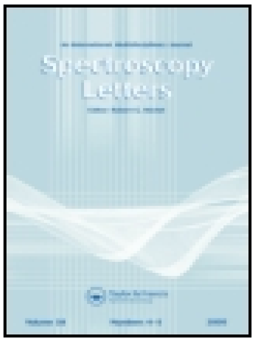

Spectroscopy Letters

An International Journal for Rapid Communication

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/lstl20

Concentrations of plant mineral nutrients and potentially toxic elements in some medicinal plants in the Asteraceae, Fabaceae, and Lamiaceae families from Southern Türkiye: insights into health implications

Faruk Karahan, Ibrahim Ilker Ozyigit, Ibrahim Ertugrul Yalcin, Asli Hocaoglu-Ozyigit, Bedriye Nazli Erkencioglu & Ahmet Ilcim

SPECTROSCOPY LETTERS
https://doi.org/10.1080/00387010.2023.2181358

Taylor & Francis
Taylor & Francis Group

Concentrations of plant mineral nutrients and potentially toxic elements in some medicinal plants in the Asteraceae, Fabaceae, and Lamiaceae families from Southern Türkiye: insights into health implications

Faruk Karahan[a], Ibrahim Ilker Ozyigit[b], Ibrahim Ertugrul Yalcin[c], Asli Hocaoglu-Ozyigit[b], Bedriye Nazli Erkencioglu[b] and Ahmet Ilcim[a]

[a]Department of Biology, Faculty of Science and Arts, Hatay Mustafa Kemal University, Hatay, Türkiye; [b]Department of Biology, Faculty of Science, Marmara University, Istanbul, Türkiye; [c]Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Bahcesehir University, Istanbul, Türkiye

ABSTRACT

Medicinal plants have been used throughout history in the treatment of many diseases in traditional Anatolian folk medicine as well as all over the world. The rapid increase in agricultural and industrial activities due to the increasing population around the world causes air, water and soil pollution, and accumulation of potentially toxic elements in medicinal plants. In this study, plant mineral nutrients and potentially toxic elements analyzes were carried out in 38 plant species belonging to the medicinally important families Asteraceae, Fabaceae and Lamiaceae. The percentage of macroelements (in %) varies between 0.20 and 1.46 for calcium, 0.08 and 1.35 for potassium, 0.04 and 0.24 for magnesium, 0.01 and 0.34 for sodium, while concentrations of microelements and potentially toxic elements (in mg kg^{-1}) vary between 3.21 and 721.28 for aluminum, 41.33 and 231.01 for boron, 0.01 and 0.61 for cadmium, 1.09 and 47.79 for chromium, 12.90 and 43.13 for copper, 17.75 and 1109.39 for iron, 51.50 and 715.48 for manganese, 0.12 and 9.42 for nickel, 1.58 and 22.11 for lead and finally 80.82 and 260.08 for zinc. In addition, estimated daily intake (EDI), target hazard quotient (THQ), and hazard index (HI) for potentially toxic elements, and Recommended Dietary Allowance (RDA) values for mineral nutrients were calculated. In some samples in industrial and mining areas, accumulation of some potentially toxic elements was slightly above the permissible limits set by the World Health Organization (WHO). In Summary, the importance of collecting medicinal plants from protected areas such as mountainous rural areas, far from mining, close to clean rivers, and regular control of values with potentially toxic elements analyzes for human health has been understood once again.

ARTICLE HISTORY
Received 2 September 2022
Accepted 8 February 2023

KEYWORDS
Dietary intake; ethnobotany; human health risk; phytoaccumulation; trace element

Introduction

Although the use of plants for medicinal purposes in traditional treatment methods in history has lost its former value due to technological developments, the demand for natural products has increased especially in recent years due to the discovery of their medicinal properties and the avoidance of chemical side effects of drugs. It is known that 80% of the world's population benefits from medicinal plants against diseases and more than 80,000 medicinal and aromatic plants (MAPs) are used for medicinal purposes.[1,2]

Asteraceae, Fabaceae and Lamiaceae families are the most important plant families used in the treatment of various diseases in traditional folk medicine worldwide due to their medicinal properties.[3] Asteraceae is the largest family of flowering plants, including 1623 genera and approximately 24,700 species spread all over the world except Antarctica.[4] Many plant species such as chamomile (*Matricaria recutita* L.), yarrow (*Achillea millefolium* L.), dandelion (*Taraxacum* L.) or wormwood (*Artemisia absinthium* L.), which are members of the family, are the most widely used plants in Taiwanese folk medicine, Korean herbal medicine, Chinese medicine, Nepalese medicine, Indian Ayurveda medicine and anatolian folk medicine since they contain essential oils, polyphenols, phenolic acids, flavonoids, diterpenoids, lignans, saponins, sterols

CONTACT Faruk Karahan fkarahan@mku.edu.tr Department of Biology, Faculty of Science and Arts, Hatay Mustafa Kemal University, Hatay, Türkiye; Ibrahim Ilker Ozyigit ilkozyigit@marmara.edu.tr Department of Biology, Faculty of Science, Marmara University, Istanbul, Türkiye.

and polysaccharides.[5] In addition, species such as artichokes, lettuce, salsify, and sunflower have been cultivated as edible and medicinal purposes for nearly 3000 years since they are a rich source of Ca, K, Mg, Na and vitamins A, B, C and D. They are also used as cooking oils, leaf vegetables, sweetening agents, coffee substitutes and herbal teas.[6,7]

Fabaceae is the third largest land plant family worldwide, with 751 genera and almost 19,500 species.[4] The family is one of the most economically important cereal groups for world agriculture after the Poaceae family.[8] Legume seeds are preferred more than other grain products due to their rich protein content and are seen as a food source with high nutritional value (Food and Agriculture Organization [FAO] http://www.fao.org/pulses-2016/en/). In the family, there are many species used as ornamental plants as well as food, agricultural, chemical, and medicinal drugs, lumber, paint, varnish, lacquer, glue, feed, green manure production, which are very important for humans and animals.[9]

Lamiaceae family is a family known as medicinal plant since ancient times and consists of approximately 245 genera and 7886 species, most of which are distributed in the Mediterranean basin.[10] Taxa belonging to the family such as *Salvia* L., *Scutellaria* L., *Stachys* L., *Plectranthus* L'Hér., *Hyptis* Jacq., *Satureja* L., *Teucrium* L., *Vitex* L., *Thymus* L., and *Nepeta* L. are used in areas such as medicine, food, cosmetics, flavoring, fragrance, perfumery, pesticide, and pharmaceutical industries due to chemical compounds in their leaves such as essential oils, aromatic compounds, alkaloids, saponins, flavonoids, glycosides, and phenols. In addition, basil (*Ocimum* spp.), mint (*Mentha* × *piperita* L.), rosemary (*Rosmarinus officinalis* L.), sage (*Salvia officinalis* L.), savory (*Satureja hortensis* L.), marjoram (*Origanum majorana* L.), oregano (*Origanum vulgare* L.), thyme (*Thymus vulgaris* L.), lavender (*Lavandula angustifolia* Mill.) and perilla (*Perilla frutescens* (L.) Britton) are grown for culinary purposes.[11,12]

Especially after the 19th century, due to rapid urbanization, industrialization and population growth with the industrial revolution, the increased mining, urban or industrial solid, gas and liquid wastes, pesticide and artificial fertilizer use, paint industry, and exhaust gases have been causing the release of excessive potentially toxic elements to the nature and destruction of natural habitats.[13–15] Some of potentially toxic elements are heavy metals, which pose a serious threat to natural habitats, are elements that have toxic effects on many living organisms through the food chain by threatening air, water and soil resources.[16,17]

Heavy metals are elements and their ions with a specific gravity greater than 5 g/cm^3, and they belong to a large group defined as the transition elements of the periodic table. Some of the heavy metals are defined in agriculture as trace elements or micronutrients.[18] Heavy metals, such as copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn), are considered essential trace elements or mineral nutrients for various biochemical and physiological functions in plants whereas, As, Cd, Hg and Pb can cause harmful and toxic effects for both plants and their consumers even at low concentrations.[19,20] Toxicity levels may differ according to potentially toxic element and organism type.[21] In addition to natural areas, medicinal plants grown in industrial areas, roads and fields, and around polluted water beds are contaminated by various polluting sources.[13,22] Among these potentially toxic elements, especially As, Cd, Cr, Ni and Pb accumulated in the plant, they can pass directly or indirectly to animals and humans, causing cardiovascular diseases, digestive, excretory, nervous, and respiratory system diseases, cancer and even death.[23–25] It is, therefore, important to be alert to potential sources of contamination in the areas where the medicinal plants are collected, to collect the medicinal plants from safe areas that are known to be clean and protected, to take the necessary precautions in places that may cause possible contamination such as packaging, transportation and storage and presentation stages when reaching the consumer. In addition, it is necessary to carry out potentially toxic element analyzes on medicinal plants at the stage of consumption at regular intervals.

The aim of this study was to determine the levels of some potentially toxic elements including chromium (Cr), cadmium (Cd), and lead

(Pb), major and minor elements such as aluminum (Al), boron (B), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), copper (Cu*), iron (Fe*), manganese (Mn*), nickel (Ni*), and zinc (Zn*) (elements indicated with "*" are both essential elements and heavy metals) in 38 plant taxa belonging to the families Asteraceae, Fabaceae and Lamiaceae, which are widely used in the Eastern Mediterranean region of Türkiye. In this study, not only estimated daily intake (EDI), target hazard quotient (THQ), and hazard index (HI) for potentially toxic elements and Recommended Dietary Allowance (RDA) values were calculated for mineral nutrients but also potentially toxic element levels in the medicinal plants were evaluated by comparing the obtained concentrations with the standard levels for potentially toxic elements published by the Food and Agriculture Organization & World Health Organization (FAO/WHO), the American Herbal Products Association (AHPA) and other relevant organizations.

Due to many trace elements that play an important role in the formation of active substances responsible for their medicinal properties, it is very important to have information about mineral nutrients and potentially toxic element contents in medicinal plants. In addition, these medicinal plants can be potentially beneficial or dangerous to people who consume these economically important plants. As a result, the current status of these widely consumed medicinal plants and whether they are suitable for consumption, and their potential as food supplements in terms of the essential plant nutrients they contain were investigated.

Materials and methods

Study area and sampling

The plant samples used in this study were collected from the province of Hatay and surroundings located in the southeastern part (35°48′–37°00′N/35°46′–36°41′ E) of Türkiye. Due to the rich geographical, topographic and ecological conditions, approximately 2000 plant taxa are distributed in the city.[21,26] In addition, since many civilizations and cultures have lived in this region throughout history, there is a rich ethnobotanical heritage in this region that has been handed down from generation to generation.[27,28]

In this study, 38 plant taxa (29 perennials and the others annuals) belonging to the families of Asteraceae (9 plants), Fabaceae (10 plants) and Lamiaceae (19 plants), which contain many medicinal and aromatic plant species in the flora of Türkiye and the world, were collected from their natural habitats in the eastern Mediterranean region of Türkiye (South-eastern part of Türkiye) (Figure 1). The taxonomic identifications of the collected plants were made according to the relevant literature[30,31]. Scientific and local names of the plant species, the parts used, and their purpose of use are given in Table 1.

Among the species investigated, Mediterranean and Irano-Turanian (12 taxa each) phytogeographic elements are most represented, followed by Euro-Siberian (5 taxa) and East Mediterranean elements (4 taxa). While 5 taxa show a cosmopolitan feature, the phytogeographic origins of the remaining taxa are unknown.

Among the studied plant species, *Astragalus schizopterus* Boiss, *Salvia pilifera* Montbret & Aucher ex Bentham, *Salvia recognita* Fisch. & Mey., *Stachys cretica* L. ssp. *mersinaea* and *Stachys rupestris* Montbret et Aucher ex Bentham are endemic to Türkiye. In addition, among these species, *Mentha longifolia* and *Thymus eigii* are commercially cultivated (Table 1).

Determination of mineral content and sample analysis

Plant samples were transferred to sterile bags and brought to the laboratory and dried in petri dishes in an oven at 80 °C for 48 h. Plant samples were powdered in a porcelain mortar and weighed. Following that, samples in the range of 0.200–0.250g were transferred to Teflon wessels with 8 mL of 65% Merck brand HNO_3. The prepared samples were thawed using a Berghof-MSW2 brand microwave device. After the procedure, the samples were transferred to 50 mL sterile falcon tubes using ultrapure water, filtered with a blue band Whatman filter. Afterwards, the total volume was made up to 50 mL. In the

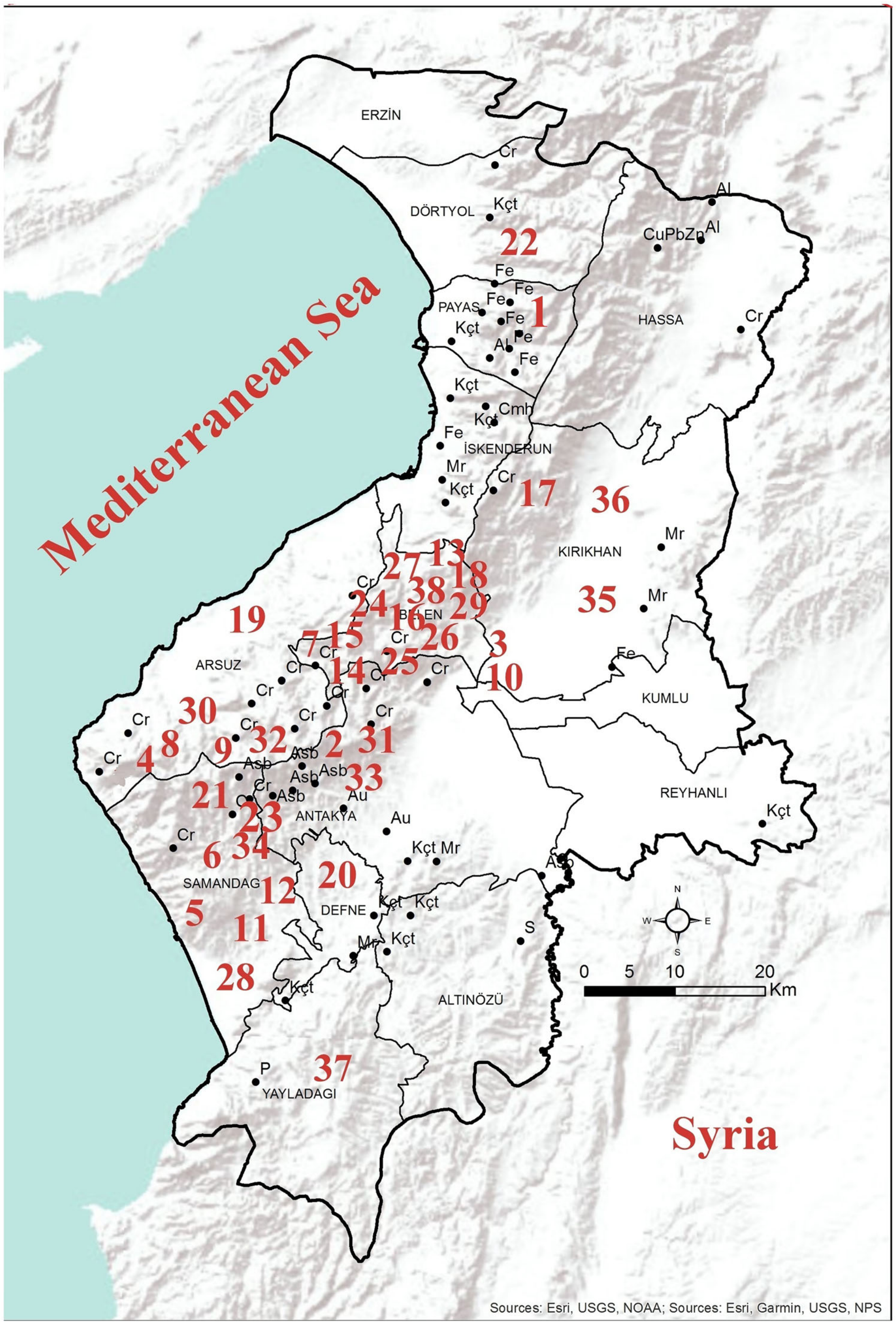

Figure 1. Map showing the distribution and sampling localities of the studied medicinal plants and mineral maps of the study area modified from MTA[29].

samples prepared for measurement, macroelements (Ca, K, Mg, and Na) were measured as percent (%) and others elements (Al, B, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) were measured as mg kg^{-1} dry weight in inductively coupled plasma optical emission spectroscopy (ICP-OES) PerkinElmer-Optima 7000DV brand model device.[20]

Quality control and assurance

The chemicals used in this study were of analytical grade. As in all stages of the experiments, ultrapure water (Human-Zeener Power I) was used as a solvent in dilution processes. Elemental values of medicinal plant samples were investigated in triplicate to ensure linearity and all

Table 1. Ethnobotanical properties and localities of medicinal herbs belonging to studied three families.

