Assessment of heavy metals accumulation in Celtis tournefortii Lam and Prosopis farcta from Mazne subdistrict, Kurdistan region of Iraq

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Abstract

Most of the world's population relies on medicinal plants as their main source of healthcare. Therefore, it is crucial to ascertain the amount of heavy metals accumulated in medicinal plants. In this study, elements (Ca, P, Mg, Na, K, S, Fe, Cu, Zn, Se, Cd, V, Cr, Ni, Ag, Be, Sr, Ba, Al, Pb, Bi, Rb, B, As, and Sb) found in *Celtis tournefortii* Lam and *Prosopis farcta* that were gathered from the Mazne sub-district of Kurdistan in Iraq were identified. Using inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma optical emission spectrometry (ICP-OES), concentrations of 25 elements in the leaves, fruit (*Celtis tournefortii* Lam), pod, and seed (*Prosopis farcta*) were identified. An exploratory study of samples was conducted using principal component analysis (PCA) and hierarchical cluster analysis (HCA). For Cd, Cr, Ni, Pb, and As. The elements quantified by ppm are: Ca (3403–81948), Mg (1573–7578), Na (108–291), K (6481–23212), Fe (184–623), Cu (8–16), Zn (3–48), Se (0.5–33), Cd (0.11–0.40 ppm), V (1–3), Cr (2–25), Ni (2–4), Ag (0.5–1.7), Be (0.20–0.40), Sr (79.3–454), B (3–86), Al (100–738), Bi (0.7–2.30), Rb (1–7), B (0.7–2.3), As (0.1–3.9), Sb (6.60–12). All of the samples under investigation contained similar levels of phosphorus and lead (218 and 1, respectively). The samples were divided into three major categories, as demonstrated by PCA and HCA. According to the findings, the fruit of *Celtis tournefortii Lam* is a source of Mg, K, Cu, Cd, Cr, Be, Sr, Ba, and Rb. The seeds of *Prosopis farcta* had accumulated a significant level of S, Zn, Se, and Ni. The data usually implies that using these plants poses a risk to people.

Introduction

The global population increasingly relies on medicinal herbs and products for basic medical care. Seventy percent of the world's population, according to estimates from the World Health Organization (WHO), uses medicinal herbs and products for basic medical care (Abdulwahid-Kurdi 2023). Many believe using plants is a safer, less harmful, and more accessible alternative to conventional medicine, especially in rural areas (Baljinnyama et al. 2019). Natural resources are essential in the development of new drugs for medical usage since they provide an extra source of vitamins and minerals (Hlihor et al. 2022). Narendhirakannan et al. (2005) reported that various inorganic trace elements such as K, V, Zn, Cr, Cu, Ni, and Na in the leaves of *Murraya koenigii, Mentha piperitae, Ocimum sanctum, and Aegle marmelos* could account for the hypoglycemic nature of the plants. Concerns about the safety of herbal remedies have developed over time. The secondary metabolites and essential oils of medicinal plants are crucial to their effectiveness (Stanojkovic-Sebic et al. 2015), and consuming large amounts of these bioactive compounds over time may be detrimental if heavy metal concentrations are above tolerable levels (Sadgrove 2022). Heavy metals may reach the body through a variety of pathways, including skin contact, dust inhalation, and soil ingestion (Hlihor et al. 2022). This is due to the higher risk of cardiovascular, neurological, and renal disorders in humans (Hlihor et al. 2022). Here, it is easy to introduce pollutants into medicinal herbs through human activities such as industry and agricultural processing (Stanojkovic-Sebic et al. 2015). Several heavy metals, namely Ba, Co, Cu, Fe, Mn, Mo, Se, Si, Sr, V, and Zn, are absorbed by plants and required for a variety of physiological and biological activities, mostly through soils and industrial processes (chemistry, engineering, and mining) (Da Cruz Ferreira et al. 2021). Pruteanu and Muscalu (2014) observed that the capabilities of medicinal plants vary, and some of them have demonstrated the ability to: (i) tolerate high doses of heavy metals and accumulate them in huge quantities; (ii) remove, contain, inactivate, or degrade harmful environmental contaminants, such as Cd, Ni, Pb, Zn, and Cr; (iii) absorb a significant number of elements from soil and water; and (iv) be compared to solar-powered plants. In terms of application, it was found that the local topography, type of soil, and their compositions have an impact on any plant's chemical profile. Famuyide and his colleagues (2013) reported that in several developed and developing countries, the harvested medicinal plants were documented as contaminated by high levels of potentially toxic heavy metals. These horrible remnants of the Iran-Iraq war, lasting from 1980 to 1988, stretch over three decades. The Kurdistan Region government's (KRG) Mine Action Agency estimates that there were around 13,400 victims of mine explosions in the 1990s. Due to soil pollution, people from border towns continue to lose their lives and limbs to active mines dispersed throughout the Kurdistan border regions (Qadir 2021). The American military reported using over 944,000 rounds of depleted uranium ammunition in Iraq and Kuwait during the 1991 war. Individuals are likely to have been exposed acutely and repeatedly to various hazardous substances, heavy metals, and particulate matter, which could have toxic effects on wild edible plants and herbs and their health (Zwijnenburg and Postma 2017). Appropriate quantities of macro- and micronutrients are crucial for the healthy operation of the key organs, while at high concentrations, some of these metals are poisonous to living things. Hazardous elements, including Cd, Ni, and Pb, must be monitored in biological samples and drugs, especially those made from plants. About 90% of the herbs and medicinal plants used in India's industries come from wild sources (Wayal and Gurav 2019). Kurdish people utilized two wild plants, namely *Celtis tournefortii* Lam and *Prosopis farcta*, as traditional medicines to treat conditions for many diseases. *Celtis Tournefortii* Lam, a deciduous tree, can reach a height of 6 meters in hot climatic plains and dry forests. *Prosopis farcta*, a perennial shrub that grows to a height of 30 to 100 cm, is a common plant in the Middle East, where it dominates the entire belt of agricultural Mediterranean-style alluvial soils. It can be found in a variety of habitats in Iraq, from the north to the south (Abdulwahid-Kurdi 2023). The Mazne region has a Mediterranean climate, which features cold winters and mild summers. Overall results clearly demonstrated that heavy metals are present in Kurdish wild trees, and these plants are rich in specific elements, suggesting a potential link to contamination of the environment. In the samples, the most prevalent elements were detected. Thus, the aim of this study was to determine 27 elements, macro (Ca, P, Mg, Na, K, S, Fe, Cu, and Zn), and microelements (Cd, V, Cr, Ni, Ag, Be, Sr, Ba, Al, Pb, Bi, Rb, B, As, and Sb) by inductively coupled plasma-optical emission spectrometry (ICP-OES) and inductively coupled plasma mass spectrometry (ICP-MS) in fruit and leaves of Celtis *tournefortii Lam and pods with their seeds of Prosopis farcta* from Mazne sub-district Kurdistan region.

Material and methods

Description of the study area

At the intersection of Iraq, Iran, and Turkey, the district of Mergasor is located in the governorate of Erbil's extreme north. It has four of the most well-known mountains in the district: Shireen, Piran, Qalander, and Bradost. Mesrgasor consists of five sub-districts: Barzan, Goratu, Piran, Shirwan Mezn, and Mazne **(**Fig. 1). Mazne sub-district is about 135 kilometers away from the central Erbil province, 25 kilometers from Mergasor district, and 15 kilometers from the center of Soran district, which is on the general road between Zargali and Mergasor district. The Mazne subdistrict has 31 villages and is located 25 km from the Mergasor district. Using the global positioning system (GPS), these sites were identified at 36°47'28.5"N latitude and 44°25'24.5"E longitude (Abdulwahid-Kurdi 2023). *Celtis tournefortii*-Lam and *Prosopis farcta* were collected in November 2021 from the Mazne sub-district. Plants identified by a National Herbarium of Kurdistan expert were coded and kept at the Salahaddin University Herbarium Education College's herbarium (ESUH) (Table 1 **and** Fig. 2).

Table 1
The scientific names and a list of the therapeutic uses for the plants in Mazne Sub-district that were under investigation.

Scientific name and voucher species	English and Kurdish Local names	Family	Uses/ailments treated
Celtis tournefortii lam (ESUH7901)	Hackberry (Tawk)	Cannabaceae	Diarrhea, diuretic.
Prosopis farcta (ESUH7913)	Syrian mesquite (Khrnuk)	Fabaceae (Leguminosa)	Stomach aches, diabetes, and diarrhea.

