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THE ELEMENTAL CHEMICAL COMPOSITION OF SOME PLANTS OF THE GENUS HELIOTROPIUM GROWING IN THE FERGANA VALLEY OF UZBEKISTAN

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Abstract

The elemental chemical composition of the underground (u/g) and aboveground parts (a/p) of plants of the genus *Heliotropium* of the Boraginaceae family: *H. lasiocarpum* Ledeb. and *H. dasycarpum* Ledeb., growing in the Ferghana Valley of Uzbekistan, has been studied for the first time by inductively coupled argon plasma mass spectrometry (ICP-MS). The data obtained show that 18 out of 21 elements were found in the organs of the studied plants, including 4 macronutrients (Ca, K, Na, Mg), 7 essential trace elements (Co, Cr, Cu, Fe, Mn, Se, Zn), 4 conditionally essential trace elements (Ni, V, As, Li), 3 toxic elements (Pb, Ba, Al). Salts of toxic elements Ag, Be, Cd, and Hg were not detected. It was revealed that of the detected elements in the organs of the studied plants, concentrations of more than 1000 mg/kg contain 3 macronutrients (Ca, K, and Mg), concentrations of 50 to 1000 mg/kg contain 4 elements (Na, Fe, and Zn), and concentrations of 10 to 100 mg/kg contain 1 element. (Mn), ranging from 1–10 mg/kg – 5 elements (Cr, Ni, V, Li, Cu), ranging from 1–5 mg/kg – 2 elements (Se, Co). The composition of trace elements of the body does not decrease the roots of the a/p of *H. lasiocarpum* are large in Fe (a/p 700,112 mg/kg, u/g 197,725 mg/kg). The composition of the roots and a/p of *H. dasycarpum* also contains a large proportion of Fe (a/p – 527.441 mg/kg and u/g – 486.441 mg/kg). It was found that A1 accounts for the highest content of toxic elements in plant organs: *H. lasiocarpum* (355.55 mg/kg and 154.20 mg/kg, respectively) in a/p and *H. dasyocarpum* (341.44 mg/kg and 276.75 mg/kg, respectively). Salt content of the studied heavy metals of the plant boiler, growing in Uzbekistan, meeting the requirements set by the State Pharmacopoeia XIV of the Russian Federation and WHO.

Keywords: *Heliotropium lasiocarpum, H. dasycarpum, Boraginaceae family, elemental chemical composition, ICP OES method*

Introduction

Heliotropium is a genus of plants in the Boraginaceae family, which has over 325 species worldwide, distributed in tropical and subtropical regions of the globe. The name *Heliotropium* comes from the Greek word "helios" – the sun, from the idea that the inflorescences of these plants turn their rows of flowers to the sun, which means to turn by rotation – "trope". *H. lasiocarpum* is an annual poisonous herbaceous plant with a branched stem, 20–50 cm high; leaves are elliptical, petiolate, pubescent; flowers are small, white, in whorls; the fruit is a nutlet (*Heliotropium*). *H. dasycarpum* is a perennial with a thick root and several branched stems covered with hairs, 20–50 cm tall; leaves on petioles, the upper ones are almost sessile; flowers on long legs; fruits are nuts, ovate, smooth, covered with hairs or glabrous (*Heliotropium dasycarpum*). Plants of the genus *Heliotropium* are exclusively grasses or semi-shrubs, being weeds that grow everywhere along roads, in vegetable gardens, and litter crops of cereals (wheat, barley) (Vvedensky A. I., 1961). Despite their toxicity, heliotropes are medicinal plants, they are actively used in alternative medicine. A decoction of heliotrope leaves is used in small doses and concentrations as an anthelmintic, for kidney stones and to eliminate lichen. Fresh heliotrope leaves are used externally for removing warts and resorption of benign tumors, for baths for lichen and other skin diseases (*Heliotropium; Heliotropium dasycarpum*).

