Altitudinal Variation of Mineral Elements in Common Plant Species, and Soils of Erzincan Province-Ergan Mountain (Türkiye)

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ABSTRACT

This study was carried out with 30 plant species growing at different altitudes of Mount Ergan in Erzincan (Türkiye) province in 2021-2022. The concentration of mineral elements was determined in the collected plants and the soils in which they grew at 1500 m of altitude (*Glaucium leiocarpum* Boiss., *Alcea calvertii*, *Genista aucheri*, *Astragalus ornithopodioides*, *Anchusa leptophylla*, *Linum mucronatum*, *Euphorbia virgata*) at 2000 m (*Genista aucheri*, *Hypericum scabrum*, *Tanacetum mucroniferum*, *Barbarea auriculata*, *Onobrychis cornuta*, *Inula oculus-christi*, *Euphorbia virgata*, *Globularia trichosantha*) at 2500 m (*Aster alpinus*, *Lallemantia canescens*, *Scutellaria orientalis*, *Dianthus orientalis*, *Coronilla orientalis*, *Campanula tridentata*, *Crepis armena*, *Anthemis cretica*, *Euphorbia petrophila*, *Papaver fugax*) and at 3000 m (*Senecio hypoleucus*, *Pedicularis comosa*, *Scorzonera sericea*, *Anthemis cretica*, *Astragalus nezaketiae*, *Papaver fugax*, *Campanula tridentata*, *Senecio hypoleucus*, *Hedysarum erythroleucum*). The collected plant (root, leaf, flower) and soil samples were pretreated and analyzed by ICP-MS. The data obtained were statistically evaluated and it was determined that there were differences between altitudes. It was observed that the elements in the soil generally decreased as the altitude increased.

Keywords: Altitude, mountain, mineral element, plant, ICP-MS

Erzincan İli-Ergan Dağı'nda (Türkiye) Yaygın Bitki Türleri ve Topraklarındaki Mineral Elementlerin Rakımsal Değişimi

ÖZ

Bu çalışma, 2021-2022 yıllarında Erzincan il sınırları içerisinde yer alan Ergan Dağı'nın farklı yüksekliklerinde yetişen 30 bitki türü ile yapılmıştır. Bunun için 1500 m yükseklikte (*Glaucium leiocarpum* Boiss., *Alcea calvertii*, *Genista aucheri*, *Astragalus ornithopodioides*, *Anchusa leptophylla*, *Linum mucronatum*, *Euphorbia virgata*) 2000 m'de (*Genista aucheri*, *Hypericum scabrum*, *Tanacetum mucroniferum*, *Barbarea auriculata*, *Onobrychis cornuta*, *Inula oculus-christi*, *Euphorbia virgata*, *Globularia trichosantha*) 2500 m'de (*Aster alpinus*, *Lallemantia canescens*, *Scutellaria orientalis*, *Dianthus orientalis*, *Coronilla orientalis*, *Campanula tridentata*, *Crepis armena*, *Anthemis cretica*, *Euphorbia petrophila*, *Papaver fugax*) ve 3000 m'de (*Senecio hypoleucus*, *Pedicularis comosa*, *Scorzonera sericea*, *Anthemis cretica*, *Astragalus nezaketiae*, *Papaver fugax*, *Campanula tridentata*, *Senecio hypoleucus*, *Hedysarum erythroleucum*) olacak şekilde farklı rakımlardan toplanan bitkiler ve yetiştikleri topraklarda mineral elementlerin konsantrasyonu belirlenmiştir. Toplanan bitki (kök, yaprak, çiçek) ve toprak örnekleri ön işlemlerden geçirildikten sonra ICP-MS cihazında analiz edilmiştir. Elde edilen veriler istatistiksel olarak değerlendirilerek, rakımlar arasındaki farklılıklar olduğu tespit edilmiştir. Yükselti arttıkça topraktaki elementlerin genel olarak azaldığı görülmüştür.

Anahtar Kelimeler: Yükseklik, dağ, mineral element, bitki, ICP-MS

INTRODUCTION

Plants need certain amounts of mineral elements in order to continue their development normally [1-4]. Physiologically, macro and micro elements are very important for plants. Elements generally play an important role in the production of oxidation and reduction reactions, enzyme activities, energy transfer, organic substance production and electron transport in plants [3]. In addition, elements have important roles in metabolic processes such as seed and fruit formation, pollen health, fertilization, protein synthesis, carbohydrate transport, calcium transport and hormones, development and formation of cell tissues, structural and physiological properties of roots and flowers, stability of plant tissue, cell division, cell wall formation, cell expansion and activation of enzymes in plants. Due to the deficiency of essential nutrients, necrosis of young leaves, vegetative development, growth, fruit blossom end rot, significant losses in crop yield and quality, reduction in cell lysis and plant productivity, loss of membrane integrity and problems in plant functions may take place [4-7].

The forms and concentrations of the elements in the soil, the functions of which are precisely determined in plants, are of great importance in terms of plant nutrition. During the uptake of plant nutrients by plant roots, many factors such as plant type, age, root growth, physical, chemical and biological properties of the soil, the types and amounts of elements in the soil, and weather conditions have an effect.

Plants obtain essential nutrients from their surrounding environment. While the majority of these nutrients are absorbed through the root system serving as the primary interface with the soil a smaller fraction is assimilated by aerial structures such as stems, branches, and leaves. [3, 8, 9]. The effect of the physical and chemical structure of the soil on plant growth and propagation is very important. The natural content of metals in soil depends on geochemical and geophysical processes. The factors and time of soil formation are highly influential on the concentration of metals [10, 11].

Geomorphological factors such as lithology, landforms, elevation, slope and aspect are among the important factors affecting vegetation diversity and distribution. Among these factors, elevation is known to be effective in determining the character of vegetation [12]. Elevation plays a crucial role in shaping both biodiversity and the physicochemical properties of soils. Ecosystems at higher altitudes are typically associated with lower temperatures. Fluctuating precipitation patterns decreased atmospheric pressure, and nutrient limitations in the soil further influence biodiversity dynamics in these environments [13-15]. The amount of mineral elements varies according to plant type and elevation. As the elevation increases, climatic characteristics such as temperature and precipitation conditions change. In addition, the land becomes more sloping and faulted. This change in the geographical environment has important effects on the distribution of plant species. At low elevation values, plant species with less precipitation and high temperature demand can grow, while at high elevations, plant species with high precipitation demand and low temperature demand can grow [16].

The primary aim of this study is to examine whether an altitude-dependent relationship exists between the mineral element concentrations in the growing environment and different parts (roots, stems, leaves) of common plant taxa found at four distinct altitudes on Mount Ergan, with each altitude separated by a 500 m difference. This investigation seeks to understand how variations in altitude influence the uptake and distribution of mineral elements within plant structures.

Additionally, the study aims to evaluate whether plants belonging to common floral groups exhibit specific patterns of association with the mineral element concentrations of their respective growing environments at these altitudes. By analyzing these relationships, the research seeks to provide insights into how environmental and altitudinal factors shape the mineral element composition of plants, contributing to a deeper understanding of plant-environment interactions and adaptations in mountainous ecosystems.

MATERIAL and METHODS

Study area and plant species

This study was conducted at Mount Ergan with an elevation of 3256 m, which is a continuation of the Munzur Mountains in the province of Erzincan (Türkiye). There is a difference of approximately 2000 m between the average elevation of the Erzincan plain (1200 m) and the average elevation of Mount Ergan (3256 m). The province of Erzincan is covered by mountains and plateaus. Mountains extend in various directions but along a certain line. Munzur to southwest and Refahiye Mountains to northwest constitute the borders of the province. The Karasu River coming from Erzurum to the east and extending towards the west and the Otlukbeli Mountains divide the provincial area in depth, leaving wide plains between them. The mountains cover approximately 60% of the provincial territory [17, 18]. Mount Ergan is composed of pelagic, massive and reefal layered limestone, metamorphic rocks, ophiolites, clastic rocks, mixed ophiolites, vulcanite's, and volcano-sedimentary series and evaporites [19]. In the present study, during the years 2021-2022, plants with different flower coloration (yellow, white, pink-blue-violet, green) and samples were collected from the soils growing at an altitude of 1500 m at Mount Ergan (*Glaucium leiocarpum* Boiss., *Alcea calvertii* (Boiss) Boiss., *Genista aucheri* Boiss., *Astragalus ornithopodioides Lam.*, *Anchusa leptophylla* Roem. & Schult, *Linum mucronatum* Bertol, *Euphorbia virgata* Waldst. & Kit.), at 2000 m (*Genista aucheri* Boiss., *Hypericum scabrum* L., *Tanacetum mucroniferum* Hub. Mor. Et Grierson, *Barbarea auriculata* Hausskn. ex Bornm, *Onobrychis cornuta* L., Desv., *Inula oculus-christi* L., *Euphorbia virgata* Waldst. & Kit., *Globularia trichosantha* Fisch. & C.A.Mey) at 2500 m (*Aster alpinus* L., *Lallemantia canescens* (L.) Fisch. & Mey., *Scutellaria orientalis* L., *Dianthus orientalis* Adams., *Coronilla orientalis* Miller, *Campanula tridentata* Schreber, *Crepis armena* DC., *Anthemis cretica* L., *Euphorbia petrophila* C.A. Meyer, *Papaver fugax* Poiret,) and at 3000 m (*Senecio hypoleucus* Benth, *Pedicularis comosa* L., *Scorzonera* *sericea* DC., *Anthemis cretica* L., *Astragalus nezaketiae* A.Duran & Aytaç, *Papaver fugax* Poiret, *Campanula tridentata* Schreber, *Senecio hypoleucus* Benth, *Hedysarum erythroleucum* Boiss.) (Fig.1).

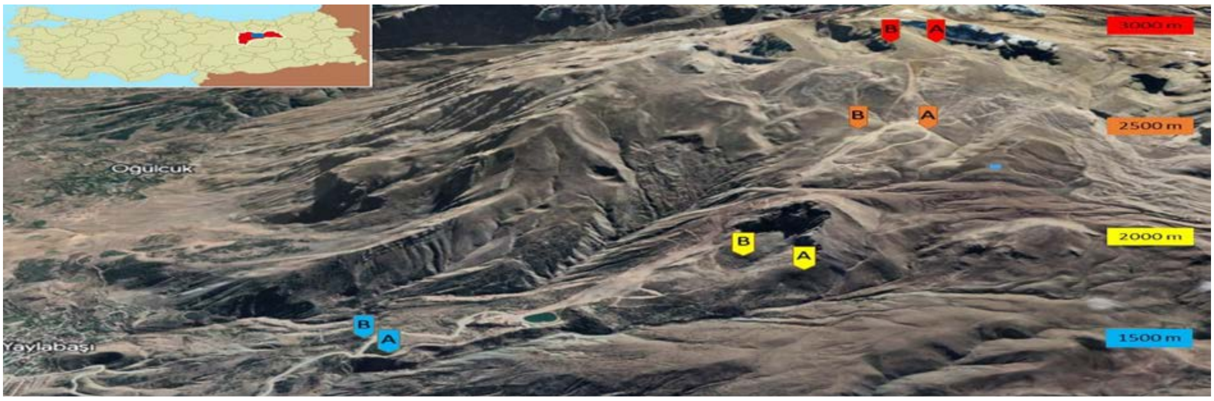

Figure 1. Study of area

The plant samples used in this study were collected within the framework of ethical rules and relevant legal regulations. Necessary permissions were obtained during the collection process and care was taken not to harm the plant species. The plants were selected to represent the study area. The collected plants were identified. Each identified plant specimen was deposited in Erzincan Binali Yıldırım University Herbarium to create a permanent record [20].

