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COMPARATIVE ANALYSIS OF THE ELEMENTAL COMPOSITION OF FERULA KYZYLKUMICA AND ZYGOPHYLLUM MACROPHYLLUM LEAVES FROM THE KYZYLKUM DESERT.

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ABSTRACT

This study comparatively examined the elemental composition of leaves and the acid–base properties of aqueous leaf extracts of Ferula kyzylkumica and Zygophyllum macrophyllum growing naturally in the Kyzylkum Desert. Concentrations of 20 elements in composite leaf samples were determined by inductively coupled plasma optical emission spectrometry (ICP-OES), and relative differences between the two species were evaluated using $\log_2$ fold change ($\log_2$FC). Potassium had the highest concentration among the elements examined in both species. Strontium, manganese, and nickel concentrations were higher in the Zygophyllum macrophyllum sample, whereas aluminum was more abundant in the Ferula kyzylkumica sample. In particular, the strontium concentration in Zygophyllum macrophyllum was 902.8 mg/kg, while the aluminum concentration in Ferula kyzylkumica was 3.162 mg/kg. The pH values of the aqueous leaf extracts were 7.5 and 5.5, respectively, indicating differences in their acid–base properties. These findings provide preliminary comparative analytical data on the elemental profiles and aqueous extract characteristics of the two species. Because only one composite sample per species was analyzed, the observed differences were assessed descriptively.

Introduction

Arid and semi-arid regions are characterized by low precipitation, high air temperatures, intense evaporation, and limited water resources. These environmental factors substantially affect plant photosynthetic activity, water relations, mineral nutrition, and metabolic processes [1]. Accordingly, investigating the elemental composition of plants growing naturally under dry conditions is scientifically important for characterizing their mineral profiles and identifying biochemical differences between species.

Mineral elements play essential roles in plant physiological and biochemical processes. In particular, potassium (K) contributes to cellular osmotic balance and stomatal regulation; iron (Fe) participates in electron transport and redox reactions; manganese (Mn) is involved in the light reactions of photosynthesis; and zinc (Zn) and copper (Cu) participate in various enzymatic processes [2, 3]. In addition to essential mineral nutrients, plant tissues may contain elements such as strontium (Sr), aluminum (Al), barium (Ba), lithium (Li), and rubidium (Rb). Their accumulation levels may vary depending on species-specific biological characteristics, environmental availability, and biological uptake [2, 3].

The Kyzylkum Desert, one of the major arid regions of Central Asia, is distinguished by its particular environmental conditions and diversity of plants adapted to them. Previous studies in this region have addressed the chemical composition and ecological adaptations of extremophilic plants, as well as the development of phytoremediation strategies for degraded areas [7, 9]. In addition, the mineral phase composition of Kyzylkum soil samples has been examined using X-ray diffraction, providing information on certain mineralogical characteristics of the region [8]. Together, these studies provide a scientific basis for integrated investigations of desert ecosystems.

The chemical composition of plants belonging to the genera Ferula and Zygophyllum has been investigated in international studies using different analytical approaches. Asilbekova and co-authors examined the lipid and essential oil composition of the aboveground parts of Ferula kyzylkumica [4]. Yelkenci and co-authors determined mineral element concentrations in 20 Ferula species using inductively coupled plasma optical emission spectrometry (ICP-OES) [5]. Research findings on the mineral composition of Zygophyllum gaetulum have also been published [6]. Although these studies provide valuable information on plant chemical composition, they differ in the species investigated, analytical targets, and methods employed.

Among the scientific sources reviewed, no study was identified that jointly compares the concentrations of 20 elements in the leaves of Ferula kyzylkumica and Zygophyllum macrophyllum and the pH values of their aqueous extracts. A comparative analysis of leaf elemental distributions in these two species growing at the same geographical sampling site can help characterize differences in their chemical profiles. The pH of an aqueous leaf extract is an

additional analytical indicator reflecting the overall acid–base properties of components transferred into the extract

Materials and Methods

Leaf samples of Ferula kyzylkumica and Zygophyllum macrophyllum were collected on 18 April 2026 from a natural growing site on the southern foothills of Kuljuktau in the Kyzylkum Desert, approximately 6–8 km west of Ayakguzhumdi (40.733629° N, 63.730471° E; 374 m above sea level).