Plants of the genus *Heliotropium* are typical alkaloids (they contain pyrrolizidine alkaloids heliothrin, lasiocarpine, supinine, cynoglossin, etc.) (Yunusov S. Y., 1981; Shakirov R., Vinogradova V. I., Aripova S. F., Sultankhodzhaev M. N., Bessonova I. A., Akhmedzhanova V. I., Tulaganov T. S., Salimov B. T., 2013). characterized by high toxicity (Kakar F., Akbarian Z., Leslie T., Laice M., Watson D., Van Hans E., Fahim O., Mofle D., 2010; Chuanhui Ma, Yang Liu, Lin Zhu, Hong Ji, Xun Song, 2018; Xia Q., Yan J., Chou M. W., Fu P. P. (2008). Plants of the genus *Heliotropium* L. – *H. lasiocarpum* Ledeb. and *H. dasycarpum* Ledeb., which also grow on the sands in the republics of Central Asia and Azerbaijan, are widespread in Uzbekistan (Vvedensky A. I., 1961). *H. lasiocarpum*, whose reserves are significant in Kashkadarya, Bukhara, and Jizzakh regions (several tons of air-dry raw materials can be harvested annually), contains significant amounts of alkaloids, the main of which is (Heliothrin Yunusov S. Y., 1981). A method for producing Heliotrine, which is used worldwide as a bioreactive agent in biomedical research to create a "Heliotrine hepatitis model" has been developed in the pilot production of ICPS based on *H. lasiocarpum*. Heliotrin is included in the Catalog of the French company «*Latoxan*», is in demand and is still exported by the institute abroad.

However, it should be noted that the toxicity of Heliotrope is due only to the pyrrolizidine alkaloids contained in them, which can be easily removed by simple, alkaloid-specific methods, and the resulting meal, which does not contain alkaloids, is not used. In order to recycle the meal and use plants of the genus *Heliotropium*, which have significant reserves and contain a minimum amount of the alkaloids (depending on the place of growth, the removal of which is not difficult), is of practical interest. By the way, the organs of the species *H. lasiocarpum* and *H. dasycarpum* collected in another region (east of Uzbekistan, Ferghana Valley) contains insignificant amounts of alkaloids (0,1–0,3%) (Omonova S. S., Khuzhaev V. U., Aripova S. F., 2025). In addition to toxic alkaloids, the plant contains other non-toxic primary and secondary metabolites, which in the future can be used in practice in veterinary medicine and agriculture.

The plants *H. lasiocarpum* and *H. dasycarpum* have been little studied chemically. In this regard, we began studying other plant components (flavonoids, proteins, amino acids, polysaccharides, lipids, vitamins, etc., including elements). In addition to alkaloids, we studied the protein components isolated from *H. lasiocarpum*, studied their toxicity and pharmacological activity (RakhimovaSh. Kh., Mezhlumyan L. G., Omonova S. S., Azamatov A. A., Aripova S. F., Nabieva F. S., 2025). The research results showed that the acute toxicity of the studied substances was higher than 5000 mg/kg, which makes it possible to classify them as practically non-toxic substances. Studying the properties proteins of *H. lasiocarpum* showed, that they showed moderate hypoglycemic (inferior to metformin) and hypocholesterolemic activity in comparison with the drug «Roxera» (Rosuvastatin), reducing cholesterol levels in rats by 41.4–53.6% (Omonova S. S., Matchanov O. D., Khasanov R. S., Aripova S. F., 2024).). Considering that minerals can also be biologically active or toxic (Oberlis D., Harland B., Skalny A., 2018), the study of the elemental composition of these plants growing in the territory of the Republic of Uzbekistan, with a view to their further possible use as raw materials for the pharmaceutical industry or agriculture, is relevant.

In connection with the above, the purpose of the study is to study the chemical elemental composition of the organs of *H. lasiocarpum* and *H. dasycarpum*, growing on the territory of the Republic of Uzbekistan. Previously, the elemental composition of these plants had not been studied. The plants for research were collected in 2024 in Namangan region (Mingbulak), during the same growing season (August), the aboveground part and the roots of the plants were collected. The collected raw materials were air-dried in a well-ventilated room protected from direct sunlight and milled to 2–4 mm particles. The plant samples were identified by Candidate of Biological Sciences A. M. Nigmatullaev. Herbarium specimens are kept in the collections of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan.