Sample preparation and analysis

Plant samples were chosen at random, and each tree in the plant specimen was replicated three times. Ripe wild plant fruits, leaves, pods, and seeds were mashed, cleaned, and shade-dried until crisp. After sieving twice, the dry material was ground into powder using a mechanical mixer. The dried samples (0.5 g) and the solid sample were then placed in borosilicate glass digestion tubes. Ten milliliters of HNO3-HCl-H2O2 (8:1:1, v/v/v) were added to each tube, and the tubes were put on a heating block with the temperature set at 120°C for around 3 hours, or until the solutions were thoroughly digested. Following digestion, the clear solutions were transferred to 50 ml volumetric flasks and brought to volume with ultrapure (UP) water. The diluted samples were kept in high-density polyethylene bottles until they were analyzed. The samples were examined in pairs. A blank solution that was composed of 10 mL of HNO3-HCl-H2O2 (8:1:1, v/v/v) was included (Okem et al. 2012). It was then examined using an inductively coupled plasma-optical emission spectrophotometric (ICP-OES) instrument (Optima 5300 DV ICP-OES, Perkin Elmer Instruments, USA) and an inductively coupled plasma mass spectrometry (ICP-MS) instrument (4500 Elan DRC, Perkin Elmer, ION 300X, USA model), both of which have a wide operating range (Tormen et al. 2011).

Statistical analysis

For each mineral, the sample data was examined using one-way analysis of variance (ANOVA), and the means were compared by the Tukey test as described by the graph Pad Prism 9.5.1 program, with significant differences defined at the $P < 0.01$ level. The results of mineral concentration were expressed as the mean ± standard error of the mean (SEM). The data analyzed with XLSTAT were further subjected to principal component analysis (PCA) and hierarchical cluster analysis (HCA) to separate the various elements into plant parts.

Results and discussion

It is essential to monitor and assess the amount of these metals in our diet, as dietary consumption has a substantial impact on how exposed individuals are to heavy metals. Information on the mineral content of meals is pertinent and should be taken into consideration when suggesting the recommended daily consumption of minerals. The minimum requirements and dangerous doses of minerals in the diet are being studied by researchers. Factors like crop species, climatic conditions, soil characteristics, and plant maturity affect mineral levels (Martínez-Ballesta et al. 2010). For elemental analysis, inductively coupled plasma-optical emission spectrometry (ICP-OES) is a powerful tool capable of determining metals in diverse sample matrices (Okem et al. 2012). In recent years, the combination of inductively coupled plasma with mass spectrometry has given rise to inductively coupled plasma-optical mass spectrometry (ICP-MS) equipment, enabling the measurement of mineral elements with remarkable sensitivity and low detection limits. Additionally, mass spectrometers provide the advantage of distinguishing and quantifying different isotopes of the same element (Gomez et al. 2007, Yeung et al. 2017).

Calcium (Ca) is crucial in various bodily processes (Lumachi et al. 2011). The amount of Ca found within plants of plant origin varies notably. In the current study, the accumulation of Ca in the leaf > fruit of *Celtis tournefortii* Lam > pod > seed of *Prosopis farcta* was 81948, 77584, 4370, and 3403 ppm, respectively. The leaf and fruit of *Celtis tournefortii* Lam had significantly higher Ca content compared to the pod and seed of *Prosopis farcta* (Table 2). In raw mint leaves, Xozak et al. (2002) evaluated amounts of Ca (15.331 mg/kg), the recommended daily allowance (RDA) for Ca is (500 mg/kg). Apples (*Malus domestica*), green peppers (*Capsicum annuum*), and potatoes (*Solanum tuberosum*) have the lowest amounts (< 8.7 mg/100 g), whereas broccoli (*Brassica oleracea L*. var. Italica) and spinach (*Spinacia oleracea*) have the highest values (100 mg/100 g and 600 mg/100 g, respectively). According to Martínez -Ballesta et al. (2010), the sample study's Ca content concentration was greater than the RDA (800–1300 mg/day), with potentially harmful health effects for consumers. Hypercalcemia can result from calcium excess due to failure in control mechanisms, including increased bone mobilization, tubular reabsorption, kidney filtration, and increased food intake (Thomas and Gropper 1996). Climate factors, such as light and temperature, can affect plant growth rates and the uptake of mineral ions, thereby influencing the mineral content of different plant species.

Table 2

Profile heavy metals concentration of wild plants from Mazne subdistrict Kurdistan region of Iraq.

	(ppm)	***Celtis tournefortii Lam***		***Prosopis farcta***		**P-Value**
		Leaf	**Fruit**	**Pod**	**Seed**	
1	Calcium (Ca)	81948 ± 0.57a	77584 ± 2.30b	4370 ± 3.51c	3403 ± 0.57d	< 0.0001
2	Phosphorus (P)	218 ± 1.1a	218 ± 1.15a	218 ± 1.15a	218 ± 1.2a	1
3	Magnesium (Mg)	4569 ± 0.58b	7578 ± 1a	1573 ± 0.57d	2646 ± 0.58c	< 0.0001
4	Sodium (Na)	291 ± 0.33a	108 ± 0.33c	137 ± 0.57b	108 ± 0.33c	0.001
5	Potassium (K)	6481 ± 0.03d	23212 ± 0.02a	18011 ± 0.03b	12335 ± 0.02c	0.0001
6	Sulfur (S)	1701 ± 0.54d	2060 ± 0.56c	2599 ± 0.57b	4494 ± 0.57a	< 0.0001
7	Iron (Fe)	623 ± 0.57a	424 ± 0.57b	196 ± 0.57c	184 ± 0.58d	< 0.001
8	Copper (Cu)	8 ± 0.15c	16 ± 0.87a	12 ± 0.36b	16 ± 0.87a	< .0001
9	Zinc (Zn)	3 ± 0.28d	8 ± 0.15c	17 ± 0.57 b	48 ± 1a	< .000
10	Selenium (Se)	0.5 ± 0.02c	0.5 ± 0.03c	2.76 ± 0.08b	33.48 ± 0.57a	< 0.001
11	Cadmium (Cd)	0.30 ± 0.02b	0.40 ± 0.01a	0.11 ± 0.1d	0.20 ± 0.05 c	0.001
12	Vanadium (V)	3 ± 0.01a	1 ± 0.00b	1 ± 0.02b	1 ± 0.01b	< 0.0001
13	Chromium (Cr)	6 ± 0.06b	25 ± 0.58a	2.01 ± 0.04d	4 ± 0.05c	< 0.0001
14	Nickel (Ni)	4 ± 0.29b	2 ± 0.28c	2 ± 0.29c	5 ± 0.28a	0.0002
15	Silver (Ag)	1 ± 0.17bc	1.4 ± 0.20 ab	1.7 ± 0.11a	0.50 ± 0.15c	0.004
16	Beryllium (Be)	0.30 ± 0.01ab	0.40 ± 0.05a	0.20 ± 0.57b	0.20 ± 0.67b	0.025
17	Strontium (Sr)	430 ± 1b	454 ± 0.57a	133 ± 0.57c	79.3 ± 0.40d	< 0.0001
18	Barium (Ba)	77 ± 1.15b	86 ± 0.57a	3 ± 0.05c	3 ± 0.11c	< 0.0001
19	Aluminum (Al)	738 ± 1.15a	100 ± 0.57b	100 ± 1.154b	100 ± 0.57b	0.0001
20	Lead (Pb)	1 ± 0.10a	1 ± 0.04a	1 ± 0.05a	1 ± 0.05a	0.9

The data are expressed as mean ± SEM. Means with different letters were significantly different at the level of $P < 0.05$. SEM = standard error of the mean.

	(ppm)	*Celtis tournefortii Lam*		*Prosopis farcta*		P-Value
		Leaf	**Fruit**	**Pod**	**Seed**	
21	Bismuth (Bi)	0.80 ± 0.03c	0.70 ± 0.01c	2.3 ± 0.05 a	1.60 ± 0.89b	< .0001
22	Rubidium (Rb)	1 ± 0.28c	7 ± 0.3a	5 ± 0.28b	2 ± 0.27c	0.0001
23	Boron (B)	0.8 ± 0.03c	0.7 ± 0.01d	2.3 ± 0.05a	1.6 ± 0.08b	0.0001
24	Arsenic (As)	1.8 ± 0.05b	0.1 ± 0.01c	3.9 ± 0.05a	1.8 ± 0.5b	< 0.001
25	Antimony (Sb)	7 ± 0.05bc	6.60 ± 0.09c	12 ± 0.57a	9.5 ± 0.28b	< .0001

The data are expressed as mean ± SEM. Means with different letters were significantly different at the level of P < 0.05. SEM = standard error of the mean.

