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COMPARATIVE SCREENING OF ESSENTIAL AND TOXIC ELEMENTS IN WILD AND CULTIVATED LYCIUM BARBARUM L. FOR PHYTOPHARMACEUTICAL STANDARDIZATION

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Abstract

This study presents a comparative analysis of the qualitative and quantitative elemental composition of vegetative organs (leaves, stems, and root bark) and generative organs (fruits) of wild and cultivated *Lycium barbarum* L. Energy-dispersive X-ray fluorescence spectrometry (EDXRF) was used to determine the levels of essential macro- and microelements, including K, Ca, S, P, Fe, Zn, Mn, Cu, and Ni, as well as potentially toxic and other trace elements. Distinct differences in elemental profiles were observed between wild-growing and cultivated plant materials. Cultivated samples generally exhibited higher accumulation of potassium, aluminum, and zinc, whereas wild populations showed comparatively greater accumulation of selected trace elements, particularly manganese, copper, and silver. These differences may be associated with contrasting edaphic conditions, mineral fertilization, irrigation practices, and plant adaptive responses to natural environmental stressors.

Keywords: *Lycium barbarum; elemental profile; macroelements; microelements; X-ray fluorescence spectrometry; edaphic factors; wild and cultivated plants; phytopharmaceutical standardization*

Introduction

Lycium barbarum L. (Solanaceae), commonly known as goji or wolfberry, is widely used as a medicinal and food plant. In addition to polysaccharides, carotenoids, and phenolic compounds, its elemental composition contributes to the nutritional quality and safety of the raw material (Khalimova

et al., 2025; Niro et al., 2017; Nomura et al., 2015).

Elemental accumulation in medicinal plants is influenced by soil properties, geographical origin, climate, irrigation, fertilization, and plant organ. These factors may cause substantial differences between wild-growing and cultivated L. barbarum and may also affect the accumulation of potentially toxic elements (Lu et al., 2021). Therefore, the present study compared the elemental profiles of different organs of wild-growing and cultivated L. barbarum to assess the influence of growing conditions and their relevance to raw-material quality and safety.

Objects and Methodology of Research

Ethanolic extracts of leaves, stems, fruits, and root bark of *Lycium barbarum* L. were analyzed. Wild-growing samples (D) were collected in Boysun District, Surxondaryo Region, Uzbekistan, while cultivated samples (K) were obtained from experimental plots of Tashkent State Agrarian University under regulated irrigation and potassium fertilization.

Elemental composition was determined by energy-dispersive X-ray fluorescence spectrometry (EDXRF) using a Rigaku spectrometer (Japan). Element concentrations were quantified by the fundamental parameters (FP) method. All measurements were performed in five replicates (n = 5).

Results and Discussion

The elemental composition of *Lycium barbarum* varied considerably depending on both plant organ and growing conditions. These differences are relevant to the nutritional value, quality, and safety assessment of wild-growing and cultivated plant materials. Particular attention was given to essential elements and potentially toxic elements, including Pb, Cd, Hg, and As, in accordance with applicable food-safety and phytopharmaceutical requirements (Republic of Uzbekistan, 2019; World Health Organization, 2007; European Directorate for the Quality of Medicines & HealthCare, 2023; State Pharmacopoeia of the Republic of Uzbekistan, 2021).

Elemental Profile of Vegetative Organs (Leaves and Stems)

Energy-dispersive X-ray fluorescence analysis revealed distinct elemental profiles in the leaves and stems of wild-growing and cultivated *L. barbarum*. The concentrations of detected macro-, micro-, and trace elements are presented in Table 1, allowing comparison of organ-specific accumulation patterns and differences associated with growing conditions.