No	Taxa	Chorotypes/ Life forms	English and local names	Used parts	Ethnobotanical properties	Locality
	Asteraceae					
1	*Bellis perennis* L.	ES/P	Common daisy/Yoğurt Otu	Aerial parts	Against bruises and wounds, measurement of postpartum blood loss[32,33]	Payas
2	*Bellis sylvestris* Cyr.	MA	Southern daisy/Çayır Papatyası	Aerial parts	Wounds, bruises, broken bones, sore throat, headache, stomach ache, common cold, eczema, diarrhea, peptic ulcer, gastritis, rheumatism, asthma, hemorrhoids and as a vulnerary, expectorant and laxative[33,34]	Kızıldağ
3	*Cnicus benedictus* L.	İR/A	St. Benedict's thistle/Mübarek dikeni	Aerial parts	Appetizing, diuretic, antipyretic, sedative, against kidney stones and hemorrhoids[35,36]	Topboğazı
4	*Crupina crupinastrum* (Moris) Vis.	M/A	Southern Crupina/Gelind öndüren	Aerial parts	Antiinflammatuar, Infections, wound healing, antifungal[37–39]	Arsuz
5	*Eupatorium cannabinum* L.	ES/P	Hemp-agrimony Sıtma otu	Aerial parts	Antiinflammatuar, antipyretic, laxative, diuretic, hypocholesterolemic, agains hepatitis, headache, diarrhea, diabetes mellitus, hypertension, psoriasis, eczema, boils[40,41]	Samandağ
6	*Inula crithmoides* L.	İR/P	Golden samphire/Bozot	Aerial parts	As astringent, for bronchitis, tuberculosis, anemia, malaria, and urinary diseases[42]	Samandağ
7	*Leontodon crispus* Vill. subsp. *asper.* var. *setulosus*	IN/P	Hawkbits/Aslandişi	Aerial parts	Antiinflammatuar, antitumoral, diuretic, bile stimulant[43,44]	Belen
8	*Pallenis spinosa* (L.) Cass.	M/A	Spiny Starwort Yıldızotu	Aerial parts	Astralgia, inflammatory contusions, skin injuries, and mouth infections[45]	Arsuz
9	*Scorzonera kotschyi* Boiss	IR/P	Viper's-grass/Teke Sakalı	Aerial parts	Agains atherosclerosis, high blood pressure, diabetes and kidney disorders, and used as antioxidant[26,35]	Arsuz
	Fabaceae					
10	[a]*Astragalus schizopterus* Boiss	M/P	Milkvetch/Mor geven, Kediçomağı	Aerial parts	Antimicrobial, protecting the liver, boosting the immune system in chemotherapy, expectorator and for coughing, against cardiovascular diseases and diabetes[26,46]	Topboğazı
11	*Genista lydia* Boiss	M/P	Common woadwaxen/Geyik Borçağı	Flowering branches	Menopausal symptoms, and estrogen-related diseases, and cardiovascular diseases, diuretic, diaphoretic and laxative[35,47]	Samandağ
12	*Lathyrus aphaca* L. var. *aphaca*	M/A	Yellow pea/İmirdik	Aerial parts	Agains urinary tract infections, diuretic, aphrodisiac, tonic, epileptic, sedative[26]	Samandağ
13	*Lathyrus variabilis* (Boiss. and Ky.) Maly	EM/P	Sweet Peas Burçak	Aerial parts	Agains urinary tract infections, used as diuretic, sedative, and anti-jaundic[26]	Atik
14	*Onobrychis caput-galli* L. Lam.	M/A	Sainfoin Küçük korunga	Aerial parts	For the development of secondary characters in women and killing cancer cells[48]	Belen
15	*Onobrychis gracilis* BESSER	IN/P	Sainfoin Kuyruk Yaran	Aerial parts	Agains cold and flu[49]	Belen
16	*Ononis spinosa* L.	IN/P	spiny restharrow Kayışkıran	Aerial parts	Agains kidney stones, skin diseses (eczema and wounds), used as diuretic[49]	Atik
17	*Ononis viscosa* L. *ssp. breviflora* (DC.) NYMAN	M/A	Sticky Restharrow/Yapışkan Otu	Aerial parts	Diuretic, antifungal, anti-inflammatuar, antipyretic[50]	Ceylanlı
18	*Pisum sativum* L. ssp. *elatius*	M/A	The pea/Yaban Baklası	Aerial parts	For reduce blood sugar, antioxidant, antimicrobial, liver protective[51]	Soğukoluk
19	*Vicia cracca* L. subsp. *stenophylla*	ES/P	tufted vetch/ Dağ yoncası	Aerial parts	Burns and hemorrhoid[52].	Nergizlik
	Lamıaceae					
20	*Calamintha grandiflora* (L.) Moench.	ES/P	showy calamint/Dağ nanesi	Leaves	Pain reliever, antiseptic, diaphoretic and expectorant, strengthens the central nervous system, agains stomach and sore throat and kidney disorders[53]	Defne
21	*Lavandula stoechas* L. ssp. *stoechas* L.	M/P	Spanish lavender Lavanta, Karabaş otu	Flowering branches	Expectorant, menstrual regular, antispasmodic and carminative[27,54]	Karaçay
22	*Mentha longifolia* (L.) Hudson	IR/P (ϕ)	Horse mint/Nane Yarpuz	Aerial parts	Antiseptic, appetizer, carminative, gas remover, cold, cough, fever, sore throat, tonsillitis, grib, hair loss, headache, hemorrhoids, intestinal ailments (for babies), menstrual pain, nausea and vomiting, rash and other skin, shortness of breath, stomach ache, sunstroke[27,55–59]	Dörtyol
23	*Mentha pulegium* L.	IN/P	Squaw mint/Nane Otu	Aerial parts	Antiseptic, digestive, diuretic, energizing, expectorant, insecticidal, menstrual regulator,	Karaçay

(*continued*)

Table 1. Continued.

No	Taxa	Chorotypes/ Life forms	English and local names	Used parts	Ethnobotanical properties	Locality
					asthma, cold, throat affection, and flu, diarrhea, indigestion stomach aches[60–64]	
24	*Nepeta betonicifolia* C.A. Meyer.	IR/P	Catmint/Kedi Nanesi	Aerial parts	Agains eczema, stomach diseases, colds, coughing, cancers, rheumatism, used as diuretic, wound healing[26,65]	Belen
25	*Nepeta nuda* L. ssp. *albiflora* (BOISS.) GAMS	IN/P	Naked catmint/Pisik Otu	Aerial parts	Asthenia, syphilis fever, used as anti-asthma, analgesic, antiseptic, antipyretic, diuretic, spasmolytic, wound healing, bronchodilator, antioxidant, antibacterial[47,66–68]	Belen
26	*Salvia multicaulis* Vahl.	IR/P	Many stemmed sage/Adaçayı, Dağ Reyhanı	Whole plant	Anorexia, respiratory and urinary tract disorders, weakness, cough, stomach diseases, kidney stones, asthma, throat inflammation, pharyngitis, bronchitis, diabetes, tonsil infection, indigestion, pain, cold, natural antibiotic, sedative[69]	Belen
27	*Salvia palestina* Bentham	IR/P	Palestine/İğneli Adaçayı	Aerial parts	Antimicrobial, wound healing, antitumoral[70,71]	Belen
28	[a]*Salvia pilifera* Montbret and Aucher ex Bentham	IR/P	Sage/Mor Adaçayı	Aerial parts	Agains alzheimer's and nerve damage, used as antibacterial and antioxidant[72,73]	Samandağ
29	[a]*Salvia recognita* Fisch. and Mey.	IR/P	Turkish Cliff Sage/Yaygın Adaçayı	Aerial parts	Agains cold, antibacterial, antifungal, antioxidant, antiseptic, carminative, diuretic, spasmolytic, stomachic, diaphoretic[74,75].	Belen
30	*Salvia tomentosa* Miller. (A)	M/P	Balsamic Sage/Şalva	Aerial parts	analgesic, antiseptic, antimicrobial, antioxidant, antiseptic, stimulant, stomachic, gas removed, tonic, vasoconstrictor in bleeding, wound healing, bronchitis, dyspepsia, febrifuge, cough, hypoglycemia, kidney stone, laryngitis, pharyngitis, uterine cancer, vaginitis[58,76–78].	Arsuz
31	*Salvia verticillata* L. ssp. *amasiaca* (FREYN ET BORNM.) BORNM.	IR/P	The lilac sage/Dadırak, Karabaş	Aerial parts	Agains cold and nausea, stomachic, analgesic, antimicrobial, wound healing, antioxidant, antiseptic, laxative, vasoconstrictor in bleeding, toothache[59,62,79,80].	Kızıldağ
32	*Satureja thymbra* L.	M/P	Savory of Crete/Taşkıran	Aerial parts	Antioxidant, antitumor, antimicrobial, analgesic, antifungal, blood purifying, nephropathy, antiseptic, antidiarrheal, cardiotonic, antispasmodic, anti-inflammatory, stomachic angiogenic, antiparasites, for flu, cough, sickness, and gingivitis. Also it use as spice[77,81–83].	Arsuz
33	[a]*Stachys cretica* L. ssp. *mersinaea*	EM/P	Cretan hedgenettle/Deli Adaçayı Ballıbaba	leaves	Agains colds, hypertension, upper respiraroty diseases, stomach aches, constipation, weakness, high blood pressure, used as antifungal, antimicrobial, antifungal, wound healing[10,79,84,85].	Kızıldağ
34	[a]*Stachys rupestris* Montbret et Aucher ex Bentham	EM/P	Marsh woundwort/Kestere	Aerial parts	Agains anorexia, genital tumors, sclerosis of the spleen, inflammatory tumors and cancerous ulcers, kidney disorders, skin infections, respiratory diseases, stomach ailments, used as antibacterial, antioxidant, antipyretic, antispasmodic, diuretic, sedative, digestive, carminative, tonic, throat pain reliever[86–88]	Samandağ
35	*Teucrium chamaedrys* L.	ES/P	The wall germander/Kısamahmut	Aerial parts	For coughs, asthma, diabetes, abscesses, conjunctivitis, cellulite, weakness, fissure on fingertips, hemorrhoids, stomachic and gastric pains, inflammations, heart diseases, intestinal colic, kidney diseases, and chapped, used as antirheumatic, digestive, antipyretic, appetizing antihelmintic, astringent, anti-rheumatic, diuretic, antiseptic, antimalarial, antispasmodic[89–91]	Alan plateau
36	*Teucrium polium* L.	IR/P	Felty germander/Peryavşan Mayasıl otu	Aerial parts	Agains stomach pain, diabetes, abortion, body and joint pains, carminative gynaecological, infections, menstruation disorders, toothache, rheumatic complaints[92]	Gölbaşı
37	*Thymus eigii* (M.Zohary and P.H.Davis) Jalas	EM/P (ϕ)	Thyme/Kekik	Aerial parts	Increasing bile, soothing, stomachic, disinfectant, antiseptic, reducing intestinal worms, stimulating blood circulation, stimulative, expectorant and relaxing[35,93,94]	Yayladağı
38	*Ziziphora capitata* L.	IR/A	Wild basil Dağ Reyhanı	Aerial parts	Stomach aches, gas spasm, skin wounds, gastric, cough, sore throat, hypertension, diuretic, intestinal worms, regulating the operation of the heart, spasmolytic, antiseptic,[77,85,94,95]	Belen

ES: Euro-Siberian; EM: East Mediterranean; IN: Imperfectly Known; IR: Irano-Turanian; LF: Life form; M: Mediterranean; P: Perennial; PO: Phytogeographical origin A: Annual; [a](Endemic).

Table 2. ICP-OES parameters of the analytical method.

Elements	Spectral lines (nm)	Plasma torch (position)	LoD (mg kg^{-1})	LoQ (mg kg^{-1})	RSD (%)	R^2
Al	396.153	Axial	0.093	0.310	0.92	.999385
B	249.677	Axial	0.026	0.087	0.88	.999593
Ca	317.933	Radial	0.722	2.407	0.97	.999735
Cd	228.802	Axial	0.006	0.020	1.22	.999649
Cr	267.716	Axial	0.021	0.070	1.25	.999892
Cu	327.393	Axial	0.034	0.113	1.72	.999884
Fe	238.204	Axial	0.217	0.723	1.04	.999449
K	766.490	Radial	0.305	1.017	0.85	.999792
Mg	285.213	Radial	0.271	0.903	1.33	.999653
Mn	257.610	Axial	0.095	0.317	1.51	.999796
Na	589.592	Radial	0.138	0.460	1.97	.999892
Ni	231.604	Axial	0.008	0.027	0.71	.999611
Pb	220.353	Axial	0.013	0.043	0.82	.999756
Zn	213.857	Axial	0.154	0.513	1.15	.999825

LoD: limit of detection; LoQ: limit of quantification; RSD: relative standard deviation; R^2: determination coefficient.

elemental concentrations were determined with a quite low margin of error of ±0.71–1.97% (RSD) using previously prepared calibration standards (Table 2). In order to dissolve plant samples, the EPA 3051 A Analytical Method for ICP-OES was applied with Mars Microwave. Contents of Al, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn of the samples were investigated by ICP-OES (PerkinElmer Optima 7000DV). The benefits of ICP are providing few or no organic molecules, few ionization interferences, as well as the ability to analyze many elements sequentially.[96] Calibration standards were prepared by diluting 1000 mg L^{-1} of ICP multi-element standard solution (Merck) to calculate the concentration values of each element examined for plant samples. Calibration curves were obtained by using calibration standards prepared in eight different concentrations for each element and $R^2 > 0.999$ was found (Table 2). Following the first calibration, the calibration standards were remeasured every ten samples during the experiments and the margins of error were controlled to verify that the early measured calibration parameters stayed steady during the analysis.

Additionally, the accuracy and consistency of elemental analyzes is demonstrated by repetetive analyzes of multi-element calibration solutions with previously known concentrations. LoD (Limit of Detection) and LoQ (Limit of Quantification) values were detected by analyzing blank solutions and then calculated for each of the elements (Table 2):

$$LoD = \emptyset_n \times SD,$$

$$LoQ = \emptyset_q \times SD.$$

In the equations given above, the term SD represents the standard deviation of ten replicates of the blank solution, whilst the values $\emptyset_n$ and $\emptyset_q$ represent multiplying factors of 3 and 10.[97,98] In order to detect the elemental compositions of the samples, spectral lines were picked according to the related literature as listed in Table 2.[98–100]

Risk assessment for toxic metals (Cd-Cr-Ni-Pb)

Exposures of Cd, Cr, Ni and Pb, which threatens lives of consumers through the consumption of plant leaves, were evaluated in accordance with the estimated daily intake (EDI), target hazard quotient (THQ), and hazard index (HI).[101]

$$\mathrm{EDIn} = (\mathrm{Cn} \times \mathrm{IR} \times \mathrm{TRn})/(\mathrm{BW} \times 1000);\ \mathrm{n} = \mathrm{Cd} - \mathrm{Cr} - \mathrm{Ni} - \mathrm{Pb} \tag{1}$$

In this equation above: Cn represents the toxic metal concentrations of the samples (mg kg^{-1}); n represents the toxic metals (Cd-Cr-Ni-Pb); IR represents the uptake rate of the plant for an adult (11.4 g/person/day); TRn represents the transference rate of the toxic metal; and BW means the body weight (70 kg of an adult).[101,102] The TR values used are 6.6% for Cd, 42% for Cr, 30% for Ni and 19.8% for Pb, respectively.[101,103,104]

$$\mathrm{THQn} = \mathrm{EDIn}/\mathrm{RfDn};\ \mathrm{n} = \mathrm{Cd} - \mathrm{Cr} - \mathrm{Ni} - \mathrm{Pb} \tag{2}$$

THQ was used for the quantitative assessment of the potential non-carcinogenic effects of each toxic metal.[101] A THQ value less than 1 shows no significant risk of carcinogenicity for the exposed population. RfDn (mg/kg/day) for each metal (n) represents the reference dose defined by the FAO/WHO. EDIn represents the daily average exposure dose (mg/kg/day) and THQn represents the target hazard quotient of the toxic metal. The combined risk of multiple toxic metals on overall human health with the consumption of medicinal plants may result from exposure to multiple pollutants. Thus, the Hazard Index (HI) was used to forecast the total health hazards that are carcinogenic caused by exposure to various toxic metals.

$$HI = \Sigma THQn = THQCd + THQCr + THQNi + THQPb \quad (3)$$

In this equation, HI shows the total health risk associated with exposure to toxic metals. A HI value less than 1 represents those adverse effects of toxic metals on human health are unlikely to arise. In opposition, if the HI value is greater than 1, the toxic metals are high likely to cause negative effects on human health.

Statistical data analysis and evaluation of recommended dietary allowance values

"Hierarchical Cluster Analysis" and "Pearson Correlation" were performed using IBM SPSS Statistics 20 software. The levels of correlation statistical significance were expressed as 0.01 (**) and 0.05 (*) levels (2-tailed). Based on the similarity/dissimilarity relationships obtained between plant species, a dendrogram was constructed using total potentially toxic element accumulation and essential element levels in all plant specimens studied. Additionally, in order to reveal the Dietary Reference Intake potentials of *P. sativum, M. longifolia, M. pulegium, S. multicaulis, T. eigii* and *Z. capitata* species used as daily food, spice and tea among the plants examined in this study, Recommended Dietary Allowance (RDA) values were calculated for Ca, Cu, Fe, K, Mg, Mn, Na ve Zn elements.[21,105]

$$RDA(\%) = (MV/10) \times (100/RDAst)$$

In this equation: RDA (%) is Recommended Dietary Allowance percentages in 100 g/dw; MV is mineral nutrient values in studied the plant samples (mg kg^{-1}; ppm); RDAst is international standards (mg per 100 g/dw).