Table 3

Loading of principle components (PC) of 25 elements for different plant parts of *Celtis tournefortii* Lam *and Prosopis farcta*

Elements	**PC1**	**PC2**	**PC3**
Ca	**0.997**	-0.075	-0.003
P	0.000	0.000	0.000
Mg	0.880	0.409	-0.243
Na	0.481	-0.843	0.240
K	0.012	**0.982**	0.190
S	-0.783	0.060	-0.619
Fe	0.908	-0.414	0.059
Cu	-0.283	**0.798**	-0.533
Zn	-0.783	0.043	-0.621
Se	-0.647	-0.082	-0.758
Cd	**0.902**	0.251	-0.351
V	0.550	-0.829	0.100
Cr	**0.701**	**0.689**	-0.187
Ni	-0.228	-0.642	-0.732
Ag	0.142	0.434	**0.889**
Be	**0.918**	0.390	-0.074
Sr	**0.996**	0.030	0.087
Ba	**0.999**	0.045	-0.029
Al	0.550	-0.829	0.100
Pb	0.000	0.000	0.000
Bi	-0.916	0.030	0.401
Rb	0.144	**0.937**	0.318
B	-0.916	0.030	0.401
As	-0.707	-0.342	**0.619**
Sb	-0.903	0.023	0.429

Phosphorus (P) consumption is crucial for the development and mineralization of bones (Ciosek et al. 2023). In plants, P is the second-most important nutrient after nitrogen, serving as a critical macronutrient involved in various biochemical processes (Muindi, 2019). Phosphorus concentrations range from 16.2 to 437 mg/100 g in vegetables (Szefer and Grembecka 2007). The total P level in this research indicated 218 ppm in both plants, with no notable fluctuations across the plant portions that were investigated (Table 2). The findings of the current study were lower than the recommendations made by the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes in 1997 regarding the dietary allowances (RDAs) for phosphorus, which are set at 700 mg. Ingesting dosages of P exceeding 3000–4000 mg /day may be harmful as it can interfere with Ca absorption (Moe 2008). This suggests that the circulation of P within these plants occurs evenly, possibly due to the distribution of transporters throughout the plant tissues (Karik et al. 2018). In addition, P concentrations varied among plant species, according to Karik et al. (2018), with *Gypsophila bicolor* having a concentration of 0.65 g/kg and *Ranunculus polyanthemos* L. having a concentration of 5.63 g/kg. The findings of the current study were lower than the recommendations made by the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes in 1997 regarding the dietary allowances (RDAs) for phosphorus, which are set at 700 mg. Ingesting dosages of P exceeding 3000–4000 mg /day may be harmful as it can interfere with Ca absorption (Moe 2008).

Magnesium (Mg), is abundant in vegetable diets and plays a crucial role in maintaining human health throughout the lifespan. The accumulation of Mg concentration in the fruit > leaf of *Celtis tournefortii* Lam > seed > pod of *Prosopis farcta is* 7578, 4569, 2646, and 1573 ppm, respectively (Table 2). Similarly, in raw mint leaves, Xozak et al. (2002) evaluated amounts of Mg (5778 mg/kg). The RDA for varies between men and women, with men consuming 410–420 mg/day and women consuming 320–360 mg/day (Volpe 2013). Magnesium levels in fruits and vegetables typically range from 5.5 to 191 mg/100 g of fresh weight, with daily consumption of 200 to 400 mg/day (Martínez-Ballesta et al. 2009). The results of the current study are higher in mg content than limited daily intake; the most prevalent adverse effects of excessive consumption of the Mg are headache, nausea, hypotension, and generalized bone and stomach pain (Guerrero-Romero and Rodrguez-Morán 2005).

Sodium (Na) is an essential element for maintaining acid-base equilibrium and osmotic pressure in body fluids (British Medical Association 1993). In the current study, the accumulation of Na in the leaf > pod > fruit ≥ seed was 291, 137, 108, and 108 ppm, respectively (Table 2). *Celtis tournefortii* Lam exhibited the highest concentration of Na in its leaves compared to other plant parts studied. The RDA for Na is < 1500 mg as recommended by the American Heart Association (Bossola et al. 2020). In the current study, Na content in plants was greater than the permissible limit of 20 mg/kg (Kronzucker et al. 2013). High concentrations of Na have been linked to heart failure and high blood pressure in certain cases (Ullah et al. 2012). In contrast, the Na content in raw vegetables and fruit juices is relatively low, ranging from 2.28 to 94.0 mg/100 g and 0.04 to 277 mg/100 g, respectively (Szefer and Grembecka 2007).

Potassium (K) is essential for plant activities like enzymes, photosynthesis, starch, and protein synthesis (Hughes 2002). The current study showed that the levels of K in the fruit > pod > seed > leaf were 23212, 18011, 12335, and 6481 ppm, respectively (Table 2). The Na concentration was significantly higher in the fruit of *Celtis tournefortii* Lam (23212 ppm) than in the pod, seed, and leaves. Similarly, in the study of Martínez-Ballesta et al. (2009), the levels of K in seeds and nuts are very high, reaching up to 2240 mg/100 g. Typically, plants have K contents of 20 to 730 mg/100 g of fresh material (Martínez-Ballesta et al. 2009). The K content in *Prosops farcta* and *Celits tournetilam* is higher than the RDA of 550–5625 mg (Ivey and Elmen 1986). Excess K can be damaging to the organism as a whole when oliguria (caused by kidney failure) and hyperkalemia in a catabolic situation are present (Sobotka et al. 2008).

Sulfur (S) as a versatile element is efficient for structure, transport of electrons, regulation of plant growth, and enhancing the photosynthetic process by producing the required oxygen (Hell et al. 2010) The accumulated sulfur in *Prosopis farcta* is more than that accumulated in *Celtis tournefortii* Lam. The results revealed that the S uptake was significantly different in each studied part of plants, and the detected values were ordered as: seed > pod of *Prosopis farcta* > fruit > leaves of *Celtis tournefortii* Lam, and their concentrations were 4494, 2599, 2060 and 1701 ppm, respectively (Table 2). The S and amino acid consumption recommendations from the WHO and the RDA are both 13 mg/day of body weight (Van De Poll et al. 2006). According to the broad consensus, these numbers may be two or three times higher during diseases and following trauma (Van De Poll et al. 2006). When there is an overabundance of S in the soil or the air, plants often absorb too much S (Rennenberg 1984). Many legumes, including globulins in soybean (*Glycine max* L.) and lupine (*Lupinus sp.*), as well as globulins and albumins in pea (*Pisum sativum* L.), have well-documented seed protein accumulation that is controlled by the S status in plants (Pandurangan et al. 2015). Similarly, according to Tabe and Droux (2002), S is transferred to seeds through the phloem in reduced forms, such as glutathione in rice grains and S-methylmethionine in wheat, or as sulfate in the pods of legumes. Due to their high S content, these two wild trees can be utilized as supplements and are an excellent alternative (Feng et al. 2016).

In the present study, the iron (Fe) level of *Celtis tournefortii* leaf was significantly higher (P 0.05) than the pod and seed of *Prosopis farcta.* The Fe concentration level was ordered descending: leaf > fruit of *Celtis tournefortii* > pod > seed of *Prosopis farcta*, with concentrations of 623, 424, 196, and 84 ppm, respectively (Table 2). The results of the present study had a higher Fe level than the RDA (10–18 mg/day) (Ivey and Elmen, 1986) and may need special attention to prevent iron poisoning; an excess of iron can cause nausea, vomiting, diarrhea, and liver issues (Prashanth et al. 2015). Nuts and cocoa powder may both be rich sources of iron (respectively at 16.1 and 25.8 mg/100 g) (Szefer and Grembecka 2007). According to the study by Ebrahimzadeh et al. (2019), the aerial parts of *Grammosciadium platycarpum* and *Leonurus cardiana*, showed a range of Fe concentration in plant samples of 184 to 623 ppm (mg/kg), which included significant quantities of phenol and flavonoid contents. In a different investigation, *Withania somnifera* samples were taken from the PCSIR Lab complex's field in Karachi (Pakistan), and it was found that the amounts of Fe (9417.7 and 3750.3 mg/kg) in the shoot and leaves were higher than allowed (Shirin et al., 2010). According to De Aragão Tannus et al. (2021), this volatility may be a result of changes in the soil, the weather, and the seasons. Hence, people with low iron levels are recommended to consume *Celtis tournefortii* Lam and *Prosopis fractal.*