The quantitative analysis of the elemental composition was studied by inductively coupled plasma mass spectrometry (ICP-OES). The analysis was carried out on three series of raw material samples, carrying out five repeated analyses of each sample. The exact weight of the studied raw materials (0,0500–0,5000 g) was placed in Teflon autoclaves DAP-60+ (or similar). The samples were then filled with 5 ml of purified nitric acid and 3 ml of purified hydrogen peroxide. Decomposition was carried out on a microwave decomposition device, the contents in autoclaves were quantitatively transferred to measuring flasks with a volume of 100 ml and the volume was adjusted to the mark with 2% nitric acid. The determination of the elemental composition was carried out on an Avio 200 device (Perkin Elmer USA) using a multi–element standard (for ISP ECO) and a standard Hg. Analysis conditions: generator power (for plasma) 1300–1500 W, argon flow (plasma) – 12 l/min, nebulizer – 0.8 l/min, peristaltic pump – 1.2 ml/min.

The tools and equipment used. ISP ECO Avio-200 (ICP-OES). Programmable microwave oven – Berghof. Teflon autoclaves, measuring flasks for 50 ml, 100 ml. Reagents: Multi–element standard for ECO (21); multi-element standard for ECO (rare metals); standard – Hg (mercury); purified nitric acid; purified hydrogen peroxide; deionized water; argon (purity 99.995%). Device parameters: nebulizer-Meinhard; spray chamber – glass, cyclone; sample feed rate 0.5 ml/min; RF generator power – 1500 Watts; nebulizer gas supply – 0.5 l/min; auxiliary gas supply – 0.2 l/min; plasma gas supply – 8 l/min. Sample preparation: The sample (0.1000 g) was quantitatively transferred to Teflon autoclaves, 3 ml of purified concentrated nitric acid (HNO_3) and 2 ml of purified hydrogen peroxide (H_2O_2) were added to it. The autoclaves were closed and installed in a Berghof microwave oven (Speed Wave Xpert or a similar microwave oven). We used a decomposition command based on a ready-made program from the device interface. The number of autoclaves was indicated, while the temperature and pressure inside them were automatically controlled by the device.

The process information was controlled by a liquid crystal display. The method was carried out under wet decomposition for 35–45 minutes under conditions of minimum temperature T (50 °C) and maximum temperature T (230 °C), pressure R [bar] max 40 bar inside the autoclaves. The autoclaves were cooled to room temperature and the liquid contained in them was quantitatively transferred to measuring flasks with a capacity of 50 or 100 ml (up to the mark). In this case, the autoclaves were rinsed 2–3 times, and then bidistilled water was added to the tube. The solution was thoroughly mixed, poured into an autosampler tube and placed in an autosampler in a certain sequence. The position of each tube, the withdrawn mass and the dilution coefficient are entered into the program (so that the device can automatically calculate the concentration). The mineralized solution was quantitatively analyzed using a Perkin Elmer Avio-200 inductively coupled plasma optical emission spectrometer (ICP-OES) (or a similar analog instrument) in comparison with a standard sample containing a number of macro- and microelements, salts of heavy metals and rare metals. The analytical results automatically calculate the precision and standard deviation (RSD) value by recalculating the results based on the sample weight and dilution values at the end of the process. Sample analysis and data processing were performed using PerkinElmer (USA) – Syngistix™ software. Statistical processing was carried out in the Excell and Origin Pro 8.6 software package (Microsoft, USA) and according to the OFS.1.1.0013.15 (OFS.1.1.0013.15., 2018) the value of P=0,01 with Student's coefficient and n=5.

Discussion of the results. The results of experiments on the study of the elemental composition of samples, classified according to (Polyanskaya I. S., 2014), carried out by inductively coupled argon plasma mass spectrometry (ICP-OES), are shown in Table 1 and Figures 1–6.

Table 1. *Data from a comparative analysis of the elemental composition of the aboveground part and roots of H. lasiocarpum and H. dasycarpum plants (P=0.01)*

No.	Elements	Aboveground parts (mg/kg)		Underground (mg/kg)	
		H. lasiocarpum	H. dasycarpum	H. lasiocarpum	H. dasycarpum
1	Ca	9133.25	11110.42	3731.21	5580.52
2	K	15950.22	9768.25	10190.12	13810.52
3	Na	5500.41	1646.23	2645.45	973.64
4	Mg	2115.25	1975.53	1662.56	1777.19
5	Fe	700.11	572.42	197.73	486.44
6	Zn	42.58	52.71	53.13	14.61
7	Cu	8.983	11.00	7.71	7.98
8	Mn	82.20	105.65	22.15	65.92
9	Co	n/d	n/d	n/d	0.19
10	Se	5.98	3.35	5.44	4.98
11	Cr	8.20	10.14	7.71	11.20
12	Ni	5.18	5.27	7.53	9.06
13	V	1.24	0.09	1.05	1.11
14	As	n/d	n/d	n/d	0.00218
15	Li	7.311	6.85	0.89	1.10
16	Pb	1.53	3.60	2.74	0.15
17	Al	355.55	341.44	154.2	276.75
18	Ba	25.95	45.58	41.42	22.13

Note: n/d – not detected.