Results and discussion

As a result of the analyzes in the examined MAPs, the percentages of macroelements ranged between 0.197% (*C. crupinastrum*) and 1.297% (*E. cannabinum*) in Asteraceae, 0.240% (*L. variabilis*) and 1.092% (*O. spinosa*) in Fabaceae, and 0.242% (*L. stoechas*) and 1.464% (*S. palaestina*) in Lamiaceae for Ca; 0.290% (*C. crupinastrum*) and 1.268% (*S. kotschyi*) in Asteraceae, 0.081% (*V. cracca*) and 1.354% (*O. spinosa*) in Fabaceae, and 0.277% (*S. thymbra*) and 1.181% (*N. nuda*) in Lamiaceae for K; 0.043% (*C. crupinastrum*) and 0.240% (*I. crithmoides*) in Asteraceae, 0.042% (*V. cracca*) and 0.181% (*O. spinosa*) in Fabaceae, and 0.051% (*S. rupestris*) and 0.183% (*L. stoechas*) in Lamiaceae for Mg; 0.029% (*C. crupinastrum*) and 0.344% (*I. crithmoides*) in Asteraceae, 0.022% (*O. gracilis*) and 0.246% (*V. cracca*) in Fabaceae, and 0.013% (*S. multicaulis*) to 0.175% (*M. pulegium*) in Lamiaceae for Na; the levels of other elements and potentially toxic metals (mg kg^{-1}) varies between 3.206 (*C. crupinastrum*) to 721.281 (*L. crispus*) in Asteraceae, 5.290 (*L. variabilis*) to 189.407 (*O. caput-galli*) in Fabaceae, and 8.436 (*T. eigii*) to 408.608 (*M. pulegium*) in Lamiaceae for Al; 41.332 (*B. sylvestris*) to 231.012 (*I. crithmoides*) in Asteraceae, 46.193 (*V. cracca*) to 152.207 (*O. spinosa*) in Fabaceae, and 45.430 (*S. tomentosa*) to 160.052 (*T. chamaedrys*) in Lamiaceae for B; 0.030 (*I. crithmoides*) to 0.390 (*P. spinosa*) in Asteraceae, 0.013 (*O. spinosa*) to 0.418 (*O. caput-galli*) in Fabaceae, and 0.013 (*S. tomentosa*) to 0.607 (*S. rupestris*) in Lamiaceae for Cd; 1.088 (*C. crupinastrum*) to 40.820 (*L. crispus*) in Asteraceae, 1.118 (*V. cracca*) to 22.544 (*O. caput-galli*) in Fabaceae, and 1.966 (*S. cretica*) to 47.790 (*S. tomentosa*) in Lamiaceae for Cr, 19.320 (*C. crupinastrum*) to 43.129 (*S. kotschyi*) in Asteraceae, 17.372 (*L. aphaca*) to 36.309 (*G. lydia*) in Fabaceae, and 12.904 (*T. eigii*) to 37.824 (*S. cretica*) in Lamiaceae for Cu; 17.571 (*C. crupinastrum*) to 1109.385 (*L. crispus*) in Asteraceae, 47.746 (*P. sativum*) to 1087.935 (*O. caput-galli*) in Fabaceae, and 68.453 (*T. eigii*) to 900.740 (*T. polium*) in Lamiaceae for Fe; 65.908 (*C. crupinastrum*) to 715.478 (*L. crispus*) in Asteraceae, 61.715 (*O. gracilis*) to 378.250 (*O. caput-galli*) in Fabaceae, and 51.502 (*S. recognita*) to 542.884

(*M. longifolia*) in Lamiaceae for Mn; 0.570 (*I. crithmoides*) to 7.643 (*B. perennis*) in Asteraceae, 0.997 (*O. gracilis*) to 8.931 (*G. lydia*) in Fabaceae, and 0.118 (*C. grandiflora*) to 9.416 (*T. eigii*) in Lamiaceae for Ni; 2.790 (*C. crupinastrum*) to 12.267 (*B. perennis*) in Asteraceae, 1.583 (*L. variabilis*) to 20.488 (*A. schizopterus*) in Fabaceae, and 1.749 (*C. grandiflora*) to 22.112 (*N. betonicifolia*) in Lamiaceae for Pb and 96.458 (*I. crithmoides*) to 260.084 (*L. crispus*) in Asteraceae, 94.812 (*O. gracilis*) to 208.576 (*A. schizopterus*) in Fabaceae, and 80.822 (*S. recognita*) to 191.061 (*N. betonicifolia*) in Lamiaceae for Zn (mg kg^{-1}) (Table 3).

Furthermore, the results of our study were compared with the permissible limits set for medicinal plants by FAO/WHO and the American Herbal Products Association (AHPA). It was determined that the potentially toxic element concentrations determined in the study materials were mostly within permissible limits.[22,106–116]

In addition to Türkiye, some countries such as Brazil, Canada, China, Germany, India, Malaysia, Singapore, European Union, the United Kingdom and Thailand have implemented their own programmes to ensure safe plant-based production regarding the potentially toxic element content (Table 4).

When evaluated in terms of permissible values including Türkiye; value of Al was higher than permissible values in *B. perennis* and *L. crispus* (Asteraceae), *M. pulegium* (Lamiaceae), and *O. caput-galli* (Fabaceae) taxa, while it was normal in other taxa; value of Cd was slightly higher than permissible values in *S. rupestris* (Lamiaceae), while it was normal in all others; value of Cr was higher than permissible values in *S. tomentosa, M. pulegium,* and *T. polium* (Lamiaceae), *L. crispus, B. perennis, B. sylvestris, C. benedictus* (Asteraceae), *O. caput-galli* (Fabaceae), while it was normal in others; value of Cu was slightly higher than permissible values in *S. kotschyi* and *C. benedictus* (Asteraceae), *S. cretica* (Lamiaceae), *G. lydia* (Fabaceae), while it was normal in others; value of Fe was higher than permissible values in *L. crispus*, *B. perennis B. sylvestris* (Asteraceae), *T. polium, S. tomentosa, M. pulegium, S. palestina, N. betonicifolia, N. nuda, S. thymbra, Z. capitata, C. grandiflora*, and *S. multicaulis* (Lamiaceae), *O. caput-galli* and *L. aphaca* (Fabaceae), while it was normal in others; value of Mn was slightly higher than permissible values in *L. crispus* (Asteraceae), *M. longifolia, M. pulegium*, *S. tomentosa* (Lamiaceae), and *O. caput-galli* (Fabaceae), while it was normal in others; value of Ni was higher than permissible values in *T. eigii, M. pulegium, S. cretica, S. recognita, S. verticillata, T. polium, Z. capitata* (Lamiaceae), *B. perennis* (Asteraceae), and *G. lydia*, *L. variabilis*, *O. caput-galli, O. viscosa* (Fabaceae), while it was normal in others; value of Pb was slightly higher than permissible values in *N. betonicifolia, S. cretica, S. palestina*, *M. pulegium*, *Z. capitata* (Lamiaceae), *A. schizopterus, L. aphaca, O. viscosa, O. gracilis, O. caput-galli* taxa (Fabaceae), and *B. perennis* (Asteraceae), while it was normal in others; value of Zn was slightly higher than permissible values in *B. sylvestris, E. camabinum*, *L. crispus* (Asteraceae), *N. betonicifolia, N. nuda*, *L. stoechas*, *S. palestina*, *M. pulegium*, *T. polium* and *S. thymbra* (Lamiaceae), *A. schizopterus*, *O. spinosa, O. viscosa, G. lydia* (Fabaceae), while it was normal in other taxa (Table 3).

On the map of Hatay mines of MTA, it is seen that there is a Cr mine in Kızıldağ, there are iron and steel, fertilizer, cement and paint factories in the Payas-İskenderun region, Arsuz has soils rich in Cr and Kırıkhan has Fe deposits.[29] According to our results, while *B. sylvestris* and *B. perennis* distributed in these regions have high Cr content; *L. crispus* and *O. caput-galli* species have high Al, Fe, Cr; *N. betanicifolia*, *N. Nuda*, *S. muticaulis* and *S. palestina* species are seen to have high Fe content (Fig. 1 and Table 3).

Our results revealed that the concentrations of Cr in *B. sylvestris*, *C. benedictus*, *L. crispus*, *O. caput-galli*, *M. pulegium*, *S. tomentosa*, and *T. polium*, the concentrations of Fe in *B. perennis* and *M. longifolia*, the concentrations of Pb in *B. perennis*, *A. schizoxopterus*, *O. caput-galli*, *O. gracilis*, *O. viscosa*, *S. palestina*, *S. cretica*, *Z. capitata* and the concentrations of Ni in *B. perennis, C. benedictus, O. caput-galli, M. pulegium, S. recognita* were found to be significantly higher compared to the results detected in previous studies and the permissible limits determined by FAO/WHO.[106–108] Based on our evaluation

Table 3. The value of macroelements (%), concentrations of microelements and potentially toxic elements (mg kg^{-1}) in the selected MAPs from three studied families.

Sample number	Sample name	Ca (%)	K (%)	Mg (%)	Na (%)	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
	ASTERACEAE														
1	*Bellis perennis*	0.614 ± 0.010	0.647 ± 0.022	0.080 ± 0.001	0.296 ± 0.006	237.674[a] ± 2.012	112.735 ± 4.113	0.298 ± 0.009	36.742[a] ± 1.210	24.696 ± 0.249	1063.609[a] ± 23.523	283.454 ± 4.350	7.643[a] ± 0.181	12.267[a] ± 0.236	141.303 ± 3.027
2	*Bellis sylvestris*	0.573 ± 0.009	0.464 ± 0.009	0.064 ± 0.002	0.103 ± 0.002	56.956 ± 2.090	41.332 ± 0.894	0.041 ± 0.001	27.531[a] ± 0.422	23.602 ± 0.200	528.313[a] ± 4.932	100.887 ± 0.984	3.920 ± 0.066	7.250 ± 0.109	196.136[a] ± 5.480
3	*Cnicus benedictus*	1.065 ± 0.011	0.815 ± 0.008	0.092 ± 0.003	0.041 ± 0.000	26.524 ± 0.702	101.712 ± 2.189	0.202 ± 0.004	22.369[a] ± 0.824	34.593[a] ± 0.744	53.396 ± 0.898	121.055 ± 2.936	4.638 ± 0.077	6.741 ± 0.169	153.015 ± 4.274
4	*Crupina crupinastrum*	0.197 ± 0.002	0.290 ± 0.009	0.043 ± 0.001	0.029 ± 0.000	3.206 ± 0.063	46.947 ± 1.229	0.057 ± 0.001	1.088 ± 0.029	19.320 ± 0.313	17.571 ± 0.642	65.908 ± 0.621	3.005 ± 0.081	2.790 ± 0.041	123.343 ± 1.932
5	*Eupatorium camabinum*	1.297 ± 0.031	0.460 ± 0.009	0.165 ± 0.003	0.060 ± 0.001	16.230 ± 0.133	174.557 ± 6.397	0.091 ± 0.001	1.333 ± 0.013	29.054 ± 0.568	135.019 ± 3.221	137.315 ± 2.989	1.655 ± 0.047	5.221 ± 0.180	163.931 ± 5.753
6	*Inula crithmoides*	0.868 ± 0.025	0.304 ± 0.004	0.240 ± 0.004	0.344 ± 0.008	28.388 ± 0.770	231.012 ± 4.218	0.030 ± 0.000	8.196 ± 0.104	26.124 ± 0.282	109.084 ± 1.021	76.181 ± 2.308	0.570 ± 0.017	7.032 ± 0.131	96.458 ± 1.912
7	*Leontodon crispus*	1.140 ± 0.025	0.807 ± 0.024	0.141 ± 0.004	0.032 ± 0.001	721.281[a] ± 25.060	102.940 ± 3.460	0.133 ± 0.003	40.820[a] ± 1.164	28.883 ± 0.887	1109.385[a] ± 27.213	715.478[a] ± 16.820	1.412 ± 0.047	8.086 ± 0.168	260.084[a] ± 8.831
8	*Pallenis spinosa*	0.816 ± 0.010	0.449 ± 0.006	0.097 ± 0.002	0.113 ± 0.001	19.967 ± 0.565	195.449 ± 3.226	0.390 ± 0.012	5.292 ± 0.070	28.194 ± 0.909	153.153 ± 5.709	109.254 ± 1.890	3.258 ± 0.114	7.389 ± 0.084	125.067 ± 3.802
9	*Scorzonera kotschyi*	0.726 ± 0.008	1.268 ± 0.012	0.139 ± 0.001	0.113 ± 0.003	27.772 ± 0.573	93.224 ± 1.211	0.077 ± 0.002	1.531 ± 0.034	43.129[a] ± 1.280	85.191 ± 2.497	155.004 ± 3.858	5.322 ± 0.075	8.248 ± 0.155	152.382 ± 3.317
	FABACEAE														
10	*Astragalus schizopterus*	0.701 ± 0.014	0.515 ± 0.008	0.071 ± 0.002	0.041 ± 0.001	44.356 ± 0.468	85.415 ± 1.670	0.128 ± 0.002	4.284 ± 0.124	31.267 ± 1.179	168.564 ± 4.537	210.532 ± 3.256	4.895 ± 0.068	20.488[a] ± 0.268	208.576[a] ± 5.490
11	*Genista lydia*	0.409 ± 0.008	0.440 ± 0.013	0.058 ± 0.001	0.034 ± 0.001	8.852 ± 0.317	117.230 ± 3.153	0.046 ± 0.001	1.439 ± 0.044	36.309[a] ± 0.999	80.326 ± 1.844	301.234 ± 9.790	8.931[a] ± 0.270	4.949 ± 0.059	162.139 ± 4.720
12	*Lathyrus aphaca*	0.642 ± 0.021	0.417 ± 0.014	0.055 ± 0.001	0.057 ± 0.001	91.744 ± 3.233	74.953 ± 1.344	0.189 ± 0.004	10.656 ± 0.215	17.372 ± 0.297	499.385[a] ± 6.077	191.602 ± 3.284	5.369 ± 0.063	20.164[a] ± 0.451	148.629 ± 2.556
13	*Lathyrus variabilis*	0.240 ± 0.007	0.680 ± 0.010	0.074 ± 0.002	0.061 ± 0.002	5.290 ± 0.093	78.289 ± 2.489	0.084 ± 0.001	3.415 ± 0.090	25.724 ± 0.551	56.317 ± 1.743	154.119 ± 3.048	7.655[a] ± 0.106	1.583 ± 0.056	154.442 ± 5.573
14	*Onobrychis caput-galli*	0.492 ± 0.006	0.372 ± 0.005	0.091 ± 0.003	0.066 ± 0.001	189.407[a] ± 3.848	136.256 ± 4.630	0.418 ± 0.008	22.544[a] ± 0.836	21.905 ± 0.662	1087.935[a] ± 25.237	378.250[a] ± 5.656	6.096 ± 0.215	12.996[a] ± 0.274	133.393 ± 2.079
15	*Onobrychis gracilis*	0.452 ± 0.008	0.326 ± 0.006	0.086 ± 0.001	0.022 ± 0.000	9.177 ± 0.273	105.070 ± 2.695	0.070 ± 0.003	2.705 ± 0.082	19.180 ± 0.258	85.803 ± 2.681	61.715 ± 1.043	0.997 ± 0.014	13.183[a] ± 0.386	94.812 ± 2.942
16	*Ononis spinosa*	1.092 ± 0.041	1.354 ± 0.017	0.181 ± 0.005	0.129 ± 0.002	16.281 ± 0.188	152.207 ± 1.387	0.013 ± 0.000	2.360 ± 0.072	30.266 ± 0.394	133.820 ± 1.802	147.974 ± 1.930	4.965 ± 0.114	3.013 ± 0.094	181.523[a] ± 2.886
17	*Ononis viscosa ssp breviflora*	0.413 ± 0.008	0.372 ± 0.013	0.061 ± 0.002	0.025 ± 0.000	30.327 ± 0.307	57.644 ± 1.454	0.099 ± 0.003	5.736 ± 0.073	18.992 ± 0.444	212.064 ± 3.615	234.684 ± 3.101	7.485[a] ± 0.271	16.183[a] ± 0.602	180.695[a] ± 3.046
18	*Pisum sativum ssp. elatius*	0.545 ± 0.011	0.593 ± 0.008	0.068 ± 0.002	0.096 ± 0.003	8.265 ± 0.081	67.515 ± 2.504	0.054 ± 0.001	1.434 ± 0.043	19.541 ± 0.273	47.746 ± 1.154	149.532 ± 1.538	1.355 ± 0.037	4.192 ± 0.066	106.681 ± 1.009
19	*Vicia cracca ssp. sterophyla*	0.515 ± 0.004	0.081 ± 0.003	0.042 ± 0.001	0.246 ± 0.005	7.145 ± 0.156	46.193 ± 0.608	0.030 ± 0.001	1.118 ± 0.014	30.123 ± 0.267	54.01 ± 0.598	62.764 ± 2.212	2.152 ± 0.029	2.835 ± 0.078	116.714 ± 4.377
	LAMIACEAE														
20	*Calamintha grandiflora*	0.568 ± 0.014	0.680 ± 0.006	0.062 ± 0.002	0.076 ± 0.002	41.838 ± 1.180	133.967 ± 4.867	0.043 ± 0.001	7.713 ± 0.114	20.108 ± 0.431	267.697 ± 9.328	95.605 ± 3.453	0.118 ± 0.002	1.749 ± 0.026	120.056 ± 4.457
21	*Lavandula stoechas*	0.242 ± 0.008	0.392 ± 0.010	0.183 ± 0.004	0.039 ± 0.001	16.048 ± 0.477	82.024 ± 0.723	0.091 ± 0.001	6.334 ± 0.067	17.005 ± 0.423	92.916 ± 3.403	63.748 ± 2.420	3.173 ± 0.053	4.904 ± 0.119	171.102[a] ± 1.377
22	*Mentha longifolia*	0.600 ± 0.012	0.527 ± 0.008	0.167 ± 0.005	0.079 ± 0.001	35.175 ± 0.295	110.256 ± 2.060	0.016 ± 0.000	4.320 ± 0.164	19.688 ± 0.621	218.610 ± 2.601	542.884[a] ± 18.763	1.165 ± 0.020	4.112 ± 0.109	140.486 ± 1.754
23	*Mentha pulegium*	0.557 ± 0.019	0.320 ± 0.012	0.140 ± 0.002	0.175 ± 0.002	408.608[a] ± 10.995	83.953 ± 1.069	0.113 ± 0.002	11.218 ± 0.208	29.290 ± 0.249	561.020[a] ± 11.145	482.583[a] ± 13.715	8.990 ± 0.324	14.579[a] ± 0.345	163.002[a] ± 4.215

(*continued*)

Table 3. Continued.