Heavy metal quantification

Studied plants area common at different elevations. In the laboratory, the collected plant samples were partitioned into flowers (petals), leaves, and roots. The samples were initially dried in an oven at 80°C for 24 hours. Subsequently, the dried material was ground using a dry mortar and passed through a 1.5 mm sieve. To prevent cross-contamination, the drying equipment was cleaned with ethyl alcohol after processing each sample before proceeding with further pulverization [21, 22]. Soil samples were taken using a hoe at a depth of 10 cm from the surface of each area after removing debris. Approximately 500 g of each sample was collected and stored in bags to prevent contamination. Soil samples brought to the laboratory were air-dried and sieved through a 1.5 mm mesh. For further analysis, 0.5 g of the dried and powdered plant and soil samples was measured and transferred into microwave digestion containers. 6 mL HNO_3 65%, 2 mL H_2O_2 30% was added to the plant samples, while 3 mL HNO_3 65%, 9 mL HCl 37% was added to the soil samples. The samples were homogenized in a magnetic stirrer for 10 minutes. After placing the containers in the microwave, dissolution was carried out in acid medium up to 2000 ^{0}C with 45 bar of pressure for 15 minutes. The samples burned in the container were taken into a balloon jug and filled to 50 mL. 10 mL was withdrawn from the 50 mL samples using a Teflon filter. Finally, the samples were placed in falcon tubes to determine the element concentrations and metal concentrations were determined by ICP-MS [21, 22]. In the study, B, Na, Ca, Mg, K, Al, Fe, Mn, Zn, Ni metal analyzes were carried out in plants and soil. The data obtained are given as "µg/g dw: micrograms per gram dry weight.

Statistical analysis

The data collected in the study were subjected to statistical analysis. A significance level of $p \leq 0.05$ was used for all statistical assessments. Data were analyzed using the ANOVA test within a 95% confidence interval, employing the SPSS 22 software package. Multiple comparisons among samples were evaluated using the Student-Newman-Keuls (S-N-K) and Tukey's tests to identify significant differences [21].

RESULTS AND DISCUSSION

This study is highly comprehensive in scope, given the diversity of collected plant species, the analysis of various plant parts, and the investigation across multiple altitudinal gradients. Na element was found to have different data in plant parts and soils. *Astragalus ornithopodioides* growing at 1500 m altitude had the highest Na content in root (490.6±11.6 µg/g dw) and flower (413.8±21.6 µg/g dw) respectively while *Campanula tridentata* growing at 2500 m altitude had the highest values in leaf (464.6±5.2 µg/g dw). Na in the soil (306.8±24.8 µg/g dw) was highest at 1500 m altitude. Separate statistical evaluations were made for plants grown at four different altitudes and significant differences were observed for Na in plants grown at each location (Table 1). In addition, Mg concentration was found to have different data depending on the altitude. Among the plant parts, the highest value was found in the root (34764.1±4337.3 µg/g dw) in *Astragalus ornithopodioides* growing at 1500 m altitude. Mg concentration in soil decreased significantly with increasing altitude $p<0,001$. Statistical evaluations of the plants grown at each altitude showed significant differences in terms of Mg element (Table 2). Al concentration was generally higher in the flower parts of the studied plants at 2500 m and in the root part at 2000 m p<0,001. *Globularia trichosantha* in flower (36029,0±963,8 µg/g dw) and leaf (12859±669,1 µg/g dw) and *Barbarea auriculata* in root (19970,7±2617,3 µg/g dw) were found to have the highest Al content in plant species growing at 2000 m altitude. Al concentration in soil was (43136.3±2502.1 µg/g dw) at 2000 m altitude, which is higher than that at other altitudes (Table 3). The highest concentrations of K in leaf (61902,3±5432,9 µg/g) and flower (51864,8±1812,5 µg/g) respectively were found in *Anchusa leptophylla* growing at 1500 m. As a result of soil analysis, differences were found between altitudes. The soil with the highest K content was observed in the samples taken from 2000 m (Table 4). Ca concentration had different data for each elevation in the studied plants. Ca element in the soil was close to each other at other elevations except at 2000 m. In terms of statistical evaluations showed significant differences in plant parts (Table 5). The highest values of Fe and Mn were observed in *Globularia trichosantha* in flower and *Barbarea auriculata* in root growing at 2000 m and in *Crepis armena* species growing at 2500 m altitude in leaves. Fe and Mn elements in the soil were found to have similar values at different elevations p<0,001 (Table 6, 7). Cu concentration was found to be close to each other in plant leaves and roots. The amount of Cu in the soil decreased depending on the elevation (Table 8). The highest value of Zn concentration was found in the flower (201.7±62.3 µg/g dw) in *Genista aucheri*, which grows at 2000 m, and in the leaf (149.8±5.3 µg/g dw) in *Campanula tridentata*, which grows at 3000 m. Statistical evaluations of soil and plant parts showed significant differences between the altitudes p<0,001 (Table 9). Moreover, Ni content decreased significantly in both plant parts and soil depending on the altitude (Table 10). In the study, Ca/Mg ratio was determined at different elevations and while the ratio was 0.1 at 1500 m, it was found to be 1.36 at 3000 m.

It was recorded that plants with yellow flowers were more dominant and dense at 1500 m and 2000 m, and plants with purple-violet flowers were more dominant and dense at 2500 m and 3000 m on Mount Ergan. Statistical analyses were performed on plants with yellow and blue-violet flowers. It was seen that B, Mn, Fe, Ni, Cu and Zn concentrations did not differ in plants with yellow color and Cu, Zn, Na concentrations did not differ in plants with blue-violet color (Table 11, 12.). There is a strong correlation between the mineral composition of the rocks and soils in an area and the minerals found in the plants growing in that area. However, there is a difference in the mineral composition of some plants in the same region depending on the altitude. This study was compared with previous studies in areas with different geographical characteristics.

Mineral elements were examined in trees and shrubs growing in the mountainous region of Pakistan called Gilgit Baltistan. When the element data they analyzed were compared with the data obtained in this study, it was identified that Ca was very high, Fe was low, Mg, Mn, Zn and Cu had similar levels [23]. The amount of some metals in trees and herbaceous plants at 600 and 1100 m altitudes of Mount Kaz (Türkiye) was determined. There appeared to be a difference in metal concentrations in the studied plants depending on the elevation. The metal data they obtained are different from the data obtained in this study [24]. Mineral elements in the soils where the endemic *Salvia hydrangea* L. plant growing in the elevations of 1100, 1700, 2000 m were found in Mazanadarn, Iran. The amount of the elements decreased as the altitude increased [14]. Element analysis was conducted as well at different elevations (1000-1400 m, 1400-1800 m, 1800-2200 m) on *Hylocomium splendens* moss species growing in the southeastern Alps of Italy. Significant differences were discovered in the elements studied depending on the elevation [25]. The data obtained as a result of the analysis of Ni, Fe, Mn and Zn in plants growing at 1000 m and 1600 m of Murat Mountain (Türkiye) based on the elevation. The results suggest that some of the plants studied were able to accumulate some metals in their organs and roots [26]. In the element analysis of plants growing at 1000 m and 1600 m altitudes on Mount Honaz (Türkiye), significant differences were found between the two altitudes [27]. According to the data with regards element obtained in the study conducted in Mount Kaz (100 m-1726 m), it was observed that the concentrations of B, Ca, Cu, Mg, Mn and Ni decreased at low altitudes, and the concentrations of these minerals increased up to a certain point and then decreased (except Mg 1600-1700 m) as the altitude increased. The highest average values for B, Ca and Mn were determined at 600 m and for Cu and Ni at 1000 m. Unlike other elements, Al, Fe and Na had relatively low values at 600 m [28]. They determined the content of Al, Ba, Cu, Fe, Mn, Zn, Fe, Mn and Zn in plants growing in Kumalar Mountain (Türkiye) (900-1200 m and 1200-1900 m). Element accumulation values were higher in the 1200-1900 m range [29]. In the study conducted on Alabna rock in Saudi Arabia, the effects of altitude on species diversity, plant community and soil components were examined. As a result of the study, the diversity and distribution of species were affected by the elevation and element contents in the soil [30]. Research on Mount Changbai (500-2300 m) in China has shown that carbon (C), nitrogen (N) and phosphorus (P) concentrations in plant leaves vary significantly with altitude. They found that as altitude increased, these changes were influenced by plant growth forms, climate and soil properties [31]. In this study, leaf N, P, Ca, K and Mg concentrations were analyzed in six different plant species (trees, shrubs, weeds) at 1400, 1600 and 3100 m altitudes. The data suggest that summer drought, reduced microbial activity and slowed soil development may have indirect effects on plant growth at high altitudes. They suggested that these factors may reduce nutrient pools and possibly nutrient supply at high altitudes [32]. Considering the data obtained in the studies, it was seen that coincided with the data obtained in this study.

