DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

International Journal of Chemistry and Technology

http://dergipark.org.tr/ijct

Research Article

Determination and comparison of element analysis in the species belonging to different families by inductively coupled plasma-mass spectrometry (ICP-MS)

Adil UMAZ[1,*], Firat AYDIN[2], Mehmet FIRAT[3], Abdulselam ERTAS[4]

[1]Department of Medical Laboratory, Vocational School of Health Services, Mardin Artuklu University, Mardin, Türkiye

Department of Chemistry, Faculty of Science, Dicle University, Diyarbakir, Türkiye

[3]Department of Biology, Faculty of Education, Van Yüzüncü Yıl University, Van, Türkiye

[4]Department of Pharmacognosy, Faculty of Pharmacy, Dicle University, Diyarbakır, Türkiye

Received: 14 March 2022; Revised: 17 June 2022; Accepted: 17 June 2022

*Corresponding author e-mail: adilumaz@gmail.com

Citation: Umaz, A.; Aydin, F.; Firat, M.; Ertas, A. *Int. J. Chem. Technol.* **2022**, 6 (1), 39-47.

ABSTRACT

The consumption of plants and their use for medicinal purposes are increasing day by day. Therefore, knowing the plant contents is important for human health. In this study, multi-element contents of nineteen species belonging to four different families were determined. The multi-element contents of different species of the same genus belonging to these families were compared. Also, the element contents of different parts of the same genus were compared. The element contents of different species of the same genus and different parts of the same species have been determined that be different from each other. In addition, the Cd and Pb content results of the species were compared with the maximum allowable concentration values in raw plant material of World Health Organization's (WHO). Cd content in all species was found to be higher than the value determined by the WHO. Only the Pb content of the *Sternbergia clusiana* Boiss. (A3) was found to be higher than the value detected by WHO.

Keywords: Plants, macro, micro and toxic elements, ICP-MS

Farklı familyalara ait türlerdeki element analizlerinin indüktif eşleşmiş plazma kütle spektrometrisi (ICP-MS) ile belirlenmesi ve karşılaştırılması

ÖZ

Bitkilerin tüketimi ve tıbbi amaçlı kullanımları her geçen gün artmaktadır. Bu nedenle bitki içeriklerinin bilinmesi insan sağlığı açısından önemlidir. Bu çalışmada dört farklı familyaya ait on dokuz türün çoklu element içerikleri belirlenmiştir. Bu familyalara ait aynı cinsin farklı türlerinin çoklu element içerikleri karşılaştırılmıştır. Ayrıca, aynı cinsin farklı kısımlarının element içerikleri karşılaştırılmıştır. Aynı cinsin farklı türlerinin ve aynı türün farklı kısımlarının element içerikleri birbirinden farklı olduğu tespit edilmiştir. Ayrıca, türlerin Cd ve Pb içerik sonuçları Dünya Sağlık Örgütü'nün (WHO) ham bitki materyalinde izin verilen maksimum konsantrasyon değerleri ile karşılaştırılmıştır. Tüm türlerde Cd içeriği WHO tarafından belirlenen değerden yüksek bulunmuştur. Yalnızca, *Sternbergia clusiana* Boiss'in Pb içeriği. (A3) WHO tarafından tespit edilen değerden daha yüksek olduğu tespit edildi.

Anahtar Kelimeler: Bitkiler, makro, mikro ve toksik elementler, ICP-MS

1. INTRODUCTION

The plants are estimated that there are about one million in the world. About five hundred thousand of these plants have been described and named. Twenty thousand of them were determined to be medicinal plants used for therapeutic purposes as a result of the research conducted by the WHO.[1] There are 10754 plant species in the flora of Türkiye, 3708 of which are endemic.[2] The Amaryllidaceae family is a perennial, flowering structure containing 73 genera and at least 1600 species and is particularly distributed in tropical and subtropical regions

DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

of the world. Members of the family; have underground roots, lanceolate leaves, usually three or six bowl-shaped flowers and fruits.[3] Plants belonging to the Amaryllidaceae family are used in folk medicine all over the world, for ornamental purposes in public gardens and parks due to their beautiful flowers. Species of this family have a wide variety of biological effects, including antitumor, antiviral, antibacterial, antifungal, antimalarial, analgesic, and cytotoxic activities.[4] In addition, some species in this family have been used in folk medicine to treat tumors.[5]

Caryophyllaceae is a large family represented worldwide by about 86 genera and more than 2200 species. This family consists of annual or perennial herbaceous plants with swollen nodes, root structure, oblong rims, and diagonally opposite leaves. This family is distributed in the temperate and warm temperate zone of the Northern hemisphere. The distribution center is mainly the Mediterranean region, which is part of Europe and Asia. The Caryophyllaceae family is represented by 32 genera and 500 species in the flora of Türkiye.[6]

Iridaceae is one of the families of flowering plants. This family is known for ornamental genera such as Iris, Gladiolus, and Crocus. The family is a mostly perennial plant family that includes about 80 genera and 1700 species. There are also several shrubs and evergreen herbaceous species of this family. Although the family is distributed almost worldwide, it is most abundant and diverse in Africa. Most species grow in temperate, subtropical, and tropical regions.[7]

Malvaceae, known as hollyhock or mallow, is a family that includes about 243 genera and at least 4225 species of plants, shrubs, and trees. Species of this family are spread all over the world except for the coldest regions of the world, but the spread is greatest in the tropics. Economically important species of this family; Cotton, Cocoa, Linden, Durian, Hibiscus, and Okra.[8]

The World Health Organization (WHO) states that the maximum allowable concentrations of cadmium, arsenic, and lead in raw plant materials are 0.3, 1.0, and 10 mg kg^{-1}, respectively. The determination of macro, micro and toxic element concentrations in plant samples are used various methods such as Atomic Absorption Spectrometry (AAS), Flame Atomic Absorption Spectrometry (FAAS), Graphite Furnace Atomic Absorption Spectrometry (GF-AAS), Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and X-ray Fluorescence Spectrometry (XRF).[9] In this study; Macro, micro, and toxic element contents of nineteen species belonging to four different families were determined by ICP-MS and the species belonging to these families were compared within themselves. The obtained multi-element content results were compared with the maximum acceptable concentration values in raw plant materials of WHO. In addition, the multi-element contents of the root and aerial parts of some species were determined and the plant parts were compared with each other.

