Research Article GU J Sci, Part A, 11(1): 203-209 (2024) 10.54287/gujsa.1444350

Gazi University
Journal of Science
PART A: ENGINEERING AND INNOVATION
http://dergipark.org.tr/gujsa

Strontium Accumulations by *Teucrium polium* which Grows Naturally in Serpentine Soils

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Keywords

Strontium

Teucrium Polium

Guleman

Serpentine Soils

Accumulation

Abstract

The study area is located in the Guleman region which hosts Turkey's most important chromite deposits and extensive serpentine soils. In this study, strontium uptake accumulations in the shoots and roots of the *Teucrium polium* plant growing on serpentine soils in the Guleman region were examined. In this context, 17 *Teucrium polium* plants growing in different locations of serpentine soils were collected together with their shoots, roots and soil, and then chemically analyzed for strontium. Chemical analyses were carried out in ICP-MS. On average, strontium values of 15.2 ppm in the soil, 26.4 in the root and 76.3 ppm in the shoots were detected. Strontium enrichment values in the soil, roots and shoots of this plant were determined as 1.8 for ECR (The enrichment coefficient for root), 5.3 for ECS (The enrichment coefficient for shoot) and 2.9 for TLF (Translocation factor). Results of this study show that the *Teucrium polium* plant accumulates significant amounts of strontium from the soil, both in the root and in the shoots. As a result, this plant can be used as a bioaccumulator plant, especially in the reclamation of strontium-polluted soils and the improvement of such areas.

Cite

Konakci, N. (2024). Strontium Accumulations by *Teucrium polium* which Grows Naturally in Serpentine Soils. *GU J Sci, Part A, 11*(1), 203-209. doi:10.54287/gujsa.1444350

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Article Process

Submission Date	28.02.2024
Revision Date	11.03.2024
Accepted Date	15.03.2024
Published Date	21.03.2024

1. INTRODUCTION

Weathering of ultramafic rocks results in formation of serpentine soils, which have low amounts of plant nutrients like P, K, and Ca but high quantities of metals such as Ni, Cr, and Co. Less than 45% of the silica in these rocks is composed of ferromagnesian silicate minerals (Nascimento et al., 2022). The serpentinite, dunite, and peridotite are the most common ultramafic rocks. Heavy metal levels in serpentine soils are high, including Mn, Ni, Co, Cr, and Zn. Although certain metal concentrations are necessary for plant growth at trace levels, excessive concentrations might be harmful since they can disrupt cellular processes (Konakci et al., 2023).

Strontium is one of the prevalent trace elements found in the lithosphere at amounts between 260 and 370 ppm. It is commonly contained in felsic magmatic and carbonate rocks. In carbonate rocks, sulfur is mobilized as readily soluble strontianite ($SrCO_3$), which subsequently precipitates as celestite ($SrSO_4$). These minerals breakdown and cause environmental issues for people, animals and plants, particularly in terrestrial settings (Kabata-Pendias, 2011; Sasmaz et al., 2021). The main factors controlling the Sr content in superficial soils are the type of host rocks and weathering. Strontium in mining soils and igneous rocks can be hazardous to the environment. Strontium is found in veins connected to gypsum and halite lenses or layers, within the sedimentary rocks, and is also observed as an accessory element in other minerals (Burger & Lichtscheidl, 2019; Kilic &Ates, 2015; Kilic & Inceoz, 2015). Sr levels vary 300 to 450 ppm in clay soils, 140 to 20 ppm in sandstones, 3100 to 20 ppm in cambisol soil, 500 to 70 ppm in histosols, and 1000 to 20 ppm in podzols, with the highest amounts seen in heavy loamy soils (Kabata-Pendias, 2011). Because of its non-biodegradability,