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Table 1. Na concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower	Leaf	Root	Soil
1500 m	*Linum mucronatum* Bertol	Yellow	256,9 ± 9,8^{b}	342,1 ± 4,1^{d}	165,7 ± 1,7^{b}	306,8 ± 24,8^{c}
	Genista aucheri Boiss.	Yellow	257,0 ± 6,9^{b}	329,9 ± 12,6^{cd}	140,1 ± 16,7^{a}	
	Anchusa leptophylla Roem. & Schult	Blue	250,9 ± 7,0^{b}	307,4 ± 10,0^{c}	222,6 ± 2,4^{d}	
	Euphorbia virgata Waldst. & Kit.	Green	260,0 ± 37,8^{b}	338,0 ± 11,5^{cd}	189,1 ± 5,4^{bc}	
	Glaucium leiocarpum Boiss.	Orange	312,6 ± 5,0^{b}	160,2 ± 2,7^{a}	206,5 ± 9,1^{cd}	
	Astragalus ornithopodioides Lam.	Purple	413,8 ± 21,6^{c}	222,0 ± 10,0^{b}	490,6 ± 11,6^{e}	
	Alcea calvertii (Boiss) Boiss.	White	147,7 ± 2,8^{a}	160,6 ± 5,3^{a}	218,7 ± 3,2^{cd}	
2000 m	*Genista aucheri* Boiss.	Yellow	326,8 ± 22,2^{b}	394,7 ± 11,3^{d}	178,5 ± 5,5^{a}	90,2 ± 7,0^{b}
	Euphorbia virgata Waldst. & Kit.	Green	367,6 ± 19,1^{bc}	446,2 ± 8,4^{e}	183,2 ± 1,9^{ab}	
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	175,7 ± 5,2^{a}	159,9 ± 2,0^{ab}	218,8 ± 4,0^{cd}	
	Inula oculus-christi L.	Yellow	144,1 ± 2,3^{a}	182,1 ± 3,1^{bc}	194,7 ± 3,0^{ab}	
	Hypericum scabrum L.	Yellow	425,5 ± 16,0^{c}	147,9 ± 4,2^{a}	178,3 ± 3,6^{a}	
	Barbarea auriculata Hausskn. ex Bornm	Yellow	401,4 ± 56,7^{bc}	200,7 ± 5,0^{c}	233,5 ± 9,3^{d}	
	Globularia trichosantha Fisch. & C.A.Mey	Purple	319,3 ± 10,2^{b}	181,4 ± 5,7^{bc}	203,5 ± 6,6^{bc}	
	Onobrychis cornuta (L.) Desv.	Purple	151,9 ± 3,9^{a}	145,9 ± 2,2^{a}	196,0 ± 9,3^{ab}	
2500 m	*Crepis armena* DC	Yellow	262,9 ± 3,7^{b}	381,9 ± 10,7^{c}	161,1 ± 2,6^{b}	45,2 ± 3,4^{a}
	Anthemis cretica L.	White	299,8 ± 9,5^{c}	426,4 ± 24,0^{d}	290,7 ± 4,1^{g}	
	Campanula tridentata Schreber	Purple	235,6 ± 7,7^{b}	464,6 ± 5,2^{e}	204,2 ± 6,0^{d}	
	Euphorbia petrophila C.A. Meyer	Green	321,9 ± 11,7^{d}	350,9 ± 14,9^{c}	209,2 ± 2,5^{d}	
	Papaver fugax Poiret	Pink	358,7 ± 12,6^{e}	340,0 ± 13,8^{c}	258,8 ± 4,9^{f}	
	Aster alpinus L.	Purple	296,0 ± 11,2^{c}	369,3 ± 11,5^{c}	179,0 ± 3,8^{c}	
	Scutellaria orientalis L.	Yellow	197,9 ± 4,9^{a}	195,4 ± 10,5^{ab}	164,8 ± 1,9^{b}	
	Coronilla orientalis Miller	Yellow	176,1 ± 0,8^{a}	159,9 ± 3,5^{a}	170,0 ± 5,8^{bc}	
	Lallemantia canescens (L) Fisch. & Mey.	Purple	179,4 ± 3,0^{a}	189,6 ± 5,3^{ab}	133,8 ± 2,1^{a}	
	Dianthus orientalis Adams.	Purple	285,6 ± 11,8^{bc}	211,7 ± 1,7^{b}	232,3 ± 2,9^{e}	
3000 m	*Anthemis cretica* L.	White	331,4 ± 4,4^{d}	400,3 ± 14,0^{d}	203,0 ± 9,9^{b}	41,0 ± 2,6^{a}
	Campanula tridentata Schreber	Blue	354,8 ± 5,3^{e}	357,2 ± 17,5^{c}	198,1 ± 2,5^{b}	
	Papaver fugax Poiret	Pink	276,7 ± 13,0^{c}	369,7 ± 12,1^{cd}	186,6 ± 8,9^{b}	
	Hedysarum erythroleucum Boiss.	Purple	373,7 ± 10,8^{e}	385,4 ± 7,9^{cd}	169,2 ± 2,8^{a}	
	Pedicularis comosa L.	White	180,5 ± 4,4^{ab}	192,3 ± 5,0^{b}	165,2 ± 4,2^{a}	
	Scorzonera sericea DC.	Yellow	206,8 ± 6,1^{b}	157,8 ± 1,3^{ab}	156,3 ± 2,4^{a}	
	Senecio hypoleucus Benth	Yellow	196,1 ± 9,3^{b}	169,5 ± 2,9^{ab}	201,0 ± 5,2^{b}	
	Astragalus nezaketiae A.Duran & Aytaç	Purple	162,1 ± 2,5^{a}	146,9 ± 0,9^{a}	189,9 ± 2,0^{b}	

Table 2. Mg concentrations (µg/g dw) of plants grown and soil in different altitude (*$p<0.05$).

Altitude	Plant species	Flower Color	Flower	Leaf	Root	Soil
	Linum mucronatum Bertol	Yellow	9751,4 ± 563,1^{e}	12507,3 ± 344,5^{d}	3590,4 ± 92,7^{a}	
	Genista aucheri Boiss.	Yellow	2497,7 ± 182,0^{b}	8591,6 ± 221,1^{b}	2705,9 ± 81,4^{a}	
	Anchusa leptophylla Roem. & Schult	Blue	3110,2 ± 120,5^{bc}	10891,4 ± 202,3^{c}	6742,9 ± 672,6^{a}	
1500 m	*Euphorbia virgata* Waldst. & Kit.	Green	958,4 ± 149,7^{a}	4401,4 ± 129,1^{a}	1932,9 ± 114,7^{a}	42618,3 ± 4631,0^{c}
	Glaucium leiocarpum Boiss.	Orange	3165,6 ± 207,0^{bc}	3918,0 ± 44,3^{a}	4412,3 ± 426,6^{a}	
	Astragalus ornithopodioides Lam.	Purple	5621,3 ± 586,6^{d}	10680,0 ± 1290,0^{c}	34764,1 ± 4337,3^{c}	
	Alcea calvertii (Boiss) Boiss.	White	3795,3 ± 25,8^{c}	7761,9 ± 96,8^{b}	18649,1 ± 1796,8^{b}	
	Genista aucheri Boiss.	Yellow	1670,7 ± 53,8^{ab}	6793,3 ± 133,8^{e}	1614,1 ± 121,6^{a}	
	Euphorbia virgata Waldst. & Kit.	Green	1550,4 ± 114,0^{ab}	6633,6 ± 98,5^{e}	2303,8 ± 97,1^{a}	
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	2296,4 ± 72,2^{c}	6118,6 ± 96,9^{d}	5452,3 ± 246,3^{b}	
2000 m	*Inula oculus-christi* L.	Yellow	1392,4 ± 30,1^{a}	3378,6 ± 138,6^{a}	5406,7 ± 349,3^{b}	9838,0 ± 586,5^{b}
	Hypericum scabrum L.	Yellow	2943,4 ± 41,2^{d}	3517,2 ± 16,4^{ab}	2208,5 ± 219,6^{a}	
	Barbarea auriculata Hausskn. ex Bornm	Yellow	1999,0 ± 247,5^{bc}	4826,8 ± 160,6^{c}	6391,1 ± 665,3^{b}	
	Globularia trichosantha Fisch. & C.A.Mey	Purple	13368,5 ± 262,0^{e}	5945,9 ± 229,8^{d}	5085,3 ± 511,2^{b}	
	Onobrychis cornuta (L.) Desv.	Purple	3097,4 ± 94,0^{d}	3898,3 ± 19,3^{b}	6705,2 ± 957,4^{b}	
	Crepis armena DC	Yellow	3171,2 ± 116,5^{d}	13985,1 ± 274,9^{g}	2882,5 ± 86,4^{bc}	
	Anthemis cretica L.	White	2653,3 ± 56,8^{c}	6720,3 ± 73,3^{e}	1797,2 ± 111,1^{a}	
	Campanula tridentata Schreber	Purple	987,5 ± 105,8^{a}	6614,7 ± 24,4^{e}	3117,8 ± 610,2^{c}	
	Euphorbia petrophila C.A. Meyer	Green	3492,4 ± 194,0^{d}	10053,9 ± 97,3^{f}	4001,8 ± 23,2^{d}	4303,8 ± 197,5^{a}
2500 m	*Papaver fugax* Poiret	Pink	5160,6 ± 197,8^{e}	6916,7 ± 346,6^{e}	2929,5 ± 37,7^{bc}	
	Aster alpinus L.	Purple	1640,2 ± 151,0^{b}	6207,5 ± 211,7^{e}	2274,5 ± 165,5^{abc}	
	Scutellaria orientalis L.	Yellow	3726,1 ± 141,2^{d}	5158,6 ± 589,8^{d}	4148,8 ± 193,7^{d}	
	Coronilla orientalis Miller	Yellow	1021,6 ± 6,6^{a}	3506,8 ± 18,9^{b}	5971,7 ± 457,0^{e}	
	Lallemantia canescens (L) Fisch. & Mey.	Purple	3361,4 ± 30,3^{d}	4215,7 ± 28,0^{c}	4156,2 ± 71,7^{d}	
	Dianthus orientalis Adams.	Purple	1212,3 ± 18,9^{a}	2375,1 ± 26,1^{a}	2022,6 ± 86,6^{ab}	
	Anthemis cretica L.	White	2866,0 ± 33,6^{c}	5697,6 ± 35,5^{f}	1886,6 ± 112,4^{b}	
	Campanula tridentata Schreber	Blue	1775,8 ± 119,5^{b}	9632,8 ± 344,5^{g}	1978,4 ± 30,5^{b}	
	Papaver fugax Poiret	Pink	782,8 ± 55,4^{a}	5245,6 ± 408,2^{ef}	1513,4 ± 61,0^{a}	
3000 m	*Hedysarum erythroleucum* Boiss.	Purple	1796,2 ± 385,5^{b}	5054,1 ± 45,5^{ef}	1450,1 ± 27,6^{a}	
	Pedicularis comosa L.	White	2632,8 ± 55,1^{c}	4702,9 ± 378,8^{de}	1910,9 ± 102,8^{b}	3066,2 ± 123,2^{a}
	Scorzonera sericea DC.	Yellow	1761,5 ± 65,5^{b}	3817,2 ± 62,1^{bc}	2876,4 ± 27,6^{d}	
	Senecio hypoleucus Benth	Yellow	1566,9 ± 60,3^{b}	4210,9 ± 14,9^{cd}	2472,6 ± 186,6^{c}	
	Astragalus nezaketiae A.Duran & Aytaç	Purple	1768,6 ± 64,5^{b}	3312,2 ± 13,4^{b}	2404,7 ± 26,5^{c}	

