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Variation of Gallium Concentrations in Some Forest Trees Depending on Species, Organ and Soil Depth

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Abstract: Heavy metal pollution is one of the most critical environmental problems threatening the environment and human health. Therefore, studies on monitoring and reducing heavy metal pollution are among the prioritized study topics. Plants are one of the most effective tools to monitor and reduce heavy metal pollution. However, the potential of heavy metal accumulation in various organs of plants is quite different. Therefore, it is necessary to determine the most suitable species and organs for this purpose and to have information on the transfer of heavy metals in the plant and the way of entry into the plant. In this study, the concentrations of Gallium, one of the most critical and dangerous heavy metals for human health, were evaluated at different soil depths in the soils where *Pinus nigra* Arnold., *Pinus sylvestris* L., *Fagus orientalis* Libsky. and *Abies nordmanniana* subsp. *bornmülleriana* Mattf. species grow in leaves, bark, wood, cones, and root organs. As a result of the study, there was no statistically significant difference between soil depths in terms of mean values of Gallium concentrations. In contrast, the highest importance on a species basis was obtained in *Fagus orientalis* Libsky. The lowest values were obtained in *Abies nordmanniana* subsp. *bornmülleriana* Mattf. Regarding organs, the lowest values were obtained in wood and the highest in roots.

Keywords: Gallium, Heavy metal, Plant, Biomonitor.

1. INTRODUCTION

In the last century, the increasing world population, the concentration of people in urban areas, and industrial developments have brought along many interrelated problems. The most critical issues worldwide are global climate change (Varol et al., 2021; Canturk & Kulaç, 2021; Koç & Nzokou, 2022a, 2022b, 2023), urbanization (Dogan et al., 2023; Zeren Cetin et al., 2023), and environmental pollution (Elsunousi et al., 2021; Cesur et al., 2022; Guney et al., 2023). Environmental pollution, especially air pollution, is the most essential social health problem worldwide. The WHO reported that more than 8 million people died yearly, exceeding air pollution limits (Isinkaralar et al., 2023a, 2023b; Sulhan et al., 2023).

Heavy metals are recognized as the most dangerous and harmful component of air pollution. Heavy metals are known as pollutants that do not quickly degrade and disappear in nature, bioaccumulate in living organisms, and some of them, such as Pb, Hg, and Ni, can be toxic, poisonous, carcin, and fatal even at low concentrations (Turkyilmaz et al., 2020; Key & Kulaç, 2022). Even heavy metals, essential for living organisms as nutrients, are harmful at high concentrations (Aricak et al., 2019; Ateya et al., 2023a, 2023b; Cobanoglu et al., 2023a). It is emphasized that heavy metals are much more dangerous when inhaled into the body (Ghoma et al., 2022).

Heavy metals pose a significant danger to humans, other living organisms, and the ecosystem (Koç, 2021). Therefore, monitoring and reducing heavy metal pollution is one of the priority study topics (Savas et al., 2022). It is stated that plants are the most effective elements that can be used to monitor the change of heavy metal pollution and reduce pollution. Plants grown in places with high levels of heavy metal pollution accumulate heavy metals in soil, water, and air. Thus, they contribute to reducing heavy metal pollution in these environments (Sharma et al., 2023; Li et al., 2023).

However, the accumulation potential of heavy metals in various organs of plants is quite different. For plants to be used effectively in reducing heavy metal pollution, the level of knowledge on issues such as in which organs plants grown under similar environmental conditions can accumulate heavy metals more, in which ways heavy metals enter the plant body more intensively, and how heavy metal concentrations change depending on soil depth in soils where different plants are grown is quite limited (Erdem et al., 2023a, 2023b). In this study, it was aimed to contribute to the elimination of these knowledge gaps. Within the scope of the study, it tried to determine the changes in Ga, one of the heavy metals used extensively in various fields. Still, it can be extremely harmful to human and environmental health in different organs of different plants and soil.