The data obtained show that 18 out of 21 elements were found in the organs of the studied plants, including 4 macronutrients (Ca, K, Na, Mg), 7 essential trace elements (Co, Cr, Cu, Fe, Mn, Se, Zn), 4 conditionally essential trace elements (Ni, V, As, Li), 3 toxic elements (Pb, Ba, Al). Salts of toxic elements Ag, Be, Cd, and Hg were not detected. It was revealed that of the detected elements in the organs of the studied plants, concentrations of more than 1000 mg/kg contain 3 macronutrients (Ca, K, and Mg), concentrations of 50 to 1000 mg/kg contain 4 elements (Na, Fe, and Zn), and concentrations of 10 to 100 mg/kg contain 1 element. (Mn), ranging from 1–10 mg/kg of 5 elements (Cr, Ni, V, Li, Cu), ranging from 1–5 mg/kg of 2 elements (Se, Co). The macronutrients were arranged in the following order according to their quantitative content (Fig. 1–2). In the a/p of *H. lasiocarpum*: K (49%)>Ca (28%)>Na (17%)>Mg (6%); in the u/g of *H. dasycarpum*: K (48%)>Ca (39%)>Mg (7%)>Na (6%); in the roots of *H. dasycarpum*: K (54%)>Ca (31%)>Mg (10%)>Na (5%).

Figure 1. *Macronutrients of the roots (1) and the aboveground part (2) of H. lasiocarpum (relative to the total macronutrient content, %)*

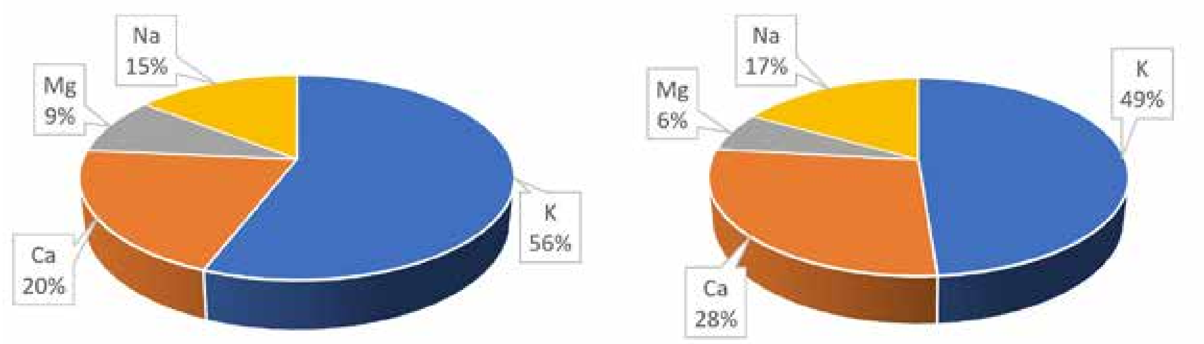
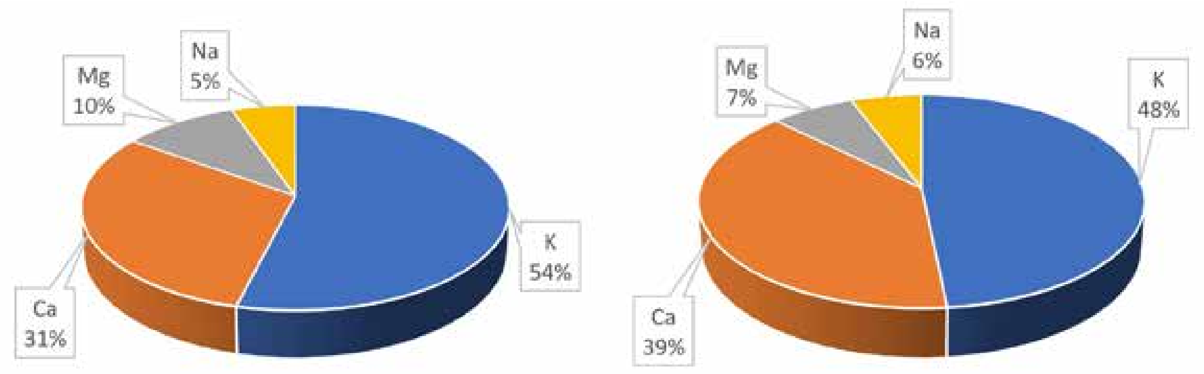