Copper (Cu) is a vital component of the proteins found in enzymes that control the escalation of a number of metabolic processes in plants (Rehm and Schmitt 1997). The accumulation level of Cu in the fruit > seed, pod > leaf was 16, 16, 12, and 8 ppm, respectively. The Cu level in the fruit of *Celtis tournefortii* Lam and the seed of *Prosopis farcta* was significantly higher than in the pod and leaves, as shown in Table 2, with the lowest levels of the present study being higher than the allowed daily exposure (PDE) to Cu, which is 2–3 mg (Başgel and Erdemoğlu 2006). The quantities of Cu (245.7 and 135.8 mg/kg) in the shoot and leaves were found to be greater than permitted in a different experiment including *Withania somnifera* samples from the PCSIR Lab complex's field in Karachi (Pakistan) (Shirin et al. 2010). In contrast, Szefer and Grembecka (2007) demonstrated that vegetables have been shown to have low Cu contents, ranging from 0.004 to 0.24 mg/100 g, with the exception of legumes, which can contain up to 0.5 mg/100 g. The World Health Organization reported that the RDA of Cu is less than 1.3 mg/day (Başgel and Erdemoğlu 2006). This suggests that *Celtis tournefortii* Lam and *Prosopis farcta* contain adequate quantities of Cu. If the amount of Cu in dried plant material is greater than 20 to 100 mg/kg, it becomes phytotoxic (Khan 2008). Toxic levels of Cu have been associated with gastrointestinal symptoms such as cramps, nausea, diarrhea, and vomiting in acute episodes as well as liver damage in chronic poisoning (Guerrero-Romero and Rodrguez-Morán 2005). The excessive accumulation of Cu in the environment and in plants is primarily caused by human activity, including mining, smelting, manufacturing, agriculture, and waste disposal techniques (Sharma and Agrawal 2005). The plants that were seen in this case should not be utilized as daily dietary supplements or in excess.

Zinc (Zn) is essential for nucleic acid metabolism, stabilizes membranes, and stimulates the immune system (Obi et al., 2006). In the current study, accumulation levels in seed > pod of *Prosopis farcta* > fruit > leaf of *Celtis tournefortii* Lam were 48, 17, 8, and 3 ppm, respectively (Table 2). The concentration of Zn in plants generally varies from 0.05 to 11.8 mg/100 g (Szefer and Grembecka 2007). FAO/WHO (1984) recommended 27.4 mg/kg of Zn as the permissible limit in edible plants. The seeds of *Prosopis farcta* contained a higher zinc concentration than the recommended limit. *Withania somnifera* samples were collected from the PCSIR Lab complex's field in Karachi (Pakistan) in a different inquiry, and it was discovered that the levels of Zn (422.2 and 375 mg/kg) in the shoot and leaves were greater than permitted (Shirin et al. 2010). Higher concentrations of other elements, such as Fe or Cu, lower the bioavailability of Zn (Shenkin 2008). The estimated safe and adequate daily intake of Zn is between 10 and 20 mg/day (Food and Nutrition Broad 1980). Acute Zn poisoning symptoms include nausea, vomiting, diarrhea, fever, and lethargic behavior (Obi et al. 2006).

Selenium (Se) is essential for selenoproteins, antioxidants, cancer prevention, hormones, reproductive systems, and plants' reproductive organs (Antal et al. 2010, DalCorso et al. 2014). In the present study, accumulation levels of Se in the seed > pod of *Prosopis farcta* > fruit ≥ leaf of *Celtis tournefortii* Lam were 33.48, 2.76, 0.5, and 0.5 ppm, respectively. The results showed that Se was significantly more accumulated in the seed of *Prosopis farcta*, than in the seed of *Celtis tournefortii* Lam (Table 2). According to Tamaoki et al. (2008), results showed that S and Se had shared metabolic and root absorption mechanisms, which were present and distributed similarly in many plants. Selenium concentrations in most plants, grains, and grasses are typically between 0.05 and 1 mg/kg, with few exceeding 30 mg/kg (Schrauzer 2004). European fruits, vegetables, and cereals provide between 0.002–0.88 mg/kg of Se (Schrauzer 2004). High concentrations of Se accumulated are reported in the genera *Astragalus, Stanleya, Morinda, Neptunia, Oonopsis and Xylorhiza.* They can accumulate from hundreds to thousands of mg Se/kg dry mass in their tissues (Terry et al. 2000). Concerning the daily requirement for humans, the WHO (1996) established that the basal requirement of Se is 0.02 mg/day. Dietary reference intake (DRI) in the USA was determined to be 0.055 mg Se/day (Antal et al. 2009). *Prosopis farcta* seeds have higher Se levels, potentially enhancing sperm and the reproductive system, but excessive Se can cause symptoms like gastrointestinal discomfort, hair loss, fatigue, and nerve damage (Guerrero-Romero and Rodríguez-Morán 2005).

The amount of cadmium (Cd) accumulated in *Celtis tournefortii* Lam was significantly (P 0.05) higher than that in *Prosopis farcta*; the concentration was arranged in descending order as follows: fruit > leaf > seed > pod of *Celtis tournefortii* Lam; their concentrations were, respectively, 0.40, 0.30, 0.20, and 0.11 ppm (Table 4). According to the WHO and FAO (1993), Cd is tolerable at 100 µg/kg in cereals and food legumes and at 100 and 300 µg/kg in medicinal plants. The RDA for Cd was 0.01–0.2 mg/day (De Arago Tannus et al. 2021). The results of the current investigation indicated that Cd buildup exceeds the permissible level. Long-term exposure to Cd increases lung, liver, and kidney cancer risk due to heavy reliance on Cd-based pesticides, herbicides, and fertilizers in agricultural areas. Factors like industrial and mining waste, atmospheric events, sewage sludge, and phosphate fertilizers contribute to Cd accumulation (Sekeroglu et al. 2008, Rahimzadeh et al. 2017). Genetic factors dominate species-level Cd accumulation (Gross et al. 1987). According to Sekeroglu et al. (2008), there was no proof that samples of *Glycyrrhiza glabra*, licorice extract, linden flowers, or nettle leaves contained any Cd. However, Cd was found in the 19 medicinal plants in the range of 7-126 µg /kg, with chamomile leaf having the highest content. Also, Baye and Hymete (2010) discovered that the majority of samples taken from rural locations in Shirka and Bonga contained a significant quantity of Cd, with the majority of them being at dangerous levels.

The concentration of vanadium (V) in *Celtis tournefortii* Lam leaf was (P 0.05) significantly higher than in *Prosopis farcta*, the concentration level was ordered descending as leaf > fruit of *Celtis tournefortii* Lam, pod, and seed of *Prosopis farcta*, with their concentrations being 3, 1, 1 and 1 ppm, respectively (Table 2). The concentration of V in the present study was higher than the RDA for humans, which is estimated to be between 0.01 and 0.03 mg/day (Willsky et al. 2011). The majority of dietary V is typically eliminated in feces. Vanadium contamination mainly originates from oil burning, industrial enterprises, and mining (Scior et al. 2005). Plant material tolerates V and accumulates in roots more than shoots and fruits, detoxifying through intercellular spaces and binding to cell walls, making it crucial for phytoremediation programs (Hou et al. 2019, Tian et al. 2015). Here, it has been found that pectin and caffeic acid aid in reducing potentially dangerous V compounds. In order to shield the tissues, some plants, including *Ipomoea aquatica*, can lower V(V) to V(IV) (Chen et al. 2011). For the treatment of diabetes, atherosclerosis, and cancer, molecules related to V have been researched (Trevio et al. 2019). Parsley, leafy greens like lettuce and spinach, spears of asparagus, some cereal goods (like rye flour), black pepper, and mushrooms should all be included in the diet as good sources of V and vitamins (Gupta et al. 2020). Additionally, *Prosopis farcta* seeds and *Celtis tournefortii* Lam fruit are considered sources of V.

In the accumulation of chromium (Cr) in fruit > leaf of **Celtis tournefortii Lam** > seed > pods of *Prosopis farcta*, the concentrations were 25, 6, 4, and 2 ppm, respectively (Table 4). Fruits and veggies are the main food sources of Cr intake (Martínez -Ballesta et al. 2010). Plant samples from the study had a higher amount of Cr accumulation than the RDA (0.02–0.25 mg) (Ivey et al. 1986). The high Cr levels in plants are evidence that the soil in these places has high Cr levels (Karahan 2023). Exposure to Cr can harm morpho-physiological processes, yield, and crop growth in plants by causing oxidative stress (Sharma et al. 2020). Excessive Cr exposure has been associated with constraints, metallic minerals, chromosome damage, and kidney and liver abnormalities. The study by Sungur et al. (2013), determined the accumulation of Cr in 22 species of medicinal plants, which were collected from five different local herbalists in Hatay, Turkey, using inductively coupled plasma atomic emission spectroscopy. The highest Cr concentrations were detected in chamomile (4.21 ± 0.18 mg/kg) and the lowest in *Riesen fenchel* (*Ferula communis*) (0.33 ± 0.01 mg/kg). Because dangerous Cr (VI) from herbal teas offers no threat, the average daily dietary intake of Cr is not increased (Fecka and Turek 2007).