Table 3. Al concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower			Leaf			Root			Soil		
	Linum mucronatum Bertol	Yellow	3703,0	±	216,9[d]	740,3	±	53,8[a]	1056,9	±	34,1[a]			
	Genista aucheri Boiss.	Yellow	790,4	±	75,6[b]	1807,6	±	225,0[c]	1925,4	±	107,1[ab]			
	Anchusa leptophylla Roem. & Schult	Blue	573,3	±	59,2[b]	737,8	±	20,9[a]	3614,3	±	200,2[cd]			
	Euphorbia virgata Waldst. & Kit.	Green	79,3	±	10,9[a]	448,5	±	50,6[a]	2383,1	±	215,8[b]	29307,6	±	1929,6[b]
	Glaucium leiocarpum Boiss.	Orange	1998,3	±	120,6[c]	545,0	±	62,2[a]	2690,5	±	481,5[bc]			
	Astragalus ornithopodioides Lam.	Purple	653,0	±	63,0[b]	1352,8	±	193,6[b]	6321,6	±	654,7[e]			
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	557,8	±	8,4[b]	680,9	±	38,4[a]	4128,1	±	441,5[d]			
	Genista aucheri Boiss.	Yellow	394,3	±	42,1[a]	940,6	±	169,6[a]	1790,8	±	296,3[a]			
	Euphorbia virgata Waldst. & Kit.	Green	257,2	±	41,0[a]	1252,5	±	105,9[a]	5484,4	±	388,9[a]			
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	767,4	±	47,4[a]	1001,3	±	165,5[a]	10125,8	±	547,4[b]			
	Inula oculus-christi L.	Yellow	623,2	±	48,0[a]	1842,9	±	41,3[a]	10279,1	±	752,2[b]	43136,3	±	2502,1[c]
	Hypericum scabrum L.	Yellow	802,9	±	33,2[a]	507,7	±	25,7[a]	2972,0	±	416,0[a]			
	Barbarea auriculata Hausskn. ex Bornm	Yellow	731,1	±	104,9[a]	7375,8	±	708,1[b]	19970,7	±	2617,3[c]			
	Globularia trichosantha Fisch. & C.A.Mey	Purple	36029,0	±	963,8[c]	12859,0	±	669,1[c]	12893,3	±	1439,0[b]			
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	2374,2	±	229,2[b]	794,8	±	36,9[a]	11240,9	±	1820,6[b]			
	Crepis armena DC	Yellow	10240,0	±	400,8[a]	17934,6	±	1203,2[c]	6792,8	±	277,0[c]			
	Anthemis cretica L.	White	2818,4	±	59,9[a]	1239,0	±	43,3[a]	4078,1	±	269,1[b]			
	Campanula tridentata Schreber	Purple	1755,9	±	245,7[a]	871,6	±	14,6[a]	2991,5	±	318,7[ab]			
	Euphorbia petrophila C.A. Meyer	Green	4856,8	±	328,8[a]	757,4	±	45,4[a]	6887,4	±	156,4[c]			
	Papaver fugax Poiret	Pink	1864,6	±	93,7[a]	1513,3	±	37,1[a]	3596,4	±	154,1[ab]	19918,7	±	1105,3[a]
	Aster alpinus L.	Purple	2174,1	±	470,0[a]	1614,9	±	210,7[a]	6429,5	±	621,1[c]			
	Scutellaria orientalis L.	Yellow	8279,9	±	689,4[a]	4045,6	±	868,3[b]	6538,3	±	639,2[c]			
	Coronilla orientalis Miller	Yellow	308,7	±	8,7[a]	1059,4	±	115,9[a]	6713,8	±	1058,5[c]			
	Lallemantia canescens (L) Fisch. & Mey.	Purple	1000,6	±	78,4[a]	914,2	±	62,5[a]	2075,9	±	195,4[a]			
2500 m	*Dianthus orientalis* Adams.	Purple	399,7	±	23,4[b]	180,5	±	6,2[a]	2886,6	±	171,0[ab]			
	Anthemis cretica L.	White	1660,7	±	35,7[c]	2390,6	±	55,3[d]	4320,9	±	384,6[d]			
	Campanula tridentata Schreber	Blue	818,4	±	124,3[b]	304,3	±	9,8[a]	869,1	±	23,7[a]			
	Papaver fugax Poiret	Pink	771,7	±	64,5[b]	1504,5	±	68,3[bc]	1069,6	±	50,9[ab]			
	Hedysarum erythroleucum Boiss.	Purple	813,3	±	272,1[b]	267,8	±	4,6[a]	1440,1	±	90,2[ab]			
	Pedicularis comosa L.	White	1450,6	±	115,4[c]	3420,9	±	719,6[e]	2307,3	±	294,3[bc]	13810,8	±	621,7[a]
	Scorzonera sericea DC.	Yellow	271,3	±	14,8[a]	1751,1	±	251,3[cd]	2005,2	±	366,0[abc]			
	Senecio hypoleucus Benth	Yellow	259,5	±	5,3[a]	881,5	±	53,5[ab]	2983,8	±	347,2[c]			
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	724,3	±	82,2[b]	175,6	±	5,5[a]	2966,3	±	74,8[c]			

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 4. K concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower	Leaf	Root	Soil
	Linum mucronatum Bertol	Yellow	16942,5 ± 549,3[b]	30472,5 ± 5302,3[cd]	4383,3 ± 66,3[b]	
	Genista aucheri Boiss.	Yellow	19020,6 ± 864,8[b]	20763,6 ± 449,5[abc]	2501,8 ± 58,8[a]	
	Anchusa leptophylla Roem. & Schult	Blue	51864,8 ± 1812,5[e]	61902,3 ± 5432,9[e]	20945,7 ± 1284,3[e]	2677,4 ± 341,3[b]
	Euphorbia virgata Waldst. & Kit.	Green	11223,8 ± 1679,0[a]	38060,6 ± 803,0[d]	4924,3 ± 309,0[b]	
	Glaucium leiocarpum Boiss.	Orange	42516,5 ± 3160,3[d]	27466,7 ± 352,6[bcd]	17280,4 ± 175,8[d]	
	Astragalus ornithopodioides Lam.	Purple	22065,1 ± 760,8[b]	15515,2 ± 184,0[a]	3633,7 ± 92,9[ab]	
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	32380,1 ± 564,0[c]	17470,9 ± 134,3[ab]	11634,3 ± 112,1[c]	
	Genista aucheri Boiss.	Yellow	16871,9 ± 1270,1[c]	18252,2 ± 194,8[c]	8484,0 ± 2862,2[a]	
	Euphorbia virgata Waldst. & Kit.	Green	10489,0 ± 1352,8[b]	23630,9 ± 426,6[de]	6540,4 ± 123,6[a]	
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	31930,2 ± 581,3[a]	24900,4 ± 311,6[e]	14489,3 ± 197,3[b]	
	Inula oculus-christi L.	Yellow	22675,6 ± 126,8[a]	20706,0 ± 1812,9[d]	16001,1 ± 277,5[b]	5506,6 ± 314,0[c]
	Hypericum scabrum L.	Yellow	18602,6 ± 234,4[a]	9949,9 ± 98,7[a]	9665,6 ± 293,3[a]	
	Barbarea auriculata Hausskn. ex Bornm	Yellow	32607,4 ± 3899,1[a]	30451,1 ± 403,2[f]	16527,6 ± 443,7[b]	
	Globularia trichosantha Fisch. & C.A.Mey	Purple	20718,0 ± 315,0[a]	11811,1 ± 226,7[b]	9074,3 ± 292,3[a]	
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	19982,0 ± 113,2[a]	9696,9 ± 47,1[a]	6011,3 ± 192,7[a]	
	Crepis armena DC	Yellow	26735,5 ± 897,1[d]	38421,8 ± 413,6[f]	11186,4 ± 154,0[a]	
	Anthemis cretica L.	White	32629,2 ± 560,2[e]	24563,7 ± 249,1[cd]	7782,8 ± 126,4[a]	
	Campanula tridentata Schreber	Purple	9590,8 ± 813,6[a]	56571,9 ± 312,5[g]	23634,0 ± 3075,7[b]	
	Euphorbia petrophila C.A. Meyer	Green	15260,5 ± 789,1[b]	31151,6 ± 321,0[e]	10048,4 ± 3424,3[a]	
	Papaver fugax Poiret	Pink	18095,6 ± 655,2[c]	22753,1 ± 1077,0[c]	7498,2 ± 99,7[a]	1746,9 ± 103,0[a]
	Aster alpinus L.	Purple	13567,1 ± 740,6[b]	25247,1 ± 992,1[d]	7710,8 ± 249,2[a]	
	Scutellaria orientalis L.	Yellow	22400,7 ± 373,4[cd]	16648,4 ± 419,2[b]	11145,5 ± 384,2[a]	
	Coronilla orientalis Miller	Yellow	24686,4 ± 129,2[d]	17886,0 ± 1443,7[b]	21388,7 ± 537,3[b]	
	Lallemantia canescens (L) Fisch. & Mey.	Purple	38407,5 ± 143,9[f]	14688,3 ± 103,5[a]	22979,6 ± 654,1[b]	
2500 m	*Dianthus orientalis* Adams.	Purple	26387,2 ± 546,9[d]	17488,8 ± 119,5[b]	5692,1 ± 51,9[a]	
	Anthemis cretica L.	White	32126,3 ± 328,7[f]	36649,9 ± 226,3[g]	11785,1 ± 188,6[d]	
	Campanula tridentata Schreber	Blue	24921,9 ± 1418,4[d]	53764,7 ± 1861,8[h]	5096,4 ± 41,3[ab]	
	Papaver fugax Poiret	Pink	7056,7 ± 476,5[a]	28818,8 ± 807,9[f]	33224,4 ± 230,2[f]	
	Hedysarum erythroleucum Boiss.	Purple	11740,2 ± 1091,2[b]	17364,9 ± 256,9[d]	3768,4 ± 57,4[a]	
	Pedicularis comosa L.	White	27763,8 ± 72,7[e]	14321,3 ± 122,7[c]	7543,3 ± 388,0[bc]	1178,4 ± 64,6[a]
	Scorzonera sericea DC.	Yellow	27989,4 ± 749,7[e]	11557,2 ± 185,3[b]	10766,3 ± 1451,6[d]	
	Senecio hypoleucus Benth	Yellow	28384,7 ± 1032,8[e]	27825,4 ± 884,0[f]	19775,3 ± 1065,8[e]	
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	26782,7 ± 448,7[dc]	19713,7 ± 90,0[e]	9058,1 ± 160,1[cd]	