Figure 2. *Macronutrients of the roots (1) and the aboveground part (2) of H. dasycarpum (relative to the total macronutrient content, %)*



According to literature data, 98% of the potassium content in a plant is located inside tissue cells, contributes to the normalization of metabolism, and maintains acid-base and water-salt balance (Lysikov Yu.A., 2008; Kolomiytseva M. G., Gabovich R. D. 1970). Calcium plays an important role in the transmission of nerve impulses and in the regulation of blood pressure, as well as in the regulation of the blood coagulation system (Kolomiytseva M. G., Gabovich R. D., 1970; Greer F. R., Krebs N. F., 2006).

Figure 3. *Trace elements of the roots (1) and the aboveground part (2) of H. lasiocarpum (relative to the total content of trace elements, %)*

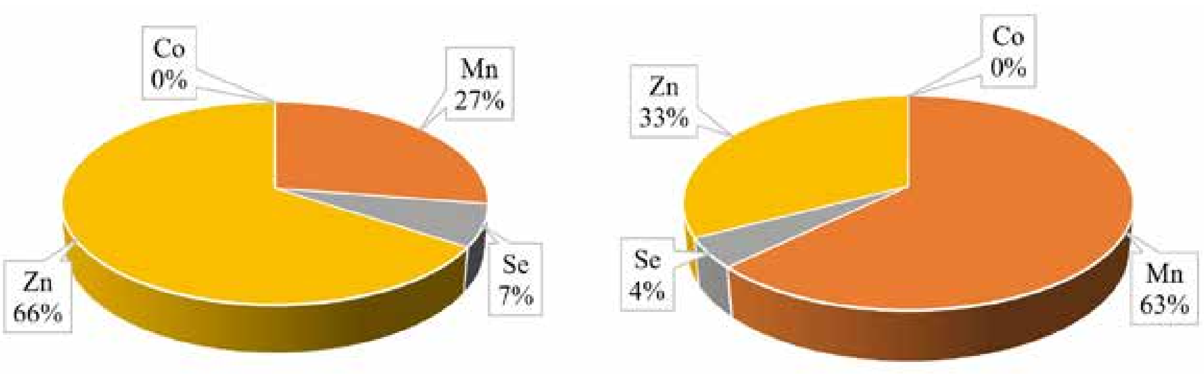
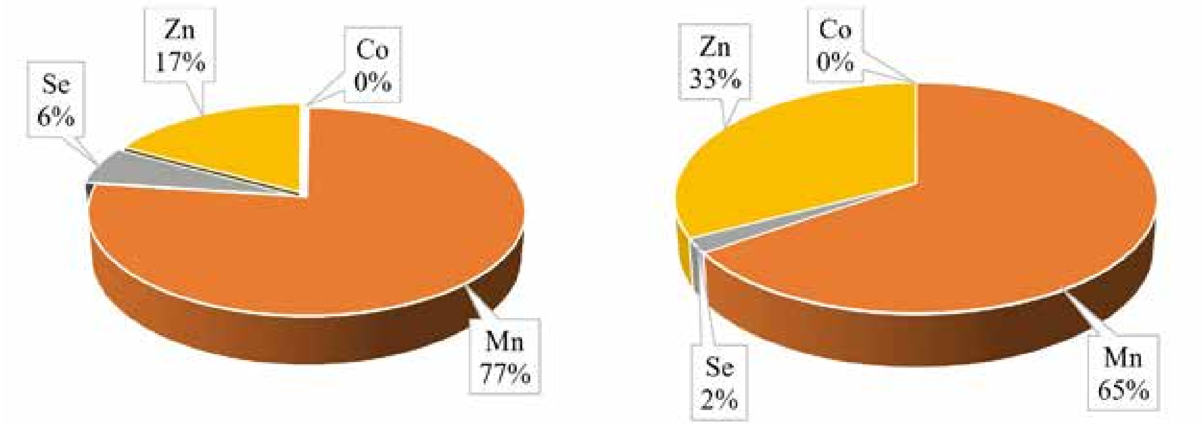