Sample number	Sample name	Ca (%)	K (%)	Mg (%)	Na (%)	Al	B	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
24	*Nepeta betonicifolia*	1.369 ± 0.023	0.421 ± 0.015	0.160 ± 0.004	0.082 ± 0.002	52.630 ± 0.586	76.946 ± 2.160	0.068 ± 0.001	7.335 ± 0.070	21.979 ± 0.704	418.914[a] ± 5.229	150.934 ± 4.740	0.856 ± 0.008	22.112[a] ± 0.673	191.061[a] ± 7.237
25	*Nepeta nuda*	0.441 ± 0.004	1.181 ± 0.017	0.116 ± 0.004	0.057 ± 0.001	47.878 ± 0.689	122.631 ± 1.792	0.021 ± 0.000	9.317 ± 0.345	30.790 ± 1.069	377.796[a] ± 11.842	95.701 ± 1.189	4.936 ± 0.083	3.558 ± 0.110	188.562[a] ± 6.260
26	*Salvia muticaulis*	0.381 ± 0.012	0.680 ± 0.022	0.141 ± 0.004	0.013 ± 0.000	20.226 ± 0.704	100.696 ± 1.712	0.025 ± 0.000	9.733 ± 0.238	22.454 ± 0.215	266.409 ± 2.680	167.832 ± 4.526	4.259 ± 0.161	5.629 ± 0.207	113.367 ± 1.311
27	*Salvia palestina*	1.464 ± 0.023	0.494 ± 0.010	0.097 ± 0.001	0.014 ± 0.000	61.092 ± 0.575	91.826 ± 1.845	0.048 ± 0.000	7.114 ± 0.086	23.206 ± 0.775	449.385[a] ± 5.685	312.017 ± 7.127	5.328 ± 0.058	12.606[a] ± 0.275	168.070[a] ± 1.559
28	*Salvia pilifera*	0.490 ± 0.016	0.718 ± 0.011	0.123 ± 0.004	0.072 ± 0.001	8.642 ± 0.078	99.546 ± 2.134	0.023 ± 0.000	2.205 ± 0.027	30.745 ± 0.607	95.084 ± 2.769	100.604 ± 1.360	4.391 ± 0.046	2.777 ± 0.077	119.763 ± 2.809
29	*Salvia recognita*	0.385 ± 0.005	0.489 ± 0.008	0.083 ± 0.003	0.030 ± 0.001	77.605 ± 0.763	60.752 ± 0.965	0.020 ± 0.000	2.778 ± 0.039	18.825 ± 0.688	216.936 ± 4.633	51.502 ± 1.163	8.526[a] ± 0.108	9.139 ± 0.256	80.822 ± 1.052
30	*Salvia tomentosa*	0.283 ± 0.004	0.418 ± 0.010	0.142 ± 0.004	0.018 ± 0.001	67.048 ± 1.560	45.430 ± 0.447	0.013 ± 0.000	47.790 ± 1.285	15.811 ± 0.290	577.412[a] ± 8.026	377.295[a] ± 7.094	3.783 ± 0.135	4.077 ± 0.080	86.656 ± 2.029
31	*Salvia verticillata*	0.477 ± 0.012	0.935 ± 0.016	0.177 ± 0.002	0.147 ± 0.005	14.741 ± 0.315	116.095 ± 4.279	0.054 ± 0.002	4.783 ± 0.138	21.986 ± 0.479	170.449 ± 3.053	81.842 ± 2.366	8.518[a] ± 0.188	2.311 ± 0.087	136.915 ± 4.950
32	*Satureja thymbra*	0.970 ± 0.011	0.277 ± 0.010	0.060 ± 0.001	0.081 ± 0.002	47.457 ± 1.009	105.739 ± 0.948	0.080 ± 0.001	7.090 ± 0.233	21.622 ± 0.388	309.385[a] ± 7.214	158.592 ± 4.963	3.922 ± 0.108	4.966 ± 0.150	158.313 ± 2.718
33	*Stachys cretica*	0.382 ± 0.009	0.728 ± 0.026	0.062 ± 0.002	0.017 ± 0.000	11.375 ± 0.164	94.703 ± 3.358	0.054 ± 0.001	1.966 ± 0.037	37.824 ± 0.966	96.068 ± 0.858	78.778 ± 1.432	7.606[a] ± 0.203	12.894[a] ± 0.438	116.989 ± 3.978
34	*Stachys rupestris*	1.029 ± 0.017	0.289 ± 0.005	0.051 ± 0.001	0.048 ± 0.001	28.273 ± 0.465	95.277 ± 1.213	0.607 ± 0.008	2.946 ± 0.072	22.130 ± 0.570	180.560 ± 5.738	103.176 ± 3.733	1.488 ± 0.014	5.162 ± 0.165	126.615 ± 1.966
35	*Teucrium chamaedrys*	0.700 ± 0.014	0.353 ± 0.006	0.110 ± 0.004	0.046 ± 0.001	27.838 ± 0.520	160.052 ± 4.065	0.164 ± 0.005	2.996 ± 0.112	27.083 ± 0.904	166.875 ± 1.745	77.899 ± 1.215	3.898 ± 0.118	5.294 ± 0.162	145.092 ± 4.480
36	*Teucrium polium*	0.596 ± 0.016	0.434 ± 0.009	0.106 ± 0.003	0.030 ± 0.001	100.700 ± 2.181	125.122 ± 3.645	0.065 ± 0.001	33.484[a] ± 1.155	24.194 ± 0.610	900.740[a] ± 29.771	131.626 ± 1.296	7.683[a] ± 0.084	3.727 ± 0.036	161.027[a] ± 1.857
37	*Thymus eigii*	0.496 ± 0.006	0.279 ± 0.004	0.113 ± 0.004	0.043 ± 0.001	8.436 ± 0.261	127.370 ± 1.787	0.037 ± 0.001	2.750 ± 0.092	12.904 ± 0.244	68.453 ± 2.133	74.709 ± 2.408	9.416[a] ± 0.156	4.322 ± 0.035	88.508 ± 1.542
38	*Ziziphora capitata*	0.773 ± 0.025	0.933 ± 0.029	0.134 ± 0.002	0.040 ± 0.001	49.340 ± 0.506	122.009 ± 4.387	0.048 ± 0.001	6.727 ± 0.167	15.146 ± 0.176	268.142 ± 3.606	192.559 ± 4.843	6.565 ± 0.113	21.936[a] ± 0.455	96.685 ± 3.123

[a]Beyond permissible limit defined by WHO

Table 4. Standard references of permissible levels of potentially toxic elements for herbal products from different countries or organizations.

			mg kg^{-1}						
Standards		Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Brazil	Herbal Tea	0.4							
Canada	Raw herbal materials	0.3	2					10	
	Finished herbal products	0.06[a]	0.02[a]					0.02[a]	
Chinese Pharmacopeia	Herbal materials	1						10	
Germany	Herbal products	0.2						5	
India	Herbal Tea							10	
Japanese Pharmacopeia	Herbal Tea							20	
Malaysia	Finished herbal products							10	
Republic of Korea	Herbal materials							30	
Poland	Herbal materials	0.1						0.2	
Singapore	Finished herbal products			150				20	
Thailand	Herbal materials, finished herbal products	0.3						10	
Taiwan	Herbal products	0.5						10	
Turkish Food Codex	Fresh herbs	0.2						0.1	
Union of Europe	Herbal materials	0.2							
British Pharmacopeia	Herbal drugs	1						5	
USP	Herbal drugs	0.3						10	
AHPA	Herbal products	4.1[b]						10[b]	
FAO/WHO	Medicinal plants	0.3	2	20–150		2	1.5	10	
	Edible plants	0.21	0.02	3	20		1.63	0.43	27.4
GSMPP	Herbal materials	0.3			20			5	

[a]mg/day^{-1}; [b]μg/day; AHPA: American Herbal Products Association; GSMPP (Green standards of medicinal plants and preparations for foreign trade and economy), WM/T 2-2004; USP: United States Pharmacopeia 4th.

according to the results of the total potentially toxic element profile, high Cr concentrations in *C. crupinastrum, L. crispus, O. caput-galli, M. pulegium* indicate that these samples were collected from soils rich in Cr (Samandağ, Arsuz, and Belen), while Fe accumulation of *B. perennis* and *M. longifolia* indicates that these samples were collected from soils rich in Fe (Payas). *B. perennis, S. palestina, Z. capitata* samples were collected from industrial areas and nearby (Payas, Belen), while *O. caput-galli, O. gracilis, and S. cretica* samples were collected from the mining areas and highway with heavy traffic. In addition, contamination was observed in the *C. benedictus* and *M. pulegium* samples collected from agricultural soils (Kırıkhan and Dörtyol) as high levels of Ni were detected. Lower levels of potentially toxic elements contamination were observed in plant samples collected from relatively uncontaminated areas (Fig. 1).

Studies on trace element and potentially toxic element/heavy metal accumulation in medicinal plants have been carried out in the world. In previous researches, heavy metals in the plants used in Van herby cheese (Van Herbed Cheese) produced in Eastern Anatolia in Türkiye were analyzed and it was found that Fe and Pb values were 283.23 and 1.69 in *M. longifolia*, and 492.17 and 0.23 mg kg^{-1} in *Z. capitata*, respectively.[117,118] According to our results, while the Fe value was higher in *Z. capitata*, it was found to be normal in *M. longifolia* species analyzed the heavy metals in the plants used in Van herby cheese (Van Herbed Cheese) produced in Eastern Anatolia in Türkiye. They found the Fe and Pb values were 283.23 and 1.69 in *M. longifolia*, 492.17 and 0.23 mg kg^{-1} in *Z. capitata*, respectively. According to our results, while the Fe value was higher in *Z. capitata*, it was found to be normal in *M. longifolia* species.

In another study, trace elements such as Cd, Fe, Mn, Ni, Pb and Zn accumulation from twenty-nine different plants collected form Bozdag Mountain in Western Anatolia (Türkiye) were measured.[119] In their study, it was determined that all metals in *G. lydia* and *S. cretica* taxa were within normal limits. However, in our results, Mn, Ni, and Zn concentrations of *G. Lydia* and Ni and Pb levels in *S. cretica* were found above normal limits. Dzierżanowski and Gawroński[120] measured heavy metal accumulations of Cd, Cu, Fe, Mn, Pb and Zn in plants distributed on the railways in Warsaw (Poland) and found the Cd content in *V. cracca* very high (15–20 mg kg^{-1}), while other values were found to be within normal limits. In our study, the Cd value

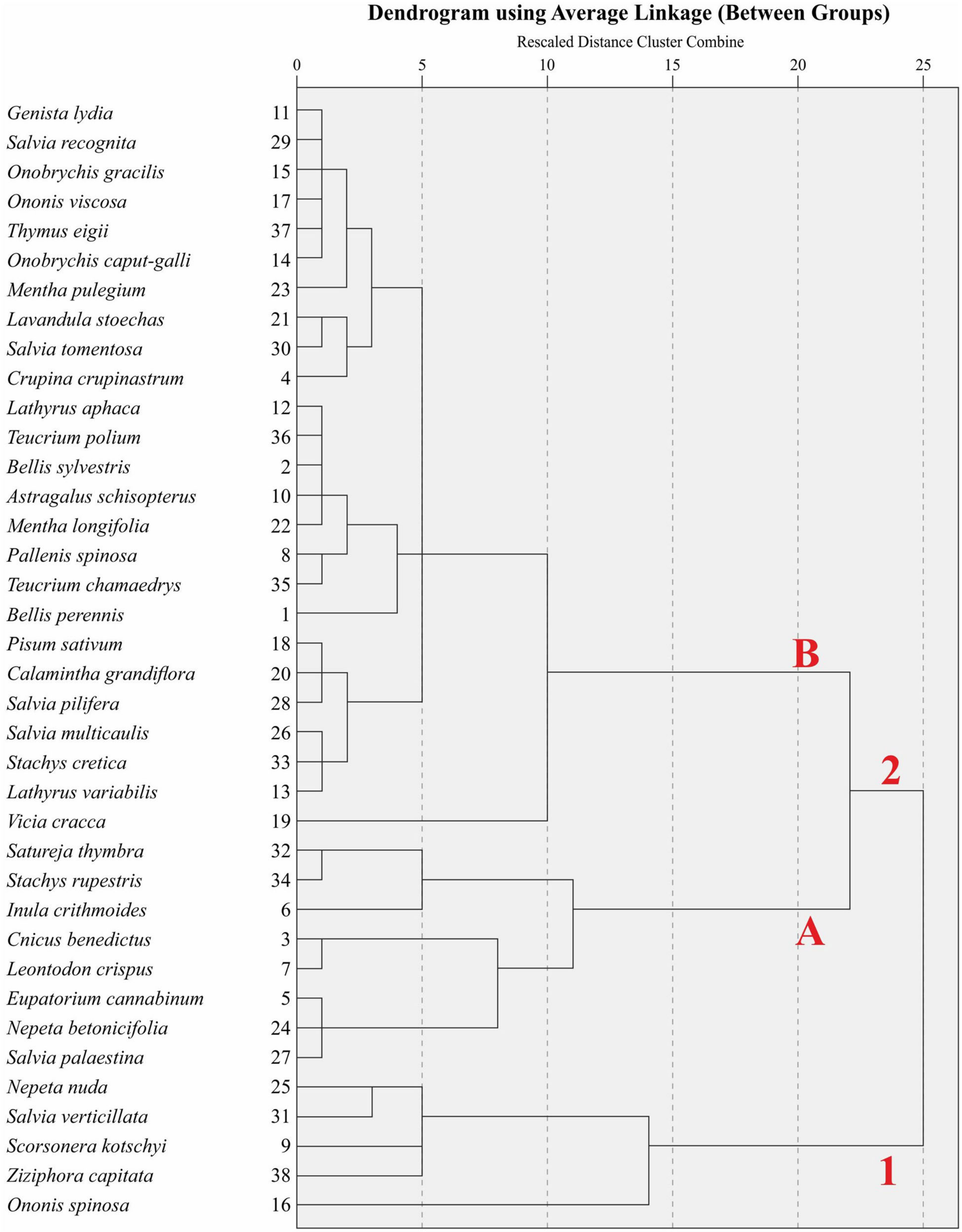

Figure 2. Dendrogram constructed from studied medicinal plants based on the element composition of samples. It is generated with a hierarchical cluster analysis with average linkage (between species).

in *V. cracca* was within normal levels. Casado et al.[121] measured the Cd and Zn levels of some plants at the El Losar mining area (Spain). It was revealed that the concentrations of Cd (2.90 mg kg^{-1}) and Zn (402.8 mg kg^{-1}) in *L. crispus* were clearly higher than permissible limits.

For *B. perennis,* the concentrations of various potentially toxic elements were measured from sixteen different locations in Niš city (Serbia), and the study suggested that mean values of Al, Fe and Ni were above normal limits in species from industrial and agricultural areas.[122] Similarly, it was found that Al, Cd, Cr, Fe, Ni, and Pb accumulations in *B. perennis* collected from the nearby industrial area (Iskenderun) above the permissible limits in our study.

In another study, *Mentha* samples were randomly obtained from supermarkets, traditional markets, herbal stores, and pharmacies in the Canary Islands (Spain), and it was determined that the levels of Fe, Mg and Al in *Mentha* sp. were above the permissible limits. In addition, Al, Fe, Mg, Mn, Ni, Pb, and Zn values of *Mentha* samples were found above the permissible limits.[123]

The growth and development of plants mainly depends on the existency of nutrients. Basic nutrients such as B, Ca, Fe, Mg, N, P, K, and Zn affect various biochemical and physiological activity processes occurring in plant metabolism; they also protect and support against various disorders that negatively affect plants.[20,124–126] However, excessive toxic element toxicity has many adverse effects on plant metabolism and physiology, such as DNA mutations, slowing of germination, inhibition of division and proliferation of stem cells, browning in plant roots, slowing of stomal movements, water uptake-transport and protein synthesis.[23,127,128]

Potentially toxic elements that accumulate in the plant above the permissible limits not only disrupt the plant metabolism, but also cause serious damage to the health of consumers. Al can cause microcytic anemia, osteomalacia, Alzheimer's disease, dementia, and breast cancer in the human body when evaluated in terms of its negative effects on human health.[129] It has been reported that Cu toxicity can cause headache, hemolytic anemia, vomiting, nausea, liver and kidney failure, diarrhea, and gastrointestinal hemorrhage in the human body.[25] High levels of Cd can cause kidney damage (kidney stones and renal tubular damage), respiratory system problems, bone abnormalities, bones structure that reduces Ca uptake.[23,24] Long term exposure to Fe toxicity can cause vomiting diarrhea, gastrointestinal system disorders, and liver damage.[129] Pb toxicity has been associated with hemoglobin synthesis problems, kidney dysfunctions, teratogenicity, skeletal and reproductive system diseases.[129] Long-term excessive Zn intake can cause growth abnormalities in children, microcytic anemia, disruption of enzyme structures, impairment of mitochondria, neurotoxicity, and induce hematological, respiratory and gastrointestinal system disorders, vomiting, fever and faintness.[24,130,131]

Herein, dendrogram created by using the results of average linkage cluster analysis revealed 2 main groups (Fig. 2). First group containing of *N. nuda*, *S. verticillata*, *S. kotschyi*, *Z. capitata*, and *O. spinosa* showed generaly distribution in close regions (Belen-Arsuz) having similar habitat characteristics, and the members of this subgroup were probably affected by the similar environmental conditions. Second group included A and B subgroups. Subgroup A comprising of *I. crithmoides*, *C. benedictus*, *E. cannabinum*, *L. crispus*, *N. betonicifolia*, *S. thymbra*, *S. rupestris*, and *S. palestina* generally belongs to the same family (Asteraceae and Lamiaceae) and showed distribution generally in close ranges.

The human body needs at least 22 essential plant nutrients in order to maintain its metabolic activities in a healthy way. Plants are the most important natural sources for these essential nutrients.[132] Therefore, the RDA values (100 g dw^{-1}) for the elements Ca, Cu, Fe, K, Mg, Mn, Na and Zn were calculated in *P. sativum, M. longifolia, M. pulegium, S. multicaulis, T. eigii* and *Z. capitata* species used as daily food, spice and tea (Table 5).

These RDA values are as follows; The RDA value of Ca was calculated in *Z. capitata* > *M. longifolia* > *M. pulegium* > *P. sativum* > *T. eigii* > *S. multicaulis*; the RDA values for Cu were found as *M. pulegium* > *S. multicaulis* > *M. longifolia* > *P. sativum* > *Z. capitata* > *T. eigii*; for Fe as *M. pulegium* > *Z. capitata* > *S. multicaulis* > *M.*

Table 5. Average level of minerals in the medicinal plants and RDA values (mg 100 g^{-1}) of selected minerals.