Nickel (Ni) levels are absorbed in seed > leaf > fruit ≥ pods, with concentrations of 5, 4, 2, and 2 ppm, respectively. The seed of *Prosopis farcta had significantly higher Ni levels when compared with the leaf, fruit, and pods* (Table 2). The present study's Ni content is higher than the RDA of (0.32–0.735) mg/day (Roychowdhury et al. 2003). Senna tea had the lowest concentration of Ni at 0.90 mg/kg, whereas fennel had the highest concentration at 5.40 mg/kg. Likewise, Basgel and Erdemog (2005) showed that Ni concentrations in the infusions ranged from 0.04 mg/kg (nettle) to 2.90 mg/kg (fennel). Additionally, samples of *Withania somnifera* submitted by the PCSIR Lab complex in Karachi, Pakistan, were found to contain higher than permitted levels of Ni (16.2 and 10.3 mg/kg) in the shoot and leaves (Shirin et al. 2010). However, Genichi and coauthors (2020) reported that the high level of Ni in seed has a crucial role in the morphology and physiological functions such as germination and productivity, but when increased, the concentration of Ni alters the metabolic activity in plants. Nickel has a potentially harmful effect on the reproductive system and supporting tissues when it is consumed at levels higher than the limit (Das and Dasgupta 2002).

The economic impact of silver (Ag) is growing, and there are numerous techniques used in the prospecting of biogeochemical ores. In the plant material used for the current study assessment, the amounts of Ag accumulation were pod > fruit > leaf > seed, with 1.7, 1.4, 1, and 0.5 ppm, respectively (Table 2). Relatively, the concentration of Ag in *Prosopis farcta* and *Celtis tournefortii* Lam was higher than the RDA (0.01 mg/kg) (Kabata-Pendias and Pendias 2001). Long-term exposure to high amounts of Ag can cause argyria, which appears to be a cosmetic concern and causes the skin and other bodily tissues to turn blue-gray (Lokeshappa et al. 2012). Experimental studies suggest that concentrations of 60 ppm Ag^+ should be sufficient to control the majority of bacterial and fungal pathogens. AJ-Ameri (2006) investigated that an aqueous extract of *Prosopis farcta* had antifungal and antibacterial effects against all the tested microorganisms. Ag agents are used in new drugs for the therapy of microbial diseases in humans. The author suggested that the presence of Ag in the present study sample is antifungal and antibacterial.

In general, the obtained results revealed that alkaline metals were more steadily accumulated in *Celtis tournefortii* Lam than in *Prosopis farcta*. Beryllium (Be) and barium (Ba) were more abundant within the fruit and leaf parts of *Celtis tournefortii* Lam, which were estimated at 0.4 and 0.3 ppm of Be and 86 and 77 ppm of Ba, respectively. Whereas, they were only 0.2 ppm Be and 3 ppm Ba within the pods and seeds of *Prosopis farcta*, which is significantly lower than that recorded in *Celtis tournefortii* Lam, as depicted in Table 2. Beryllium and Ba levels in plant samples were greater than the recommended daily allowances (RDA) for Be (0.00012 mg/day) (Luttrell 2008) and Be (0.75 mg/kg) (ICRP 1974). Ba forms insoluble salts with other common components of the environment, such as carbonate and sulfate. Ba is not mobile and poses little risk (Rudnyk-Ivashchenko and Yaruta 2016). However, it has been asserted that the substantial accumulation of beans, alfalfa, and soybeans (up to 1260 mg/kg) could harm domestic cattle. Dry tobacco leaves typically contain 105 mg/kg of Ba, most of which is likely to remain in the ash after burning (WHO 1990). However, Rudnyk-Ivashchenko and Yaruta (2016) investigated that Ba in the roots (20.77 mg/kg) was higher than in the seed (0.2 mg/kg) from belladonna plants. Barium and Sr may accumulate in the body and harm teeth, bones, and the skin (Prashanth et al. 2015). The maximum permissible ratio of Ba in plants is 0.7 and Be 0.0002 ppm (Rudnyk-Ivashchenko and Yaruta 2016). Beryllium compounds cause genetic changes in cultured mammalian cells (Leonard and Lauwerys 1987). When exposed for short periods and with a low concentration of B, there is a chance of developing acute pneumonitis (berylliosis) and skin ulcers (Cooper and Harrison 2009). Naturally occurring levels of Be in soils range from 1 to 15 mg/kg (Luttrell 2008). The Ba and Be are known to be human carcinogens based on sufficient evidence of carcinogenicity from studies in humans (Luttrell 2008).

Strontium (Sr) concentration level was in Fruit > leave of *Celtis tournefortii* Lam > pod > seed of *Prosopis farcta* with 454, 430, 133 and 79 ppm, respectively (Table 2). The fruit and leaves of *Celtis tournefortii* Lam were significantly higher than those of *Prosopis farcta* in Sr levels. Plant samples used in the study exceeded the RDA for Sr by 1.6 mg/day (Başgel and Erdemoğlu 2006). The fruit samples, according to Parveen et al. (2020), ranged from 2.03 mg/kg in *Solanum nigrum* to 61.4 mg/kg in *Opuntia dillenii*. High levels of Sr, Ca, and Mg were found in *Opuntia dillenii* fruit; Sr seems to have strong physical and chemical correlations with Ca, an essential element for plants (Dresler et al. 2018). Strontium is absorbed easily from the soil and is most effective in sandy soils with low clay and organic matter content (Hollriegl and Munchen 2011). Sr was heavily accumulated in the plant's above-ground tissues as a result of the elevated translocation of this element to the leaves (Dresler et al. 2018). An excess of Sr in the nutrition medium might affect the concentration of secondary metabolites and prevent phytoestrogen production in soybean tissues (Dresler et al. 2018). Low concentrations of stable Sr have no known physiological effect, but high concentrations can be fatal in animals. Young animals are more severely affected by Sr effects on bone formation than adults (Agency for Toxic Substances and Disease Registry 2004). Radioactive strontium exposure can have negative effects on health and increase the risk of bone cancer and other bone ailments (Hollriegl and Munchen 2011).

Aluminum (Al) has no biological purpose and is thought to be a potentially hazardous metal for living beings. The current investigation demonstrated that the Al level of *Celtis tournefortii* Lam was substantially greater in leaves (738 >) than in fruit, pods, and seeds (100 ppm) (Table 2). The maximum permissible ratio of Al in plants was 20 mg/kg (Rudnyk and Yaruta 2016). Many ionic forms of Al, the most dangerous of which is Al_3^+, are widely distributed in soil because Al is a stress-signaling agent and causes the soil to become acidic, it harms plants (Panda, Baluska et al., 2009). De Aragão et al. (2021) reported that the highest concentrations of Al found in *Cynara scolymus* L., *Harpagophytum procumbens*, and *Maytenus ilifolia* (Mart) ex Reiss ranged between (0.020–1.261 mg/g) in Brazil. It was determined that Al was the only potentially harmful element present in all samples. In humans, Al in the present study was higher than the RDA, which is estimated to be 7.2 mg/day (De Aragão et al. 2021). The accumulation of toxic elements, especially when ingested in larger amounts (Rudnyk and Yaruta 2016). Alzheimer's disease, dementia, and hyperactivity and learning difficulties in children are among the harmful effects of Al that have been described in recent years (Klotz et al. 1017). The amount of Al varies according to geographical and meteorological factors, growing methods, and plantation management (De Aragão et al. 2021).

As shown in Table 2, there were no statistically significant differences in the concentration of lead (Pb) in various plant components. However, the current study's Pb accumulations are higher than what is advised by the FAO/WHO's provisional weekly lead intake limit of 0.025 mg/kg body weight (Arpadjan et al. 2008). It was found that *Withania somnifera* samples from the field of the PCSIR Lab complex in Karachi, Pakistan, contained higher than permitted levels of Pb (60.6 and 23.3 mg/kg) in the shoot and leaves (Shirin et al. 2010). When Pb concentrations of *Rudbeckia chalepensis* were analyzed at several sites in Ethiopia, it was found that the mean levels of Pb (22.8 mg kg) in samples from industrial and agricultural areas were beyond normal limits (Fuh et al. 2003). Even though Pb sulfide is present in trace amounts in the Earth's crust, human activities like mining, smelting, refining, recycling, and the use of aviation fuel are the main drivers of substantial environmental exposure (WHO 2019). Lead accumulates in teeth and bones and is a chronic, harmful substance that affects many physiological systems, particularly those of young children (WHO 2019).