For elemental analysis, dried leaf samples were ground in a porcelain mortar to a particle size of approximately 1–2 mm. An aliquot of 0.20–0.27 g from each composite sample was weighed on an analytical balance and placed in a microwave digestion vessel. Concentrated nitric acid (HNO_3; 3.0 ml) and hydrogen peroxide (H_2O_2; 1.5 ml) were added. The mixtures were left to undergo preliminary reaction for 30 min at room temperature with the vessel lids open. The vessels were then sealed, and digestion was performed using a Speedwave ENTRY microwave digestion system (Berghof, Germany). The temperature was raised to 150 °C and maintained for 21 min. After digestion, the resulting solutions were quantitatively transferred to 100 ml volumetric flasks and brought to volume with double-distilled water. A reagent blank containing no plant material was also prepared.

The digested solutions were analyzed using a PlasmaQuant 9100 inductively coupled plasma optical emission spectrometer (ICP-OES; Analytik Jena, Germany) equipped with an ASX-560 autosampler (Teledyne CETAC Technologies). Concentrations of 20 elements - Li, Be, K, Ba, Sr, Al, Rb, Cu, Fe, Zn, Mn, As, Cr, Ni, Pb, Hg, Co, Ag, Cd, and Se were assessed. Results were expressed in mg/kg. Concentrations below the limit of detection were reported as <LOD (limit of detection).

To determine the pH of the aqueous leaf extracts, dried plant material was ground to a powder. A 1.00 g portion of each sample was mixed with 10.0 ml of distilled water (1:10, mass/volume). The mixture was shaken for 3–5 min, left to stand at room temperature for 30 min, and mixed occasionally during this period. The extract was then filtered through filter paper. Filtrate pH was estimated using universal indicator strips with a measurement range of 0–14 and an approximate resolution of 0.5 pH units. Each strip was immersed in the filtrate for 1–2 s, and the resulting color was compared with the reference color scale after 10–15 s. Between-species ratios were calculated descriptively as $\log_2(CZ/CF)$; ratios were not calculated for values below the detection limit (<LOD).

Results and Discussion

Twenty elements were assessed by ICP-OES in one composite leaf sample from each species (Table 1). Potassium showed the highest concentration: 36080 mg/kg in Ferula kyzylkumica and 38050 mg/kg in Zygophyllum macrophyllum (5.5% higher in the latter). Potassium plays an

important role in plant osmotic regulation and enzymatic processes [2]; however, these findings do not demonstrate a mechanism of drought tolerance.

Table 1.

Elemental composition of the leaves of Ferula kyzylkumica and Zygophyllum macrophyllum (mg/kg).

№	Element	Ferula kyzylkumica	Zygophyllum macrophyllum	№	Element	Ferula kyzylkumica	Zygophyllum macrophyllum
		Elemental concentration (mg/kg				Elemental concentration (mg/kg	
1.	Li	<LOD	6.631	**11.**	Mn	14.18	63.93
2.	Be	<LOD	<LOD	**12.**	As	<LOD	<LOD
3.	K	36080	38050	**13.**	Cr	<LOD	<LOD
4.	Ba	7.410	3.446	**14.**	Ni	0.0304	0.5336
5.	Sr	158.5	902.8	**15.**	Pb	0.6943	<LOD
6.	Al	3162	360.2	**16.**	Hg	0.0164	0.0168
7.	Rb	31.39	24.27	**17.**	Co	<LOD	0.0352
8.	Cu	6.576	6.257	**18.**	Ag	8.801	15.78
9.	Fe	200.8	228.6	**19.**	Cd	<LOD	<LOD
10.	Zn	26.14	37.45	**20.**	Se	<LOD	<LOD

Note: <LOD – Below the limit of detection.

The aluminum concentration in Ferula kyzylkumica was 3,162 mg/kg, 8.78 times that in Zygophyllum macrophyllum (360.2 mg/kg). Conversely, strontium was 5.70 times higher in Z. macrophyllum (902.8 mg/kg) than in Ferula kyzylkumica (158.5 mg/kg). Barium and rubidium concentrations were higher in Ferula kyzylkumica. These differences indicate distinct mineral profiles in the two composite samples but do not establish active accumulation or tolerance to toxic effects. Concentrations of Fe (200.8 and 228.6 mg/kg), Zn (26.14 and 37.45 mg/kg), Mn (14.18 and 63.93 mg/kg), and Cu (6.576 and 6.257 mg/kg) were recorded for Ferula kyzylkumica and Zygophyllum macrophyllum, respectively. Manganese was 4.51 times higher in the latter species. Nickel reached 0.5336 mg/kg in Zygophyllum macrophyllum, 17.55 times its concentration in Ferula kyzylkumica (0.0304 mg/kg), whereas silver concentrations were 15.78 and 8.801 mg/kg, respectively.