2. MATERIALS AND METHODS

2.1. Plant materials

Species belonging to different families were collected and identified by Mehmet Fırat. The current names of the plants were written by controlling the IPNI (International Plant Name Index). The species were dried with suitable drying methods and stored in VANF (Van Yüzüncü Yıl Faculty of Science Herbayum)

2.2. Reagent and solutions

Analytical purity HNO_3 (70%), H_2O_2 (34.5-36.5%) (Sigma Aldrich, Germany), and ultrapure water (18.2 MΩ) were used in the microwave resolution process. The accuracy and precision of the method were evaluated using the certified reference material NIST 1515 apple leaf (National Institute of Standards and Technology, NIST, Gaithersburg, MD, USA).

The mix standard ((100 mg l^{-1}, VHG Labs PN.: VHG ZLGC1813) (Ag, Al, As, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Sn, Sr, Ti, Tl, V, and Zn)) was used in ICP-MS measurements. Calibration standard solutions (10-4000 µg l^{-1}) were prepared by appropriate dilution of stock mix standards (1 mg l^{-1}). Limit of detection (LOD) and limit of quantity (LOQ) values for twenty elements were calculated using 10 independent blank solutions.

2.3. Instrument

Macro, micro and toxic element contents in the species were determined using Agilent 7700s model ICP-MS device (Table 2)

2.4. Preparation of plant samples for multi-element analysis

In order to carry out multi-element analysis, the samples dried in the shade were homogenized and ground in a mortar. The samples were then weighed about 0.1 g and placed in microwave teflon tubes. 6 ml of HNO_3 and 2 ml of H_2O_2 were added to the tubes in a 6:2 ratio. In the microwave device, the samples were first heated at 500 W energy for 15 min heated up to 300 °C. Then the samples were kept at 1500 W energy for 15 min at 300 °C throughout.

Finally, samples have gradually reduced the temperature from 300 °C to 90 °C in 500 W energy for 10 min and

DOI: http://dx.doi.org/10.32571/ijct.1087834 **E-ISSN: 2602-277X**

during this time solubilization was carried out in the microwave closed system. After microwave solubilization, the mixture in teflon tubes was filtered with blue banded filter paper. The obtained filtrate was diluted up to 100ml with ultrapure water by taking 100ml bolon. Then, the diluted samples were put into screw-closed analysis tubes and made ready for analysis.[9,10]

Table 1. Information about of studied the species (plant species, species codes, collection location and collection time)

Plant species	Species Codes	Gathering Places	Harvesting Times	Herbarium Number
		Amaryllidaceae familyası		
Ixiolirion tataricum (Pall.) Herb. & Traub	A1	Nevşehir	2014	M. FIRAT 32330 (VANF)
Narcissus tazetta L. subsp. *tazetta.*	A2	Van	2015	M. FIRAT 32469 (VANF)
Sternbergia clusiana Boiss.	A3	Van	2015	M. FIRAT 32625 (VANF)
Sternbergia vernalis (Mill.) Gorer & J.H.Harvey	A4	Van	2015	M. FIRAT 32446(VANF)
		Caryophyllaceae familyası		
Gypsophyla nodiflora (Boiss.) Barkoudah	C1	Adıyaman	2015	M. FIRAT 32652 (VANF)
Silene compacta Fisch. ex Hornem.	C2	Bitlis	2015	M. FIRAT 32655 (VANF)
Silene conoidea L.	C3	Erzincan	2017	M. FIRAT 33733 (VANF)
Silene subconica Friv.	C4	Kars	2014	M. FIRAT 31347(VANF)
Vaccaria hispanica (Mill.) Rauschert	C5	Adıyaman	2015	M. FIRAT 32651 (VANF)
		Iridaceae familyası		
Gladiolus italicus Mill.	I1	Hakkari	2015	M. FIRAT 32466 (VANF)
Gladiolus kotschyana Boiss.	I2	Van	2014	M. FIRAT 32468(VANF)
Iris pseudocaucasica Grossh.	I3	Van	2014	M. FIRAT 32332(VANF)
Iris sari Schott ex Baker	I4	Adıyaman	2014	M. FIRAT 32420(VANF)
		Malvaceae familyası		
Alcea apterocarpa (Fenzl) Boiss.	M1	Van	2014	M. FIRAT 31523(VANF)
Alcea biennis Winterl	M2	Hakkari	2015	M. FIRAT 32527(VANF)
Alcea rosea L.	M3	Diyarbakır	2015	M. FIRAT 32531(VANF)
Alcea setosa (Boiss.) Alef.	M4	Van	2014	M. FIRAT 31327(VANF)
Malva neglecta Wallr.	M5	Van	2015	M. FIRAT 32457(VANF)
Malvella sherardiana (L.) Jaub. & Spach	M6	Diyarbakır	2014	M. FIRAT 30674 (VANF)