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endurance in nature, and accumulation in living animals and plants, the toxicity of heavy metals is a large issue for the natural environments (Sasmaz & Sasmaz, 2017). In urban and mining areas, heavy metals of Sr, Th, U, Zn, Pb, Ni, Cr, Co, Hg, Tl, Sb, As and Se contaminate surface soils and streams/rivers (Rađenović et al., 2016). Element accumulation is possible for the plants through their stems, leaves, and roots. Different species have varying capacity for absorbing metals, and using these species for bioremediation offers a number of advantages for the environment and economy, including cheap cost, high efficiency, energy savings, and the avoidance of secondary pollution. Aquatic plants can uptake large amounts of metals from water and sediment through active and passive absorption. Sr is taken by plants for their metabolic needs and employed in exchange diffusion and mass transport mechanisms since it is not a micronutrient for plants like Ca. Few research have been conducted on the accumulation and toxicity of Sr in plants; Shacklette et al. (1978) determined the hazardous value of Sr in plants to be 30 ppm. Inhaled as dust or mist, strontium sticks to the lung surface, dissolves there, and mixes with blood rapidly. Sr may be hold in the lungs for an extended period of time if it does not sufficiently mix with the blood (ATSDR, 2004). As a result, it can affect the lungs in many ways resulting in undesired physiological and biochemical issues in both people and animals.

Heavy metals are extracted from soil using a variety of methods (Yalcin et al., 2008; Qi & Zhao, 2020; Pehoiu et al., 2020; Sharma, 2020; Yalcin et al., 2020; Mikavica et al., 2023; Uras & Yalcin, 2022; Mileti´c et al., 2024; Timofeeva et al., 2024). Phytoremediation illustrates each plant's capacity to remove metals based on its physiological, genetic, anatomical and morphological characteristics. Few researches have been done on stable Sr accumulation in terrestrial and aquatic plants, despite the fact that several have been carried out on radioactive Sr removing in terrestrial plants. Thus, the primary goals of this research are to examine the Sr accumulation in the root and shoots of 17 terrestrial *Teucrium polium* plants naturally growing in serpentine soils that are contaminated by strontium. The movement and absorption of Sr from the soil into plants and the usability of plants in studies pertaining to the restoration and rehabilitation of Sr-polluted soils are the other aspects of study.

2. MATERIAL AND METHOD

2.1. The Study Area

The serpentine soils in the Guleman chromite deposits are the material of this study (Figure 1). The Guleman region, one of the most significant areas for the chromite ore production in Turkey, is divided into several mining sectors based on the lithological features, type of deposits, structural and geographic locations. The dunite, peridotite and pyroxenites exposing near the Guleman district are rich in Cr, Ni and Co and linked to the chromium deposits (Engin et al., 1983). Open pits or galleries in the study area are used to recover the chromite ore. Following the application of open pit method, underground mining was introduced in the region in 1950 due to the diminishing number of ore. Today both open pit and underground mining techniques are in use (Engin et al., 1983).

2.2. Soil and Plant Samples

Seventeen plant samples grown in different areas on the serpentine soils of the Bahro and Dereboyu mining areas were collected together with their soil (Figure 1). *Teucrium polium* plant, locally called peryavşan was described by Semsettin Civelek (Firat University, Biology Department) and is one of the 300 species of the *Lamiaceace* family (Kırkık et al., 2020). *Teucrium polium* is a shrub that grows 20–50 cm high and has stemless, oblong or linear leaves. It is usually found in Iran and in rocky areas of practically in all the Mediterranean countries, Southwest Asia, Europe and the northern hills and deserts (Tapeh et al., 2018; Kırkık et al., 2020). *Teucrium polium* is a perennial herbaceous plant that resembles a semi-shrub and can grow up to 40 cm tall with pale blooms. This plant was sampled separately from the roots, shoots and soil on which it grows in ore/non-ore locations. It is a prominent species in the soils of the research area and grows widely throughout the region. At depths of 0.10 to 0.40 meters, soil samples were extracted from *Teucrium polium* root feeding zones. After being removed from the serpentine soil, the *Teucrium polium* plant was cleaned with pure water and then tap water. The root and shoot samples were burned for 24 hours at 300 °C in a flameless oven after dried for 24 hours at 60 °C. The result was ash.

In the laboratory, 0.10 g of ash and soil samples were mixed separately with 2 ml of pure HNO_3 (Merck, Darmstadt, Germany), then the mixture was heated at 95 °C for one hour to dry. The dried materials were mixed with 2 ml of HNO_3 and HCl-HNO_3-H_2O (6 ml of each mixture made by taking 1:1:1 from acid and 0.10 g of ash and soil sample) (Sasmaz & Sasmaz, 2017). Sr element analyses were performed with ICP-MS instrument once all soil samples were dissolved in the mixture. ICP-MS was used to assess Sr in plant ash samples in a manner similar to those of soils. Analysis was carried out at the ACME laboratory (Canada).