Fe, Zn, Mn, Cu, and Ni are physiologically important trace elements [3], whereas Ag is not classified as an essential micronutrient.

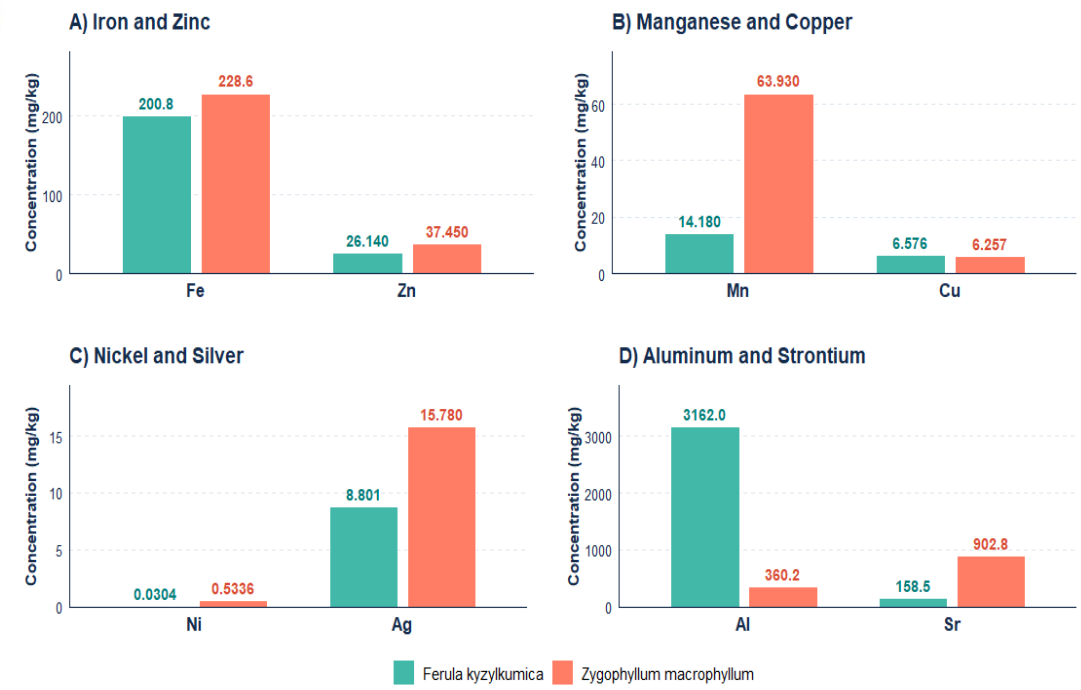


Figure 1. Comparative concentrations of Fe, Zn, Mn, Cu, Ni, Ag, Al, and Sr (mg/kg).

The relative differences in elemental concentrations between the two species were calculated using the $\log_2$FC metric according to the following equation:

$$\log_2 FC = \log_2 \left(\frac{C_Z}{C_F} \right)$$

Where C_Z and C_F represent the concentrations of the corresponding elements (mg/kg) in the leaves of Zygophyllum macrophyllum and Ferula kyzylkumica, respectively. Positive values indicate higher concentrations in the former species, whereas negative values indicate higher concentrations in the latter.

The highest positive $\log_2$FC values were observed for Ni (+4.13), Sr (+2.51), and Mn (+2.17), whereas Al showed the largest negative value (−3.13). Values for K (+0.08), Fe (+0.19), and Cu (−0.07) were close to zero.

