Research Article

Elucidating the leaf-based heavy metal bioindication in two significant plant taxa from Caucasus

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Abstract

The present study was aimed at assessing the potential of two important plants of the Transcaucasia – *Betula medwediewii* Regel (Caucasian birch) and *Veratrum album L.* (white hellebore) - as bioindicators of pollution of the environment. *Betula medwediewii* is a subalpine and alpine deciduous tree species that is significant for soil and habitat development. *Veratrum album* is found in the high altitude regions, is also known to withstand extreme conditions and has been used in herbal medicine. Elemental analysis was conducted on the plant leaves for total heavy metals such as aluminium, cadmium, cobalt, lead, and zinc. Results of the study showed that, in the leaves of *B. medwediewii*, aluminium, cadmium, and zinc heavy metals were found to be within permissible levels but levels of cobalt and lead were above permissible levels. For *V. album* cadmium and zinc also remained within the normal range but aluminum, cobalt and lead levels were notably high. The results of the study indicate the distinct accumulation characteristics that these species possess a unique behaviour in the presence of heavy metal pollution in the Transcaucasian environment and both plants have a potential capability as bio indicators.

Keywords: *Betula medwediewii*, pollution, phytotoxicity, *Veratrum album*

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Introduction

Since plants are one of the structural elements contributing significantly to the realization and maintenance of ecological functions in existing ecosystems, the study of these natural components and an elucidation of their Eco physiological relationships with their habitats facilitates the understanding of the pollution to which plants are exposed [1 - 9]. In recent years it is often stated that plant diversity is threatened by pollution [7 - 8, 10].

The pollution potential resulting from anthropogenic activities causes negative impacts on natural resources as an environmental problem [11]. One of the

most important environmental factors causing pollution are heavy metals, which are released from various anthropogenic sources and potentially lead to toxic effects, causing several stress problems at alarming levels in plants with fixed ecological niches, the reason being their easy transport to varying distances [11 - 13]. The toxicity caused by the heavy metals is mainly due to their widespread release into different habitats from industrial, agricultural, chemical, domestic and technological sources, all increasing the concentration levels of such metals and ending up with serious water, soil and air pollution problems [14].

No detailed pollution studies have been carried out on the current status of *Betula medwediewii* (Medwediew's birch) and *Veratrum album* (white hellebore). Therefore, these two species were studied to assess their potential as bioindicators of heavy metal accumulation in their leaves.

Materials and Methods

Studied species and study areas

The plant samples were collected from different sites in the eastern Black Sea region of Turkiye, namely Artvin-Murgul: Tiryal Mountain (1900 m) for the *B. medwediewii*, and Artvin-Şevvaltepe (1700 m) for *V. album* [6].

Data analysis

Leaves of the studied plants were separately wrapped in filter paper and labelled. All leaves were oven dried for 48 hours at 80°C in the lab to produce a consistent dry weight and prevent the spread of mold [7, 8, 15].

Eight milliliters of 65% nitric acid were used to decompose the leaf samples (HNO3). Following digestion, materials were filtered using ultrapure water and Whatman blue band filter paper before being placed into sterile 50 mL Falcon tubes [9]. Inductively coupled plasma optical emission spectrometry (ICP-OES) was used to perform elemental analyses for aluminum (Al), cadmium (Cd), cobalt (Co), lead (Pb), and zinc (Zn) after these preparatory processes [7, 8, 15].

Results and Discussion

The results of elemental analysis from leaf samples from the two plants are presented in Table 1. Zn was found to be the element with the greatest concentration in B. medwediewii leaves, with all other elements showing the same general order of concentration: Zn > Al > Pb > Co > Cd (Table 1). Al, Cd, and Zn elements concentrations in B. medwediewii leaf sections were found to be within the limit values, but Co and Pb elemental concentrations were found to be over the limit values in Table 1.

Table 1: Elemental analysis (mg kg^{-1}) of leaf samples from the plants

Element	*Betula medwe-diewii*	*Veratrum album*	Limit values (min-max) [8, 16, 17]
Al	130	775	40-500
Co	1.5	2	0.05-0.57
Cd	0	0.5	0.05-0.5
Pb	67	81	5-30
Zn	135	114	20-150

In *V. album*, the maximum concentrations in leaves were recorded for Al. The order of the elements with greatest concentrations was typically Al > Zn > Pb > Co > Cd (Table 1). In the leaf parts of *V. album,* the element concentrations of Cd and Zn were determined to be within the limit values, whereas Al, Co and Pb were above the limit values (Table 1). In the leaves of these plants the lowest concentration of Cd was recorded.

