., & Küçük, Ö. Bio-climatic Comfort and Climate Change Nexus: A Case Study in Burdur Basin. Kastamonu University Journal of Forestry Faculty, 2023. 23(3), 241-249.

[2] Cantürk, U., Koç, İ., Özel, H. B., & Şevik, H. (2024). Possible changes of Pinus nigra distribution regions in Türkiye with the impacts of global climate change. BioResources, 19(3), 6190.

[3] Zeyad, A. M., Bayraktar, O. Y., Tayeh, B. A., Öz, A., Özkan, İ. G. M., & Kaplan, G. (2024). Impact of rice husk ash on physico-mechanical, durability and microstructural features of rubberized lightweight geopolymer composite. Construction and Building Materials, 427, 136265.

[4] Yaprak, H., Memis, S., Kaplan, G., Yilmazoglu, M. U., & Ozkan, I. G. M. (2018). Effects on compressive strenght of accelerated curing methods in alkali activated mortars. Int J Sci Technol Res, 4.

[5] Şen, G., Güngör, E., & Şevik, H. (2018). Defining the effects of urban expansion on land use/cover change: a case study in Kastamonu, Turkey. Environmental monitoring and assessment, 190, 1-13.

[6] Bayraktar, O. Y., Yılmazoğlu, M., Mütevelli, İ., Çetin, M., Çitoğlu, G. S., Dadula, C. P., & Dadula, D. P. (2022). Usability of organic wastes in concrete production; Palm leaf sample. Kastamonu University Journal of Engineering and Sciences, 8(1), 69-77.

[7] Özkan, İ. G. M., Aldemir, K., Alhasan, O., Benli, A., Bayraktar, O. Y., Yılmazoğlu, M. U., & Kaplan, G. (2024). Investigation on the sustainable use of different sizes of sawdust aggregates in eco-friendly foam concretes: Physico-mechanical, thermal insulation and durability characteristics. Construction and Building Materials, 438, 137100.

[8] Kaplan, G., Bayraktar, O. Y., Li, Z., Bodur, B., Yılmazoglu, M. U., & Alcan, B. A. (2023). Improving the eco-efficiency of fiber reinforced composite by ultra-low cement content/high FA-GBFS addition for structural applications: Minimization of cost, CO2 emissions and embodied energy. Journal of Building Engineering, 76, 107280.

[9] Guney, D., Koc, I., Isinkaralar, K., Erdem, R. Variation in Pb and Zn concentrations in different species of trees and shrubs and their organs depending on traffic density. Baltic Forestry, 2023. 29(2), id661-id661.

[10] Ghoma, W. E. O., Sevik, H., & Isinkaralar, K. Using indoor plants as biomonitors for detection of toxic metals by tobacco smoke. Air quality, atmosphere & health, 2022. 15(3), 415-424.

[11] Isinkaralar K. Removal of Formaldehyde and BTEX in Indoor Air Using Activated Carbon Produced from Horse Chestnut (Aesculus Hippocastanum L.) Shell. Ph.D. Thesis Hacettepe University Institute of Science Department of Environmental Engineering. Ankara, Türkiye. 2020.

[12] Isinkaralar, K., Isinkaralar, O., Özel, H. B., & Şevik, H. (2024). A Comparative Study About Physical Properties of Copper Oxide and Zinc Oxide Nanoparticles on Fagus orientalis L. as Bioindicator. Water, Air, & Soil Pollution, 235(11), 738.

[13] Ucun Ozel H, Gemici BT, Gemici E, Ozel HB, Cetin, M, Sevik H. Application of artificial neural networks to predict the heavy metal contamination in the Bartın River. Environ sciences and pollution research. 2020; 27:42495–42512.

[14] Cetin M, Aljama AMO, Alrabiti OBM. Adiguzel F, Sevik H, Zeren Cetin I. Using topsoil analysis to determine and map changes in Ni, Co pollution. Water, air and soil pollution. 2022; 233:293(2022).

[15] Isinkaralar, K., Gullu, G., Turkyilmaz, A., Dogan, M., & Turhan, O. Activated carbon production from horse chestnut shells for hydrogen storage. International Journal of Global Warming, 2022. 26(4), 361-373.

[16] Işınkaralar, K., Işınkaralar, Ö., & Şevik, H. Usability of some landscape plants in biomonitoring technique: an anaysis with special regard to heavy metals. Kent Akademisi, 2022. 15(3), 1413-1421.

[17] Kuzmina N, Menshchikov S, Mohnachev P, Zavyalov K, Petrova I, Ozel HB, Aricak B, Onat SM, and Sevik H. Change of aluminum concentrations in specific plants by species, organ, washing, and traffic density, BioResources, 2023. 18(1); 792-803.