Table 1. *Element content (mg/ml) in extracts of L. barbarum leaves, stems, fruits and roots*

Element	Wild leaves	Cult. Leaves	Wild. stems	Cult. stems	Wild. fruits	Cult. fruits	Wild. roots	Cult. roots
Cl	11069.0	8878.0	748.0	952.0	2750.0	1594.0	287.0	1975.0
Al	4930.4	4220.2	2182.0	3169.0	4012.0	4744.0	1680.0	2519.0
K	5601.3	3316.6	602.0	2020.0	3783.0	5000.0	294.0	972.0
S	906.1	906.0	n/d	n/d	194.0	117.0	n/d	n/d
Ca	n/d	621.0	n/d	n/d	n/d	n/d	n/d	341.0
Fe	14.8	11.6	9.50	9.78	9.98	13.8	8.05	10.8
Mn	n/d	19.0	n/d	n/d	n/d	n/d	n/d	n/d
Br	4.25	23.0	n/d	6.62	0.662	1.03	n/d	n/d
Zn	1.66	5.62	1.64	2.71	2.99	5.10	0.988	1.97
Cu	6.75	7.38	n/d	n/d	S5.47	8.22	n/d	n/d
P	n/d	n/d	n/d	n/d	n/d	80.0	n/d	n/d
Ni	n/d	n/d	n/d	n/d	4.64	5.22	n/d	n/d
Ag	n/d	n/d	n/d	n/d	n/d	2.54	n/d	n/d
Si	n/d	n/d	n/d	n/d	n/d	n/d	n/d	70.8

Note: n/d – not detected (below the detection limit of the method)

Elemental Profile of Leaf Extracts

Leaves showed marked differences in elemental accumulation between wild-growing and cultivated *L. barbarum*. Wild leaves contained higher levels of Cl (11,069.0 vs. 8,878.0), K (5,601.3 vs. 3,316.6), Al (4,930.4 vs. 4,220.2), and Fe (14.8 vs. 11.6), whereas S remained nearly unchanged (906.1 vs. 906.0). The higher Cl and K levels in wild plants may reflect differences in soil ion availability and adaptation to natural edaphic conditions.

In contrast, Ca (621.0) and Mn (19.0) were detected only in cultivated leaves. Cultivation also increased Zn from 1.66 to 5.62 (~3.4-fold) and Br from 4.25 to 23.0 (~5.4-fold), while Cu remained relatively stable (6.75–7.38). Overall, wild leaves preferentially accumulated Cl, K, Al, and Fe, whereas cultivated leaves showed greater accumulation of Ca, Mn, Zn, and Br.

Elemental Profile of Stem Extracts

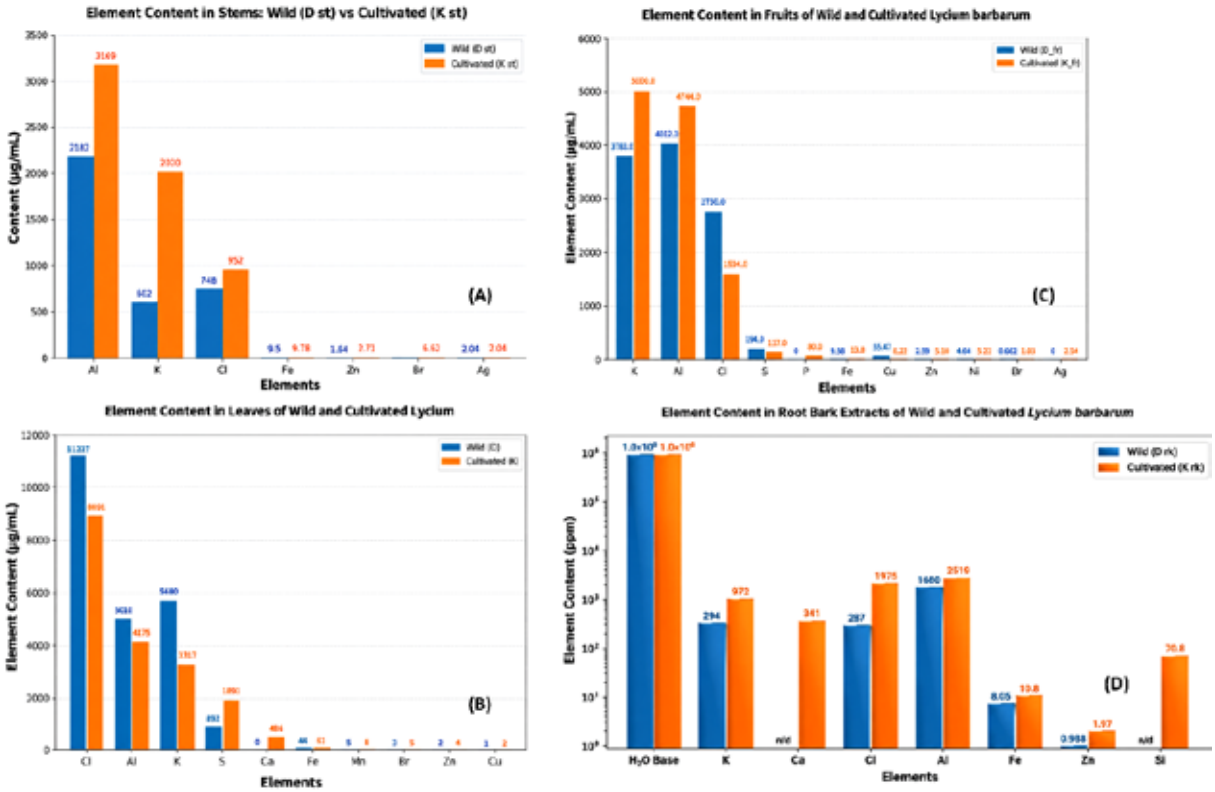
Stem samples also showed clear cultivation-related differences. K increased from 602.0 in wild stems to 2,020.0 in cultivated stems (~3.4-fold), while Al and Zn increased from 2,182.0 to 3,169.0 and from 1.64 to 2.71, respectively. Cl was also moderately higher in cultivated stems (952.0 vs. 748.0), whereas Fe remained nearly unchanged (9.50–9.78).