Table 2. ICP-MS instrument analytical contitions

Parameters	
RF Power	1550 W
Plasma gas	Argon
Plasma gas flow rate	15 l min^{-1}
Helium gas flow rate	4.3 ml min^{-1}
Nebulizer peristaltic pump intake speed	0.3 rps
Nebulizer peristaltic pump intake time	50 sec
Nebulizer peristaltic pump stabilization time	45 sec
Repeat/example reading	3
Number of scan repetitions	100
Measured element isotopes	^{27}Al, ^{52}Cr, ^{59}Co, ^{63}Cu, ^{7}Li, ^{23}Na, ^{24}Mg, ^{27}Al, ^{39}K, ^{55}Mn, ^{56}Fe, ^{58}Ni, ^{64}Zn, ^{80}Se, ^{9}Be, ^{112}Cd, ^{5}B, ^{22}Ti, ^{138}Ba ve ^{208} Pb

3. RESULTS AND DISCUSSION

3.1. Calibration studies

The linear calibration chart for elements was generated in the range of 10-4000 µg l^{-1} given in Table 3. Correlation coefficients (r^2) were found to vary between 0.9990 and 0.9999. The LOD and LOQ values were calculated from 3s m^{-1} and 10s m^{-1}. S was the standard deviation of the blank and m was the slope of calibration plot. LOD and LOQ values are given in Table 3.

3.2. Recovery studies for elements

In this study, % recovery values of elements were obtained by using NIST 1515 apple leaf reference material. It was determined that the recovery values ranged between 91-110% (Table 4).

3.3. Determination of multi-element content in species

3.3.1. Multi-element analysis results of species belonging to Amaryllidaceae family

Na, K, Mg, Fe, Al, Ti, Mo, Li, Cu, Cr, Ni, Zn, Se, and Ba contents of the sample of the aerial part of the A1 species

DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

were found to be higher than the root. The element contents of the aerial part of this species were determined as 3069, 38162, 2906, 430, 625, 68.89, 4.46, 1.23, 7.59, 2.15, 5.13, 71.23, 49.00 and 83.82 mg kg^{-1}, respectively. In addition, the contents of B, Mn, Co, Cd, and Pb of the root part of this species were determined that were higher than the aerial. The element contents of the root part of this species were determined as 223, 34.70, 0.86, 2.98 and 3.34 mg kg^{-1}, respectively (Table 5).

Table 3. Analytical parameters of the ICP-MS analysis method

Elements	Liner Range (µg l^{-1})	Calibration Equation	r^2	LOD (µg l^{-1})	LOQ (µg l^{-1})
Na	500-4000	y = 5142.84 x + 357838	0.9997	48.500	161.680
K	500-4000	y = 2308.80 x + 315707	0.9997	17.030	56.780
Mg	100-4000	y = 2226.27 x + 12319	0.9994	4.240	14.130
Fe	1000-4000	y = 34007.92 x + 701914	0.9990	5.120	17.080
Al	100-4000	y = 1121.76 x + 1922	0.9995	2.730	9.080
Se	100-4000	y = 829.63 x + 75232	0.9991	0.061	0.202
Li	50-4000	y = 189.10 x + 213	0.9997	0.591	1.970
Ba	10-4000	y = 198949.48 x + 11780	0.9998	0.088	0.290
Be	10-4000	y = 22829.54 x + 709	0.9999	0.730	2.430
Cu	10-4000	y = 31809.14 x + 16409	0.9994	0.330	1.100
Co	10-4000	y = 55754.88 x + 1543	0.9997	0.150	0.490
Cd	10-4000	y = 42086.25 x + 885	0.9996	0.400	1.330
Cr	10-4000	y = 29985.59 x + 4895	0.9994	0.210	0.690
Mn	10-4000	y = 18139.19 x + 5333	0.9995	0.280	0.920
Ni	10-4000	y = 28319.45 x + 6335	0.9995	1.080	3.580
Zn	10-4000	y = 9123.21 x + 7916	0.9994	0.580	1.920
Pb	10-4000	y = 126261.36 x + 6134	0.9996	0.110	0.360
B	10-4000	y = 5768.54 x + 33073	0.9994	0.011	0.035
Mo	10-4000	y = 4155.44x + 196	0.9998	0.078	0.259
Ti	10-4000	y = 260.23 x + 36	0.9994	0.058	0.193

Table 4. Standard reference material (SRM) values and recovery % (mean concentration ± standard deviation, n=3)

Elements	Certificate Value (mg kg^{-1})	Measurement Value (mg kg^{-1})	Recovery %
Na	24.40±2.10	22.15±0.29	91
Mg	2710±120	2467±4	91
Al	285±6	314±2	110
K	16080±210	14478±91	90
Mn	54.10±1.10	50.85±0.19	94
Fe	82.70±2.60	80.77±0.27	98
Ni	0.936±0.094	0.95±0.01	101
Cu	5.69±0.13	5.86±0.10	103
Zn	12.45±0.43	13.7±0.46	110
Ba	48.80±2.30	48.20±0.30	99
Pb	0.470±0.024	0.490±0.002	104
Mo	0.095±0.011	0.089±0.007	94
B	27.60±2.80	28.20±1.57	102

Table 5. Multi-element results of species belonging to Amaryllidaceae family (n = 3)