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 5. Ca concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower	Leaf	Root	Soil
	Linum mucronatum Bertol	Yellow	613,4 ± 16,2^{a}	4192,2 ± 179,9^{c}	463,5 ± 12,2^{a}	
	Genista aucheri Boiss.	Yellow	613,8 ± 31,1^{a}	3540,6 ± 30,4^{b}	1078,7 ± 22,6^{b}	
	Anchusa leptophylla Roem. & Schult	Blue	867,8 ± 31,2^{b}	4663,3 ± 137,8^{d}	2335,0 ± 122,9^{c}	
	Euphorbia virgata Waldst. & Kit.	Green	517,3 ± 78,8^{a}	2815,4 ± 84,2^{a}	899,9 ± 39,1^{b}	4294,5 ± 496,6^{c}
	Glaucium leiocarpum Boiss.	Orange	1407,0 ± 109,2^{c}	10397,9 ± 334,3^{f}	5289,8 ± 268,7^{e}	
	Astragalus ornithopodioides Lam.	Purple	1494,1 ± 48,6^{c}	3309,7 ± 28,7^{b}	2755,9 ± 211,4^{d}	
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	1916,8 ± 28,1^{d}	8134,4 ± 35,7^{e}	6981,0 ± 232,0^{f}	
	Genista aucheri Boiss.	Yellow	534,5 ± 23,1^{a}	3830,9 ± 101,8^{b}	867,9 ± 66,3^{a}	
	Euphorbia virgata Waldst. & Kit.	Green	599,5 ± 45,5^{a}	4135,3 ± 80,2^{c}	1193,8 ± 22,4^{a}	
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	1908,3 ± 78,9^{e}	5007,2 ± 67,4^{a}	11884,6 ± 510,5^{d}	
	Inula oculus-christi L.	Yellow	873,9 ± 11,2^{b}	5665,6 ± 184,4^{a}	1951,3 ± 39,2^{b}	880,7 ± 56,2^{a}
	Hypericum scabrum L.	Yellow	1351,9 ± 10,9^{c}	1877,3 ± 7,8^{a}	2307,9 ± 280,1^{b}	
	Barbarea auriculata Hausskn. ex Bornm	Yellow	1256,8 ± 156,6^{c}	4308,3 ± 18,3^{a}	2330,7 ± 90,9^{b}	
	Globularia trichosantha Fisch. & C.A.Mey	Purple	1654,6 ± 54,0^{d}	2666,1 ± 15,8^{a}	1032,5 ± 63,9^{a}	
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	2421,1 ± 15,9^{e}	7132,3 ± 58,2^{a}	8468,5 ± 508,6^{c}	
	Crepis armena DC	Yellow	587,3 ± 22,1^{a}	4088,5 ± 28,3^{bc}	1236,3 ± 37,7^{a}	
	Anthemis cretica L.	White	779,6 ± 15,2^{b}	2323,6 ± 22,4^{a}	864,1 ± 62,4^{a}	
	Campanula tridentata Schreber .	Purple	313,0 ± 43,4^{a}	4487,7 ± 18,9^{c}	1449,6 ± 134,0^{a}	
	Euphorbia petrophila C.A. Meyer	Green	2682,0 ± 201,5^{e}	3381,9 ± 48,3^{b}	1726,1 ± 84,7^{a}	
	Papaver fugax Poiret	Pink	1605,4 ± 54,3^{d}	2528,9 ± 144,6^{a}	1499,3 ± 23,5^{a}	3333,6 ± 349,6^{b}
	Aster alpinus L.	Purple	389,0 ± 45,1^{a}	2313,7 ± 79,1^{a}	1492,8 ± 123,4^{a}	
	Scutellaria orientalis L.	Yellow	1235,2 ± 55,4^{c}	5918,6 ± 929,4^{d}	1273,1 ± 60,4^{a}	
	Coronilla orientalis Miller	Yellow	1520,7 ± 11,4^{d}	10126,8 ± 68,7^{e}	8562,3 ± 1089,5^{c}	
	Lallemantia canescens (L) Fisch. & Mey.	Purple	3943,4 ± 159,5^{f}	6170,0 ± 35,4^{d}	4136,4 ± 301,4^{b}	
2500 m	*Dianthus orientalis* Adams.	Purple	638,0 ± 27,4^{a}	5745,7 ± 31,9^{d}	4199,0 ± 130,5^{b}	
	Anthemis cretica L.	White	986,1 ± 20,4^{cd}	2762,9 ± 30,8^{a}	1611,9 ± 286,1^{ab}	
	Campanula tridentata Schreber	Blue	475,9 ± 73,2^{b}	4922,0 ± 184,6^{b}	3576,9 ± 108,1^{c}	
	Papaver fugax Poiret	Pink	244,6 ± 18,8^{a}	3418,5 ± 106,9^{a}	1149,5 ± 22,3^{a}	
	Hedysarum erythroleucum Boiss.	Purple	532,5 ± 119,8^{b}	2690,6 ± 22,5^{a}	2257,6 ± 42,1^{b}	
	Pedicularis comosa L.	White	1712,6 ± 82,0^{e}	7093,6 ± 664,4^{d}	2133,3 ± 79,6^{b}	4183,1 ± 176,4^{c}
	Scorzonera sericea DC.	Yellow	1039,6 ± 32,8^{cd}	3421,7 ± 85,1^{a}	4253,2 ± 255,7^{c}	
	Senecio hypoleucus Benth	Yellow	1126,1 ± 45,9^{d}	5922,6 ± 28,4^{c}	3615,7 ± 269,9^{c}	
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	1124,8 ± 38,1^{d}	5160,7 ± 36,8^{b}	5564,6 ± 174,5^{d}	

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 6. Fe concentrations (μg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower	Leaf	Root	Soil
	Linum mucronatum Bertol	Yellow	5769,5 ± 352,4^{c}	1267,8 ± 85,1^{b}	1759,6 ± 51,1^{a}	
	Genista aucheri Boiss.	Yellow	726,5 ± 76,2^{b}	1874,6 ± 284,5^{c}	1943,1 ± 102,1^{a}	
	Anchusa leptophylla Roem. & Schult	Blue	609,9 ± 48,4^{ab}	834,3 ± 34,1^{ab}	4405,6 ± 250,4^{b}	
	Euphorbia virgata Waldst. & Kit.	Green	89,9 ± 12,5^{a}	463,5 ± 45,7^{a}	2064,7 ± 195,8^{a}	38363,5 ± 1411,5^{c}
	Glaucium leiocarpum Boiss.	Orange	1153,8 ± 84,9^{b}	441,8 ± 53,0^{a}	1953,4 ± 345,7^{a}	
	Astragalus ornithopodioides Lam.	Purple	1090,2 ± 149,4^{b}	2219,1 ± 418,8^{c}	10870,6 ± 1321,5^{d}	
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	606,4 ± 15,5^{ab}	774,0 ± 43,8^{ab}	5995,6 ± 659,7^{c}	
	Genista aucheri Boiss.	Yellow	361,0 ± 30,1^{a}	865,2 ± 153,4^{ab}	1563,9 ± 284,2^{a}	
	Euphorbia virgata Waldst. & Kit.	Green	272,9 ± 35,2^{a}	1159,5 ± 87,2^{ab}	4483,4 ± 311,5^{ab}	
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	561,6 ± 31,4^{a}	719,1 ± 112,4^{ab}	6875,3 ± 392,4^{bc}	
	Inula oculus-christi L.	Yellow	505,6 ± 37,8^{a}	1452,5 ± 37,9^{b}	8024,4 ± 612,9^{c}	38604,0 ± 2019,3^{c}
	Hypericum scabrum L.	Yellow	635,5 ± 21,9^{a}	372,2 ± 18,5^{a}	2194,2 ± 304,6^{a}	
	Barbarea auriculata Hausskn. ex Bornm	Yellow	580,5 ± 79,0^{a}	4845,5 ± 429,6^{c}	14775,7 ± 1995,6^{d}	
	Globularia trichosantha Fisch. & C.A.Mey	Purple	27497,6 ± 572,9^{c}	9423,7 ± 529,5^{d}	10038,8 ± 1167,7^{c}	
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	1862,9 ± 177,5^{b}	647,6 ± 26,2^{ab}	8838,8 ± 1434,5^{c}	
	Crepis armena DC	Yellow	8460,8 ± 344,1^{a}	15385,8 ± 1082,2^{c}	6064,5 ± 293,6^{e}	
	Anthemis cretica L.	White	2225,9 ± 51,4^{a}	1155,5 ± 25,5^{ab}	3646,6 ± 243,9^{cd}	
	Campanula tridentata Schreber	Purple	1438,7 ± 202,5^{a}	839,0 ± 14,3^{a}	2905,0 ± 337,3^{bc}	
	Euphorbia petrophila C.A. Meyer	Green	4868,9 ± 312,2^{a}	738,0 ± 45,2^{a}	958,6 ± 38,3^{a}	
	Papaver fugax Poiret	Pink	1595,0 ± 81,1^{a}	1320,2 ± 43,4^{ab}	2822,6 ± 115,2^{bc}	20497,7 ± 829,2^{b}
	Aster alpinus L.	Purple	1866,0 ± 402,9^{a}	1387,6 ± 185,8^{ab}	5870,8 ± 588,5^{e}	
	Scutellaria *orientalis* L.	Yellow	5575,9 ± 522,4^{a}	2621,3 ± 529,6^{b}	4739,4 ± 463,6^{de}	
	Coronilla orientalis Miller	Yellow	268,2 ± 6,5^{a}	787,6 ± 87,1^{a}	4901,3 ± 784,9^{de}	
	Lallemantia canescens (L) Fisch. & Mey.	Purple	851,5 ± 70,5^{a}	713,4 ± 41,3^{a}	1755,9 ± 172,4^{ab}	
2500 m	*Dianthus orientalis* Adams.	Purple	333,7 ± 14,4^{b}	154,0 ± 4,5^{a}	2151,0 ± 138,3^{ab}	
	Anthemis cretica L.	White	1378,4 ± 19,4^{d}	2092,4 ± 56,0^{d}	3846,2 ± 294,1^{d}	
	Campanula tridentata Schreber	Blue	951,8 ± 144,6^{bc}	413,9 ± 13,9^{ab}	6933,5 ± 213,9^{e}	
	Papaver fugax Poiret	Pink	623,1 ± 49,1^{ab}	1249,9 ± 51,7^{c}	968,1 ± 26,4^{a}	
	Hedysarum erythroleucum Boiss.	Purple	721,6 ± 233,0^{b}	289,5 ± 3,7^{ab}	1150,7 ± 54,3^{a}	
	Pedicularis comosa L.	White	1134,5 ± 92,2^{cd}	2363,5 ± 446,8^{d}	1787,8 ± 222,6^{abc}	14330,5 ± 461,5^{a}
	Scorzonera sericea DC.	Yellow	234,5 ± 11,6^{a}	1287,1 ± 180,2^{c}	1545,9 ± 275,2^{ab}	
	Senecio hypoleucus Benth	Yellow	248,4 ± 4,9^{a}	791,3 ± 40,8^{bc}	2667,6 ± 306,9^{c}	
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	599,3 ± 61,6^{ab}	192,8 ± 4,1^{a}	2275,7 ± 46,2^{bc}	