Br was detected only in cultivated stems (6.62), while S, Ca, Mn, Cu, P, Ni, Ag, and Si were not detected in either sample. Thus, cultivation was mainly associated with increased accumulation of K, Al, Zn, Cl, and Br in stems.

Elemental Profile of Fruits and Root Bark

Fruits exhibited substantial differences between wild-growing and cultivated plants. Cultivated fruits contained higher levels of K (5,000.0 vs. 3,783.0), Al (4,744.0 vs. 4,012.0), Fe (13.8 vs. 9.98), and Zn (5.10 vs. 2.99). P (80.0) and Ag (2.54) were detected only in cultivated fruits, while Br and Ni also increased slightly.

Figure 1. *Comparative elemental profiles of wild-growing and cultivated Lycium barbarum L. organs determined by energy-dispersive X-ray fluorescence spectrometry (EDXRF). (A) stems; (B) leaves; (C) fruits; and (D) root bark*



Conversely, wild fruits contained higher Cl (2,750.0 vs. 1,594.0), S (194.0 vs. 117.0), and particularly Cu (55.47 vs. 8.22). The approximately 6.7-fold difference in Cu

suggests a pronounced influence of growing conditions on its accumulation and warrants further investigation of soil availability and plant uptake.

Cultivated root bark showed higher concentrations of Cl (1,975.0 vs. 287.0), K (972.0 vs. 294.0), Al (2,519.0 vs. 1,680.0), Fe (10.8 vs. 8.05), and Zn (1.97 vs. 0.988) than wild samples. Ca (341.0) and Si (70.8) were detected only in cultivated roots. The strongest differences were observed for Cl and K, which increased by approximately 6.9- and 3.3-fold, respectively.

Together with the fruit data, these results demonstrate that cultivation modifies elemental accumulation in an organ-specific manner. Cultivated fruits generally contained higher K, Al, Fe, Zn, P, and several trace elements, whereas wild fruits retained higher Cl, S, and particularly Cu. Thus, the effects of cultivation were selective rather than uniform across plant organs (Lu et al., 2021).

Assessment of the Elemental Safety of Raw Materials

Pb, Cd, Hg, and As were not detected in the analyzed vegetative and generative organs of either wild-growing or cultivated *L. barbarum*, indicating that their concentrations were below the detection limits of the analytical method.

Conclusion

The elemental composition of *Lycium barbarum* was strongly influenced by both plant organ and growing conditions. Cultivated samples generally showed increased accumulation of K, Al, Zn, and several other elements, while some elements, including Cl, S, and Cu, were higher in selected wild-growing organs. Ca, Mn, P, Si, and Ag were detected selectively in cultivated samples.

The absence of detectable Pb, Cd, Hg, and As supports a favorable elemental safety profile of the investigated raw materials. However, definitive compliance with regulatory requirements should be established using validated analytical limits and direct comparison with applicable pharmacopoeial standards.

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