The calculation of the enrichment coefficients (ECR) for roots involved dividing the soil concentration of the plant roots for every individual plant. Dividing the soil metal contents of each plant by shoot values, the enrichment coefficients (ECS) for shoot were determined. The metal ratio that was transferred from the plant roots to the shoot was known as the translocation factor (TLF). TLF is greater than 1 in hyperaccumulator plants. Thisfactor shows the ability of the plant to move metal from its roots to its shoots (Sasmaz et al., 2021).

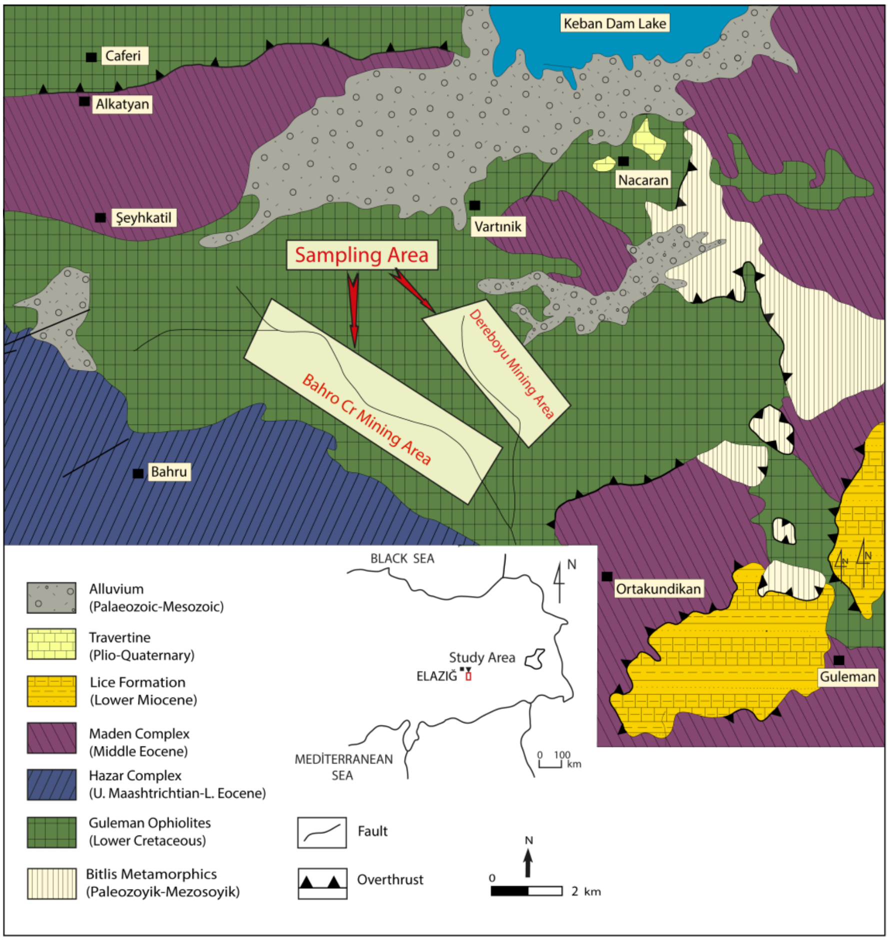

Figure 1. *Geological map of the study area (Özkan, 1983)*

3. RESULTS AND DISCUSSION

3.1. Strontium in Soil

Loamy and peaty clay with a pH of 7.6-7.8, an organic matter level of 8–12% and an average composition of 35% sand, 27% clay, and 23% silt make up the serpentine soils. Typically, their colour ranges from dark brown to light grey. It has been shown that the amount of organic matter is lower in serpentine soils than in other mineral soils. The studied soils had an average strontium content of 15.2 ppm, a maximum of 24.2 ppm and a minimum of 10.2 ppm (Figure 2). The low strontium content in Guleman serpentine soils is attributed to the chemistry of rocks. The Keban (Elazığ) Pb-Zn ore field had Sr values between 112 and 717 ppm (Sasmaz & Sasmaz, 2009), whereas the Gumuşkoy (Kütahya) mine field had Sr concentrations in the range of 22.6 to