Bismuth (Bi) concentration in pod > seed of *Prosopis farcta* > fruit > leaf of *Celtis tournefortii Lam* was 2.3, 1.60, 0.80. and 0.70 ppm, respectively (Table 2). The concentration of Bi in the plant samples used in the current study was greater than the RDA (0.005 to 0.02 mg/day) (Fowler et al., 2015). Oral administration of Bi is not harmful to rats; the no-observed-adverse-effect level (NOAEL) is 1000 mg/kg, and the fatal dose (LD50) is 2000 mg/kg (Sano et al. 2005). Being that Bi is a "green" heavy metal, substituting it for Pb in some industries may assist in lessening the environmental problems caused by heavy metal pollution. Since bismuth is not toxic to humans, it is used in therapy as an anti-Helicobacter pylorus (H. pylori) drug (Sano et al. 2005). However, the toxicity of Bi can be used to treat blood, liver, kidney, brain, bone, and tropical dermatological creams (Geyikoglu et al. 2007). *Prosopis farcta's* pod and seed had a substantially higher level of Bi than *Celtis tournefortii* Lam's fruit and leaf. Agirman and colleagues (2022) found that *Prosopis farcta* fruit extract may have protective effects, while seed extract may cause damage to hepatocytes and enzyme leakage. Ahmed and Mahmud (2021) found fruit extract effective in treating lithiasis and EG-induced kidney stones, suggesting it may be an effective antiurolithiatic drug. According to the authors, the treatment of kidney stones and digestive problems may be associated with the presence of Bi in *Prosopis farcta* seeds and pods (2.3 and 1.60 ppm, respectively).

The 16th most common element in the crust of the earth is rubidium (Rb). It is frequently employed as a 'tracer' for this element in plants because of how similar it is to K (Tyler, 1983). According to the current investigation, Rb concentration was in fruit > pod > seed > leaf with 7, 5, 2, and 1 ppm, respectively (Table 2). The current investigation examined the *Celtis tournefortii* Lam and the *Prosops farcta at levels* greater than the RDA of Rb (0.02 mg /day) BW (Merian et al. 2004). Although the safety of Rb levels is unknown, hazardous effects in mammals with high-Rb, low-K diets have been observed (Rodrigues et al. 2009). Consideration should be given to the hypotheses that a lack of K may be the cause of the higher Rb uptake by plants in acidic soils (Tyler 1983). In Amanita *rubescens* and *Collybia peronata*, a similar dependence on soil acidity of the Rb concentration and the K:Rb ratio of the sporophore biomass was demonstrated, with Rb absorbed by organisms 'preferentially' over K (Johanson et al. 2004). A Rb-rich dietary source was identified, including cacao (60 mg/kg), black tea (100 mg/kg), and coffee (41 mg/kg) (Antal et al. 2009). Species like comfrey (Symphytum), blueweed (Echium), or coltsfoot (Tussilago), though Rb-rich, cannot be employed as foods due to their content of harmful pyrrolizidine alkaloids (Istudor et al. 2005).

Boron (B) is a crucial element for plants that is mostly absorbed by the roots in the form of boric acid (Rodrigues et al. 2009). Boron has an impact on the structure of several body organs, including the skeleton, brain, and hormone transport, and is linked to the metabolism of a number of other nutrients, such as Ca, Cu, N, and cholecalciferol (Brdar-Jokanović 2020). The present study showed that B levels were in the pod > seed >fruit > leaf of Prosopis farcta > *Celtis tournefortii* Lam with concentrations of 2.3, 1.6, 0.8 and 0.7ppm, respectively (Table 2). The recommended daily allowance of B was (1.5–2.5) mg/day (WHO, 1996). The B content in *Prosops farcta* and *Celtis tournefortii* Lam was within the RDA (1.5–2.5) mg/day (WHO, 1996). However, raisins, peaches, and peanuts are foods high in B, with 1.5, 0.80, and 0.48 mg/serving for the US population (Rainey et al. 1999). Basically, Nielsen et al. (1986) reported that B supplements of 3.0 mg/day fed to postmenopausal women who had been consuming 0.25 mg/day of B for 119 days markedly reduced their urinary excretion of Ca and Mg (Nielsen et al. 1986). Based on the authors, the plant species may be a beneficial supplemental source of B.

Most herbs contain a significant amount of arsenic (As), which is believed to be passively absorbed by plants via water movement. The current study showed that As levels were in pod > seed of *Prosopis farcta ≥ leaf > fruit Celtis tournefortii* Lam with concentrations of 3.9, 1.8 and 0.1 ppm, respectively (Table 2). The tolerance level for this element in plants has been set at 2 mg/kg (Stanojkovic-Sebic et al. 2015). The root of potato plants has the highest concentration of As, reaching up to 2.9 mg/kg, while there are relatively low levels of As in various vegetable components, including tomato, Lal Shak, Datashak, cabbage, and cauliflower (Ali et al. 2003). In order to determine the presence of As using ICP-MS, rice samples were obtained from local Australian markets, according to Watson and Gustave's study from 2022. All rice samples had mean As levels that ranged from 0.026 to 0.464 ppm. Due to variations in geographic origins, there were variations in As content. The plant samples used in this investigation had a higher As concentration than the average weekly intake (0.015-0.1 mg/kg body weight), as recommended by FAO and WHO (Arpadjan et al. 2008). Most of the aspartame ingested is quickly eliminated in the urine. Arsenic poisoning also happens at doses of 1 mg/kg/day or more, and it can be followed by hepatotoxicity and anemia (Lin et al. 2007).

Antimony (Sb) is a non-essential element for plants, animals, and humans. In the present study, the accumulation of Sb was found to be in the pod > seed in *Prosopis farcta* > leaf > fruit of *Celtis tournefortii* Lam, with concentrations of 12, 9.5, 7, and 6.60 ppm, respectively (Table 2). Due to this pattern, the Sb content in the plant study is typically higher than the RDA (0.006 mg/day), as suggested by the World Health Organization (Chung et al. 2008, Belzile et al. 2011). However, some edible plants, such as radish, mushrooms, and radish, have been found to contain high quantities of Sb in polluted areas (Borovicka et al. 2006, He 2007). Belzile et al. (2011), reported that increased anthropogenic inputs from mining and industrial activities cause a linear relationship between soil Sb content and plant leaves, with some translocated to shoots (Vidya et al. 2022). Sb and its compounds can cause hypoxia, impair enzyme function, and damage cell balance, affecting various organ systems, including the neurological system (Xiao-bao and Ning 2007).

Multivariate analysis of Celtis tournefortii Lam and Prosops farcta

According to the 25 key characteristics (Ca, P, Mg, Na, K, S, Fe, Cu, Zn, Se, Cd, V, Cr, Ni, Ag, Be, Sr, Ba, Al, Pb, Bi, Rb, B, As, and Sb), HCA and PCA categorized the elements in plant parts of two wild plants. The Ward linkage approach was used to do cluster analysis (Fig. 3). Based on this research, the plants were separated into three primary groups. The leaf was identified as the element in the first cluster with the greatest values for Na, V, Al, and Fe. Due to the maximum accumulation of Be, Mg, Cd, Ba, and Sr in the second cluster, the fruit's constituent elements were identified in *Celtis tournefortii* Lam. The *Prosopis fracta* seed and pod belonged to the third cluster, which contained the elements Sb, B, Bi, Zn, S, Se, As, and Ni. The PCA classification supported the cluster analysis's findings (Fig. 4). To make the multidimensional graphs simpler and provide a two-dimensional map that explains the observed variance, a PCA was used. The first and second PCA components (53.84% and 27.53%, respectively) explained 81.34% of the total variance. The elements that accumulate in leaves are strongly correlated with the first component (PC1), while the elements that accumulate in the fruit of *Celtis tournefortii* Lam are strongly correlated with (PC2). The PC1's Zn, S, Se, Bi, B, As, and Sb stand out, while PC2's Cr, Cu, K, and Rb, together with PC3's Ag and As, do the same. Furthermore, neither PC2 nor PC3 are affected by the element Bi. Additionally, neither PC1 nor PC3 have any impact on K or Rb, as presented in Table 4. For the analysis of the major components, a data matrix with 4 variables and 25 variables (4×25) was used, and the data was auto-scaled as a type of preliminary processing (Table 5). One can see that Cd has a substantial association with V, Cr, Cu, Ni, Ag, Zn, Na, Se, Al, K, and Rb, but Fe has a correlation with Cr, Ni, Ag, K, and Rb. Ag, Zn, Na, and Al with Cr. Cu displayed a strong association with Ni, Ag, Be, Ba, Mg, B, and Sb. Silver also had relationships with Na, Mg, Ca, Ba, Al, and Sb. Zn, K, Rb, and As were connected to one another. Beryllium, Mg, and As were associated with sodium. Al and K were connected with the Be. Potassium, Rb, and As were connected to selenium. Alone, however, linked with Bi. Arsenic and Sb showed a correlation with boron. Only K was associated with Ba and Mg. Potassium and Rb both have a correlation with calcium. According to the study's results, Ca, K, Mg, Na, P, Cu, Fe, Mn, Se, and Zn can be found in leaves, fruits, pods, and seeds. If samples were divided into three groups of elements from two wild plants, *Celtis tournefortii* Lam and *Prosopis fract*, PCA and HCA would be valid techniques for assessing element accumulation. Wild plants have had many elements in their leaves, fruits, and seeds examined. These plants can be seen as sources of accumulating elements. Numerous studies have found that these pharmacological components are advantageous to human health. " Furthermore, care must be taken when consuming these two wild plants due to their possible toxicity; they might contain harmful substances.