The presence of the Murgul copper mine in the region is known to cause heavy metal pollution due to the mixing of waste pond

water with the soil, which contains many heavy metals including copper (Cu) and Co, Pb, Cd, chromium (Cr), iron (Fe), nickel (Ni), mercury (Hg) and Zn [7].

While Al, Cd, Co and Pb are among the non-essential heavy metals that are toxic to plants, heavy metals such as Zn are also among the essential heavy metals which play an important role in plant development and metabolism [11]. Considering the results obtained in this study, the high concentration of Zn in the leaves of these plants indicates that it is effective in the growth and development of the plants. Similar results were reported by Lopes et al. [18] in a similar situation.

In general, due to the long operating life of copper mines, some studies have reported an increase in concentration values of some important heavy metals such as copper, lead and zinc in their immediate vicinity [7, 19 - 21]. In a recent study conducted around the Murgul mine, it was reported that both soil acidity and SO_4 concentrations increased with increasing proximity to existing mining activities in the region [7]. In particular, it was reported that the pH of surface soil samples outside the study area varied between 5.1 and 5.9, while the pH of samples collected near the smelter varied between 4.1 and 5.5 [7]. Another study has reported that the pH of rain samples in the vicinity varied between 3.8 and 5.0 and could be acidic even at a distance of about 3-5 km from the region [22]. In this case, atmospheric fallout from ore smelting plants was reported to be a significant contributor to heavy metal soil contamination, which is detrimental to the plant cover in general [23].

According to Ozturk et al. [24], Al is generally toxic to plants in acidic soils. Ozturk et al. [7] have reported that pH values of many soil samples recorded here ranged from 4.13 to 7.64, indicating that the area around the Murgul copper mine still has an acidic character. The Al concentration exceeded the limit at the site. In general, the low acidic pH at the site is an important factor for Al uptake by plants [24]. Partially reduced pH during the periods when no measurements were made may have caused abnormal Al uptake by the plant [24]. **Co** uptake by plants can vary depending on species, soil pH, concentration, and the presence of various metals [25].

Concentrations of heavy metals in the plants can vary depending on their uptake by roots and accumulation in organs such as leaves and bark [26]. Understanding these elements' mobility in soil and plant tissues is crucial to comprehending the processes of accumulation and transfer [27]. In general, the Pb is generally known as an immobile element with very low transport from soil to leaves [26, 28], because it tends to accumulate in roots and is rarely transported to aboveground plant organs [16, 29].

Focusing on the current heavy metal accumulation in leaves, the accumulation of the studied elements in plant leaves can be attributed mainly to their direct uptake from the atmosphere through absorption from the leaves rather than their transport from the soil to the leaves. A similar situation was emphasized in a study by Maistro et al. [30]. Thus, it can be said that the distinction between heavy metal load obtained through accumulation from soil and air is directly effective [31].

Due to its physical and chemical properties, Pb is one of the heavy metals widely used in various industries. For this reason, it can be easily transferred from air, water and soil to plants [32]. The pollution due to Pb is generally represented by anthropogenic outputs such as vehicle exhausts and industrial wastes [8, 32 - 33]. The main impacts of these anthropogenic sources are the use of fossil fuels, corrosion products of vehicle bodies, and emissions from vehicles such as tyre wear [8, 34 - 35].

Recent population growth has led to increased urbanisation in the region and, as a result, anthropogenic activities such as road construction and a high output of domestic waste have contributed towards an increase in the Pb concentrations [7, 36 - 37]. This highlights the fact that Pb pollution is caused by anthropogenic activities together with mining. Therefore, Pb concentrations in leaf samples of these plants collected from the study area are likely to be very high.

Conclusion

The results presented here include ecological findings on heavy metal contamination in the leaves of *B. medwediewii* and *V. album*, which are sensitive plants of the Caucasus region. It was found that Co and Pb concentrations were higher in the leaves of *B. medwediewii*, while Al, Co and Pb concentrations were higher in the leaves of *V. album*. Thus, the leaves of these species have the potential to be used as bioindicators of heavy metal pollution. Further studies are needed to follow, assess continuously and monitor the exposure of plant diversity to pollution in the Caucasus region.

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