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 7. Mn concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower	Leaf	Root	Soil
	Linum mucronatum Bertol	Yellow	123,9 ± 6,5^{d}	113,9 ± 4,7^{c}	118,1 ± 3,7^{ab}	
	Genista aucheri Boiss.	Yellow	70,5 ± 3,7^{c}	141,5 ± 4,9^{d}	84,2 ± 2,7^{a}	
	Anchusa leptophylla Roem. & Schult	Blue	34,0 ± 1,6^{ab}	132,3 ± 4,1^{d}	185,6 ± 10,4^{c}	
	Euphorbia virgata Waldst. & Kit.	Green	35,0 ± 3,9^{ab}	86,3 ± 1,4^{b}	140,0 ± 13,3^{b}	627,4 ± 28,5^{c}
	Glaucium leiocarpum Boiss.	Orange	37,8 ± 2,7^{ab}	86,0 ± 1,9^{b}	83,2 ± 8,0^{a}	
	Astragalus ornithopodioides Lam.	Purple	46,3 ± 2,6^{b}	88,8 ± 6,6^{b}	226,6 ± 21,9^{d}	
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	29,0 ± 0,2^{a}	64,4 ± 0,8^{a}	142,4 ± 12,3^{b}	
	Genista aucheri Boiss.	Yellow	52,0 ± 1,2^{b}	113,2 ± 7,4^{c}	81,3 ± 12,9^{a}	
	Euphorbia virgata Waldst. & Kit.	Green	49,7 ± 4,3^{b}	102,6 ± 1,7^{bc}	143,0 ± 6,0^{ab}	
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	51,3 ± 3,1^{b}	115,3 ± 3,4^{c}	165,3 ± 8,9^{bc}	
	Inula oculus-christi L.	Yellow	28,3 ± 0,9^{a}	87,2 ± 1,2^{b}	213,6 ± 14,7^{bc}	639,5 ± 35,6^{c}
	Hypericum scabrum L.	Yellow	35,8 ± 0,6^{ab}	42,2 ± 0,5^{a}	61,9 ± 6,9^{a}	
	Barbarea auriculata Hausskn. ex Bornm	Yellow	36,2 ± 4,8^{ab}	163,8 ± 11,8^{e}	408,6 ± 53,4^{d}	
	Globularia trichosantha Fisch. & C.A.Mey	Purple	538,8 ± 11,5^{d}	201,2 ± 11,1^{f}	212,0 ± 23,7^{bc}	
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	92,3 ± 4,2^{c}	145,0 ± 2,0^{d}	242,4 ± 35,9^{c}	
	Crepis armena DC	Yellow	188,6 ± 8,2^{a}	362,9 ± 22,1^{d}	209,0 ± 9,2^{d}	
	Anthemis cretica L.	White	79,6 ± 1,6^{a}	77,4 ± 0,9^{b}	160,9 ± 9,4^{c}	
	Campanula tridentata Schreber	Purple	43,5 ± 5,8^{a}	61,1 ± 0,4^{ab}	115,2 ± 12,9^{b}	
	Euphorbia petrophila C.A. Meyer	Green	136,1 ± 9,6^{a}	87,7 ± 3,5^{b}	94,5 ± 6,5^{ab}	
	Papaver fugax Poiret	Pink	83,8 ± 3,7^{a}	77,0 ± 7,7^{b}	77,4 ± 2,9^{ab}	496,5 ± 23,4^{b}
	Aster alpinus L.	Purple	61,9 ± 10,6^{a}	79,4 ± 4,9^{b}	194,8 ± 18,6^{cd}	
	Scutellaria *orientalis* L.	Yellow	166,0 ± 15,2^{a}	141,3 ± 15,3^{c}	391,0 ± 24,1^{e}	
	Coronilla orientalis Miller	Yellow	23,5 ± 0,2^{a}	76,3 ± 1,0^{b}	121,7 ± 18,6^{b}	
	Lallemantia canescens (L) Fisch. & Mey.	Purple	44,4 ± 2,0^{a}	35,9 ± 1,1^{a}	60,4 ± 5,0^{a}	
2500 m	*Dianthus orientalis* Adams.	Purple	24,2 ± 0,5^{b}	90,5 ± 2,1^{b}	85,0 ± 3,4^{ab}	
	Anthemis cretica L.	White	101,4 ± 1,6^{e}	196,4 ± 2,7^{g}	160,8 ± 10,0^{de}	
	Campanula tridentata Schreber	Blue	36,7 ± 3,9^{bc}	34,9 ± 1,2^{a}	185,1 ± 5,0^{e}	
	Papaver fugax Poiret	Pink	27,9 ± 2,1^{ab}	124,7 ± 9,6^{e}	51,4 ± 1,3^{a}	
	Hedysarum erythroleucum Boiss.	Purple	47,0 ± 7,7^{c}	100,4 ± 1,0^{d}	94,7 ± 2,6^{b}	
	Pedicularis comosa L.	White	60,8 ± 3,3^{d}	157,0 ± 10,6^{f}	92,0 ± 8,0^{b}	342,6 13,9^{a}
	Scorzonera sericea DC.	Yellow	22,1 ± 0,8^{a}	74,2 ± 5,1^{c}	94,6 ± 9,5^{b}	
	Senecio hypoleucus Benth	Yellow	16,4 ± 0,4^{a}	54,2 ± 1,6^{b}	124,7 ± 14,0^{bc}	
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	42,6 ± 2,1^{c}	76,4 ± 0,5^{c}	120,2 ± 1,7^{bc}	

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 8. Cu concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower			Leaf			Root			Soil		
	Linum mucronatum Bertol	Yellow	65,2	±	9,3[a]	15,4	±	1,1[d]	10,6	±	0,2[ab]			
	Genista aucheri Boiss.	Yellow	48,9	±	4,6[a]	10,8	±	0,4[b]	12,2	±	0,3[b]			
	Anchusa leptophylla Roem. & Schult	Blue	128,7	±	44,7[b]	12,9	±	0,2[c]	18,0	±	0,9[c]			
	Euphorbia virgata Waldst. & Kit.	Green	51,9	±	15,8[a]	15,4	±	0,5[d]	12,3	±	0,2[b]	27,9	±	1,0[c]
	Glaucium leiocarpum Boiss.	Orange	8,4	±	0,5[a]	5,9	±	0,1[a]	12,1	±	0,7[b]			
	Astragalus ornithopodioides Lam.	Purple	5,4	±	0,4[a]	6,5	±	0,5[a]	9,4	±	0,6[a]			
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	7,0	±	0,4[a]	5,3	±	0,0[a]	9,6	±	0,5[a]			
	Genista aucheri Boiss.	Yellow	193,3	±	78,1[b]	15,5	±	0,3[a]	12,6	±	1,2[a]			
	Euphorbia virgata Waldst. & Kit.	Green	51,0	±	4,2[a]	35,3	±	7,9[b]	11,7	±	0,2[a]			
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	9,6	±	1,0[a]	8,7	±	0,1[a]	11,8	±	0,2[a]			
	Inula oculus-christi L.	Yellow	8,4	±	0,2[a]	10,7	±	0,5[a]	12,4	±	0,4[a]	25,2	±	1,3[c]
	Hypericum scabrum L.	Yellow	9,4	±	0,1[a]	5,6	±	0,2[a]	9,3	±	0,2[a]			
	Barbarea auriculata Hausskn. ex Bornm	Yellow	5,9	±	0,8[a]	8,7	±	0,4[a]	18,0	±	1,6[b]			
	Globularia trichosantha Fisch. & C.A.Mey	Purple	23,6	±	0,3[a]	10,7	±	0,3[a]	19,4	±	0,4[b]			
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	8,0	±	0,1[a]	5,0	±	0,1[a]	9,8	±	1,0[a]			
	Crepis armena DC	Yellow	44,9	±	4,8[a]	17,2	±	0,5[c]	18,7	±	0,5[e]			
	Anthemis cretica L.	White	65,4	±	8,6[a]	22,0	±	0,8[d]	15,8	±	0,7[d]			
	Campanula tridentata Schreber	Purple	43,2	±	8,4[a]	15,4	±	0,1[c]	18,9	±	1,4[e]			
	Euphorbia petrophila C.A. Meyer	Green	24,4	±	0,8[a]	10,6	±	0,5[b]	11,9	±	0,1[c]			
	Papaver fugax Poiret	Pink	28,5	±	5,6[a]	8,5	±	0,1[b]	8,2	±	0,3[b]	14,9	±	0,5[b]
	Aster alpinus L.	Purple	47,3	±	10,1[a]	15,5	±	0,6[c]	13,4	±	0,7[c]			
	Scutellaria orientalis L.	Yellow	8,6	±	0,3[a]	11,1	±	2,3[b]	8,0	±	0,4[b]			
	Coronilla orientalis Miller	Yellow	8,4	±	0,1[a]	9,1	±	0,7[b]	9,6	±	0,5[b]			
	Lallemantia canescens (L) Fisch. & Mey.	Purple	3,8	±	0,1[a]	3,6	±	0,1[a]	7,4	±	0,2[b]			
2500 m	*Dianthus orientalis* Adams.	Purple	3,7	±	0,1[b]	3,5	±	0,0[a]	4,2	±	0,1[a]			
	Anthemis cretica L.	White	34,7	±	2,1[a]	12,0	±	0,4[f]	13,3	±	0,2[d]			
	Campanula tridentata Schreber	Blue	76,0	±	20,5[b]	11,1	±	0,4[e]	20,0	±	0,2[e]			
	Papaver fugax Poiret	Pink	22,6	±	2,7[a]	7,8	±	0,2[c]	10,1	±	1,4[c]			
	Hedysarum erythroleucum Boiss.	Purple	33,2	±	3,5[a]	10,0	±	0,2[d]	10,1	±	0,1[c]			
	Pedicularis comosa L.	White	6,7	±	0,2[a]	5,1	±	0,6[a]	6,6	±	0,1[b]	10,9		0,5[a]
	Scorzonera sericea DC.	Yellow	6,9	±	0,3[a]	4,1	±	0,2[a]	4,5	±	0,2[a]			
	Senecio hypoleucus Benth	Yellow	9,8	±	1,0[a]	4,4	±	0,1[a]	8,5	±	0,5[c]			
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	4,4	±	0,2[a]	4,2	±	0,0[a]	4,6	±	0,0[a]			