Elements	A1 (Root)	A1 (Aerial part)	A2	A3	A4
Na	2994±8	3069±19	4015±118	2910±11	2393±19
K	3480±26	38162±227	27639±983	11867±94	14137±18
Mg	1818±15	2906±11	3288±90	10831±42	2280±3
Fe	285±3	430±4	2698±105	16916±42	780±12
Al	368±2	625±2	5716±220	23983±151	971±21
B	223±4	222±3	262±1	243±3	194±3
Ti	52.00±0.57	68.89±0.72	124±1	933±8	72.66±0.86
Mo	2.80±0.01	4.46±0.11	0.65±0.03	2.04±0.12	1.19±0.09
Li	0.68±0.10	1.23±0.31	3.50±0.69	17.43±1.29	1.95±0.24
Cu	3.56±0.07	7.59±0.01	12.04±0.38	17.60±0.18	9.70±0.02
Be	0.01±0.00	0.01±0.00	0.12±0.00	0.91±0.01	0.02±0.00
Cr	1.89±0.02	2.15±0.00	13.05±0.43	77.53±0.74	3.05±0.04
Mn	34.70±0.30	25.49±0.06	148±5	498±5	35.63±0.23
Ni	3.15±0.01	5.13±0.05	21.74±0.73	104±1	8.22±0.07
Co	0.86±0.02	0.67±0.04	1.84±0.07	7.69±0.07	0.71±0.03
Zn	38.73±0.35	71.23±0.49	62.43±1.64	109±1	48.81±0.37
Se	48.01±0.29	49.00±0.47	50.36±0.54	49.64±0.51	50.95±0.23
Cd	2.98±0.02	2.52±0.02	0.95±0.04	1.94±0.01	1.89±0.02
Ba	9.68±0.02	83.82±0.11	25.07±0.37	68.37±0.37	9.60±0.11
Pb	3.34±0.03	1.77±0.01	1.14±0.02	13.76±0.02	1.53±0.01

Measured value = mean concentration ± SD. (mg kg^{-1}). **A1:** *Ixiolirion tataricum*, **A2:** *Narcissus tazetta* subsp. *tazetta*, **A3:** *Sternbergia clusiana*, **A4:** *Sternbergia vernalis*

DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

When the element contents of different species of the same genus are evaluated; it was determined that Na, Mg, Fe, Al, B, Ti, Mo, Li, Cu, Be, Cr, Mn, Ni, Co, Zn, Cd, Ba and Pb contents of A3 species were higher than A4. K and Se contents of A4 species were found to be higher than that of A3 (Table 5). The different element content of samples belonging to different species of the same genus can be said that the species changes depending on genetic factors, geographical location, climatic factors, vegetation period, air pollution, and environmental factors.

When the Cd and Pb contents in species belonging to the Amaryllidaceae family were compared with the maximum allowable concentration amount in raw plant materials of WHO; Cd content of all species belonging to this family was found to be higher than WHO values. In addition, the Pb content of only the A3 sample from this family was found to be higher than WHO values.

3.3.2. Multi-element analysis results of species belonging to Caryophyllaceae family

K, Mg, Fe, Al, B, Ti, Mo, Li, Cu, Be, Cr, Mn, Ni, Co, Zn, Se, Ba, and Pb contents of samples belonging to the aerial part of the C1 species were detected to be higher than the root. The element contents of the aerial part of this species were determined as 18808, 14443, 3556, 4143, 199, 147, 3.21, 2.06, 23.41, 0.04, 17.19, 205, 34.50, 10.55, 43.41, 39.62, 16.96 and 3.37 mg kg^{-1}, respectively. In addition, the element contents of Na and Cd of the root part of this species were determined that were higher than the aerial part and element contents were determined as 2488 and 3.50 mg kg^{-1}, respectively (Table 6).

In the study of determination of the macro and micronutrient content in the leaf samples of some shrub plants; element contents of *Gypsophila sphaerocephala* plant were determined by AAS device. Macro elements in the leaf part of the species were determined as N; 1.52%, P; 0.14%, K; 0.96%, Ca; 3.71% and Mg; 0.47%. Concentrations of micro elements were determined as Fe; 367.23, Zn; 11.40, Mn; 42.10 and Cu; 2.82 mg kg^{-1}.[11] Na, K, Mg, Fe, Al, B, Ti, Mo, Li, Cu, Be, Cr, Mn, Ni, Co, Zn, and Pb contents in samples belonging to the aerial part of the C4 species were found to be higher than the root. The element contents of the aerial part of this species were determined as 2329, 45449, 8469, 1805, 2743, 205, 120, 14.62, 2.45, 9.07, 0.12, 6.99, 105, 15.81, 1.34, 50.90 and 1.11 mg kg^{-1}, respectively. The contents of Ba and Cd of the root part of species were determined that were higher than the aerial part and the element contents were determined as 146 and 1.69 mg kg^{-1}. In addition, Se content could not be detected in both parts of the species (Table 6). The contents of B, Mo, Mn, Zn, Se, and Cd of the aerial part of the C5 species were determined that were higher than the root. The element contents of the aerial part of this species were determined as 224, 8.30, 69.66, 57.88, 52.84, and 4.68 mg kg^{-1}, respectively. Na, K, Mg, Fe, Al, Ti, Li, Cu, Be, Cr, Ni, Co, Ba, and Pb contents of the root part of the species were found to be higher than the aerial. The element contents of the root part of this species were determined as 2485, 55420, 3575, 2399, 3816, 199, 2.99, 6.59, 0.08, 9.33, 15.89, 1.33, 51.19 and 0.66 mg kg^{-1}, respectively. In addition, Se content could not be detected in both parts of the species (Table 6).