		P. sativum		*M. longifolia*		*M. pulegium*		*S. multicaulis*		*T. eigii*		*Z. capitata*	
Mineral	RDA	Amount	RDA (%)	Amount	RDA (%)	Amount	RDA (%)	Amount	RDA (%)	Amount	RDA (%)	Amount	RDA (%)
Ca	1000 mg	544.75	54.47	599.65	59.96	556.76	55.68	380.62	38.06	495.59	49.56	773.20	77.32
Cu	0.9 mg	1.95	217.13	1.97	218.75	2.93	325.44	2.25	249.49	1.29	143.37	1.51	168.29
Fe	8 mg	4.77	59.68	21.86	273.26	56.10	701.27	26.64	333.01	6.85	85.57	26.81	335.18
	18 mg[b]		26.53		121.45		311.68		148.00		38.03		148.97
K	4700 mg	592.91	12.62	526.90	11.21	320.39	6.82	679.89	14.47	279.34	5.94	932.54	19.84
Mg	420 mg	67.53	16.08	139.57	33.23	160.46	38.21	141.25	33.63	113.44	27.01	133.51	31.79
	320 mg[b]		21.10		43.62		50.14		44.14		35.45		41.72
Mn	2.3 mg	14.95	650.14	54.29	2360.37	48.26	2098.19	16.78	729.71	7.47	324.82	19.26	837.21
	1.8 mg		830.73		3016.02		2681.02		932.40		415.05		1069.77
Na	1500 mg	95.81	6.39	79.15	5.28	174.98	11.67	13.39	0.89	42.76	2.85	39.75	2.65
Zn	11 mg	10.67	96.98	14.05	127.71	16.30	148.18	11.34	103.06	8.85	80.46	9.67	87.90
	8 mg		133.35		175.61		203.75		141.71		110.63		120.86

[a]For adults, [b]For premenopausal women.

longifolia > *T. eigii* > *P. sativum*; for K as *Z. capitata* > *S. multicaulis* > *P. sativum* > *M. longifolia* > *M. pulegium* > *T. eigii*; for Mg as *M. pulegium* > *S. multicaulis* > *M. longifolia* > *Z. capitata* > *T. eigii* > *P. sativum*; for Mn in *M. longifolia* > *M. pulegium* > *Z. capitata* > *S. multicaulis* > *P. sativum* > *T. eigii*; for Na as *M. pulegium* > *P. sativum* > *M. longifolia* > *T. eigii* > *Z. capitata* > *S. multicaulis*; for Zn as *M. pulegium* > *M. longifolia* > *S. multicaulis* > *P. sativum* > *Z. capitata* > *T. eigii*. As it is known, these plants have edible properties and can be used as herbal teas and/or spices. This indicates their possible usability as dietary supplements.

Ca is one of the most important essential nutrients for the structure and functions of the human body which affects many intracellular and extracellular processes. It is crucial for the development, growth and maintenance of teeth and bone as well as for the stability of the cytoskeleton.[133] Ca plays a crucial role in vitamin D absorption, regulation of the activity of intracellular enzymes, and neuronal transmission.[134] Ca deficiency can cause osteoporosis, sarcopenia, scurvy and rickets in adults and children.[135] Dairy products contain high levels of Ca and the RDA value for Ca is defined as 1000 mg day^{-1}. In accordance with our results, the RDA value of Ca was found to be a minimum of 380.62 in *S. multicaulis*, and a maximum of 773.20 in *Z. capitata*. In other words, daily consumption of 100 gr *S. multicaulis* meets ~38.06% of daily Ca need, while this rate is ~77.32% for *Z. capitata* (Table 5).

Cu is another element vital to human metabolism. It is necessary for maintenance of hematopoietic activity, growth, immune system, energy metabolism, bone mineralization, brain development, transport of Fe and its metabolism.[136] Cu deficiency may cause many diseases such as bone abnormalities and retarded growth, the leukopenia, anemia, and gray hair.[137] It can be obtained from some foods such as meat and offal, grain products, seafood, vegetables and fruits, and the value of RDA for Cu is defined as 0.9 mg per day^{-1}.[138] The RDA value of Cu varies between 1.29 (*T. eigii*) and 2.93 (*M. pulegium*). In other words, daily consumption of 100 g of *T. eigii* meets ~143.37% of daily Cu need, while *M. pulegium* is ~325.44% (Table 5).

Fe has a significant role in the synthesis of oxygen transport proteins, in the formation of enzymes in electron transfer and oxidation-reductions.[139] It is also important for many biochemical pathways such as uptake and transport of oxygen, transport of hemoglobin, and electron transfer in the redox cycling.[140] Fe deficiency can often lead to anemia in adults, fatigue, weakened immune function, weakness, reduced cognitive function in children, and many health problems including adverse maternal and infant outcomes, risk of sepsis, maternal and perinatal death, miscarriage, and low birth weight in pregnant women.[141,142] It can be obtained from many food sources such as pulses, eggs and black mulberry, cereals, legumes, vegetables and fruits. The RDA value for Fe is defined as 8 mg day^{-1} for men and 18 mg day^{-1} for women.[143] In accordance with our results, the RDA value of Fe was found to be minimum 4.77 in *P. sativum*, and maximum 56.10 in *M. pulegium*, respectively. In other words, daily consumption of 100 g *P.*

Sativum meets ~59.68% of daily Fe need in men and ~26.53% in women, while this ratio is ~701.27% and ~311.68% in *M. pulegium*, respectively (Table 5).

K is required for healthy nerve activity, skeletal and cardiac muscle.[144] Its deficiency can cause high blood pressure, cardiovascular disease, kidney disease, and bone demineralization. Foods and vegetables such as blueberries, tomato, potato, beet greens, milk, and yoghurt are rich in potassium.[145,146] The RDA for K has been defined as 4700 mg day^{-1} for men.[147] Our study showed that the RDA values for K were between 279.34 (*T. eigii*) and 932.54 (*Z. capitata*), which shows that daily consumption of 100 g *T. eigii* provides ~5.94% and *Z. capitata* ~19.84% the required daily amounts of K, respectively (Table 5).

Mg has a significant role in the permeability of cell membranes, the transport of electrolytes across cell membranes, the preservation of the anatomical and functional integrity of several cellular organelles, the maintenance of DNA and tRNAmolecules, normal muscle contraction, neuron excitability, and the release of hormones and neurotransmitters.[133] Mg deficiency causes atrial fibrillation, hypertension, atherosclerosis, cerebrovascular disease, congestive heart failure, migraines, asthma, Alzheimer's, hypocalcemia, and hypophosphatemia, premenstrual syndrome, dermatological allergy.[148] The RDA for Mg is reported as 420 mg day^{-1} for men and 320 mg day^{-1} for women.[147] Our study revealed that the RDA values of Mg were between 67.53 in *P. sativum* and 160.46 in *M. pulegium*, which means daily consumption of 100 g *M. pulegium* provides ~38.21% and 50.14% and *P. sativum* ~16.08% and 21.10% of the daily requirements of Mg for men and women, respectively (Table 5).

Manganese (Mn) is an essential trace element. It has an important role in immune and neural functions, bone development, amino acid, lipid and carbohydrate metabolism. It is found in various enzymes, e.g. mitocondrial Mn superoxide dismutase, glutamine synthetase and arginase, and it also activates various hydrolases, transferases and carboxylases.[149,150] It can be obtained from cereals, tea, and nuts. Mn deficiency is associated with birth defects, impaired fertility, abnormal glycosylation patterns, skeletal abnormalities, and general psychomotor disability.[151,152] The RDA values for Mn is stated as 2.3 mg day^{-1} for men and 1.8 mg day^{-1} for women.[143] In accordance with our results, the RDA values of Mn were detected to be minimum 7.47 in *T. eigii* and maximum 54.29 in *M. longifolia*, respectively. As a result, daily consumption of 100 g of *T. eigii* provides ~324.82% and 415.05%, while *M. longifolia* provides ~2360.37% and 3016.02% of the daily requirements of Mn for men and women, respectively (Table 5).

Na is essential for healthy muscle, nerve activity, the maintainence of acid-base balance and plasma volume.[144].ts deficiency can cause anorexia, nausea, vomiting, muscle cramps and weakness, headache, lethargy, confusion, seizures, coma, and altered consciousness.[153] The RDA for Na is defined as 1500 mg day^{-1} for men.[154] Our study revealed that the RDA values of Na were between 13.39 in *S. multicaulis* and 174.98 in *M. pulegium*, respectively. Therefore, daily consumption of 100 g of *S. multicaulis* provides ~0.89% of daily required Na and ~11.67% of *M. pulegium* (Table 5).

Zn is an important mineral nutrient required for natural bone structure and plays a structural and regulatory role in proteins and transcription factors. It is also structurally and functionally involved in more than 300 metalloenzymes, including Zn matrix metalloproteinases. Zn can be obtained from oysters, crab, beans, nuts, whole grains, red meat, and dairy products.[149,155,156] Zn deficiency causes neurosensory disorders, mental lethargy, infertility, thymic atrophy, skin lesions, acrodermatitis, decreased wound healing, hair thinning, hypogonadism, immune systems disorders, and growth retardation in children. The RDA value of Zn is listed as 11 mg day^{-1} for men and as 8 mg day^{-1} for women.[157,158] In accordance with our results, the lowest RDA values of Zn were found in *T. eigii* (8.85), while the highest in *M. pulegium* (16.30). Thus, a daily intake of 100 g of *T. eigii* provides ~80.46% and 110.63% of the daily requirement for men and women, while *M. pulegium* provides ~148.18% and 203.75% of the daily requirement (Table 5). However, it is predicted that more than 60% of the world's population are Fe and more than

Table 6. EDI (mg/kg/day), THQ of Cd, Cr, Ni, and Pb and HI values for adults[a] associated with the consumption of medicinal plants samples.

	Cd		Cr		Ni		Pb		
Species	EDI	THQ	EDI	THQ	EDI	THQ	EDI	THQ	HI
Asteraceae									
B. perennis	3.20E-04	1.07E-03	2.51E-01	1.26E-01	3.73E-02	2.49E-02	3.96E-02	3.96E-03	0.156
B. sylvestris	4.37E-05	1.46E-04	1.88E-01	9.42E-02	1.92E-02	1.28E-02	2.34E-02	2.34E-03	0.109
C. benedictus	2.18E-04	7.25E-04	1.53E-01	7.65E-02	2.27E-02	1.51E-02	2.17E-02	2.17E-03	0.095
C. crupinastrum	6.09E-05	2.03E-04	7.44E-03	3.72E-03	1.47E-02	9.79E-03	9.00E-03	9.00E-04	0.015
E. camabinum	9.83E-05	3.28E-04	9.12E-03	4.56E-03	8.09E-03	5.39E-03	1.68E-02	1.68E-03	0.012
I. crithmoides	3.22E-05	1.07E-04	5.61E-02	2.80E-02	2.78E-03	1.86E-03	2.27E-02	2.27E-03	0.032
L. crispus	1.43E-04	4.76E-04	2.79E-01	1.40E-01	6.90E-03	4.60E-03	2.61E-02	2.61E-03	0.147
P. spinosa	4.20E-04	1.40E-03	3.62E-02	1.81E-02	1.59E-02	1.06E-02	2.38E-02	2.38E-03	0.032
S. kotschyi	8.31E-05	2.77E-04	1.05E-02	5.24E-03	2.60E-02	1.73E-02	2.66E-02	2.66E-03	0.026
Fabaceae									
A. schizoxopterus	1.37E-04	4.57E-04	2.93E-02	1.47E-02	2.39E-02	1.59E-02	6.61E-02	6.61E-03	0.038
G. lydia	4.97E-05	1.66E-04	9.84E-03	4.92E-03	4.36E-02	2.91E-02	1.60E-02	1.60E-03	0.036
L. aphaca	2.03E-04	6.78E-04	7.29E-02	3.64E-02	2.62E-02	1.75E-02	6.50E-02	6.50E-03	0.061
L. variabilis	9.01E-05	3.00E-04	2.34E-02	1.17E-02	3.74E-02	2.49E-02	5.10E-03	5.10E-04	0.037
O. caput-galli	4.50E-04	1.50E-03	1.54E-01	7.71E-02	2.98E-02	1.99E-02	4.19E-02	4.19E-03	0.103
O. gracilis	7.56E-05	2.52E-04	1.85E-02	9.25E-03	4.87E-03	3.25E-03	4.25E-02	4.25E-03	0.017
O. spinosa	1.41E-05	4.68E-05	1.61E-02	8.07E-03	2.43E-02	1.62E-02	9.71E-03	9.71E-04	0.025
O. viscosa ssp breviflora	1.06E-04	3.53E-04	3.92E-02	1.96E-02	3.66E-02	2.44E-02	5.22E-02	5.22E-03	0.050
P. sativum ssp. elatius	5.79E-05	1.93E-04	9.81E-03	4.90E-03	6.62E-03	4.41E-03	1.35E-02	1.35E-03	0.011
V. cracca ssp. sterophyla	3.22E-05	1.07E-04	7.64E-03	3.82E-03	1.05E-02	7.01E-03	9.14E-03	9.14E-04	0.012
Lamiaceae									
C. grandiflora	4.64E-05	1.55E-04	5.28E-02	2.64E-02	5.77E-04	3.85E-04	5.64E-03	5.64E-04	0.027
L. stoechas	9.77E-05	3.26E-04	4.33E-02	2.17E-02	1.55E-02	1.03E-02	1.58E-02	1.58E-03	0.034
M. longifolia	1.69E-05	5.65E-05	2.95E-02	1.48E-02	5.69E-03	3.80E-03	1.33E-02	1.33E-03	0.020
M. pulegium	1.21E-04	4.05E-04	7.67E-02	3.84E-02	4.39E-02	2.93E-02	4.70E-02	4.70E-03	0.073
N. betonicifolia	7.34E-05	2.45E-04	5.02E-02	2.51E-02	4.18E-03	2.79E-03	7.13E-02	7.13E-03	0.035
N. nuda	2.23E-05	7.44E-05	6.37E-02	3.19E-02	2.41E-02	1.61E-02	1.15E-02	1.15E-03	0.049
S. muticaulis	2.73E-05	9.10E-05	6.66E-02	3.33E-02	2.08E-02	1.39E-02	1.81E-02	1.81E-03	0.049
S. palestina	5.14E-05	1.71E-04	4.87E-02	2.43E-02	2.60E-02	1.74E-02	4.06E-02	4.06E-03	0.046
S. pilifera	2.47E-05	8.22E-05	1.51E-02	7.54E-03	2.15E-02	1.43E-02	8.95E-03	8.95E-04	0.023
S. recognita	2.17E-05	7.22E-05	1.90E-02	9.50E-03	4.17E-02	2.78E-02	2.95E-02	2.95E-03	0.040
S. tomentosa	1.35E-05	4.49E-05	3.27E-01	1.63E-01	1.85E-02	1.23E-02	1.31E-02	1.31E-03	0.177
S. verticillata	5.84E-05	1.95E-04	3.27E-02	1.64E-02	4.16E-02	2.77E-02	7.45E-03	7.45E-04	0.045
S. thymbra	8.61E-05	2.87E-04	4.85E-02	2.42E-02	1.92E-02	1.28E-02	1.60E-02	1.60E-03	0.039
S. cretica	5.79E-05	1.93E-04	1.34E-02	6.72E-03	3.72E-02	2.48E-02	4.16E-02	4.16E-03	0.036
S. rupestris	6.53E-04	2.18E-03	2.02E-02	1.01E-02	7.27E-03	4.85E-03	1.66E-02	1.66E-03	0.019
T. chamaedrys	1.77E-04	5.89E-04	2.05E-02	1.02E-02	1.90E-02	1.27E-02	1.71E-02	1.71E-03	0.025
T. polium	6.98E-05	2.33E-04	2.29E-01	1.15E-01	3.75E-02	2.50E-02	1.20E-02	1.20E-03	0.141
T. eigii	3.95E-05	1.32E-04	1.88E-02	9.40E-03	4.60E-02	3.07E-02	1.39E-02	1.39E-03	0.042
Z. capitata	5.14E-05	1.71E-04	4.60E-02	2.30E-02	3.21E-02	2.14E-02	7.07E-02	7.07E-03	0.052

EDI: estimated daily intake; THQ: target hazard quotient; HI: hazard index; [a]70 kg of adult person.

30% are Zn deficient. Furthermore, high Ca, Mg, and Cu deficiencies are common in many developed as well as developing countries.[132] Therefore, our RDA results clearly show that the studied plant species have a high potential for essential elements.

As a result of our study, it was seen that the EDI, THQ, and HI values determined for medicinal plants were within the permissible limits. Considering the determined THQ values and cumulative HI values for Cd, Cr, Ni, and Pb, the risk of adverse effects in adults was within the permissible limits after exposure to the four potentially toxic elements tested through the consumption of medicinal plants. The highest HI value was 0.156 for *B. perensis* and the lowest value was 0.012 for *E. cannabinum from* Asteraceae, 0.103 for *O. caput-galli* and 0.011 for *P. sativum* from Fabaceae, and finally 0.177 for *S. tomentosa* and 0.019 for *S. rupestis* from Lamiaceae, respectively (Table 6). Moreover, risk assessment of toxic metals in these plants is important not only to assess their negative effects on human health, but also to obtain realistic predictions of their uptake through this traditional use. In addition, the Joint FAO/WHO Expert Committee on Food Additives[159] has allocated the maximum daily intake of toxic elements for a 70 kg adult (TDI: tolerable daily intake). TDI levels are considered the permissible limits for potentially toxic elements such as As, Br, Cd, Pb, and Sb, which are hazardous to human health.[21]

Table 7. Correlation matrix (*R*) between element concentrations of plant species obtained by Pearson correlation method.