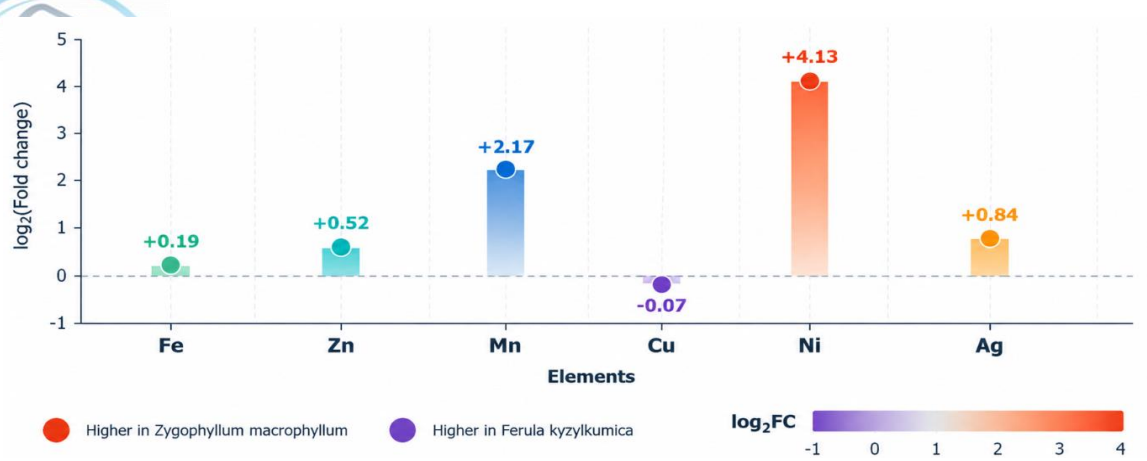


Figure 2. log_2FC [log_2(Zygophyllum/Ferula)] for Fe, Zn, Mn, Cu, Ni, and Ag.

Be, As, Cr, Cd, and Se were below the detection limit (<LOD) in both samples. Li (6.631 mg/kg) and Co (0.0352 mg/kg) were quantified only in Zygophyllum macrophyllum, whereas Pb (0.6943 mg/kg) was quantified only in Ferula kyzylkumica. Mercury concentrations were 0.0164 and 0.0168 mg/kg, respectively. A result below the detection limit does not indicate that an element is absent.

The pH of the aqueous leaf extract of Ferula kyzylkumica was 7.5 (slightly alkaline), whereas that of Zygophyllum macrophyllum was 5.5 (acidic) (Figure 3).

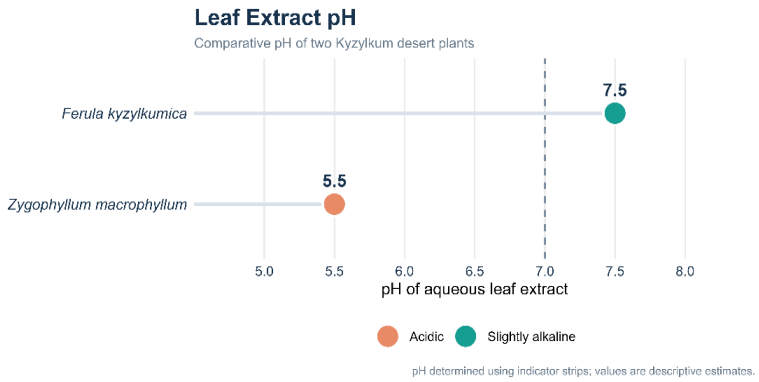


Figure 3. pH values of aqueous leaf extracts.

The difference between the two extracts was 2.0 pH units. This suggests that the water-soluble components may differ in their overall acid–base properties.

Conclusion

This study comparatively investigated the elemental composition of leaves of Ferula kyzylkumica and Zygophyllum macrophyllum growing on the southern foothills of Kuljuktau in the Kyzylkum Desert using ICP-OES and evaluated the pH of their aqueous extracts. Twenty elements were analyzed in a composite sample from each species.

Potassium had the highest concentration in both species, reaching 36080 and 38050 mg/kg, respectively. Concentrations of strontium, manganese, and nickel in Zygophyllum macrophyllum were 5.70, 4.51, and 17.55 times those in Ferula kyzylkumica, respectively, whereas aluminum was 8.78 times higher in Ferula kyzylkumica. The pH values of the aqueous leaf extracts were 7.5 and 5.5, respectively, indicating differences in their acid–base properties.

These findings provide preliminary comparative analytical information on the elemental composition and aqueous extract characteristics of the two species. Because only one composite sample per species was analyzed, the observed differences are descriptive. Further studies with independent biological replicates are needed to assess their consistency and ecological and physiological significance.

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