In the study of the determination of element concentrations in plant ash samples of *Silene compacta* species; the element concentrations of the vegetable ash sample were determined by the ICP-AES device. It was determined as Fe; 0.9, Ag; 2.0, As; 39.4, Cd; 8.0, Co; 10.4, Cu; 568, Mo; 10.3, Ni; 17.3, Pb; 79.1, Zn; 607 and V; 11.3 mg kg^{-1}.[12]

In the study of the determination of trace elements in soil-plant systems of copper mine areas in the area where the Murgul Copper mine is from the Black Sea Region of Türkiye; macro and micro element concentrations of *S. compacta* plant were determined as N; 1.24%, P; 0.24%, K; 2.60%, Ca; 1.00%, Mg; 0.48%, Fe; 9320, Cd; 0.5, Zn; 221.0, Pb; 46.0, Cu; 125.5, Co; 5.5, Ni; 16.5 and Al; 8985 mg kg^{-1}.[13]

In the study of heavy metal uptake in some plant species in Metalliferous regions in Northern Greece; heavy metal concentrations in the structure of *S. conica* plant in the Vouves area were determined by AAS device. The heavy metal concentrations of the plant were determined as Zn: 860, Pb: 450, Cd: 5, Ni: 20, Fe: 146, Mn: 35, Ca: 20850, Mg: 2550, N: 11250 and Na: 435 µg g^{-1}.[14]

In the study of the determination of the element concentrations of three different plant species in the Sari Gunay gold layer of Northwest Iran; element concentrations of 3 different plant species were determined by the ICP-MS device. Element concentrations of *S. conoidea* plant were determined as Au; 260.05, Ace; 57.1, C5; 3.7, Ag; 0.9, Mo; 1.16, Sb; 64.77, Hg; 0.10, Cu;9.7, Pb;50.6 and T1; 2.73 mg kg^{-1}.[15]

When the element contents of different species of the same genus are evaluated; it was determined that the Na, Fe, B, Li, Be, Cr, Co and Pb contents of the C2 species were higher than the other species. K, Mg, Al, Ti, Mo, Cu, Mn, Ni and Zn contents of the aerial part of the C4 species were found to be higher than the other species. In addition, the Cd and Ba contents of the root part of the species were found to be higher than the other species (Table 6). When the Cd and Pb contents in species belonging to the Caryophyllaceae family are compared with the maximum allowable concentration amount in raw plant materials of WHO; it was determined that the Cd content of all species belonging to this family was higher than the WHO values, and the Pb content was much lower than the WHO values.

DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

Table 6. Multi-element results of species belonging to the Caryophyllaceae family (n = 3)

Elements	C1 (Root)	C1 (Aerial part)	C2	C3	C4 (Root)	C4 (Aerial part)	C5 (Root)	C5 (Aerial part)
Na	2488±24	2401±21	3127±28	2218±9	2176±31	2329±27	2485±21	2246±29
K	9580±116	18808±91	27373±183	21871±197	25917±47	45449±152	55420±387	29925±69
Mg	5237±5	14443±71	5018±13	3924±28	2597±20	8469±50	3575±39	3477±19
Fe	1280±5	3556±24	2266±10	914±7	1130±4	1805±10	2399±8	384±3
Al	2181±11	4143±6	2482±9	1365±6	1871±27	2743±7	3816±25	473±3
B	194±2	199±2	443±9	172±7	159±1	205±6	155±8	224±4
Ti	68.51±0.21	147±1	94.53±1.46	66.53±0.99	74.69±0.22	120±1	199±1	42.49±0.17
Mo	1.56±0.10	3.21±0.08	0.85±0.09	5.54±0.09	4.26±0.07	14.62±0.11	1.90±0.11	8.30±0.09
Li	1.30±0.38	2.06±0.57	2.49±0.66	1.01±0.24	1.06±0.23	2.45±0.35	2.99±0.30	1.01±0.08
Cu	6.80±0.02	23.41±0.08	5.90±0.06	6.56±0.04	5.81±0.03	9.07±0.07	6.59±0.08	4.94±0.03
Be	0.01±0.00	0.04±0.00	0.16±0.01	0.09±0.00	0.08±0.00	0.12±0.01	0.08±0.00	0.01±0.00
Cr	9.76±0.02	17.19±0.09	8.36±0.02	3.83±0.01	4.64±0.03	6.99±0.04	9.33±0.06	2.53±0.01
Mn	46.41±0.46	205±1	47.21±0.24	40.42±0.15	27.61±0.12	105±1	49.72±0.28	69.66±0.54
Ni	13.47±0.01	34.50±0.09	12.09±0.03	8.37±0.02	8.67±0.01	15.81±0.05	15.89±0.09	4.04±0.02
Co	1.81±0.03	10.55±0.06	1.36±0.00	0.74±0.03	0.80±0.01	1.34±0.02	1.33±0.01	0.34±0.01
Zn	19.83±0.25	43.41±0.13	37.09±0.12	35.33±0.13	26.99±0.24	50.90±0.46	36.17±0.56	57.88±0.07
Se	36.55±0.36	39.62±0.39	N.D.	N.D.	N.D.	N.D.	49.75±0.2	52.84±0.13
Cd	3.50±0.01	3.07±0.01	2.93±0.02	3.57±0.02	3.96±0.24	1.69±0.01	2.61±0.02	4.68±0.01
Ba	7.15±0.04	16.96±0.28	10.47±0.07	148±1	197±11	146±1	51.19±0.48	11.97±0.09
Pb	0.68±0.01	3.37±0.02	1.54±0.01	0.64±0.00	0.58±0.04	1.11±0.01	0.66±0.01	0.43±0.00