Correlation matrix (R)													
Pearson correlation	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Zn
Al	−.038	.198	.172	.578**	.076	.730**	.042	.108	.759**	.095	.040	.201	.478**
B		.347*	.187	−.124	.186	−.024	.140	.490**	−.087	.317	−.136	−.137	−.086
Ca			.209	.027	.191	.142	.111	.249	.175	.089	−.346*	.249	.396*
Cd				.135	.018	.282	−.207	−.273	.080	.053	−.063	.158	.036
Cr					−.111	.807**	.009	.066	.498**	.048	.038	.032	.231
Cu						−.125	.416**	.004	.022	.176	.096	−.092	.356*
Fe							−.021	.011	.608**	.085	.128	.257	.354*
K								.305	.028	−.043	.154	−.086	.236
Mg									.156	.279	−.157	−.076	.054
Mn										−.047	.023	.198	.416**
Na											−.099	−.073	−.107
Ni												.143	−.040
Pb													.168

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

Compared with the TDI values, our results show that the Cd and Pb values of all the medicinal plants examined were above the TDI limits (for Cd 0.014 and Pb 0.021 mg/day/70 kg adult person). Based on our statistical analyses, results showed that the highest correlation coefficients were determined among Cr and Fe (>0.81), Al and Mn (>0.76), Al and Fe (>0.73), Fe and Mn (>0.61), Al and Cr (>0.58), Cr and Mn (>0.50), B and Mg (>0.49), Al and Zn (>0.48), Cu and K (>0.42), Mn and Zn (>0.42) (Table 7). These results revealed that the use of medicinal plants is a phenomenon that should be evaluated scientifically.

Conclusion

Long-term environmental damages caused by pollutants such as mining, agricultural activities, burning of fossil fuels, and wastewater, which have increased due to rapid population growth in recent years, affects many plant species living in terrestrial and aquatic ecosystems. In addition, highly toxic metals in soils pose a threat to wildlife and human health through the consumption of contaminated plants. In order to prevent this potentially toxic element accumulation, when collecting medicinal aromatic plants, rural areas, close to clean rivers or mountainous areas should be preferred, away from highway, mining and industrial areas. In addition, this accumulation should be controlled by similar potentially toxic element analyzes carried out periodically in widely used medicinal plants and the results should be shared with local users and managers. In fact, the cultivation of medicinal plant species that are suitable for meeting the increasing demand for medicinal aromatic plants, obtaining high standards of products, and protecting biological diversity is very important in terms of ensuring economic and ecological sustainability. However, if medicinal plants are to be collected from nature, they should be collected from clean rural areas where soil analyzes are carried out and away from pollution determined by local governments. A multidisciplinary team of experts, including environmentalists, toxicologists, chemists, politicians, and social workers, in coordination with government agencies, can inform the local community to reduce to use of medicinal plants collected from polluted areas. It is clearly seen from our results that in most of the analyzed plant samples, the selected potentially toxic elements are within the permissible limits set by international authorities or in some plants slightly above these limits. Briefly, it was observed that the levels of potentially toxic elements in the collected plants were generally at consumable levels, although they were slightly higher in the samples collected from the areas close to the industrial zones, mining and agricultural areas.

Ethical approval

This work is a systematic and meta-analysis review that not needed ethical approval and did not receive any technical or financial support from any institution and were done by the authors at their own personal expense.

Authors' contributions

F. Karahan: Collecting the and analysis of plant samples, writing; review & editing; I.I. Ozyigit: Conceived and designed the present study, writing; A. Hocaoglu-Ozyigit: Contributed to preparation and analysis of the samples; I.E. Yalcin: Contributed to preparation and analysis of the samples, data analysis; B.N. Erkencioglu: Contributed to preparation and analysis of the samples, editing; A. Ilcim: Collecting the plant samples; All authors contributed to revisions of the manuscript and critical discussion.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statements

The authors can confirm that all data generated or analyzed are included in the article.

References

[1] Singh, R. Medicinal Plants: A Review. *Journal of Plant Sciences* **2015**, *3*(1), 50–55. DOI: 10.11648/j.jps.s.2015030101.18.

[2] Dhanik, J.; Arya, N.; Nand, V. A Review on *Zingiber officinale*. *Journal of Pharmacognosy and Phytochemistry* **2017**, *6*(3), 174–184.

[3] Salmerón-Manzano, E.; Garrido-Cardenas, J. A.; Manzano-Agugliaro, F. Worldwide Research Trends on Medicinal Plants. *International Journal of Environmental Research and Public Health* **2020**, *17*(10), 3376. DOI: 10.3390/ijerph17103376.

[4] Christenhusz, M. J.; Byng, J. W. The Number of Known Plants Species in the World and Its Annual Increase. *Phytotaxa* **2016**, *261*(3), 201–217. DOI: 10.11646/phytotaxa.261.3.1.

[5] Bessada, S. M.; Barreira, J. C.; Oliveira, M. B. P. Asteraceae Species with Most Prominent Bioactivity and Their Potential Applications: A Review. *Industrial Crops and Products* **2015**, *76*, 604–615. DOI: 10.1016/j.indcrop.2015.07.073.

[6] Koc, S.; Isgor, B. S.; Isgor, Y. G.; Shomali Moghaddam, N.; Yildirim, O. The Potential Medicinal Value of Plants from Asteraceae Family with Antioxidant Defense Enzymes as Biological Targets. *Pharmaceutical Biology* **2015**, *53*(5), 746–751. DOI: 10.3109/13880209.2014.942788.

[7] Rolnik, A.; Olas, B. The Plants of the Asteraceae Family as Agents in the Protection of Human Health. *International Journal of Molecular Sciences* **2021**, *22*(6), 3009. DOI: 10.3390/ijms22063009.

[8] Vasconcelos, M. W.; Grusak, M.; A.; Pinto, E.; Gomes, A.; Ferreira, H.; Balázs, B.; Centofanti, T.; Ntatsi, G.; Savvas, D.; Karkanis; et al. The Biology of Legumes and Their Agronomic, Economic, and Social Impact. In *The Plant Family Fabaceae*, Hasanuzzaman, M., Araújo, S., Gill, S. S., Eds.; Springer: Singapore, 2020, 3–25.

[9] Azani, N.; Babineau, M.; Bailey, C. D.; Banks, H.; Barbosa, A. R.; Pinto, R. B.; Boatwright, J. S.; Borges, L. M.; Brown, G. K.; Bruneau, A.; et al. A New Subfamily Classification of the Leguminosae Based on a Taxonomically Comprehensive Phylogeny. *Taxon* **2017**, *66*(1), 44–77. DOI: 10.12705/661.3.

[10] Calis, I.; Baser, K. H. C. Review of Studies on Phlomis and Eremostachys Species (Lamiaceae) with Emphasis on Iridoids, Phenylethanoid Glycosides, and Essential Oils. *Planta Medica* **2021**, *87*(14), 1128–1151. DOI: 10.1055/a-1527-4238.

[11] Tzima, K.; Brunton, N. P.; Rai, D. K. Qualitative and Quantitative Analysis of Polyphenols in Lamiaceae Plants — A Review. *Plants* **2018**, *7*(2), 25. DOI: 10.3390/plants7020025.

[12] Michel, J.; Zahirah, N.; Rani, A.; Husain, K. A Review on the Potential Use of Medicinal Plants From Asteraceae and Lamiaceae Plant Family in Cardiovascular Diseases. *Frontiers in Pharmacology* **2020**, *11*, 852. DOI: 10.3389/fphar.2020.00852.

[13] Ozturk, M.; Altay, V.; Karahan, F. Studies on Trace Elements Distributed in *Glycyrrhiza* Taxa in Hatay-Turkey. *Internatıonal Journal of Plant and Envıronment* **2017**, *3*(02), 01–07. DOI: 10.18811/ijpen.v3i02.10431.

[14] Can, H.; Ozyigit, I. I.; Can, M.; Hocaoglu-Ozyigit, A.; Yalcin, I. E. Multidimensional Scaling of the Mineral Nutrient Status and Health Risk Assessment of Commonly Consumed Fruity Vegetables Marketed in Kyrgyzstan. *Biological Trace Element Research* **2022**, *200*(4), 1902–1916. DOI: 10.1007/s12011-021-02759-2.

[15] Yilmaz, N.; Ozyigit, I. I.; Demir, H. H.; Yalcin, I. E. Assessment on Phytoplankton Composition and Heavy Metal Pollution in a Drinking Water Resource: Lake Terkos (Istanbul, Turkey). *Desalınatıon AND WATER TREATMENT* **2021**, *225*, 265–274. DOI: 10.5004/dwt.2021.27221.

[16] Ozyigit, I. I.; Can, H.; Dogan, I. Phytoremediation Using Genetically Engineered Plants to Remove Metals: A Review. *Environmental Chemistry Letters* **2021**, *19*(1), 669–698. DOI: 10.1007/s10311-020-01095-6.

[17] Năstăsescu, V.; Mititelu, M.; Goumenou, M.; Docea, A. O.; Renieri, E.; Udeanu, D. I.; Oprea, E.; Arsene, A. L.; Dinu-Pîrvu, C. E.; Ghica, M.; et al. Heavy Metal and Pesticide Levels in Dairy Products: Evaluation of Human Health Risk. *Food and Chemical Toxicology* **2020**, *146*, 111844. DOI: 10.1016/j.fct.2020.111844.

[18] Yalcin, I.; Ozyigit, I.; Dogan, I.; Demir, G.; Yarci, C. Using the Turkish Red Pine Tree to Monitor Heavy Metal Pollution. *Polish Journal of Environmental Studies* **2020**, *29*(5), 3881–3889. DOI: 10.15244/pjoes/114505.

[19] Yilmaz, N.; Ozyigit, I. I.; Demir, G.; Yalcin, I. E. Determination of Phytoplankton Density, and Study of the Variation of Nutrients and Heavy Metals in the Surface Water of Riva Stream; One of the Water Sources of Istanbul. *Desalination and Water Treatment* **2015**, *55*(3), 810–820. DOI: 10.1080/19443994.2014.952674.

[20] Karahan, F.; Ozyigit, I. I.; Saracoglu, I. A.; Yalcin, I. E.; Ozyigit, A. H.; Ilcim, A. Heavy Metal Levels and Mineral Nutrient Status in Different Parts of Various Medicinal Plants Collected from Eastern Mediterranean Region of Turkey. *Biological Trace Element Research* **2020**, *197*(1), 316–329. DOI: 10.1007/s12011-019-01974-2.

[21] Ozyigit, I. I.; Karahan, F.; Yalcin, I. E.; Hocaoglu-Ozyigit, A.; Ilcim, A. Heavy Metals and Trace Elements Detected in the Leaves of Medicinal Plants Collected in the Southeast Part of Turkey. *Arabian Journal of Geosciences* **2022**, *15*(1), 27. DOI: 10.1007/s12517-021-09264-9.

[22] Keshvari, M.; Nedaeinia, R.; Nedaeinia, M.; Ferns, G. A.; Nia, S. N.; Asgary, S. Assessment of Heavy Metal Contamination in Herbal Medicinal Products Consumed in the Iranian Market. *Environmental Science and Pollution Research* **2021**, *28*(25), 33208–33218. DOI: 10.1007/s11356-021-13020-7.

[23] Hocaoglu-Ozyigit, A.; Genc, B. N. Cadmium in Plants, Humans and the Environment. *Frontiers in Life Sciences and Related Technologies* **2020**, *1*(1), 12–21.

[24] Nzediegwu, C.; Prasher, S.; Elsayed, E.; Dhiman, J.; Mawof, A.; Patel, R. Impact of Soil Biochar Incorporation on the Uptake of Heavy Metals Present in Wastewater by Spinach Plants. *Water, Air, & Soil Pollution* **2020**, *231*(3), 123. DOI: 10.1007/s11270-020-04512-2.

[25] Wang, P.; Yuan, Y.; Xu, K.; Zhong, H.; Yang, Y.; Jin, S.; Yang, K.; Qi, X. Biological Applications of Copper-Containing Materials. *Bioactive Materials* **2021**, *6*(4), 916–927. DOI: 10.1016/j.bioactmat.2020.09.017.

[26] Ilcim, A. *Hatay'ın Sessiz Güzelleri 900 Yabani Çiçek, Hatay Bitki Envanteri*; Hatay Valiliği: Hatay, 2014; 996 p.

[27] Altay, V.; Karahan, F.; Sarcan, Y. B.; Ilcim, A. An Ethnobotanical Research on Wild Plants Sold in Kırıkhan District (Hatay/Turkey) Herbalists and Local Markets. *Biological Diversity and Conservation* **2015**, *8*(2), 81–91.

[28] Altay, V.; Keskin, M.; Karahan, F. An Assessment of the Plant Biodiversity of Mustafa Kemal University Tayfur Sokmen Campus (Hatay-Turkey) for the View of Human Health. *International Journal of Scientific and Technological Research* **2015**, *1*(2), 83–103.

[29] Uzer, M.; Paker, S, Mineral Map of Antakya. 2019. Available online: https://www.mta.gov.tr/v3.0/sayfalar/hizmetler/maden-haritalari/Antakya.pdf (accessed Feb. 16, 2022).

[30] Davis, P. H. *Flora of Turkey and the East Aegean Islands*; Vol. 1–9. Edinburgh University Press: Edinburgh, 1965–1988.

[31] Guner, A.; Aslan, S.; Ekim, T., Vural, M., Babaç, M.T. *Türkiye Bitkileri Listesi (Damarlı Bitkiler)*; Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği: İstanbul, 2012; 1290 p.

[32] Oberbaum, M.; Galoyan, N.; Lerner-Geva, L.; Singer, S. R.; Grisaru, S.; Shashar, D.; Samueloff, A. The Effect of the Homeopathic Remedies *Arnica montana* and *Bellis perennis* on Mild Postpartum Bleeding-A Randomized, Double-Blind, Placebo-Controlled Study-Preliminary Results. *Complementary Therapies in Medicine* **2005**, *13*(2), 87–90. DOI: 10.1016/j.ctim.2005.03.006.

[33] Karakaş, F. P.; Karakaş, A.; Boran, Ç.; Türker, A. U.; Yalçin, F. N.; Bilensoy, E. The Evaluation of Topical Administration of *Bellis perennis* Fraction on Circular Excision Wound Healing in Wistar Albino Rats. *Pharmaceutical Biology* **2012**, *50*(8), 1031–1037. DOI: 10.3109/13880209.2012.656200.

[34] Karahan, F. Morphology, Anatomy, Palynology and Achene Micromorphology of *Bellis* L. (Asteraceae) Species from Turkey. *Acta Botanica Croatica* **2020**, *79*(1), 59–67. DOI: 10.37427/botcro-2020-006.

[35] Baytop, T. *Therapy with Plants in Turkey, Past and Present*, 2nd ed. Nobel Tip Kitapevi: Istanbul, 1999.

[36] Polat, R.; Satil, F. An Ethnobotanical Survey of Medicinal Plants in Edremit Gulf (Balikesir-Turkey). *Journal of Ethnopharmacology* **2012**, *139*(2), 626–641. DOI: 10.1016/j.jep.2011.12.004.

[37] Benítez, G.; González-Tejero, M. R.; Molero-Mesa, J. Pharmaceutical Ethnobotany in the Western Part of Granada Province (Southern Spain): Ethnopharmacological Synthesis. *Journal of Ethnopharmacology* **2010**, *129*(1), 87–105. DOI: 10.1016/j.jep.2010.02.016.

[38] Bahraminejad, S.; Abbasi, S.; Fazlali, M. In Vitro Antifungal Activity of 63 Iranian Plant Species against Three Different Plant Pathogenic Fungi. *African Journal of Biotechnology* **2011**, *10*(72), 16193–16201. DOI: 10.5897/AJB11.1203.

[39] Baydoun, S.; Chalak, L.; Dalleh, H.; Arnold, N. Ethnopharmacological Survey of Medicinal Plants Used in Traditional Medicine by the Communities of Mount Hermon, Lebanon. *Journal of Ethnopharmacology* **2015**, *173*, 139–156. DOI: 10.1016/j.jep.2015.06.052.

[40] Chen, L.-C.; Lee, T.-H.; Sung, P.-J.; Shu, C.-W.; Lim, Y.-P.; Cheng, M.-J.; Kuo, W.-L.; Chen, J.-J.

New Thymol Derivatives and Cytotoxic Constituents from the Root of *Eupatorium cannabinum* ssp. *asiaticum*. *Chemistry & Biodiversity* **2014**, *11*(9), 1374–1380. DOI: 10.1002/cbdv.201300392.

[41] Kızılpınar Temizer, I.; Turkmen, Z. Pollen Morphology of *Eupatorium cannabinum* L. *Mellifera* **2015**, *15*(1), 12–15.

[42] Fontana, G.; Bruno, M.; Senatore, F.; Formisano, C. Volatile Constituents of Aerial Parts of Two Mediterranean Species of *Inula*: *Inula crithmoides* L. and *I. verbascifolia* (Willd.) Hausskn. (Asteraceae). *Natural Product Research* **2014**, *28*(13), 984–993. DOI: 10.1080/14786419.2014.902821.

[43] Zidorn, C.; Stuppner, H.; Tiefenthaler, M.; Konwalinka, G. Cytotoxic Activities of Hypocretenolides from *Leontodon hispidus*. *Journal of Natural Products* **1999**, *62*(7), 984–987. DOI: 10.1021/np990058v.

[44] Bakar, F.; Bahadır Acıkara, Ö.; Ergene, B.; Nebioğlu, S.; Saltan Çitoğlu, G. Antioxidant Activity and Phytochemical Screening of Some Asteraceae Plants. *Turkish Journal of Pharmaceutical Sciences* **2015**, *12*(2), 36–45. DOI: 10.5505/tjps.2015.18209.

[45] Al-Qudah, M. A.; Saleh, A. M.; Alhawsawi, N. L.; Al-Jaber, H. I.; Rizvi, S. A.; Afifi, F. U. Composition, Antioxidant, and Cytotoxic Activities of the Essential Oils from Fresh and Air-Dried Aerial Parts of *Pallenis spinosa*. *Chemistry & Biodiversity* **2017**, *14*(8), e1700146. DOI: 10.1002/cbdv.201700146.

[46] Yaldiz, G. Some Antimicrobial Activity Plants Growing in Rize Region Used in Alternative Medicine. *Journal of Life Sciences* **2012**, *6*, 624–631.