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 9. Zn concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower	Leaf	Root	Soil
	Linum mucronatum Bertol	Yellow	58,8 ± $6,8^{a}$	40,7 ± $0,8^{c}$	49,0 ± $1,2^{c}$	
	Genista aucheri Boiss.	Yellow	64,8 ± $5,3^{a}$	42,7 ± $1,0^{c}$	19,1 ± $1,2^{ab}$	
	Anchusa leptophylla Roem. & Schult	Blue	117,4 ± $30,4^{b}$	42,7 ± $1,4^{c}$	100,8 ± $3,2^{e}$	
	Euphorbia virgata Waldst. & Kit.	Green	73,2 ± $13,1^{a}$	101,1 ± $5,4^{d}$	61,6 ± $5,5^{d}$	65,2 ± $2,8^{a}$
	Glaucium leiocarpum Boiss.	Orange	16,1 ± $1,0^{a}$	28,7 ± $0,7^{b}$	13,6 ± $0,9^{a}$	
	Astragalus ornithopodioides Lam.	Purple	22,1 ± $0,7^{a}$	18,9 ± $0,7^{a}$	24,4 ± $1,4^{b}$	
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	14,5 ± $0,4^{a}$	12,2 ± $0,1^{a}$	26,4 ± $1,3^{b}$	
	Genista aucheri Boiss.	Yellow	201,7 ± $62,3^{b}$	59,1 ± $1,0^{c}$	45,3 ± $10,9^{c}$	
	Euphorbia virgata Waldst. & Kit.	Green	104,0 ± $11,8^{a}$	104,0 ± $3,2^{e}$	84,0 ± $1,3^{d}$	
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	19,9 ± $1,2^{a}$	34,5 ± $0,4^{b}$	30,5 ± $0,9^{abc}$	
	Inula oculus-christi L.	Yellow	27,2 ± $0,4^{a}$	34,9 ± $1,1^{b}$	42,7 ± $1,5^{bc}$	84,3 ± $3,8^{b}$
	Hypericum scabrum L.	Yellow	26,7 ± $0,5^{a}$	13,6 ± $0,1^{a}$	15,3 ± $1,0^{a}$	
	Barbarea auriculata Hausskn. ex Bornm	Yellow	40,7 ± $4,9^{a}$	65,8 ± $2,2^{d}$	83,1 ± $6,4^{d}$	
	Globularia trichosantha Fisch. & C.A.Mey	Purple	69,4 ± $1,2^{a}$	33,2 ± $1,1^{b}$	41,3 ± $2,7^{bc}$	
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	27,3 ± $0,8^{a}$	15,4 ± $0,5^{a}$	23,7 ± $3,0^{ab}$	
	Crepis armena DC	Yellow	114,8 ± $6,1^{a}$	126,2 ± $4,7^{f}$	115,8 ± $4,3^{e}$	
	Anthemis cretica L.	White	93,9 ± $6,4^{a}$	107,0 ± $2,2^{d}$	70,2 ± $4,6^{c}$	
	Campanula tridentata Schreber	Purple	68,7 ± $8,4^{a}$	129,6 ± $0,6^{f}$	88,8 ± $9,9^{d}$	
	Euphorbia petrophila C.A. Meyer	Green	108,9 ± $4,6^{a}$	115,1 ± $1,5^{e}$	140,8 ± $1,5^{f}$	
	Papaver fugax Poiret	Pink	55,3 ± $5,5^{a}$	36,4 ± $2,4^{b}$	27,2 ± $0,8^{b}$	95,5 ± $6,4^{c}$
	Aster alpinus L.	Purple	83,1 ± $12,9^{a}$	66,8 ± $2,3^{c}$	87,1 ± $3,8^{d}$	
	Scutellaria *orientalis* L.	Yellow	47,9 ± $3,1^{a}$	37,3 ± $4,2^{b}$	40,2 ± $2,6^{b}$	
	Coronilla orientalis Miller	Yellow	22,0 ± $0,1^{a}$	40,8 ± $3,3^{b}$	39,8 ± $2,3^{b}$	
	Lallemantia canescens (L) Fisch. & Mey.	Purple	21,3 ± $0,7^{a}$	38,0 ± $0,4^{b}$	30,5 ± $1,3^{b}$	
2500 m	*Dianthus orientalis* Adams.	Purple	26,4 ± $1,6^{b}$	16,6 ± $0,4^{a}$	13,4 ± $0,4^{a}$	
	Anthemis cretica L.	White	77,6 ± $2,0^{a}$	64,5 ± $1,2^{d}$	54,9 ± $2,2^{cd}$	
	Campanula tridentata Schreber	Blue	156,4 ± $41,0^{b}$	149,8 ± $5,3^{e}$	125,0 ± $2,2^{e}$	
	Papaver fugax Poiret	Pink	37,7 ± $3,0^{a}$	49,2 ± $2,0^{c}$	63,8 ± $8,0^{d}$	
	Hedysarum erythroleucum Boiss.	Purple	57,6 ± $4,2^{a}$	62,4 ± $0,8^{d}$	36,4 ± $0,9^{ab}$	
	Pedicularis comosa L.	White	63,9 ± $0,9^{a}$	70,5 ± $5,6^{d}$	48,0 ± $1,6^{c}$	62,2 ± $5,8^{a}$
	Scorzonera sericea DC.	Yellow	27,3 ± $0,5^{a}$	38,4 ± $0,9^{b}$	53,7 ± $1,4^{cd}$	
	Senecio hypoleucus Benth	Yellow	30,2 ± $1,0^{a}$	33,5 ± $0,6^{ab}$	43,0 ± $3,0^{bc}$	
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	22,9 ± $0,8^{a}$	25,3 ± $0,3^{a}$	29,5 ± $0,4^{a}$	

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 10. Ni concentrations (µg/g dw) of plants grown and soil in different altitude (*p<0.05).

Altitude	Plant species	Flower Color	Flower			Leaf			Root			Soil		
	Linum mucronatum Bertol	Yellow	169,6	±	11,2[d]	38,2	±	4,0[c]	46,9	±	1,3[a]			
	Genista aucheri Boiss.	Yellow	25,3	±	2,2[abc]	26,6	±	3,9[bc]	29,3	±	1,7[a]			
	Anchusa leptophylla Roem. & Schult	Blue	39,8	±	9,1[bc]	21,5	±	1,4[ab]	89,0	±	10,1[b]			
	Euphorbia virgata Waldst. & Kit.	Green	19,2	±	3,7[ab]	19,8	±	0,9[ab]	33,1	±	2,8[a]	835,3	±	79,0[d]
	Glaucium leiocarpum Boiss.	Orange	12,5	±	0,9[a]	4,8	±	0,3[a]	19,7	±	3,0[a]			
	Astragalus ornithopodioides Lam.	Purple	45,2	±	4,6[c]	60,8	±	11,6[d]	280,2	±	33,9[d]			
1500 m	*Alcea calvertii* (Boiss) Boiss.	White	12,9	±	0,3[a]	17,6	±	0,9[ab]	140,8	±	16,4[c]			
	Genista aucheri Boiss.	Yellow	73,1	±	19,6[b]	19,9	±	1,6[c]	16,1	±	2,5[a]			
	Euphorbia virgata Waldst. & Kit.	Green	25,5	±	2,2[a]	26,4	±	1,3[d]	49,1	±	2,7[b]			
	Tanacetum mucroniferum Hub. Mor. Et Grierson	White	7,3	±	0,3[a]	9,7	±	0,7[ab]	50,9	±	2,6[b]			
	Inula oculus-christi L.	Yellow	6,7	±	0,3[a]	13,5	±	0,3[b]	68,0	±	5,0[bc]	361,4	±	17,3[c]
	Hypericum scabrum L.	Yellow	7,5	±	0,4[a]	4,7	±	0,5[a]	17,6	±	2,2[a]			
	Barbarea auriculata Hausskn. ex Bornm	Yellow	6,8	±	0,9[a]	30,7	±	2,5[d]	90,7	±	11,5[c]			
	Globularia trichosantha Fisch. & C.A.Mey	Purple	206,1	±	3,3[c]	73,4	±	4,0[e]	79,0	±	8,3[c]			
2000 m	*Onobrychis cornuta* (L.) Desv.	Purple	33,7	±	1,5[a]	7,1	±	0,3[a]	76,1	±	12,0[c]			
	Crepis armena DC	Yellow	60,8	±	2,7[a]	85,1	±	6,2[e]	38,4	±	1,8[bc]			
	Anthemis cretica L.	White	39,0	±	3,2[a]	13,5	±	0,4[bc]	26,0	±	1,8[abc]			
	Campanula tridentata Schreber	Purple	24,9	±	2,7[a]	7,5	±	0,5[abc]	34,7	±	8,6[bc]			
	Euphorbia petrophila C.A. Meyer	Green	40,2	±	2,3[a]	8,1	±	0,2[abc]	74,3	±	12,4[d]			
	Papaver fugax Poiret	Pink	34,8	±	2,7[a]	29,6	±	2,7[d]	35,8	±	1,2[bc]	152,6	±	6,4[b]
	Aster alpinus L.	Purple	32,0	±	6,8[a]	12,9	±	1,6[bc]	42,3	±	3,7[c]			
	Scutellaria orientalis L.	Yellow	32,8	±	2,9[a]	16,2	±	2,7[c]	27,6	±	2,7[abc]			
	Coronilla orientalis Miller	Yellow	6,4	±	0,1[a]	7,0	±	0,6[abc]	38,4	±	5,7[bc]			
	Lallemantia canescens (L) Fisch. & Mey.	Purple	6,3	±	0,4[a]	4,7	±	0,2[ab]	10,5	±	1,0[a]			
2500 m	*Dianthus orientalis* Adams.	Purple	3,4	±	0,3[b]	2,5	±	0,1[a]	14,8	±	1,0[ab]			
	Anthemis cretica L.	White	17,8	±	0,8[ab]	15,4	±	0,5[b]	29,9	±	1,8[d]			
	Campanula tridentata Schreber	Blue	45,0	±	13,7[c]	4,6	±	0,2[a]	11,6	±	0,2[a]			
	Papaver fugax Poiret	Pink	15,0	±	1,4[ab]	14,5	±	2,1[b]	11,5	±	0,5[a]			
	Hedysarum erythroleucum Boiss.	Purple	26,6	±	2,7[b]	13,3	±	0,6[b]	35,8	±	0,6[e]			
	Pedicularis comosa L.	White	8,0	±	0,5[ab]	13,7	±	2,5[b]	11,9	±	0,9[a]	91,0	±	2,4[a]
	Scorzonera sericea DC.	Yellow	3,0	±	0,1[a]	7,7	±	0,8[a]	7,3	±	1,1[a]			
	Senecio hypoleucus Benth	Yellow	4,0	±	0,1[a]	6,5	±	0,2[a]	17,7	±	1,6[b]			
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	Purple	8,7	±	0,4[ab]	3,9	±	0,0[a]	12,0	±	0,3[a]			

For a given metal, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 11. Statistical evaluation of plants with blue and violet flowers and their soil properties at different altitudes (*p<0.05).