2. MATERIALS AND METHODS

Within the scope of the study, the change of Ga element, which is used intensively in various fields today and therefore its concentrations in air, water, and soil are constantly increasing but neglected in studies on heavy metals, was determined in soils and plant organs where different forest trees grow. For this purpose, leaf, bark, wood, cone, and root samples were taken from *Pinus nigra* Arnold., (Pni), *Pinus silvestris* L. (Psi), *Fagus orientalis* Libsky., (Fo) and *Abies nordmanniana* subsp. bornmülleriana Mattf. (Abo) species are growing in a limited area with similar soil and climate conditions in a flat area within the borders of Kastamonu Araç District. *Fagus orientalis* Libsky. It was not included in the study as its cones were not available. In addition, soil samples were taken from 0-5 cm depth (topsoil), 20-30 cm depth (middle soil), and 50-60 cm depth (subsoil) under each sampled tree by removing the dead cover on the soil. The soils brought to the laboratory were kept in a dry and ventilated environment for two weeks to make them room dry. The sieved soils were then dried in an oven at 45 °C for two weeks. The same preparations were applied to the plant samples except for sieving.

The dried samples were analyzed for Ga elements using ICP-OES, and their concentrations were determined at ppb level. This method has been frequently used in recent years for elemental analysis both in soils (Cetin et al., 2022a, 2022b; Elajail et al., 2022; Istanbullu et al., 2023) and in various organs of plants (Cesur et al., 2022; Ghoma et al., 2023). The data obtained were evaluated with the help of the SPSS 22.0 package program, and analysis of variance and Duncan test were applied to the data. The data obtained were simplified, tabulated, and interpreted.

3. FINDINGS

The variation of Ga concentration in soils depending on soil type and soil depth is given in Table 1.

Table 1. Variation of Ga concentration in soils.

Species	**Depth**			**F**	**Aver**
	Top.	**Middle**	**Bottom**		
Abo	23665,75 Aa	28085,88 Aa	34762,50 Ba	7,46**	28838,04 a
Pni	38930	34438,75 b	32553,63 a	1,32 ns	35307,65 b
Psi	33613,00 ab	32670,50 b	32854,19 a	0,14 ns	33045,89 ab
Fo	31681,25 Aab	45956,63 Bc	46868,52 Bb	3,61*	41502,13 c
F	2,97*	27,84***	4,63**		8,31***
Aver	31972,64	35287,94	36759,71	2,01 ns	

When the table values are analyzed, it is seen that the variation of Ga concentration depending on soil depth is statistically significant in Abo and Fo. In both species, the lowest values were obtained in the upper soils and the lowest in the more deficient soils. According to the mean values, the variation of Ga concentration based on soil depth is not statistically significant.

The species-dependent variation of Ga concentration was statistically significant at all soil depths. According to the results of Duncan's test at all soil depths, Abo grown soils were in the first group, and Fo grown soils were in the last group. The mean values indicate that Ga concentration is Abo<Psi<Pni<Fo. The variation of Ga concentration in plants by organ and species is given in Table 2.

Table 2. Variation of Ga concentration in plants.

Species	Organ					F	Aver
	Leaf	Bark	Cones	Wood	Root		
Abo	5822,09 Aba	8080,86 ABC	10051,43 Cb	4962,71 A	9415,02 B	2,76*	7624,83 a
Pni	4727,15 Aa	9134,35 B	8826,40 Bb	4918,03 A	11719,73 B	7,80***	8075,64 a
Psi	8941,51 Cb	7966,73 B	3882,42 Aa	6073,53 A	11382,60 D	14,15***	7746,16 a
Fo	10093,77 Bb	11194,36 B	-	7325,66 A	12797,73 C	7,91**	10024,25 b
F	12,94***	1,72 ns	7,46**	0,94 ns	1,93 ns		3,00*
Aver	7539,23 AB	8996,78 B	7278,66 AB	5884,82 A	11195,23 C	11,78***	

As a result of the analysis of variance, it was determined that the species-dependent variation of Ga concentration in organs was statistically significant only in leaves and cones. According to the mean values, the highest value was obtained in Fo, and the other species were in the same group due to the Duncan test.