[47] Yildirim, A. B.; Karakas, F. P.; Turker, A. U. In Vitro Antibacterial and Antitumor Activities of Some Medicinal Plant Extracts, Growing in Turkey. *Asian Pacific Journal of Tropical Medicine* **2013**, *6*(8), 616–624. DOI: 10.1016/S1995-7645(13)60106-6.

[48] Halabalaki, M.; Alexi, X.; Aligiannis, N.; Kalpoutzakis, E.; Alexis, M. N.; Skaltsounis, A. L. *Onobrychis* Species: A Source of Novel C-Prenylated Cytotoxic 3-Formyl-2-Arylbenzofurans. *Planta Medica* **2008**, *74*(09), PB161. DOI: 10.1055/s-0028-1084505.

[49] Demirci, S.; Ozhatay, N. An Ethnobotanical Study in Kahramanmaras (Turkey); Wild Plants Used for Medicinal Purpose in Andirin. *Kahramanmaraş. Turkish Journal of Pharmaceutical Sciences* **2012**, *9*(1), 75–92.

[50] Erdemgil, F. Z.; Kurkcuoglu, M.; Baser, K. H. C. Composition of the Essential Oil of *Ononis viscosa* subsp. *breviflora*. *Chemistry of Natural Compounds* **2002**, *38*(6), 565–567. DOI: 10.1023/A:1022686721070.

[51] Bussmann, R. W.; Batsatsashvili, K.; Kikvidze, Z., Paniagua-Zambrana, N. Y.; Khutsishvili, M.; Maisaia, I.; Sikharulidze, S.; Tchelidze, D. *Pisum sativum* L. Fabaceae. In *Ethnobotany of the Mountain Regions of Far Eastern Europe: Ural, Northern Caucasus, Turkey, and Iran*, Batsatsashvili, K., Kikvidze, Z., Bussmann, R. W., Eds.; Springer: Cham, 2020, 12–4.?????

[52] Bussmann, R., W.; Batsatsashvili, K.; Kikvidze, Z., Paniagua-Zambrana, N. Y.; Khutsishvili, M.; Maisaia, I.; Sikharulidze, S.; Tchelidze, D. *Vicia faba* L., *Vicia sativa* L. Fabaceae. In *Ethnobotany of the Mountain Regions of Far Eastern Europe: Ural, Northern Caucasus, Turkey, and Iran*, Batsatsashvili, K., Kikvidze, Z., Bussmann, R. W., Eds. Springer: Cham, 2020, 1–5.

[53] Alan, S.; Kurkcuoglu, M.; Baser, K. H. C. Composition of the Essential Oil of *Calamintha grandiflora* (L.) Moench. *Turkish Journal of Pharmaceutical Sciences* **2011**, *8*(2), 127–132.

[54] Ez Zoubi, Y.; Bousta, D.; Farah, A. A Phytopharmacological Review of a Mediterranean Plant: *Lavandula stoechas* L. *Clinical Phytoscience* **2020**, *6*(1), 9. DOI: 10.1186/s40816-019-0142-y.

[55] Yesil, Y.; Akalın, E. Folk Medicinal Plants in Kurecik Area (Akçadağ/Malatya-Turkey). *Turkish Journal of Pharmaceutical Sciences* **2009**, *6*, 207–220.

[56] Mirdeilami, S. Z.; Barani, H.; Mazandarani, M.; Heshmati, G. A. Ethnopharmacological Survey of Medicinal Pants in Maraveh Tappeh Region, North of Iran. *Iranian Journal of Plant Physiology* **2011**, *2*(1), 327–338.

[57] Altay, V.; Karahan, F. Anadolu Geleneksel Tıbbında Güneş Çarpması ve Güneş Yanığı Tedavisinde Kullanılan Tıbbi Bitkiler. *Erzincan Üniversitesi Fen Bilimleri Enstitüsü Dergisi* **2017**, *10*(1), 124–137.

[58] Ozturk, M.; Altay, V.; Gonenc, T. M. Herbal from High Mountains in the East Mediterranean. In *Drug Discovery from Herbs*, Bhojraj, S., Ed.; DAYA Publishing House: New Delhi, 2017, 327–367.

[59] Karakaya, S.; Polat, A.; Aksakal, Ö.; Sümbüllü, Y. Z.; İncekara, Ü. Ethnobotanical Study of Medicinal Plants in Aziziye District (Erzurum, Turkey). *Turkish Journal of Pharmaceutical Sciences* **2020**, *17*(2), 211–220. DOI: 10.4274/tjps.galenos.2019.

[60] González-Tejero, M. R.; Casares-Porcel, M.; Sánchez-Rojas, C. P.; Ramiro-Gutiérrez, J. M.; Molero-Mesa, J.; Pieroni, A.; Giusti, M. E.; Censorii, E.; de Pasquale, C.; Della, A.; et al. Medicinal Plants in the Mediterranean Area: Synthesis of the Results of the Project Rubia. *Journal of Ethnopharmacology* **2008**, *116*(2), 341–357. DOI: 10.1016/j.jep.2007.11.045.

[61] Fakir, H.; Korkmaz, M.; Guller, B. Medicinal Plant Diversity of Western Mediterrenean Region in

Turkey. *Journal of Applied Biological Sciences* **2009**, *3*(2), 33–43.

[62] Koyuncu, O.; Yaylacı, K. O.; Ozturk, D.; Erkara, I. P. Risk Categories and Ethnobotanical Features of the Lamiaceae Taxa Growing Naturally in Osmaneli (Bilecik/Turkey) and Environs. *Biological Diversity and Conservation* **2010**, *3*(3), 31–45.

[63] Karahan, F.; Ilcim, A. The Potential Benefits of Medicinal and Aromatic Plants in Cancer Patients Undergoing Radiotherapy. *Biological Diversity and Conservation* **2017**, *10*(2), 51–61.

[64] Orch, H.; Zidane, L.; Douira, A. Ethnobotanical Study of Plants Used by the Population Bordering the Forest of Izarène. *Journal of Pharmacy & Pharmacognosy Research* **2020**, *8*(5), 392–409. DOI: 10.32859/era.19.33.1-15.

[65] Mükemre, M.; Behçet, L.; Çakılcıoğlu, U. Ethnobotanical Study on Medicinal Plants in Villages of Çatak (Van-Turkey). *Journal of Ethnopharmacology* **2015**, *166*, 361–374. DOI: 10.1016/j.jep.2015.03.040.

[66] Güneş, S.; Savran, A.; Paksoy, M. Y.; Koşar, M.; Çakılcıoğlu, U. Ethnopharmacological Survey of Medicinal Plants in Karaisalı and İts Surrounding (Adana-Turkey). *Journal of Herbal Medicine* **2017**, *8*, 68–75. DOI: 10.1016/j.hermed.2017.04.002.

[67] Sarikurkcu, C.; Eskici, M.; Karanfil, A.; Tepe, B. Phenolic Profile, Enzyme Inhibitory and Antioxidant Activities of Two Endemic *Nepeta* Species: *Nepeta nuda* subsp. *glandulifera* and *N. cadmea*. *South African Journal of Botany* **2019**, *120*(3), 298–301. DOI: 10.1016/j.sajb.2018.09.008.

[68] Sharopov, F. S.; Setzer, W. N. Medicinal Plants of Central Asia: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. In *Natural Products of Silk Road Plants*, Cooper, R., Deakin, J. J., Eds.; CRC Press: Boca Raton, 2021, 105–131.

[69] Arslan, D.; Fidan, M. Siirt İli Florasında Doğal Olarak Yetişen *Salvia multicaulis* Vahl.'in Uçucu Yağ Kompozisyonunun Belirlenmesi. *European Journal of Science and Technology* **2020**, *18*, 196–200. DOI: 10.31590/ejosat.678479.

[70] Miski, M.; Ulubelen, A.; Johansson, C.; Mabry, T. J. Antibacterial Activity Studies of Flavonoids from *Salvia palaestina*. *Journal of Natural Products* **1983**, *46*(6), 874–875. DOI: 10.1021/np50030a007.

[71] Firuzi, O.; Javidnia, K.; Gholami, M.; Soltani, M.; Miri, R. Antioxidant Activity and Total Phenolic Content of 24 Lamiaceae Species Growing in Iran. *Natural Product Communications* **2010**, *5*(2), 1934578X1000500–264. DOI: 10.1177/1934578X1000500219.

[72] Kelen, M.; Tepe, B. Chemical Composition, Antioxidant and Antimicrobial Properties of the Essential Oils of Three *Salvia* Species from Turkish Flora. *Bioresource Technology* **2008**, *99*(10), 4096–4104. DOI: 10.1016/j.biortech.2007.09.002.

[73] Orhan, I. E.; Senol, F. S.; Ozturk, N.; Akaydin, G.; Sener, B. Profiling of İn Vitro Neurobiological Effects and Phenolic Acids of Selected Endemic *Salvia* Species. *Food Chemistry* **2012**, *132*(3), 1360–1367. DOI: 10.1016/j.foodchem.2011.11.119.

[74] Tabanca, N.; Demirci, B.; Baser, K. H. C.; Aytac, Z.; Ekici, M.; Khan, S. I.; Jacob, M. R.; Wedge, D. E. Chemical Composition and Antifungal Activity of *Salvia macrochlamys* and *Salvia recognita* Essential Oils. *Journal of Agricultural and Food Chemistry* **2006**, *54*(18), 6593–6597. DOI: 10.1021/jf0608773.

[75] Janicsák, G.; Zupkó, I.; Máthé, I.; Hohmann, J. Comparative Study of the Antioxidant Activities of Eleven *Salvia* species. *Natural Product Communications* **2010**, *5*(2), 1934578X1000500–230. DOI: 10.1177/1934578X1000500211.

[76] Tepe, B.; Daferera, D.; Sokmen, A.; Sokmen, M.; Polissiou, M. Antimicrobial and Antioxidant Activities of the Essential Oil and Various Extracts of *Salvia tomentosa* Miller (Lamiaceae). *Food Chemistry* **2005**, *90*(3), 333–340. DOI: 10.1016/j.foodchem.2003.09.013.

[77] El Beyrouthy, M.; Dhifi, W.; Arnold-Apostolides, N. Ethnopharmacological Survey of the Indigenous Lamiaceae from Lebanon. *Acta Horticulturae* **2013**, *997*, 257–275. DOI: 10.17660/ActaHortic.2013.997.33.

[78] Kultur, S.; Gurdal, B.; Sari, A.; Melikoğlu, G. Traditional Herbal Remedies Used in Kidney Diseases in Turkey: An Overview. *Turkısh Journal of Botany* **2021**, *45*(4), 269–287. DOI: 10.3906/bot-2011-32.

[79] Altundag, E.; Ozturk, M. Ethnomedicinal Studies on the Plant Resources of East Anatolia, Turkey. *Procedia - Social and Behavioral Sciences* **2011**, *19*, 756–777. DOI: 10.1016/j.sbspro.2011.05.195.

[80] Keskin, C. Mardinde Geleneksel Halk Hekimliğinde Kullanılan Tıbbi Bitkiler ve Geleneksel Kullanımları. Presented at the International European Congress on Mathematics, Engineering, Natural and Medical Sciences-II, Mardin, 2018.

[81] Altay, V.; Karahan, F. Tayfur Sökmen Kampüsü (Antakya-Hatay) ve Çevresinde Bulunan Bitkiler Üzerine Etnobotanik Bir Araştırma. *Karadeniz Fen Bilimleri Dergisi* **2012**, *3*(2), 13–28.

[82] Gurdal, B.; Kultur, S. An Ethnobotanical Study of Medicinal Plants in Marmaris (Muğla, Turkey). *Journal of Ethnopharmacology* **2013**, *146*(1), 113–126. DOI: 10.1016/j.jep.2012.12.012.

[83] Nacakci, F. M.; Dutkuner, I. A Study of Ethnobotany in Kumluca (Antalya). *Turkish Journal of Forestry* **2018**, *19*(2), 113–119. DOI: 10.18182/tjf.421970.

[84] Yalcin, F. N.; Kaya, D. Ethnobotany, Pharmacology and Phytochemistry of the Genus *Lamium* (Lamiaceae). *FABAD Journal of Pharmaceutical Sciences* **2006**, *31*(1), 43–53.

[85] Ozdemir, E.; Alpinar, K. An Ethnobotanical Survey of Medicinal Plants in Western Part of Central Taurus Mountains: Aladaglar (Nigde-Turkey). *Journal of Ethnopharmacology* **2015**, *166*, 53–65. DOI: 10.1016/j.jep.2015.02.052.

[86] Erdogan, E. A.; Everest, A.; De Martino, L.; Mancini, E.; Festa, M.; De Feo, V. Chemical Composition and In Vitro Cytotoxic Activity of the Essential Oils of *Stachys rupestris* and *Salvia heldreichiana*, Two Endemic Plants of Turkey. *Natural Product Communications* **2013**, *8*(11), 1934578X1300801–1640. DOI: 10.1177/1934578X1300801134.

[87] Ugur, A.; Sarac, N.; Varol, O. Antimicrobial Activities of the Essential Oils of Endemic *Stachys rupestris* and *Stachys amanica* against Multi-Resistant Bacteria. *Indian Journal of Pharmacology* **2013**, *45*(2), 201–202. DOI: 10.4103/0253-7613.108327.

[88] Ergun, B.; Goger, F.; Kose, Y. B.; Iscan, G. Determination of Phenolic Compounds of *Stachys rupestris* Montbret Et Aucher Ex Bentham by LC-MS/MS and Its Biological Activities. *Fresenius Environmental Bulletin* **2018**, *27*, 1176–1182.

[89] Morteza-Semnani, K.; Akbarzadeh, M.; Rostami, B. The Essential oil Composition of *Teucrium chamaedrys* L. from Iran. *Flavour and Fragrance Journal* **2005**, *20*(5), 544–546. DOI: 10.1002/ffj.1479.

[90] Bagci, E.; Yazgin, A.; Hayta, S.; Cakilcioglu, U. Composition of the Essential Oil of *Teucrium chamaedrys* L. (Lamiaceae) from Turkey. *Journal of Medicinal Plants Research* **2010**, *4*(23), 2584–2587. DOI: 10.5897/jmpr10.823.

[91] Vlase, L.; Benedec, D.; Hanganu, D.; Damian, G.; Csillag, I.; Sevastre, B.; Mot, A. C.; Silaghi-Dumitrescu, R.; Tilea, I. Evaluation of Antioxidant and Antimicrobial Activities and Phenolic Profile for *Hyssopus officinalis*, *Ocimum basilicum* and *Teucrium chamaedrys*. *Molecules* **2014**, *19*(5), 5490–5507. DOI: 10.3390/molecules19055490.

[92] Mosaddegh, M.; Naghibi, F.; Moazzeni, H.; Pirani, A.; Esmaeili, S. Ethnobotanical Survey of Herbal Remedies Traditionally Used in Kohghiluyeh va Boyer Ahmad Province of Iran. *Journal of Ethnopharmacology* **2012**, *141*(1), 80–95. DOI: 10.1016/j.jep.2012.02.004.

[93] Tepe, B.; Daferera, D.; Sokmen, A.; Sokmen, M.; Polissiou, M. In Vitro Antimicrobial and Antioxidant Activities of the Essential Oils and Various Extracts of *Thymus eigii* M. Zohary et P.H. Davis. *Journal of Agricultural and Food Chemistry* **2004**, *52*(5), 1132–1137. DOI: 10.1021/jf035094l.

[94] Salim, M.; Turkmen, N. A Survey on Wild Plants with Ethnobotanical Use in the Bahçe and Hasanbeyli Districts of Osmaniye. *Turkey. GSC Biological and Pharmaceutical Sciences* **2018**, *5*(3), 28–35. DOI: 10.30574/gscbps.2018.5.3.0133.

[95] Sağıroğlu, M.; Topuz, T.; Ceylan, K.; Turna, M. An Ethnobotanical Survey from Yahyalı (Kayseri) and Tarsus (Mersin). *SAÜ Fen Edebiyat Dergisi* **2013**, *2*, 13–37.

[96] Sharma, I. I.-O. An Advance Tool in Biological Research. *Open Journal of Environmental Biology* **2020**, *5*(1), 27–33. DOI: 10.17352/ojeb.000018.

[97] Cao, L.; Zheng, J.; Tsukada, H.; Pan, S.; Wang, Z.; Tagami, K.; Uchida, S. Simultaneous Determination of Radiocesium (135Cs, 137Cs) and Plutonium (239Pu, 240Pu) Isotopes in River Suspended Particles by ICP-MS/MS and SF-ICP-MS. *Talanta* **2016**, *159*, 55–63. DOI: 10.1016/j.talanta.2016.06.008.

[98] Gonçalves, D. A.; de Souza, I. D.; Rosa, A. C. G.; Melo, E. S. P.; Goncalves, A.-M B.; de Oliveira, L. C. S.; do Nascimento, V. A. Multi-Wavelength Calibration: Determination of Trace Toxic Elements in Medicine Plants by ICP OES. *Microchemical Journal* **2019**, *146*, 381–386. DOI: 10.1016/j.microc.2019.01.021.

[99] Barin, J. S.; Pereira, J. S. F.; Mello, P. A.; Knorr, C. L.; Moraes, D. P.; Mesko, M. F.; Nóbrega, J. A.; Korn, M. G. A.; Flores, E. M. M. Focused Microwave-İnduced Combustion for Digestion of Botanical Samples and Metals Determination by ICP OES and ICP-MS. *Talanta* **2012**, *94*, 308–314. DOI: 10.1016/j.talanta.2012.03.048.

[100] Kim, J. Y.; Park, S. G.; Lee, J. H. A Study on the Hazardous Metal Content of Herbal Medicines in the Daegu Area. *Journal of Environmental Health Sciences* **2017**, *43*(4), 257–266. DOI: 10.5668/jehs.2017.43.4.257.

[101] Zhang, J.; Yang, R.; Chen, R.; Peng, Y.; Wen, X.; Gao, L. Accumulation of Heavy Metals in Tea Leaves and Potential Health Risk Assessment: A Case Study from Puan County, Guizhou Province, China. *International Journal of Environmental Research and Public Health* **2018**, *15*(1), 133. DOI: 10.3390/ijerph15010133.