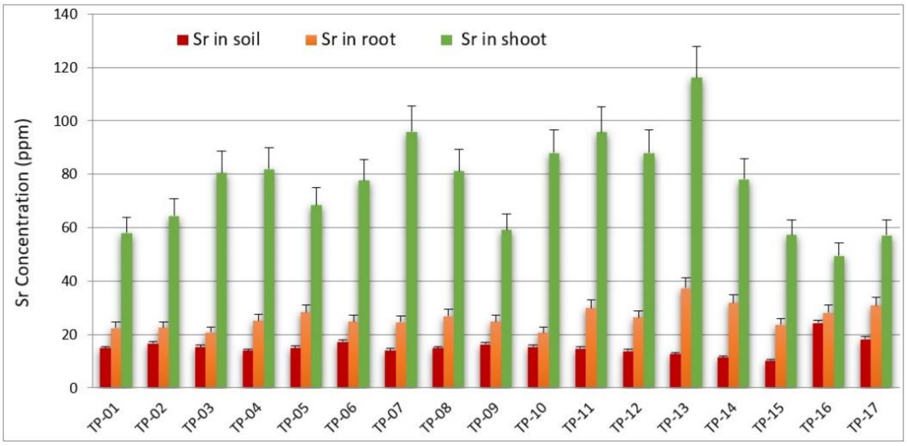

Figure 2. *Strontium accumulations in the soil, roots and shoots of the Teucrium polium plant grown in serpentine soils*

691.8 ppm (Sasmaz & Sasmaz, 2017). High amounts of Sr, ranging from 320 to 1300 ppm, have been recognized in the mineral soils of pyroxenite and carbonatitic rocks in the alkaline magmatic rocks in Norway (Myrvang et al., 2016). According to Kabata-Pendias (2011), the host rock composition is the primary indication of Sr abundance in soils and Sr concentration rises linearly from basic rocks to syenitic rocks (diorite), 13–39 ppm in Venezuela, 210 ppm in Canada, 715–1000 ppm Russia, 26–150 ppm China, 261 ppm in Great Britain, 32–130 ppm in Japan, 112–258 ppm in Sweden, and 305 ppm in USA are only a few of the nations with significantly varying Sr concentrations in their soils.

3.2. Strontium in *Teucrium polium*

In the region's serpentine soils, *Teucrium polium* plants were gathered from 17 distinct sites and chemical analyses were performed to check for strontium content in the roots and shoots. Strontium concentrations on the root fall in the range of 20.6 to 37.4 ppm. It was found that the root's average strontium content was 26.4 ppm (Figure 2). *Teucrium polium* branches have average Sr levels of 76.3 ppm with the maximum value of 116.1 ppm and the lowest value of 49.5 ppm (Figure 2). The following were calculated: ECS to show the relationship between the branch and soil; TLF values to show the strontium build up from root to shoot; and ECR, which is found by dividing the Sr levels in the root by the Sr levels in the soil of *T. polium.* The results of these computations showed that *Teucrium polium*'s average ECR values for Sr were 1.80, ECS was 5.27, and TLF was 2.93 (Figure 3). These findings display that the investigated plant's roots and shoots have a high capacity to absorb Sr from the soil. Regarding the Sr accumulation rates of the plant organs, the shoot exhibits significantly more accumulation ability than the root. This is clearly supported by the TLF results of this study (Figure 3).

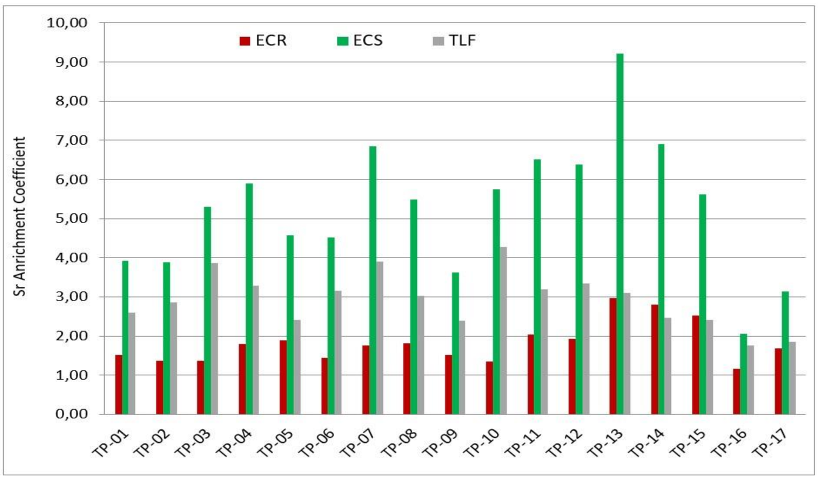

Figure 3. *ECR, ECS and TLF values for strontium in the Teucrium polium plant grown in serpentine soils*