Altitude	Plant species	B	Na	Mg	Al	K	Ca	Mn	Fe	Ni	Cu	Zn
	Anchusa leptophylla Roem. & Schult	a	b	d	a	d	c	a	a	a	a	a
1500 m	*Astragalus ornithopodioides* Lam.	a	a	a	a	a	a	a	a	a	a	a
	Globularia trichosantha Fisch. & C.A.Mey	a	a	a	c	a	a	a	c	b	a	a
2000 m	*Onobrychis cornuta* (L.) Desv.	a	a	a	a	a	a	a	a	a	a	a
	Campanula tridentata Schreber .	a	d	e	a	c	d	a	a	a	a	a
	Aster alpinus L.	a	c	c	a	c	b	a	a	a	a	a
	Lallemantia canescens (L) Fisch. & Mey.	a	a	a	b	a	a	a	a	a	a	a
2500 m	*Dianthus orientalis* Adams.	b	a	a	a	a	a	b	b	b	b	b
	Campanula tridentata Schreber	a	c	b	a	b	ab	a	a	a	a	a
	Hedysarum erythroleucum Boiss.	a	a	a	a	a	a	a	a	a	a	a
3000 m	*Astragalus nezaketiae* A.Duran & Aytaç	a	a	a	a	a	a	a	a	a	a	a

For blue-violet flowered plants, mean concentrations followed by the same letter are not significantly different (p<0.05).

Table 12. Statistical evaluation of plants with yellow flowers and their soil properties at different altitudes (*p<0.05).

Altitude	Plant species	B	Na	Mg	Al	K	Ca	Mn	Fe	Ni	Cu	Zn
	Linum mucronatum Bertol	c	b	e	b	b	c	d	b	c	a	a
1500 m	*Genista aucheri* Boiss.	e	b	c	a	b	c	c	a	a	a	a
	Genista aucheri Boiss.	d	c	b	a	b	b	b	a	b	b	b
	Inula oculus-christi L.	c	a	a	a	a	a	a	a	a	a	a
	Hypericum scabrum L.	bc	a	a	a	a	a	ab	a	a	a	a
2000 m	*Barbarea auriculata* Hausskn. ex Bornm	b	a	a	a	a	a	ab	a	a	a	a
	Crepis armena DC	e	b	d	d	c	c	f	c	b	a	a
	Scutellaria orientalis L.	a	a	a	c	a	a	e	b	a	a	a
2500 m	*Coronilla orientalis* Miller	c	a	a	a	a	a	a	a	a	a	a
	Scorzonera sericea DC.	d	a	a	a	a	a	a	a	a	a	a
3000 m	*Senecio hypoleucus* Benth	bc	a	a	a	a	a	a	a	a	a	a

CONCLUSION

As a result, in this study, it was observed that mineral element concentrations changed in both plant parts and soil at different elevations. In general, it was determined that the amount of elements in the soil decreased significantly as the elevation increased. We think that the fact that the highest elevation of 3000 m in the study area is poor in nutrients may be due to the coarse particles of stony soils and low absorption level. It was observed that the amount of element accumulation of the plants studied at different elevations differed from each other depending on the type, structure, formation and elevation at which they grew. If the mineral element concentration is very low, some plants alter their metabolic processes to improve their accumulation capacity. On the other hand, if the mineral element concentration is too high, species develop metabolic modifications where they store elements in vacuoles to prevent cellular damage or develop a tendency to get rid of these elements (Özyiğit et al. 2015). Furthermore, although macro- and micronutrients differed between elevation zones, this relationship was not always linear and varied by nutrient.

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REFERENCES

[1] Brady NC, Weil RR, Weil RR (2008) The nature and properties of soils. 13:662-710. Upper Saddle River NJ: Prentice Hall.

[2] Maathuis FJM, Diatloff E (2013) Roles and functions of plant mineral nutrients. Methods Mol Biol 953:1–21.

[3] Elveren M, Osma E, Karakoyun G (2015) Accumulation of Mineral Elements in The Component of The Scots Pine (*Pinus sylvestris* L. var. *hamata* Steven) Trees and Grown in The Soil in Different Area of Erzincan. Celal Bayar Univ J Sci 11(2): 119-126.

[4] Kaur H, Kaur H, Kaur H, Srivastava S (2022) The beneficial roles of trace and ultratrace elements in plants. Plant Growth Regula 100:219–236.

[5] Jones C, Jacobsen J (2001) Plant nutrition and soil fertility. Nutrient management module 2. Montana State University Extension Service. Publication 4449–2.

[6] Karahan F (2023) Evaluation of Trace Element and Heavy Metal Levels of Some Ethnobotanically Important Medicinal Plants Used as Remedies in Southern Turkey in Terms of Human Health Risk. Bio Trace Element Res 201(1): 493-513.

[7] Mondal S. ve Bose B (2019) Impact of micronutrient seed priming on germination, growth, development, nutritional status and yield aspects of plants. J Plant Nutr 42 (19):2577-2599.

[8] Jing J, Zhang F, Rengel Z, Shen J (2012) Localized fertilization with P plus N elicits an ammonium-dependent enhancement of maize root growth and nutrient uptake. Field Crops Res 133:176-185.

[9] López-Bucio J, Hernández-Madrigal F, Cervantes, Ortiz-Castro R, Carreón-Abud Y, Martínez-Trujillo M (2014) Phosphate relieves chromium toxicity in Arabidopsis thaliana plants by interfering with chromate uptake. BioMetals 27:363-370.

[10] Alloway BJ (2007) Heavy metals in soils blackie academic & professional: london, UK. Salonen, V; Korkka-Niemi Kinfluence of parent sediments on the concentration of heavy metals ın urban and suburban soils ın turku, Finland. App Geoche 22:906–918.

[11] Salonen, V.P. and Korkka-Niemi, K. (2007) Influence of Parent Sediments on the Concentration of Heavy Metals in Urban and Suburban Soils in Turku, Finland. Applied Geochemistry, 22, 906-918.

[12] Sundqvist M. K, Giesler R, Graae B. J, Wallander H, Fogelberg E, Wardle D. A (2010) Interactive effects of vegetation type and elevation on aboveground and below ground properties in a subarctic tundra. Oikos 120:128–142.

[13] Haider F, Kumar N, Banerjee S, Naqvi AA, Bagchi GD (2009) Effect of altitude on the essential oil constituents of *Artemisia roxburghiana* Besser var. *purpurascens* (Jacq.) Hook. Jour. Essent. Oil Res 21:302–303.

[14] Ebrahimi M, Ranjbar S (2016) Some Autecological Properties of Medicinal Plant of *Salvia hydrangea* L. in Mazandaran, Iran. Journal of Rangeland Science 6(3):253-263.

[15] Kumar S, Suyal DC, Yadav A, Shouche Y, Goel R (2019) Microbial diversity and soil physiochemical characteristic of higher altitude. PLoS ONE 14(3): e0213844.

[16] Esen F, Avcı V (2020) Effect of Lithological and Geomorphological Factors on Distribution of Vegetation in Berit Mountains (Kahramanmaraş). Gaziantep Univ J Soc Sci 19(3):664-685.

[17] Özhatay, N., (2006). Türkiye'nin BTC Boru Hattı Boyunca Önemli Bitki Alanları s. 125-127, BTC şirketi, İstanbul. Pils, G. Flowers of Turkey; a Photo Guide. Friedrich VDV, Linz.

[18] Korkmaz M, Turgut N (2014) Flora of Ergan Mountain (Erzincan/Turkey). Biol Diversity and Cons 7(3):195-216.

[19] Boz D, Yilmaz A (2020) An Approach to the Planning and Environmental Geology of Erzincan Plain and its Surroundings. J Geo Eng 44:225-254.

[20] Davis, PH. 1965-1985. Flora of Turkey and The East Agean Islands. Vol. 1-9, Edinburgh University Press.

[21] Osma E, Kandemir A (2016) Analysing the effect of elements upon some endemic plants spreading over different habitats. Feb-Frese Environ Bull 25(7):2454-2460.

[22] Yavuzer H, Osma E (2018) Evaluation of *Salix fragilis* L.as a biomonitor in heavy metal pollution.

Eskisehir Technical University J Sci Techno C- Life Sci and Biotechno 7(2):122-129.
[23] Roomi I, Hussain A, Khan SW, Nafees MA, Naqvi AUN, Akram W (2023) Mineral Evaluation of Fodder Tree Leaves and Shrubs Consumed by Livestock in The Mountain Region of Pakistan. Pak J Bot 55(2):635-642.
[24] Dogan Y, Baslar S, Ugulu IA (2014) Study on Detecting Heavy Metal Accumulatıon Through Biomonitoring: Content of Trace Elements in Plants at Mount Kazdagı in Turkey. Applied Ecology and Environmental Research 12(3):627-636.
[25] Gerdol R, Bragazza L (2006) Effects of altitude on element accumulation in alpine moss. Chemosphere 64(5):810-816.
[26] Ugulu I Dogan Y, Baslar S, Varol O (2012) Biomonitoring of trace element accumulation in plants growing at Murat Mountain. Int. J. Environ. Sci. Technol 9:527–534.
[27] Başlar S, Kula I, Doğan Y, Yıldız D, Ay G (2009) A study of trace element contents in plants growing at Honaz Dagi-Denizli, Turkey. Ekoloji 18(72):1-7.
[28] Ozyigit I. I, Severoglu Z, Vatansever R, Öztürk M. (2015) Soil–Plant Interactions in the High-Altitude Ecosystems: A Case Study from Kaz Dağı (Mount Ida), Turkey. Climate Change Impacts on High-Altitude Ecosystems 343-360.
[29] Sahin I, Akcicek E, Guner O, Dogan Y, Ugulu I (2016) An investigation on determining heavy metal accumulation in plants growing at Kumalar Mountain in Turkey. Eurasia J Biosci 10:22-29.
[30] Al-Robai SA, Mohamed HA, Ahmed AA, Al-Khulaidi AWA (2019) Effects of elevation gradients and soil components on the vegetation density and species diversity of Alabna escarpment, southwestern Saudi Arabia. Acta Eco Sinica 39(3):202-211.
[31] Zhao N, He N, Wang Q, Zhang X, Wang R, Xu Z, Yu G (2014) The Altitudinal Patterns of Leaf C:N Stoichiometry Are Regulated by Plant Growth Form, Climate and Soil on Changbai Mountain, China. J Plant Ecol 7(3), 231–240.
[32] Köhler L, Gieger T, Leuschner C (2013) Altitudinal change in soil and foliar nutrient concentrations and in microclimate across the tree line on the subtropical island mountain Mt. Teide (Canary Islands). J Veg Sci 24(6), 1044-1054.