[102] Peng, C.-Y.; Zhu, X.-H.; Hou, R.-Y.; Ge, G.-F.; Hua, R.-M.; Wan, X.-C.; Cai, H.-M. Aluminum and Heavy Metal Accumulation in Tea Leaves: An Interplay of Environmental and Plant Factors and an Assessment of Exposure Risks to Consumers. *Journal of Food Science* **2018**, *83*(4), 1165–1172. DOI: 10.1111/1750-3841.14093.

[103] Li, L.; Fu, Q. L.; Achal, V.; Liu, Y. A Comparison of the Potential Health Risk of Aluminum and Heavy Metals in Tea Leaves and Tea Infusion of Commercially Available Green Tea in Jiangxi, China. *Environmental Monitoring and Assessment* **2015**, *187*(5), 228. DOI: 10.1007/s10661-015-4445-2.

[104] Gruszecka-Kosowska, A.; Mazur-Kajta, K. Potential Health Risk of Selected Metals for Polish Consumers of Oolong Tea from the Fujian Province. *Human and Ecological Risk Assessment:*

An International Journal **2016**, *22*(5), 1147–1165. DOI: 10.1080/10807039.2016.1146572.

[105] Ozyigit, I. I.; Yalcin, B.; Turan, S.; Saracoglu, I. A.; Karadeniz, S.; Yalcin, I. E.; Demir, G. Investigation of Heavy Metal Level and Mineral Nutrient Status in Widely Used Medicinal Plants' Leaves in Turkey: Insights into Health Implications. *Biological Trace Element Research* **2018**, *182*(2), 387–406. DOI: 10.1007/s12011-017-1070-7.

[106] FAO/WHO. *Contaminants*. Vol. XVII. FAO/WHO: Rome, 1984.

[107] FAO/WHO. Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the thirty eight session ofthe codex committee on food hygiene, Houston, United States of America, ALINORM 07/30/13, 2007. Available from: ftp://ftp. fao. org/codex/R.

[108] FAO/WHO. Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Foods, Fifth Session. 2011; 52 pp., CL 2011/6-C.

[109] WHO. *Department of Technical Cooperation for Essential Drugs and Traditional Medicine. Guidelines for Assessing Quality of Herbal Medicines with Reference to Contaminants and Residues*. World Health Organization: Geneva, Switzerland, 2007.

[110] Joint FAO/WHO Expert Committee on Food Additives. Evaluation of Certain Food Additives and Contaminants : Sixty-First Report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization & Food and Agriculture Organization of the United Nations: Rome, 2003.

[111] American Herbal Products Association (AHPA). *About Us > AHPA's Policies > Guidance Policies*. AHPA: Silver Spring, MD, 2012.

[112] Tripathy, V.; Basak, B. B.; Varghese, T. S.; Saha, A. Residues and Contaminants in Medicinal Herbs-A Review. *Phytochemistry Letters* **2015**, *14*, 67–78. DOI: 10.1016/j.phytol.2015.09.003.

[113] de Oliveira, L. M.; Das, S.; da Silva, E. B.; Gao, P.; Gress, J.; Liu, Y.; Ma, L. Q. Metal Concentrations in Traditional and Herbal Teas and Their Potential Risks to Human Health. *The Science of the Total Environment* **2018**, *633*, 649–657. DOI: 10.1016/j.scitotenv.2018.03.215.

[114] Liu, C.-M.; Qin, J.-A.; Dou, X.-W.; Yang, M.-H.; Sun, X.-B. Extrinsic Harmful Residues in Chinese Herbal Medicines: Types, Detection, and Safety Evaluation. *Chinese Herbal Medicines* **2018**, *10*(2), 117–136. DOI: 10.1016/j.chmed.2018.02.002.

[115] Zolfaghari, G.; Akhgari Sang Atash, Z.; Sazgar, A. Baseline Heavy Metals in Plant Species from Some Industrial and Rural Areas: Carcinogenic and Non-carcinogenic Risk Assessment. *MethodsX* **2018**, *5*, 43–60. DOI: 10.1016/j.mex.2018.01.003.

[116] Soomro, A. H.; Jatoi, W. B.; Maitlo, A. A.; Memon, A. F.; Bhayo, M. S. Assessment of Heavy Metal Content of Commonly Consumed Herbal Medicines in Sindh, Pakistan. *Environmental Science and Pollution Research* **2021**, *28*(25), 32744–32753. DOI: 10.1007/s11356-021-13019-0.

[117] Tuncturk, M.; Tuncturk, R.; Sekeroglu, N.; Ertus, M. M.; Ozgokce, F. Lead Concentrations of Herbs Used in Van Herby Cheese. *Natural Product Communications* **2011**, *6*(10), 1473–1474. DOI: 10.1177/1934578X1100601016.

[118] Tunçtürk, M.; Eryiğit, T.; Kaya, A. R. Nutritional Properties, Minerals, and Selected Heavy Metal Contents in Herby Cheese Plants of Lamiaceae. *Applied Biological Chemistry* **2017**, *60*(1), 41–47. DOI: 10.1007/s13765-016-0245-9.

[119] Yildiz, D.; Kula, I.; Ay, G.; Baslar, S.; Dogan, Y. Determination of Trace Elements in the Plants of Mt. Bozdag, Izmir, Turkey. *Archives of Biological Sciences* **2010**, *62*(3), 731–738. DOI: 10.2298/ABS1003731Y.

[120] Dzierżanowski, K.; Gawroński, S. W. Heavy Metal Concentration in Plants Growing on the Vicinity of Railroad Tracks: A Pilot Study. *Challenges of Modern Technology* **2012**, *3*, 42–45.

[121] Casado, M.; Anawar, H.M.; Sanchez, A. G.; Regina, I. S. Cadmium and Zinc in Polluted Mining Soils and Uptake by Plants (El Losar mine, Spain). *International Journal of Environment and Pollution* **2008**, *33*(2/3), 146–159. DOI: 10.1504/IJEP.2008.019389.

[122] Stojković, M.; Jevtić, M.; Pavlović, J. Metal Content in Common Daisy (*Bellis perennis* L.) and Correspond Soils from Niš city Area (Serbia). *Chemia Naissensis* **2019**, *2*(1), 96–109.

[123] Rubio, C.; Lucas, J. R. D.; Gutiérrez, A. J.; Glez-Weller, D.; Pérez Marrero, B.; Caballero, J. M.; Revert, C.; Hardisson, A. Evaluation of Metal Concentrations in Mentha Herbal Teas (*Mentha piperita, Mentha pulegium* and *Mentha* species) by Inductively Coupled Plasma Spectrometry. *Journal of Pharmaceutical and Biomedical Analysis* **2012**, *71*, 11–17. DOI: 10.1016/j.jpba.2012.07.015.

[124] Can, H.; Ozyigit, I. I.; Can, M.; Hocaoglu-Ozyigit, A.; Yalcin, I. E. Environment-Based Impairment in Mineral Nutrient Status and Heavy Metal Contents of Commonly Consumed Leafy Vegetables Marketed in Kyrgyzstan: A Case Study for Health Risk Assessment. *Biological Trace Element Research* **2021**, *199*(3), 1123–1144. DOI: 10.1007/s12011-020-02208-6.

[125] Gondal, A. H.; Zafar, A.; Zainab, D. A Detailed Review Study of Zinc Involvement in Animal, Plant and Human Nutrition. *Journal of Pure & Applied Biosciences* **2021**, *9*(2), 262–271. DOI: 10.18782/2582-2845.8652.

[126] Toor, M. D.; Adnan, M.; Javed, M., S. Foliar Application of Zn: Best Way to Mitigate Drought Stress in Plants; A Review. *International Journal of Applied Research* **2020**, *6*, 16–20.

[127] Haider, F. U.; Liqun, C.; Coulter, J. A.; Cheema, S. A.; Wu, J.; Zhang, R.; Wenjun, M.; Farooq, M. Cadmium Toxicity in Plants: Impacts and Remediation Strategies. *Ecotoxicology and Environmental Safety* **2021**, *211*, 111887. DOI: 10.1016/j.ecoenv.2020.111887.

[128] Kaur, H.; Garg, N. Zinc Toxicity in Plants: A Review. *Planta* **2021**, *253*(6), 129. DOI: 10.1007/s00425-021-03642-z.

[129] Goher, M. E.; Ali, M. H.; El-Sayed, S. M. Heavy metals contents in Nasser Lake and the Nile River, Egypt: An overview. *The Egyptian Journal of Aquatic Research* **2019**, *45*(4), 301–312. DOI: 10.1016/j.ejar.2019.12.002.

[130] Narayanan, S. E.; Rehuman, N. A.; Harilal, S.; Vincent, A.; Rajamma, R. G.; Behl, T.; Uddin, M. S.; Ashraf, G. M.; Mathew, B. Molecular Mechanism of Zinc Neurotoxicity in Alzheimer's Disease. *Environmental Science and Pollution Research İnternational* **2020**, *27*(35), 43542–43552. DOI: 10.1007/s11356-020-10477-w.

[131] Kladsomboon, S.; Jaiyen, C.; Choprathumma, C.; Tusai, T.; Apilux, A. Heavy Metals Contamination in Soil, Surface Water, Crops, and Resident Blood in Uthai District, Phra Nakhon Si Ayutthaya, Thailand. *Environmental Geochemistry and Health* **2020**, *42*(2), 545–561. DOI: 10.1007/s10653-019-00388-2.

[132] White, P. J.; Broadley, M. R. Biofortification of Crops with Seven Mineral Elements Often Lacking in Human Diets–Iron, Zinc, Copper, Calcium, Magnesium, Selenium and Iodine. *The New Phytologist* **2009**, *182*(1), 49–84. DOI: 10.1111/j.1469-8137.2008.02738.x.

[133] Ciosek, Ż.; Kot, K.; Kosik-Bogacka, D.; Łanocha-Arendarczyk, N.; Rotter, I. The Effects of Calcium, Magnesium, Phosphorus, Fluoride, and Lead on Bone Tissue. *Biomolecules* **2021**, *11*(4), 506. DOI: 10.3390/biom11040506.

[134] Wrzosek, M.; Wo, J.; Kozioł-Kaczorek, D.; Włodarek, D. The Assessment of the Supply of Calcium and Vitamin D in the Diet of Women Regularly Practicing Sport. *Journal of Osteoporosis* **2019**, *2019*, 9214926. DOI: 10.1155/2019/9214926.

[135] Du, Y.; Oh, C.; No, J. Advantage of Dairy for Improving Aging Muscle. *Journal of Obesity & Metabolic Syndrome* **2019**, *28*(3), 167–174. DOI: 10.7570/jomes.2019.28.3.167.

[136] Toro-Román, V.; Siquier-Coll, J.; Bartolomé, I.; Grijota, F. J.; Muñoz, D.; Maynar-Mariño, M. Copper Concentration in Erythrocytes, Platelets, Plasma, Serum and Urine: Influence of Physical Training. *Journal of the International Society of Sports Nutrition* **2021**, *18*(1), 28. DOI: 10.1186/s12970-021-00426-4.

[137] Hofmann, P.; Vidovic, M.; Debrunner, J. Copper Deficiency. *Journal of Clinical Nutrition and Dietetics* **2021**, *7*, 1–4.

[138] Bost, M.; Houdart, S.; Oberli, M.; Kalonji, E.; Huneau, J.-F.; Margaritis, I. Dietary Copper and Human Health: Current Evidence and Unresolved İssues. *Journal of Trace Elements in Medicine and Biology* **2016**, *35*, 107–115. DOI: 10.1016/j.jtemb.2016.02.006.

[139] Talebi, S.; Ghaedi, E.; Sadeghi, E.; Mohammadi, H.; Hadi, A.; Clark, C. C. T.; Askari, G. Trace Element Status and Hypothyroidism: A Systematic Review and Meta-Analysis. *Biological Trace Element Research* **2020**, *197*(1), 1–14. DOI: 10.1007/s12011-019-01963-5.

[140] Dhanda, A.; Atkinson, S.; Vergis, N.; Enki, D.; Fisher, A.; Clough, R.; Cramp, M.; Thursz, M. Trace Element Deficiency Is Highly Prevalent and Associated with Infection and Mortality in Patients with Alcoholic Hepatitis. *Alimentary Pharmacology & Therapeutics* **2020**, *52*(3), 537–544. DOI: 10.1111/apt.15880.

[141] Abbaspour, N.; Hurrell, R.; Kelishadi, R. Review on Iron and Its Importance for Human Health. *Journal of Research in Medical Sciences* **2014**, *19*(2), 164–174.

[142] Hoes, M. F.; Grote Beverborg, N.; Kijlstra, J. D.; Kuipers, J.; Swinkels, D. W.; Giepmans, B. N. G.; Rodenburg, R. J.; van Veldhuisen, D. J.; de Boer, R. A.; van der Meer, P. Iron Deficiency Impairs Contractility of Human Cardiomyocytes through Decreased Mitochondrial Function. *European Journal of Heart Failure* **2018**, *20*(5), 910–919. DOI: 10.1002/ejhf.1154.

[143] Trumbo, P.; Yates, A. A.; Schlicker, S.; Poos, M. Dietary Reference İntakes: Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. *Journal of the American Dietetic Association* **2001**, *101*(3), 294–301. DOI: 10.1016/S0002-8223(01)00078-5.

[144] van Dronkelaar, C.; van Velzen, A.; Abdelrazek, M.; van der Steen, A.; Weijs, P. J. M.; Tieland, M. Minerals and Sarcopenia; The Role of Calcium, Iron, Magnesium, Phosphorus, Potassium, Selenium, Sodium, and Zinc on Muscle Mass, Muscle Strength, and Physical Performance in Older Adults: A Systematic Review. *Journal of the American Medical Directors Association* **2018**, *19*(1), 6–11.e3. DOI: 10.1016/j.jamda.2017.05.026.

[145] He, F. J.; MacGregor, G. A. Beneficial Effects of Potassium on Human Health. *Physiologia Plantarum* **2008**, *133*(4), 725–735. DOI: 10.1111/j.1399-3054.2007.01033.x.

[146] Udensi, U. K.; Tchounwou, P. B. Potassium Homeostasis, Oxidative Stress, and Human Disease. *International Journal of Clinical and Experimental Physiology* **2017**, *4*(3), 111–122. DOI: 10.4103/ijcep.ijcep.

[147] National Institutes of Health (NIH). 2021. Dietary Supplement Fact Sheet. https://ods.od.nih.gov/factsheets/list-all/ (accessed May 6, 2022).

[148] Reddy, P.; Edwards, L. R. Magnesium Supplementation in Vitamin D Deficiency. *American Journal of Therapeutics* **2019**, *26*(1), e124–e132. DOI: 10.1097/MJT.0000000000000538.

[149] Fraga, C. G. Relevance, Essentiality and Toxicity of Trace Elements in Human Health. *Molecular Aspects of Medicine* **2005**, *26*(4-5), 235–244. DOI: 10.1016/j.mam.2005.07.013.

[150] Tufarelli, V.; Laudadio, V. Manganese and Its Role in Poultry Nutrition: An Overview. *Journal of Experimental Biology and Agricultural Sciences* **2017**, *5*(6), 749–754. DOI: 10.18006/2017.5(6).749.754.

[151] Bowman, A. B.; Kwakye, G. F.; Herrero Hernández, E.; Aschner, M. Role of Manganese in Neurodegenerative Diseases. *Journal of Trace Elements in Medicine and Biology* **2011**, *25*(4), 191–203. DOI: 10.1016/j.jtemb.2011.08.144.

[152] Liu, Q.; Barker, S.; Knutson, M. D.; Molecular Cell, R. Iron and Manganese Transport in Mammalian Systems. *Biochimica Et Biophysica Acta. Molecular Cell Research* **2021**, *1868*(1), 118890. DOI: 10.1016/j.bbamcr.2020.118890.

[153] Baj, J.; Flieger, W.; Teresiński, G.; Buszewicz, G.; Sitarz, R.; Forma, A.; Karakuła, K.; Maciejewski, R. Magnesium, Calcium, Potassium, Sodium, Phosphorus, Selenium, Zinc, and Chromium Levels in Alcohol Use Disorder: A Review. *Journal of Clinical Medicine* **2020**, *9*(6), 1901. DOI: 10.3390/jcm9061901.

[154] Eckel, R. H.; Jakicic, J. M.; Ard, J. D.; de Jesus, J. M.; Houston Miller, N.; Hubbard, V. S.; Lee, I.-M.; Lichtenstein, A. H.; Loria, C. M.; Millen, B. E.; et al. 2013 AHA/ACC Guideline on Lifestyle Management to Reduce Cardiovascular Risk: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation* **2014**, *129*(25 Suppl 2), S76–S99. DOI: 10.1161/01.cir.0000437740.48606.d1.

[155] Kandasamy, S.; Narayanan, V.; Shanmugam, S. Zinc and Manganese Substituted Hydroxyapatite/CMC/PVP Electrospun Composite for Bone Repair Applications. *International Journal of Biological Macromolecules* **2020**, *145*, 1018–1030. DOI: 10.1016/j.ijbiomac.2019.09.193.

[156] Shayganfard, M. Are Essential Trace Elements Effective in Modulation of Mental Disorders? Update and Perspectives. *Biological Trace Element Research* **2022**, *200*(3), 1032–1059. DOI: 10.1007/s12011-021-02733-y.

[157] Plum, L. M.; Rink, L.; Haase, H. The Essential Toxin: Impact of Zinc on Human Health. *International Journal of Environmental Research and Public Health* **2010**, *7*(4), 1342–1365. DOI: 10.3390/ijerph7041342.

[158] Moon, N.; Figgins, B.; Altshuler, E.; Pham, A.; Kamel, A. Y. Concurrent Zinc and Vitamin B6 Deficiencies in Acutely Exacerbated İnflammatory Bowel Disease: Case Reports. *Nutrition in Clinical Practice* **2022**, *37*(1), 203–208. DOI: 10.1002/ncp.10665.

[159] FAO/WHO. Joint FAO/WHO Expert Committee on Food Additives. Summary and Conclusions. 53rd Meeting. Rome: FAO/WHO, 1999, 1–10.