Figure 4. *Trace elements of the roots (1) and the aboveground part (2) of H. dasycarpum (relative to the total content of trace elements, %)*



It follows from the data in Figures 3–4 that the relative content of trace elements (Co, Mn, Zn, Se) in the roots and aboveground parts of plants of both species is about the same order. It should be noted that the plants contain selenium (Se), which is one of the vital elements, the main function of which is its participation in the work of antioxidant systems and thyroid hormone metabolism (Struyev I. V., Simakhov R. V., 2006).

Figure 5. *Essential elements of the roots (1) and the aboveground part (2) of H. lasiocarpum (relative to the total content of essential elements, %)*

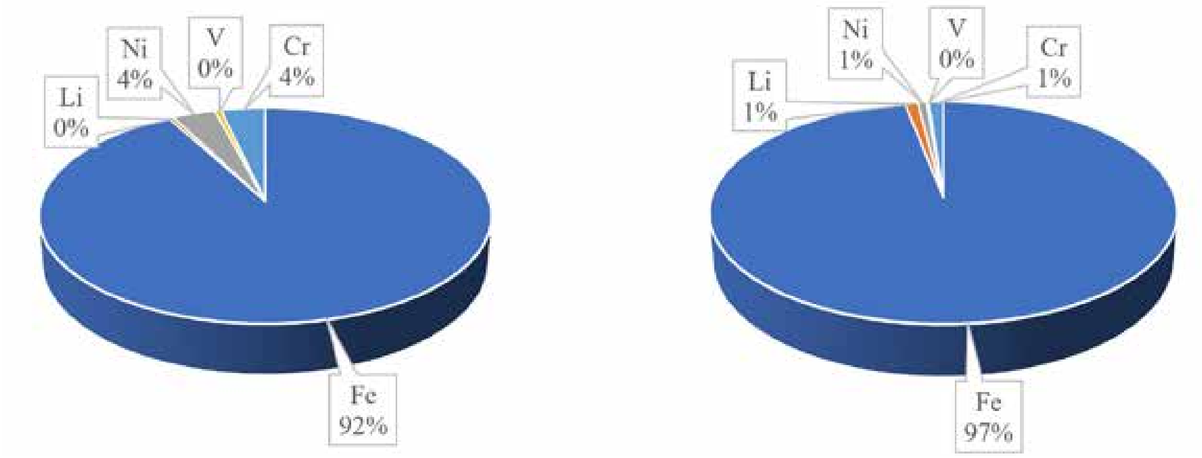
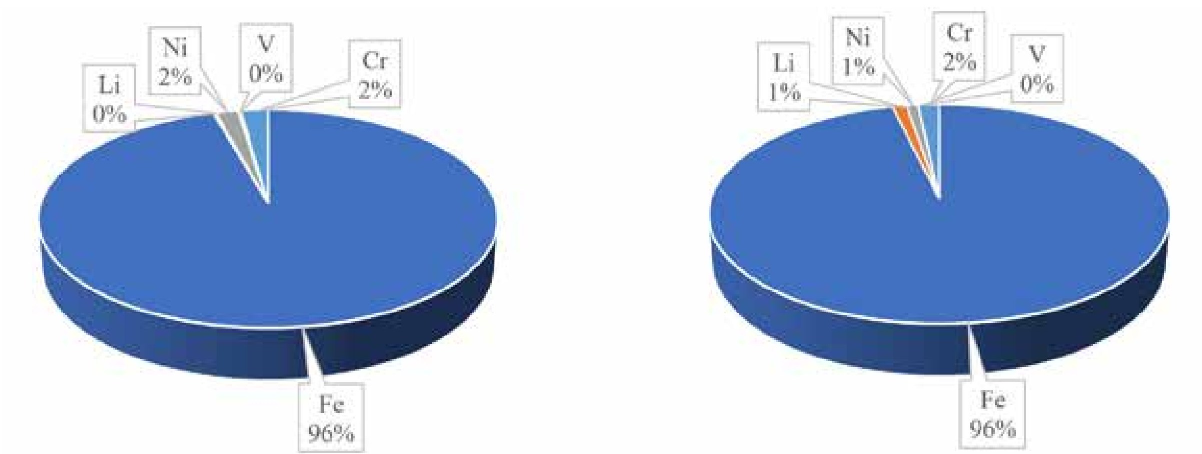