The distribution and accumulation of Sr in barley, wheat, naked oats and groats were investigated by Qi, L., & Zhao (2020), in relation to their capacity for phytoremediation. They stated that there were high Sr concentrations on average in the shoots of the barley, oat kinds and naked oat. Grain samples had the lowest Sr concentrations whereas leaf samples had the highest values. The range of average ECS values observed was 0.52 to 1.34. It was discovered in the days that followed that the rate of Sr build up from soil to shoots was more than 1.4% for a maximum of 120 days. These findings demonstrated the efficacy of using these plants to restore Sr content in soils. Shahraki et al. (2008) had contaminated the Sr concentrations in terrestrial plants that are cultivated in the soils of Sarcheshmeh copper mines. They discovered that the Sr values in shoot and root samples for *Phragmites australis* and *Tamarix ramossima* were 47.4 and 132 ppm and 98.8 and 188 ppm, respectively. Sasmaz & Sasmaz (2017) investigated the Sr accumulation and translocation in 11 native plants grown in the soils of the Gümüşköy mine. Based on ECR and ECS, plants are categorized as candidate, good, and best plants. *Verbascum thapsus*, *Cynoglossum officinale*, and *Glaucium flavum*. considered to be effective plants for accumulating Sr from soil contaminated by Sr include *Isatis* and *Phlomis sp*. The greatest Sr values in conifers were discovered by Petrescu & Bilal (2006) in *Picea excelsa* and *Abies alba* plants that were grown in mining sites. It has been noted that the aboveground sections of *Picea excelsa* and *Abies alba* plants acquire more Sr than the root sections. According to Zu et al. (2005), a hyperaccumulator plant is one that absorbs metal several times more than uncontaminated soil. These plants also include *Euphorbia macroclada*.

Keban mine soils showed Sr accumulation several times greater than the soil samples (Sasmaz & Sasmaz, 2009). Region to both aquatic and terrestrial plants were studied by Sasmaz et al. (2021). On a dry weight basis, it was discovered that the average Sr concentrations in shoots, roots and soils of terrestrial and aquatic plants were 48.2, 80.5 and 101 ppm, respectively. The studied plants were classified as candidate, bioaccumulator, and hyperaccumulator plants based on the enrichment coefficients and translocation factors of their roots (ECR) and shoots (ECS), respectively. *Xanthium* and *Pragmites sp.* bioaccumulator plants, *Typha latifolia*, *Lythnium salicaria* and *Bolboscholnus ascbersus* were assessed as hyperaccumulator plants for Sr. *Salix sp*. and *Tamarix tetrandra* were chosen as candidate plants. The ability of both bioaccumulative and hyperaccumulator plant groups to accumulate from their soil to plant parts is demonstrated by these data. As a result, it has been proposed that these plants could be helpful for research on the rehabilitation of different mine soils and municipal wastewater that have been contaminated by Sr.

4. CONCLUSION

In this study, we examine the accumulations of strontium absorption in the roots and shoots of *Teucrium polium* plants that grow on serpentine soils in the Guleman region. The average soil concentration of boron was found to be low at 7.94 ppm while *Teucrium polium* strontium readings were 15.2 ppm in the soil, 26.4 ppm in the root and 76.3 ppm in the branch. The plant's soil, roots, and shoots had strontium enrichment levels of 1.8 for ECR, 5.3 for ECS, and 2.9 for TLF. These results show that the *Teucrium polium* plant accumulates significant amounts of strontium from the soil to both roots and shoots. Therefore, the *Teucrium polium* plant can be used as a bioaccumulator plant, especially in the reclamation of strontium-polluted soils and in the remediation of such areas.

ACKNOWLEDGEMENT

This study was supported by the Firat University under grand no FUBAP-MF.20.16.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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