N.D.: No Detected, **Measured value** = mean concentration ± SD. (mg kg^{-1}). **C1:** *Gypsophyla nodiflora*, **C2:** *Silene compacta*, **C3:** *Silene conoidea*, **C4:** *Silene subconica*, **C5:** *Vaccaria hispanica*

3.3.3. Multi-element analysis results of species belonging to Iridaceae family

When the element contents of different species of the same genus are evaluated; it was determined that Na, Mg, Fe, Al, B, Ti, Li, Cu, Be, Cr, Mn, Ni, Co, Zn, Cd and Pb contents of I1 species were higher than I2. It was determined that K, Mo, Se, and Ba contents of I2 species were higher than I1. Na, Mg, Fe, Al, Ti, Be, Cr, Mn, Ni, Co, Zn, Cd, Ba, and Pb contents of I3 species were determined that be higher than I4. K, B, Li, Cu, Mo, and Se contents of the I4 species were found to be higher than the I3 (Table 7). In the study of the accumulation and distribution of heavy metals in aquatic plants; concentrations of heavy metals accumulated in the above-ground and subsoil parts of *Iris pseudocaucasica* were determined by ICP-MS device. Heavy metal concentrations accumulated in the above-ground part of the plant were determined as Cr; 8.34, Fe; 8.01, Cu 0.43, and Zn; 4.43 mg g^{-1}. Heavy metal concentrations accumulated in the subsoil part of the plant were determined as Cr; 39.98, Fe; 134.10, Cu 1.43 and Zn; 10.45 mg g^{-1}.[16]

When the Cd and Pb contents in the species belonging to the Iridaceae family are compared with the WHO's maximum allowable concentration in raw plant materials; it was determined that the Cd content of all species belonging to this family was higher than the WHO values, and the Pb content was much lower than the WHO values.

Table 7. Multi-element results of species belonging to the Iridaceae family (n = 3)

Elements	I1	I2	I3	I4
Na	2571±20	2471±4	2695±19	2417±8
K	36054±212	37561±250	10320±42	45227±292
Mg	3869±15	2709±19	3029±21	2815±25
Fe	1053±10	140±2	1143±11	307±1
Al	1410±6	203±1	1653±7	496±2
B	236±2	216±7	236±3	243±6
Ti	126±1	34.70±0.77	138±1	33.19±0.43
Mo	1.70±0.01	1.82±0.07	0.69±0.03	2.46±0.04
Li	1.72±0.33	0.73±0.10	1.32±0.26	1.65±0.51
Cu	9.31±0.08	5.14±0.06	4.37±0.03	5.88±0.03
Be	0.03±0.00	0.01±0.00	0.04±0.00	0.01±0.00
Cr	5.21±0.01	1.31±0.01	13.69±0.04	1.88±0.00
Mn	76.15±0.56	34.86±0.06	35.68±0.19	14.23±0.11
Ni	9.25±0.01	1.95±0.02	8.04±0.05	3.32±0.03
Co	1.44±0.02	0.50±0.01	0.87±0.03	0.37±0.03
Zn	63.98±0.51	52.67±0.65	22.62±0.25	22.03±0.03
Se	42.44±0.2	43.84±0.57	42.78±0.52	42.88±0.66
Cd	3.55±0.03	1.38±0.02	3.41±0.03	1.59±0.01
Ba	13.97±0.13	30.14±0.17	61.26±0.7	35.05±0.12
Pb	0.87±0.02	0.63±0.00	1.12±0.01	1.03±0.01

Measured value = mean concentration ± SD. (mg kg^{-1}).
I1: *Gladiolus italicus*, **I2:** *Gladiolus kotschyana*, **I3:** *Iris pseudocaucasica*, **I4:** *Iris sari*

DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

3.3.4. Multi-element analysis results of species belonging to Malvaceae family

Fe, Al, Ti, Li, Cr, Mn, Ni, Co, Cd, and Pb contents of the root part of M4 species were determined to be higher than the aerial. The element contents of the root part of this species were determined as 660, 1050, 47.59, 1.10, 1.66, 61.20, 4.46, 0.63, 4.08 and 0.91 mg kg^{-1}, respectively. Na, K, Mg, B, Mo, Cu, Zn, and Ba contents of the aerial part of M4 species were found to be higher than the root. The element contents of the aerial part of this species were determined as 2129, 25042, 3979, 286, 2.81, 7.42, 37.18, and 71.35 mg kg^{-1}, respectively. In addition, Be and Se contents could not be detected in the samples belonging to both parts of this species (Table 8). In the study to determine the heavy metal content of *Alcea rosea* species growing on the roadside soils of a Turkish Lake Basin; the heavy metal content of the species belonging to different locations was determined by AAS device. Metal concentrations of Fe, Mn, Cu, Zn, Cd, Cr, Ni, and Pb were found to be 300.62, 42.94, 17.20, 21.73, 11.26, 3.25, 2.63, and 2.59 mg kg^{-1}, respectively.[17]

In another study of the determination of metal concentration of this species; the metal analysis of the species was determined by the ICP-OES device and Al, As, B, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Se concentrations were detected as 30, 0.34, 9.50, 0.08, 0.15, 6.10, 15, 5.40, 0.68, 0.22 and 0.09 mg kg^{-1}, respectively.[18]