Figure 6. *Essential elements of the roots (1) and the aboveground part (2) of H. dasycarpum (relative to the total content of essential elements, %)*



Of trace elements (Fe, Cr, Li, Ni, V) in the composition of the roots and aboveground parts of *H. lasiocarpum* (a/p – 700,112 mg/kg, u/g – 197,725 mg/kg) and *H. dasycarpum* (a/p – 527,441 mg/kg, u/g – 486,441 mg/kg). A large proportion is Fe, which is part of heme-containing proteins (hemoglobin and myoglobin) and participates in oxygen transport (Idelson L. I., Vorobyev A. I., 2005), the content of which in plant organs ranges from 92–97%, which is reflected in Figures 5–6. In the organs of *H. lasiocarpum* and *H. dasycarpum*, the relative content of copper ranges from 7.71–11.00 mg/kg, and aluminum (A1) in a/p and u/g of *H. lasiocarpum* – 355.55 mg/kg and 154.20 mg/kg, respectively, and in a/p and u/g of *H. dasyocarpum* – 341.44 mg/kg and 276.75 mg/kg, respectively. The content of heavy metal salts of Pb, Co, As in the organs of the 2 studied plants, according to Table 1, is within the permissible doses (0.00218 and 3.597 mg/kg).

Comparative data on heavy metals (Tivo P. V., Bytko I. G., 1996). in *H. lasiocarpum* and *H. dasycarpum* with established international requirements for regulatory and technical documentation of the maximum permissible levels of heavy metals and arsenic in medicinal plant raw materials and herbal preparations are presented in Table 2, from which it follows that according to this criterion, the studied plants growing in Uzbekistan meet the requirements, established by the State Pharmacopoeia XIV and WHO (OFS 1.5.3.0009.15., 2015; World Health Organization et al., 2005).

Table 2. *Comparative data of heavy metals in H. lasiocarpum and H. dasycarpum with established global requirements*

Element	Maximum permissible content of heavy metals and arsenic in medicinal plant raw materials and medicinal herbal preparations (mg/kg)	*H. lasiocarpum* (a/p, u/g)	*H. dasycarpum* (a/p, u/g)
Lead	6,0	1,53; 2,74	3,60; 0,15
Cadmium	1,0	n/d; n/d	n/d; n/d
Mercury	0,1	n/d; n/d	n/d; n/d
Arsenic*	0,5	n/d; n/d	n/d; 0,00218

**Note: In accordance with the safety requirements adopted in the Russian Federation; n/d – not detected.*

The data obtained indicate that the studied plants are a natural source of vital elements and, according to their content, represent safe raw materials for humans and farm animals as feed.

Conclusions

1. For the first time, the elemental composition of the roots and aboveground parts of plants of the genus *Heliotropium: H. lasiocarpum* and *H. dasycarpum*, growing in the Ferghana Valley of the Republic of Uzbekistan, was studied and their comparative analysis was carried out; 18 elements out of 21 studied, related to macro-, micro-, essential and toxic elements were found.

2. The identified elements in the organs of the studied plants are characterized by a high content of Ca, K, Mg (more than 1000 mg/kg), a high content of Na, Fe, Zn (50–1000 mg/kg), an average content of Mn (10–100 mg/kg), a low content of Cr, Ni, V, Li, Cu (1––10 mg/kg), very low – Se, As, Co (0.002–5 mg/kg); toxic elements (Ag, Be, Cd, Hg) were not detected in the organs of the studied plants.

3. It has been established that the content of heavy metal salts in the studied plants growing on the territory of the Republic of Uzbekistan is within the limits of the norms that are normalized by the relevant Scientific and Technical Specifications (the State Pharmacopoeia XIV of the Russian Federation and WHO).

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