[18] Sulhan, O. F., Sevik, H., & Isinkaralar, K. (2023). Assessment of Cr and Zn deposition on Picea pungens Engelm. in urban air of Ankara, Türkiye. Environment, development and sustainability, 25(5), 4365-4384.

[19] Isinkaralar K, Isinkaralar O, Koç İ, Özel HB, & Şevik H. (2023). Assessing the possibility of airborne bismuth accumulation and spatial distribution in an urban area by tree bark: A case study in Düzce, Türkiye. Biomass Conversion and Biorefinery, 2023. 1-12.

[20] Ghoma WEO, Sevik H, & Isinkaralar K. Comparison of the rate of certain trace metals accumulation in indoor plants for smoking and non-smoking areas. Environmental Science and Pollution Research, 2023. 30(30): 75768-75776.

[21] Istanbullu SN, Sevik H, Isinkaralar K, & Isinkaralar O. Spatial Distribution of Heavy Metal Contamination in Road Dust Samples from an Urban Environment in Samsun, Türkiye. Bulletin of Environmental Contamination and Toxicology, 2023. 110(4); 78.

[22] Erdem R, Çetin M, Arıcak B, & Sevik H. The change of the concentrations of boron and sodium in some forest soils depending on plant species. Forestist, 2023. 73(2); 207-212.

[23] Isinkaralar, K., Isinkaralar, O., Koc, I., Cobanoglu, H., & Canturk, U. (2024). Accumulation analysis and overall measurement to represent airborne toxic metals with passive tree bark biomonitoring technique in urban areas. Environmental Monitoring and Assessment, 196(8), 689.

[24] Koc I, Cobanoglu H, Canturk U, Key K, Kulac S, & Sevik H. (2024). Change of Cr concentration from past to present in areas with elevated air pollution. International Journal of Environmental Science and Technology, 21(2): 2059-2070

[25] Isinkaralar K. Some atmospheric trace metals deposition in selected trees as a possible biomonitor. Romanian biotechnological letters. 2022; 27(1):3227-3236.

[26] Key K, Kulaç Ş, Koç İ, & Sevik H. Proof of concept to characterize historical heavy-metal concentrations in atmosphere in North Turkey: determining the variations of Ni, Co, and Mn concentrations in 180-year-old Corylus colurna L. (Turkish hazelnut) annual rings. Acta Physiologiae Plantarum, 2023. 45(10); 1-13.

[27] Erdem, R., Koç, İ., Çobanoglu, H., & Şevik, H. (2024). Variation of Magnesium, One of the Macronutrients, in Some Trees Based on Organs and Species. Forestist, 74(1). 84-93

[28] Koç, İ., Canturk, U., Isinkaralar, K., Ozel, H. B., & Sevik, H. (2024). Assessment of metals (Ni, Ba) deposition in plant types and their organs at Mersin City, Türkiye. Environmental Monitoring and Assessment, 196(3), 282.

[29] Isinkaralar K, Koc I, Erdem R, Sevik H. Atmospheric Cd, Cr, and Zn deposition in several landscape plants in Mersin, Türkiye. Water, Air, & Soil Pollution, 2022. 233(4);65-76.

[30] Cobanoglu H, Sevik H, & Koç İ. Do annual rings really reveal Cd, Ni, and Zn pollution in the air related to traffic density? An Example of the Cedar Tree. Water, Air, & Soil Pollution, 2023. 234(2); 65.

[31] Ateya, T. A. A., Bayraktar, O. Y., & Koc, I. (2023). Do Picea pungens engelm. organs be a suitable biomonitor of urban atmosphere pollution?. Cerne, 29, e-103228.

[32] Sevik, H., Koç, İ., & Cobanoglu, H. (2024). Determination of Some Exotic Landscape Species As Biomonitors That Can Be Used for Monitoring and Reducing Pd Pollution in the Air. Water, Air, & Soil Pollution, 235(10), 1-12.

[33] Sevik, H., Yildiz, Y., Ozel, H.B. Phytoremediation and Long-term Metal Uptake Monitoring of Silver, Selenium, Antimony, and Thallium by Black Pine (Pinus nigra Arnold)", BioResources, 2024. 19(3). 4824-4837.

[34] Savas DS, Sevik H, Isinkaralar K. Turkyilmaz A. Cetin M. The potential of using Cedrus atlantica as a biomonitor in the concentrations of Cr and Mn. Environmental science pollution research. 2021; doi: https://doi.org/10.1007/s11356-021-14826-1

[35] Erdem, R., Aricak, B., Cetin, M., & Sevik, H. Examining the chemical compositions of mineral concrete agents in terms of their environmental effects. Forestist, 2023. 73(3), 257-263.