The variation of Ga concentration by organ was statistically significant in all species. When the table is examined, it can be said that the lowest values were obtained in wood, and the highest values were obtained in roots in all species. According to the mean values, the lowest values were obtained in wood and the highest in roots and bark.

4. DISCUSSION

As a result of the study, the lowest Ga concentrations in both soils and plant organs were obtained in Abo, and the highest Ga concentrations in Fo. Ga concentration in the subsoils is higher in the soils where these two species grow. The results of the study show that Ga is utilized by plants at different levels. In many studies to date, it has been determined that heavy metal and element concentrations are at different levels both in the organs of different plants (Sevik et al., 2020; Isinkaralar et al., 2022) and in soils where different plants grow (Erdem et al., 2023a, 2023b).

Heavy metals can threaten humans, other living organisms, and the entire ecosystem. Therefore, many studies have been conducted on heavy metals (Key et al., 2022; Kuzmina et al., 2023). However, the studies on the subject have primarily focused on elements such as Pb, Zn, Cd, Mn, Ni, Cr, and Co (Ghoma et al., 2022; Yayla et al., 2022), and Ga has been neglected. However, acute exposure to gallium III chloride can cause throat irritation, breathing difficulties, chest pain, and fumes, which can cause serious problems such as pulmonary edema and partial paralysis. Similarly, exposure to high levels of silver vapor can cause dizziness, breathing difficulties, headaches, or irritability (TÜİK, 2023). Therefore, it is essential to determine the changes in the concentrations of these elements in the environment.

The most critical problem in the studies on this subject is the need for more to equalize environmental conditions. Plant development is shaped by the interaction of genetic structure (Kurz et al., 2023; Yigit et al., 2023; Çobanoğlu et al., 2023) and environmental conditions (Şen et al., 2018; Özel et al., 2022; Tandoğan et al., 2023; Sevik et al., 2019), and many environmental factors are involved in this process (Tekin et al., 2022; Varol et al., 2022). The potential of plants to accumulate heavy metals is related to plant habitat and development. All environmental factors affecting plant growth also jeopardize the possibility of heavy metal accumulation in plants (Cesur et al., 2022; Savas et al., 2022). Therefore, it is recommended that studies on the subject should be carried out in controlled environments or, if this is not possible, in areas where environmental conditions are as similar as possible. This study is essential as an example for future studies on the subject.

Since heavy metals are known to be harmful to the environment and human health, reducing the concentrations of these elements in the environment is important. For this purpose, the use of plants has become widespread in recent years. Plants keep heavy metals in their bodies, remove them from the environment, and clean the environment. Phytoremediation studies with the help of plants have been widely used to reduce heavy metal pollution in soil, water, and air (Bhat et al., 2022; Sharma et al., 2023; Li et al., 2023). However, studies reveal that each plant has different levels of potential to accumulate different heavy metals in their organs (Karacocuk et al., 2022). This study determined that Fo had the highest Ga accumulation potential among the plants subject to the study.

As a result of the study, the highest Ga concentration was obtained in the roots. Heavy metals can enter the plant body from the soil through the roots and air through the leaves and stem parts (Cobanoglu et al., 2023b; Key et al., 2023). Plant roots are the organs that have the most contact and interaction with the soil. Therefore, the highest Ga uptake in the plants subject to the study was from the soil.

5. RECOMMENDATIONS

Heavy metals can be highly threatening to environmental health. Therefore, studies on heavy metals are among the prioritized topics of study. Although there are many studies on heavy metals, the studies are mostly focused on comprimarily known elements such as Pb, Cr, Ni, and Co. However, many elements, such as Ga, V, discussed in this study, threaten human environmental health. Therefore, other heavy metals should be included in the studies on the subject. It may be suggested to prioritize elements such as Sr, As, and Tl, which are dangerous for human health.

The entry of heavy metals into the plant body results from a highly complex mechanism, and it is significant to know more on this subject. The studies should be carried out in controlled environments to overcome the lack of information on this subject. If this is not possible, conducting studies, at least in areas with similar environmental conditions, is recommended. This study may serve as an example for the proposed studies.

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