Conclusion and recommendation for further research

According to the current study, *Celtis tournefortii* Lam has a higher concentration of heavy metals than *Prosopis farcta*. Twenty-five elements were found during the screening of *Celtis tournefortii* Lam and *Prosopis farcta* using ICP MS and ICP OES. *Celtis tournefortii* Lam had accumulated more Cd, V, Fe, Cr, Na, Be, Mg, Ca, Sr, Ba, Al, K, and Rb. *Prosopis farcta* contained significantly more Ni, Ag, Zn, S, Se, Bi, B, As, and Sb than *Celtis tournefortii* Lam. The three elements Cu, P, and Pb are present in similar amounts in both wild plants. In order to efficiently and precisely measure trace elements in plants, both ICP-MS and ICP-OEC were utilized. The obtained results reveal that studied medicinal plants and dietary supplements contain elements in the ppm range and that elemental concentrations vary widely. This variability can be explained by environmental and agronomic conditions, variable exposure to pollution, growing in contaminated areas, poor storage conditions, and bad purchasing sources. Differences in the geographical region, genetics, and composition of the soil can also affect the level of toxic metals.

Heavy metals in herbal medicines can cause severe side effects and disrupt living organisms. Contamination occurs through soil, water, air, and proximity to the metal industry. Proper measures are needed to prevent contaminated plants from entering the human food chain. Thus, the results of the presented work suggest monitoring the concentration of toxic metals in medical plants, especially when they are used in the production of dietary supplements or drugs. The findings demonstrated that medicinal plants can serve as potential sources of macronutrients (Ca, K, Mg, Na, and P), aiding in the treatment of diseases brought on by shortages of these substances. Additionally, these results demonstrate that the use of medicinal herbs is an issue that requires scientific investigation. These plant species have been shown to be potent tools for reducing environmental pollution. In order to maintain these trees' ability to absorb heavy elements, more trees must be cultivated closer to the roadways. Research on the capacity of various plant species to absorb heavy metals in Kurdistan is relevant. PCA and HCA showed that the samples were separated into three groups. The results of the presented work suggest monitoring the concentration of toxic metals in medical plants, especially when they are used in the production of dietary supplements or drugs. This study is crucial from the perspectives of nutrition, toxicology, and food security, not just for the Kurdish population but also nationwide, due to the dearth of references and studies that are available in the field.

Abbreviations

Calcium (Ca), Sodium (Na), Potassium (K), Iron (Fe), Cupper (Cu), Zinc (Zn), Chromium (Cr), Mercury (Hg), Cadmium (Cd), Cobalt (Co), Nickel (Ni), Magnesium (Mg), Manganese (Mn), Lead (Pb), Selenium (Se), Molybedium (Mo), Arsenic (As), principal component analysis (PCA), hierarchical cluster analysis (HCA), normalized difference vegetation index (NDVI).

Declarations

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Data Availability

All data generated or analyzed during this study are included in this published article

Ethics declarations

Ethical approval

Not applicable.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

Authors contributions

Abdulwahid-Kurdi SJ, designed and major contributor to writing the manuscript. Khalid KM analyzed all samples. Abdulwahid M interpreted the obtained data. Sardar AS prepared samples. All authors read and confirmed the final version of the manuscript.

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The author states that they have no competing interests.

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Table 4

Table 4 is available in the Supplementary Files section.

Figures

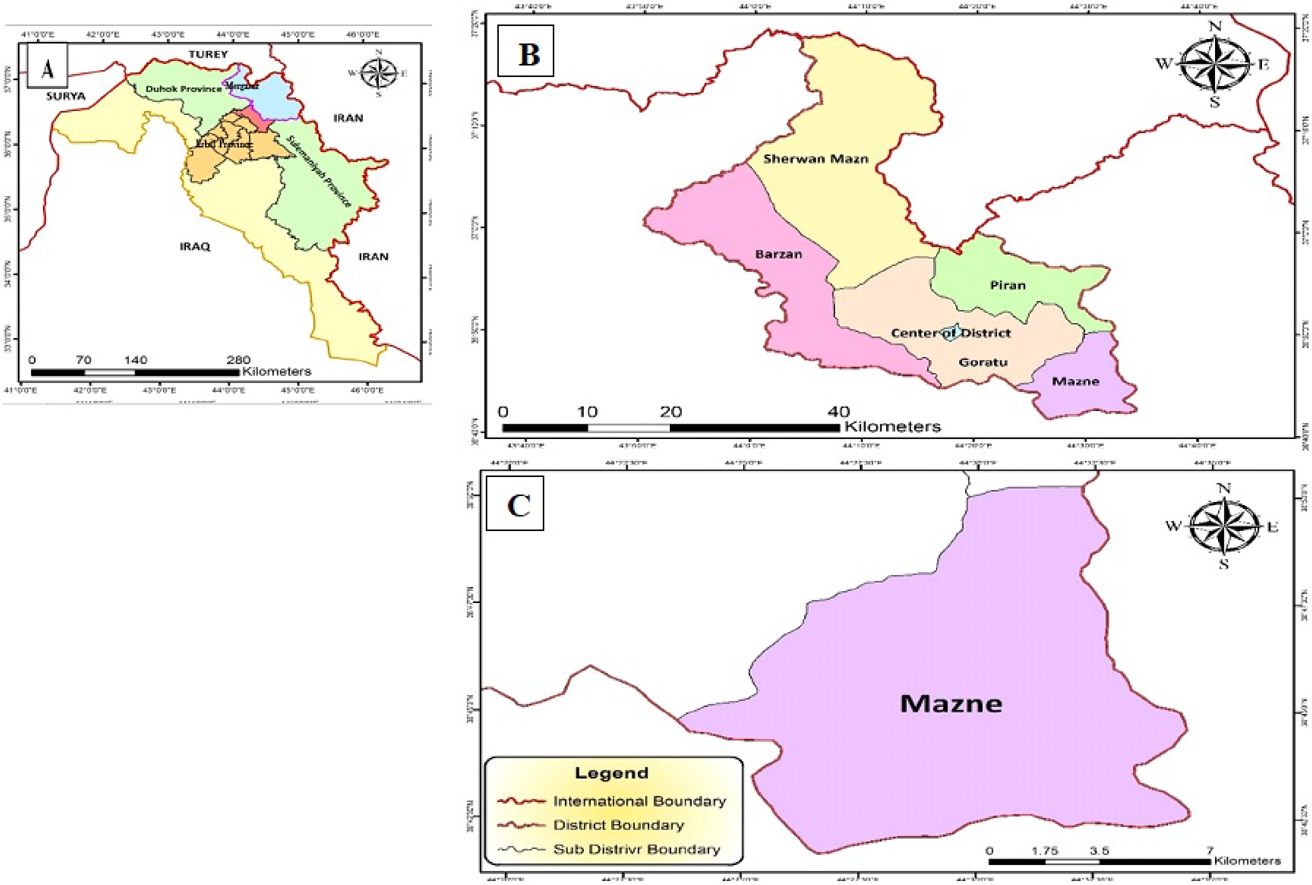

Figure 1

Maps showing the location of the research area. A. Iraqi map, B. Mergasur district, C. Mazne subdistrict.