The Na, K, Li and Se contents of the aerial part of M5 species were determined that be higher than the root. The element contents of the aerial part of this species were determined as 4688, 60744, 5.26, and 5219 mg kg^{-1}, respectively. In addition, the contents of Mg, Fe, Al, B, Ti, Mo, Cu, Be, Cr, Mn, Ni, Co, Zn, Cd, Ba, and Pb of the root part of the species were determined to be higher than the aerial. The element contents of the root part of this species were determined as 10800, 4779, 7332, 250, 335, 3.16, 11.51, 0.18, 17.36, 182, 30.00, 2.62, 53.21, 2.90, 58.04 and 1.43 mg kg^{-1}, respectively (Table 8). In the study carried out to determine the mineral composition of *Malva neglecta*, which is consumed as a vegetable in the Central Black Sea Region of Türkiye; the concentrations of the macro and micro element content of the species were determined with the AAS device. Element concentrations of the species were determined as K; 2828.6, Mg; 408.5, Fe; 19.2, Zn; 8.1, Mn; 3.0, Cu; 8.6, P; 610.8; Na; 610.2 and Ca; 1519.9 µg g^{-1}.[19] Mg, Fe, Al, B, Ti, Mo, Li, Cu, Be, Cr, Mn, Ni, Co, Zn, Se, Cd, Ba, and Pb contents of the aerial part of M6 species were detected that be higher than the root. The element contents of the aerial part of this species were determined as 7412, 6294, 5456, 274, 765, 10.78, 3.41, 20.23, 0.12, 18.32, 218, 53.11, 5.09, 62.33, 51.06, 1.94, 44.66 and 1.58 mg kg^{-1}, respectively. In addition, it was determined that the Na and K contents of the sample of the root part of this species were higher than the aerial. The element contents of the root part of this species were determined as 2295 and 28375 mg kg^{-1}, respectively (Table 8).

Table 8. Multi-element results of species belonging to the Malvaceae family (n = 3)

Elements	M1	M2	M3	M4 (Root)	M4 (Aerial part)	M5 (Root)	M5 (Aerial part)	M6 (Root)	M6 (Aerial part)
Na	2106±26	3705±30	2264±14	2113±10	2129±9	2353±7	4688±65	2295±19	2243±5
K	33256±165	23178±122	33877±30	21110±300	25042±241	49974±465	60744±362	28375±181	24215±169
Mg	4081±14	4352±42	5439±21	1817±10	3979±22	10800±70	3303±5	4908±19	7412±51
Fe	163±1	519±2	318±4	660±5	294±1	4779±12	1464±12	893±6	6294±12
Al	173±1	407±2	331±1	1050±11	380±1	7332±30	2428±25	1434±13	5456±43
B	282±11	330±10	329±8	181±7	286±5	250±3	229±3	225±5	274±4
Ti	10.20±0.21	14.45±0.50	25.82±0.35	47.59±1.30	25.75±0.38	335±2	90.15±0.33	79.83±0.98	765±10
Mo	1.74±0.10	4.10±0.08	4.43±0.06	0.75±0.05	2.81±0.12	3.16±0.11	0.88±0.04	1.05±0.08	10.78±0.05
Li	0.02±0.27	1.28±0.36	0.24±0.32	1.10±0.13	0.21±0.14	4.59±0.12	5.26±0.47	1.56±0.30	3.41±0.45
Cu	13.81±0.06	53.95±0.81	9.80±0.10	7.08±0.05	7.42±0.04	11.51±0.08	6.72±0.03	7.96±0.03	20.23±0.06
Be	N.D.	N.D.	N.D.	N.D.	N.D.	0.18±0.01	0.06±0.00	0.02±0.00	0.12±0.00
Cr	1.05±0.01	9.72±0.04	1.59±0.01	1.66±0.01	1.49±0.01	17.36±0.07	6.02±0.02	4.11±0.01	18.32±0.07
Mn	24.43±0.07	36.37±0.24	35.72±0.13	61.20±0.50	40.33±0.06	182±1	32.10±0.27	42.93±0.36	218±0.57
Ni	3.16±0.01	8.06±0.04	3.95±0.02	4.46±0.01	3.18±0.02	30.00±0.09	11.87±0.06	7.82±0.02	53.11±0.06
Co	0.36±0.01	1.08±0.02	0.32±0.01	0.63±0.01	0.42±0.01	2.62±0.02	1.02±0.01	0.66±0.01	5.09±0.02
Zn	47.41±0.18	107±1	35.33±0.23	20.26±0.13	37.18±0.18	53.21±0.52	24.88±0.51	62.09±0.31	62.33±0.21
Se	N.D.	N.D.	N.D.	N.D.	N.D.	50.90±0.39	52.19±0.45	50.77±0.62	51.06±0.40
Cd	1.67±0.01	3.02±0.02	1.47±0.01	4.08±0.01	2.87±0.02	2.90±0.02	0.39±0.00	0.72±0.01	1.94±0.01
Ba	88.08±0.56	64.28±0.25	179±1	9.77±0.03	71.35±0.61	58.04±0.65	37.06±0.10	43.85±0.22	44.66±0.41
Pb	0.78±0.01	3.39±0.04	0.98±0.01	0.91±0.01	0.83±0.01	1.43±0.02	0.75±0.02	0.69±0.00	1.58±0.01

N.D.: No Detected, **Measured value** = mean concentration ± SD. (mg kg^{-1}).
M1: ***Alcea apterocarpa***, **M2:** ***Alcea biennis***, **M3:** ***Alcea rosea***, **M4:** ***Alcea setosa***, **M5:** ***Malva neglecta***, **M6:** ***Malvella sherardiana***

In the study conducted to determine the mineral composition of the *Malvella sherardiana* plant, which is consumed as a vegetable in the Central Black Sea Region of Türkiye; the macro and micro element content of the species was determined by AAS device. Element contents of the species were determined as K; 3660.8, Mg; 416.1, Fe; 22.4, Zn; 10.1, Mn; 5.3, Cu; 9.7, P; 701.7; Na; 687.7 and Ca; 1730.0 µg g^{-1}.[19] When the element contents of different species of the same genus are evaluated; it was determined that the Na, B, Li, Cu, Cr, Ni, Co, Zn, and Pb contents of M2 species were higher than the other species. K, Mg, Mo and Ba contents of M3 species were determined that be higher than other species. Fe, Al, Ti, Mn, and Cd contents of the root part

DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

of M4 species were determined to be higher than other species. In addition, Be and Se contents could not be detected in samples of all species (Table 8).When the Cd and Pb contents in the species belonging to the Malvaceae family are compared with the WHO's maximum allowable concentration in raw plant materials; it was determined that the Cd content of all species belonging to this family was higher than the WHO values, and the Pb content was much lower than the WHO values.