[36] Cetin, M., Cebi Kilicoglu, M., & Kocan, N. Usability of biomonitors in monitoring the change of tin concentration in the air. Environmental Science and Pollution Research, 2023. 30(52), 112357-112367.

[37] Karacocuk T, Sevik H, Isinkaralar K, Turkyilmaz A, Cetin M. The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density. Landscape ecology engineering. 2022; 18:75-83.

[38] Key K, Kulaç Ş, Koç İ, & Sevik H. Determining the 180-year change of Cd, Fe, and Al concentrations in the air by using annual rings of Corylus colurna L. Water, Air, & Soil Pollution, 2022. 233(7); 244.

[39] Koç İ. 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. 2021; 28(27):35880–35886.

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

[41] Ozyurt, G., Ozel, H.B., Sevik, H. Usability of Cedrus atlantica in Monitoring Changes and Reducing Airborne Palladium Pollution, World journal of advanced research and reviews. 2024; 23(1)

[42] Canturk, U., Koç, İ., Ozel, H. B., & Sevik, H. (2024). Identification of proper species that can be used to monitor and decrease airborne Sb pollution. Environmental Science and Pollution Research, 1-11.

[43] Sevik, H., & Topacoglu, O. Variation and inheritance pattern in cone and seed characteristics of Scots pine (Pinus sylvestris L.) for evaluation of genetic diversity. Journal of Environmental Biology, 2015. 36(5), 1125.

[44] Koç İ, Nzokou P. Gas exchange parameters of 8-year-old Abies fraseri (Pursh) Poir. seedlings under different irrigation regimes. Kastamonu university journal of engineering and sciences. 2022; 10(12):2421-2429.

[45] Kurz M, Koelz A, Gorges J, Carmona BP, Brang P, Vitasse Y, ... & Csillery K. Tracing the origin of Oriental beech stands across Western Europe and reporting hybridization with European beech–Implications for assisted gene flow. Forest Ecology and Management, 2023. 531; 120801.

[46] Koç İ, Nzokou P. Combined effects of water stress and fertilization on the morphology and gas exchange parameters of 3-yeaar-old Abies fraseri (Pursh) Poir. Acta physiologiae plantarum. 2023; 234(3):49.

[47] Hrivnák, M., Krajmerová, D., Paule, L., Zhelev, P., Sevik, H., Ivanković, M., Goginashvili, N., Paule, J., Gömöry, D. (). Are there hybrid zones in Fagus sylvatica L. sensu lato?. European Journal of Forest Research, 2024. 143, 451–464. https://doi.org/10.1007/s10342-023-01634-0

[48] Sevik H, Yahyaoglu Z, & Turna I. Determination of genetic variation between populations of Abies nordmanniana subsp. bornmulleriana Mattf according to some seed characteristics, genetic diversity in plants. Chapter, 2021. 12; 231-248.

[49] Turna, İ., & Atar, F. (2024). Stand Analysis and Distribution Areas of European Aspen (Populus tremula L.) Forests in Türkiye. SilvaWorld, 3(1), 15-27.

[50] Doğmuşöz, B. B. (2023). Benefit-Cost Analysis of an Extensive Green Roof Project in Izmir Katip Celebi University Cigli Campus. Online Journal of Art & Design, 11(3).

[51] Doğmuşöz, B. (2023). Investigating the Barriers to Implementation of Green Roofs in Izmir, Turkey. ICONARP International Journal of Architecture and Planning, 11(2), 672-691.

[52] Özdikmenli, G., Yiğit, N., Özel, H. B., and Şevik, H. Altitude-dependent Variations in Some Morphological and Anatomical Features of Anatolian Chestnut. BioResources, 2024. 19(3), 4635-4651.

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

[54] Güney, D., Bayraktar, A., Atar, F., & Turna, I. (2021). The effects of different factors on propagation by hardwood cuttings of some coniferous ornamental plants. Šumarski list, 145(9-10), 467-477.

[55] Ozel, H.B., Sevik, H., Cetin, M., Varol, T., Isik, B. Impact of employment policies on disabled individuals in silvicultural activities. Environment, Development and Sustainability Environ Dev Sustain (2024). Doi: 10.1007/s10668-024-05036-z

[56] Tandoğan M, Özel HB, Gözet FT, & Şevik H. Determining the taxol contents of yew tree populations in Western Black Sea and Marmara Regions and analyzing some forest stand characteristics. BioResources, 2023. 18(2): 3496-3508.

[57] Atar, E., Atar, F., & Güney, D. (2023). Carpinus orientalis Mill. Fidanlarının Kalite Özellikleri ve Morfogenetik Varyasyonlar. Turkish Journal of Agriculture-Food Science and Technology, 11(9), 1742-1750.