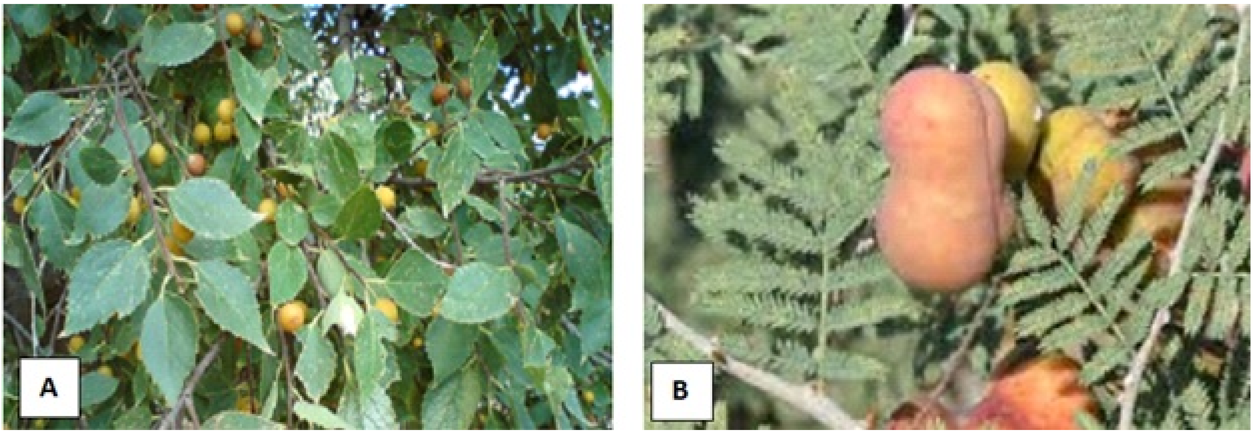

Figure 2

Two wild plants were collected in Mazne subdistrict *A. Celtis tournefortii* Lam, B. *Prosopis farcta.*

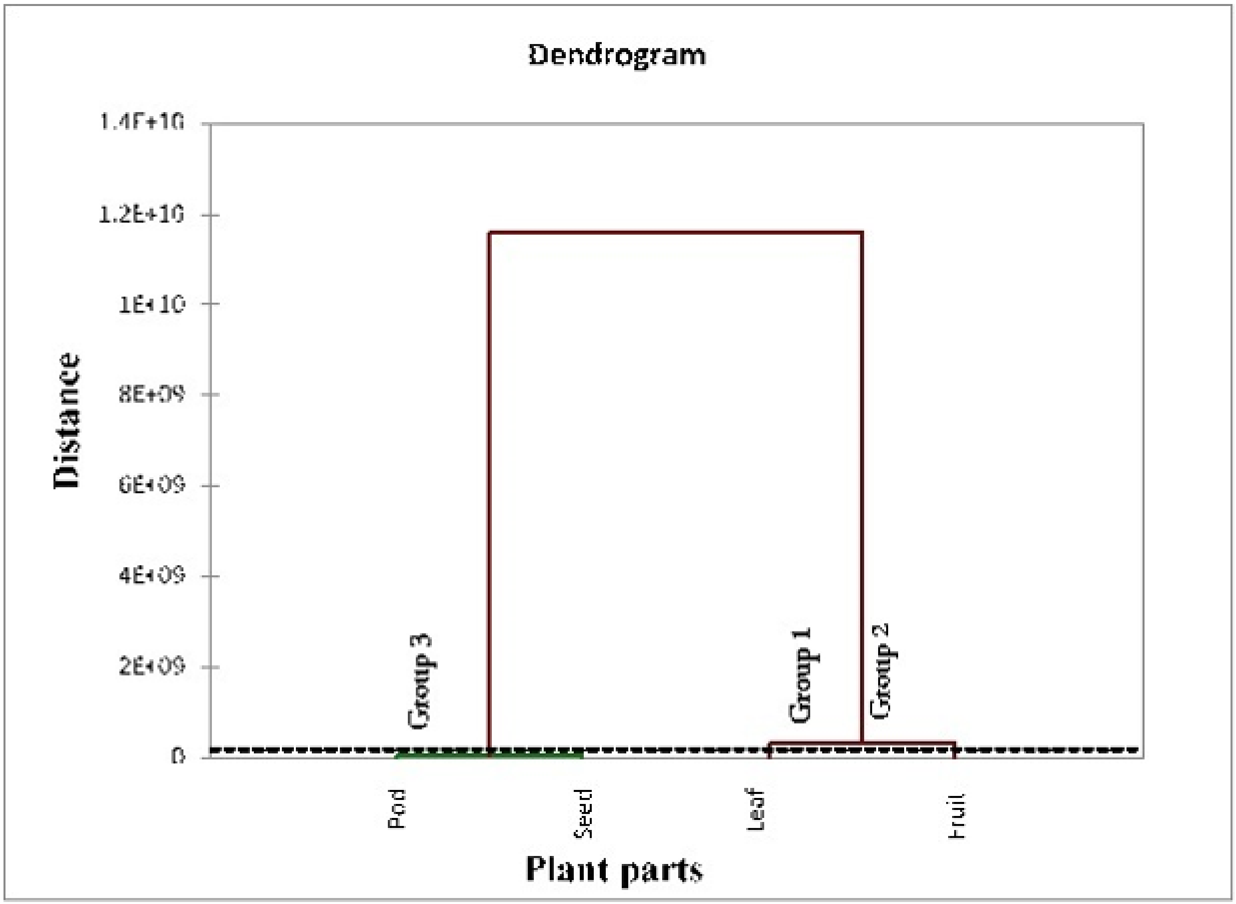

Figure 3

Hierarchical cluster analysis (HCA) of elements of two wild plant parts.

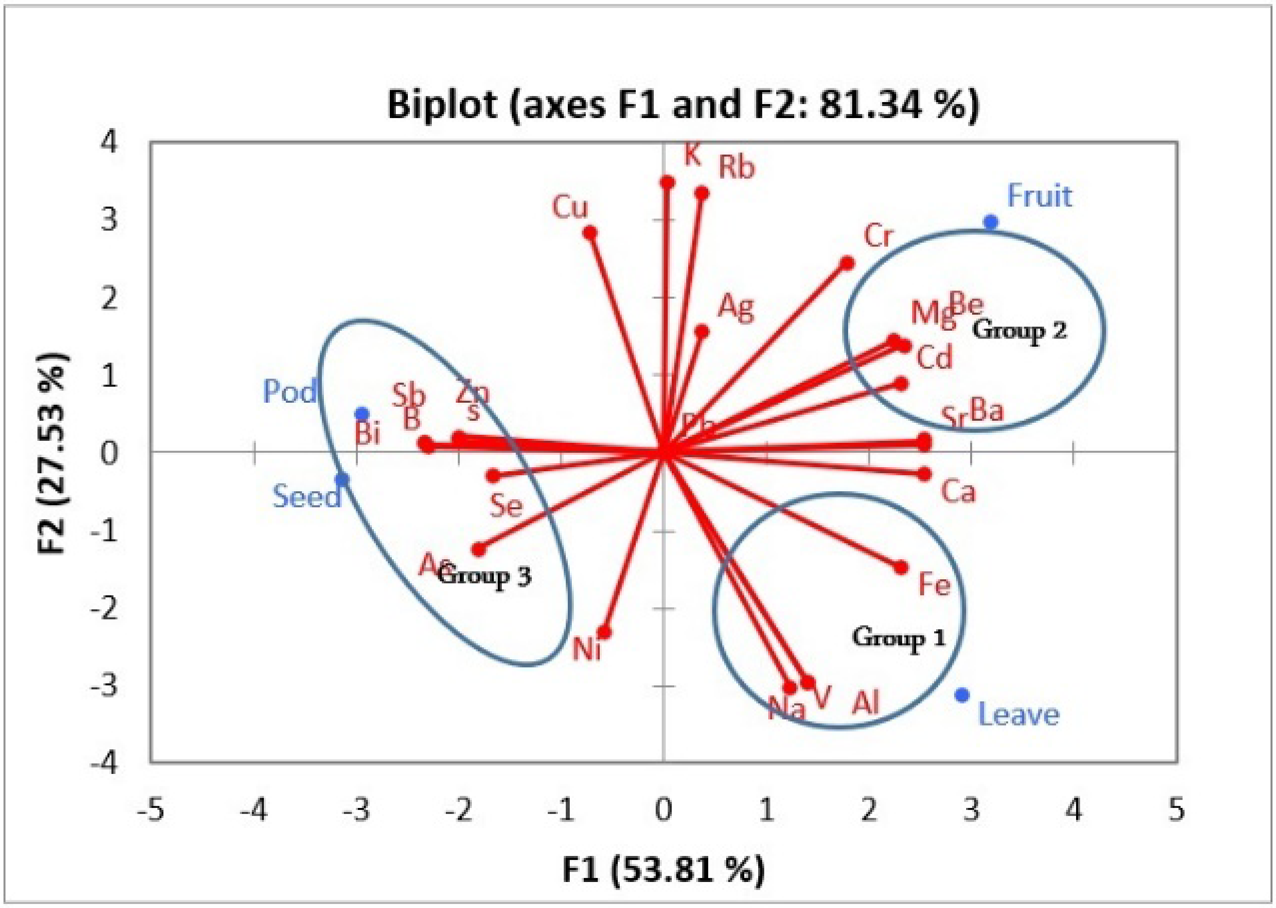

Figure 4

Principal component analysis (PCA) of two wild plants using the 25-primary characteristic.

Supplementary Files

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- Table4.docx