4. CONCLUSIONS

Although the mineral elements in the structure of plants have positive effects on human health, toxic elements pose a danger. Therefore, it is very important to determine the toxic and mineral element content in plants. In this study, nineteen different species used for purposes as edible, ornamental, and medicinal plants were investigated in terms of multi-element content. The results obtained were compared among different species of the same genus and samples belonging to different parts of the same species. The aerial parts of A1, C1, C4 and M6 samples were determined that had more multi-element content than the root. Many element contents of the root parts of the C5, M4, and M6 samples were determined to be higher than the aerial part. The element contents of different species of the same genus were determined that were different from each other and some element contents were higher than the other species. Thus, it has been determined that the multi-element content of the samples belonging to different species of the same genus will vary depending on geographical location, climatic factors, air pollution, and environmental factors. The K and Na contents of M5 species can be said that be higher than the other species, and the mineral elements of this species are more beneficial to human health. The element contents of A3 (Fe, Al, Zn), C1 (Mg), and M2 (Cu) species are higher than other species and it can be said the macro and micro element contents of these species should be used carefully considering the negative relationship of the elements above the threshold concentration levels in terms of health. The Pb content of the A3 species was determined that be higher than the value determined by the WHO, and if this species is used, the toxic dose relationship should be considered.

Conflict of interests

The authors declare that there is no conflict of interest.

REFERENCES

1. Ceylan, S.; Cetin, S.; Camadan, Y.; Saral, O.; Ozsen, O.; Tutus, A. *Irish J. of Med. Sci.* **2019**, *188* (4), 1303–1309.

2. Özer, M. Ö.; Aksoy, M. *Turk. J. of Food and Agr. Sci.* **2019**, *1* (1), 18–23.

3. Amaryllidaceae, 2016. Encyclopedia Britannica of Database. https://www.britannica.com/plant/Amaryllidaceae (accessed March 29, 2020).

4. Karakoyun, Ç.; Masi, M.; Cimmino, A.; Önür, M. A.; Somer, N. U.; Kornienko, A.; Evidente, A. *Nat. Prod. Comm.* **2019**, *14* (8), 1934578X1987290.

5. Tanker, M.; Çitoglu, G.; Gümühel, B.; Hener, B. *Pharm. Bio.* **1996**, *34* (3), 194–197.

6. Kılınç, H.; Masullo, M.; Bottone, A.; Karayıldırım, T.; Alankuş, Ö.; Piacente, S. *Nat. Prod. Res.* **2019**, *33* (3), 335–339.

7. Iridaceae.2017. Encyclopedia Britannica of Database. https://www.britannica.com/plant/Iridaceae (accessed April 17, 2020).

8. Berry, P. E. Malvaceae, 2015. Encyclopedia Britannica of Database. https://www.britannica.com/plant/Malvaceae (accessed April 10, 2020).

9 Um"az, A.; Aydin, F.; Firat, M.; Ertas, A. *Dicle Üni. Fen Bil. Ens. Derg.* **2021**, *10* (1), 47–58.

10 Akyildiz, M. H.; Ertas, A. (2021), *J. of Res. in Pharm.* **2021**, *25* (4), 464 - 478.

11 Aygün, C.; Kara, İ.; Oral, H. H.; Erdoğdu, İ.; Atalay, A. K.; Sever, A. L. *Bahri Dağdaş Bitk. Araş. Derg.* **2018**, *7* (1), 51–65.

12 Filippidis, A.; Papastergios, G.; Kantiranis, N.; Michailidis, K.; Chatzikirkou, A.; Katirtzoglou, K. *Chemie der Erde* **2012**, *72* (1), 71–76.

13 Ozturk, M.; Altay, V.; Kucuk, M.; Yalçın, I. E. *Phyton* **2019**, *88* (3), 223–238.

14 Konstantinou, M.; Tsiripidis, I. In *Mineral Resources in a Sustainable Word,* 13th SGA Biennial Meeting, Nancy, France, Aug 24-27, 2015.

15 Mehrabi, B.; Alimohammadi, H.; Farhadian-Babadi, M.; Ghahramaninejad, F. *Geopersia* **2016**, *6* (2), 223–232.

16 Sun, H.; Wang, Z.; Gao, P.; Liu, P. *Acta Phy. Plant.* **2013**, *35* (2), 355–364.

17 Kaya, I.; Gülser, F. *Polish J. of Env. Stud.* **2018**, *27* (5), 2081–2087.

DOI: http://dx.doi.org/10.32571/ijct.1087834 E-ISSN: 2602-277X

18 Yener, İ. *Iğdır Üni. Fen Bil. Ens. Derg.* **2019**, *9* (3), 1492–1502.

19 Özer, M. Ö.; Aksoy, M. *Turk. J. of Food and Agr. Sci.* **2019**, *1* (1), 18–23.