[58] Cobanoglu H, Canturk U, Koç İ, Kulaç Ş, Sevik H. Climate change effect on potential distribution of Anatolian chestnut (Castanea sativa Mill.) in the upcoming century in Türkiye. Forestist, 2023. 73(3);247-256.

[59] Güney, D., Bayraktar, A., Atar, F., Chavoshi, S. H., & Turna, İ. (2023). The effects of different rooting temperatures and phytohormones on the propagation of boxwood cuttings. Baltic Forestry, 29(1), id593-id593.

[60] Güney, D., Atar, F., Turna, İ., & Bayraktar, A. (2022). Morphogenetic variations of Pinus sylvestris L. seedlings depending on altitude. Ormancılık Araştırma Dergisi, 10(1), 80-89.

[61] Atar, F. (2022). Population Variability of Common Hornbeam (Carpinus betulus L.) in North-Eastern Part of Turkey According to the Involucre Morphology. Šumarski list, 146(11-12), 507-516.

[62] Aricak, B., Canturk, U., Koc, I., Erdem, R., Sevik, H. Shifts That May Appear in Climate Classifications in Bursa Due to Global Climate Change, Forestist. 2024. 74: 129-137. Doi:10.5152/ forestist.2024.23074

[63] Sevik, H., Guney, D., Karakas, H., & Aktar, G. Change to amount of chlorophyll on leaves depend on insolation in some landscape plants. International journal of environmental sciences, 2012. 3(3): 1057-1064.

[64] 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.

[65] Ertürk, N., Arıcak, B., Yiğit, N., & Sevik, H. (2024). Potential Changes in the Suitable Distribution Areas of Fagus orientalis Lipsky in Kastamonu Due to Global Climate Change. Forestist, doi:10.5152/ forestist.2024.23024.

[66] Güney, D., Atar, F., Turna, I., & Günlü, A. (2022). Effects of precommercial thinning intensity on growth of Fagus orientalis Lipsky stands over 6 years. Journal of Forestry Research, 1-11.

[67] Doğmuşöz, B. B. (2024). Plant selection for rain gardens in temperate climates: The case of Izmir, Turkey. Journal of Design for Resilience in Architecture and Planning, 5(1), 18-34.

[68] Yigit N, Öztürk A, Sevik H, Özel HB, Ramadan Kshkush FE, & Işık B. Clonal Variation Based on Some Morphological and Micromorphological Characteristics in the Boyabat (Sinop/Turkey) Black Pine (Pinus nigra subsp. pallasiana (Lamb.) Holmboe) Seed Orchard. BioResources, 2023. 18(3): 4850-4865

[69] Koç İ. Determining the biocomfort zones in near future under global climate change scenarios in Antalya. Kastamonu university journal of engineering and sciences. 2022; 8(1):6-17.

[70] Ertürk, N., Arıcak, B., Şevik, H., & Yiğit, N. (2024) Possible Change in Distribution Areas of Abies in Kastamonu due to Global Climate Change. Kastamonu University Journal of Forestry Faculty, 24(1), 81-91.

[71] Koç, I. (2022). Comparison of the gas exchange parameters of two maple species (Acer negundo and Acer pseudoplatanus) seedlings under drought stress. Bartın Orman Fakültesi Dergisi, 24(1), 65-76.

[72] Sevik, H., Karaca, U. Determining the resistances of some plant species to frost stress through ion leakage method. Feb-fresenius environmental bulletin, 2016. 25(8), 2745-2750.

[73] Dogmusoz, B. B., Tekbudak, M. Y., & Rice, A. (2023). The factors affecting Residents'willingness to implement green infrastructure strategies on their property. Journal of Green Building, 18(1), 17-35.

[74] Doğmuşöz, B., & Topal, H. V. (2024). Visual Preferences of College Students for an Ecological Design Project in a Campus Environment. Kent Akademisi, 17(1), 88-108.

[75] Koç İ, Nzokou P. Do various conifers respond differently to water stress? a comparative study of white pine, concolor and balsam fir. Kastamonu university journal of forestry faculty. 2022; 22(1):1-16.

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

[77] Koc I, Nzokou P. Effects of water stress and cold treatments on the germination of two conifers (Pinus nigra and Pinus brutia) species from Turkey. Hortscience. 2018;53(9):259-259.

[78] Özel, H. B., Şevik, H., Yıldız, Y., & Çobanoğlu, H. (2024). Effects of Silver Nanoparticles on Germination and Seedling Characteristics of Oriental Beech (Fagus orientalis) Seeds. BioResources, 19(2). 2135-2148.