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COMPARATIVE ANALYSIS OF MINERAL COMPOSITION IN PLANTS OF GENUS *HEMEROCALLIS* L. GROWING IN URBANIZED ENVIRONMENT

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The quality and quantity of elements of the mineral composition of a plant directly affects the nature of the physiological effect on the human body, using this plant for food or as a medicine. The ability of plants to form the mineral composition in a certain way in an urbanized environment may be one of the reasons for the risk of using these plants for the human and animal organisms in view of their possible contamination with toxic substances. Ornamental flower plants of the genus *Hemerocallis* L. growing in Europe, North America, Russia and in the countries of Southeast Asia have been used in folk medicine since ancient times, and flowers and buds are eaten. The purpose of this study was to determine and compare the content of heavy metals in 14 taxon of the genus *Hemerocallis* L. The elemental composition of roots and leaves in dried plant raw materials, of the juice and the collection site soil was studied by atomic adsorption spectrometry. The order of decrease of the studied metals in underground and aboveground organs is established as follows: Cu>Mn>Ni>Pb>Fe>Cr>As>Cd. It was noted that the average content of heavy metals Pb, Cd and Mn is higher in plant leaves. The average content of As, Cr, Fe, Cu and Ni prevailed in the roots of plants. Species- and variety-specific accumulation of heavy elements in the leaves and roots of the studied daylily taxon was noted.
Keywords: edible plants, *Hemerocallis* L., plant juice, mineral element composition, heavy metals, atomic-absorption spectroscopy.

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Introduction

In an unstable environmental situation, the safety of natural medicinal and food herbal remedies is becoming increasingly relevant. Ensuring a balanced diet of humans and animals with food rich in vitamins and mineral elements is an important aspect of the prosperity of all mankind on the planet. Minerals deficiency is a widespread health problem in both developing and developed countries. About two-thirds of the world's population is at risk of inadequate consumption of one or more vital mineral elements [1]. The importance of minerals for the optimal functioning of the human body cannot be overestimated [2, 3]. They are components of enzymes involved in the regulation of cellular energy transduction, antioxidant protection, gas transport, membrane receptor functions, integration of several physiological functions, etc. [4]. Moreover, they are indirectly involved in the anti-inflammatory, antibacterial, antifungal, and antiviral responses [5, 6]. Mineral elements help strengthen the immune system and are involved in the formation of the human skeleton building blocks [6].

It is reported that at least 17 elements are among the set of important nutrients for the plants themselves, the concentration of which in the tissues varies among different types of plant crops [7]. Understanding systematic changes in mineral elements concentrations is also important for agriculture to optimize the application of fertilizers for agricultural crops, to deliver mineral elements to human and livestock diets, in synecology, to improve

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understanding of the structure and function of plant communities and for better understanding the cycle of natural and anthropogenic minerals in the environment [8, 9]. Moreover, the systematization of information on the quantity and quality of mineral composition in various plant tissues can give an idea of the evolution of these differences within the taxon [10].

It should be noted that ornamental plants can also be used as available nutraceutical sources with valuable biological properties. Thus, representatives of the genus *Hemerocallis* L. are utilized not only as ornamental flower plants, for example, in Europe, North America and Russia, but are also in folk medicine in China and Japan [11] and even eaten [12]. Daylilies are a rich source of many chemical compounds that play an important role in various metabolic processes in the human body [13]. Among them are not only secondary plant metabolites, but also mineral elements significant for humans. Species of the genus *Hemerocallis* L. [14, 15] contain chemical elements that have various biological effects on the human and animal body; they can be conditionally divided into several groups: essential, conditionally essential, toxic and potentially toxic. Essential or vital elements (Fe, I, Mn, Cu, Cr, Zn, etc.) include bioelements for which their exclusive role in ensuring the vital functions of the human body has been established. Conditionally essential or conditionally vital (V, Si, As, Li, Ni, etc.) are elements for which more data are accumulating about their important role in ensuring the normal functioning of the body. Toxic (Al, Ba, Cd, Pb, Hg, etc.) are a large group of elements that are constantly present in trace quantities in the body, but their biological role has not yet been sufficiently studied. Because many of these elements are relatively toxic, the focus is usually on their harmful effects on the body. Conditionally toxic (W, Au, Sn, Rb, Ag, etc.) are those microelements that can lead to the development of pathological conditions when entering the body in significant quantities [16, 17].

Thus, our research was aimed at studying the mineral composition (Pb, Cd, As, Cr, Mn, Fe, Cu, Ni) of aboveground and underground organs of 14 plant taxon of the genus *Hemerocallis* L. (*H. citrina, H. fulva, H. lilioasphodelus, H. middendorfii, H. minor, H. dumortieri,* 'Beverly Hillz', 'Buzz Bomb', 'Childrens Festival', 'Dr. Regel', 'Frans Hals', 'Golden Dust', 'Missouri Beauty', 'Red Sea'). The work was carried out not only on dried raw materials, but also on plant juice. The study was supplemented and expanded with the data on the intensity of biological absorption of heavy elements from the soil and the correlation analysis between the mineral elements of dried raw materials and leaf and root juice.

Experimental Part

The field experiment was carried out in 2020–2021 at the daylilies experimental site of the laboratory of flower plants introduction and breeding of the SUBGI UFRC RAS. The plant material (leaves, roots) for the study was obtained from six species (*H. citrina* Baroni, *H. fulva* L., *H. lilioasphodelus* L., *H. middendorffii* Trautv. et C. A. Mey, *H. minor* Mill., *H. dumortieri* E. Morren) and 8 varieties ('Beverly Hillz', 'Buzz Bomb', 'Childrens Festival', 'Dr. Regel', 'Frans Hals', 'Golden Dust', 'Missouri Beauty', 'Buzz Bomb') of ornamental plants of the genus *Hemerocallis* L. The soil of the daylilies collection site was also studied (Table 1).

The field experiment was set in a randomised block design with four replications on typical pararendzinas soils, with pH 6.1 in H_2O and the subsequent nutrient content: nitrate nitrogen – 2.6 mg/kg, mobile phosphorus – 150 mg/kg, mobile potassium – 155.7 mg/kg, exchangeable calcium – 13.9 mg-eq/100 g, exchangeable magnesium – 0.94 mg-eq/100 g.

A single plot area was: 48 м^2 for varieties and species of representatives of the genus *Hemerocallis* L. (100 × 100 cm, 48 plants per plot). Planting material of perennial plants of the genus *Hemerocallis* L. was taken from the collection plot and transplanted to the experimental plot on May 18, 2021.

The field was prepared according to an adequate agronomic procedure for the tested plant species. Mineral fertilisation was quantified according to the results of the chemical analysis of the soil. Nitrogen (60 kg N ha^{-1}), phosphorus (50 kg P_2O_5 ha^{-1}) and potassium (70 kg K_2O ha^{-1}) fertilisers were applied during the field preparation, in both years of the study. During the growing season, crop management was carried out. It included mainly irrigation, weeding and soil cultivation.

Additionally, the level of contamination of the collection site soil with heavy metals was investigated (Table 2). The data obtained showed that the MAC of most elements was not exceeded, with the exception of Cu. The content of mobile forms of Cu in the soil of the daylilies collection site was 7.04 mg/kg, which 2.35 times exceeds the MAC.

Table 1. The content of mobile forms of heavy metals in the soil of SUBGI UFRC RAS

Sampling location	Amount of heavy metals mg/kg							
	Pb	Cd	As	Cr	Mn	Fe	Cu	Ni
Collection site	0.70±0.17	0.01±0.00	0.37±0.12	0.29±0.10	1.10±0.35	0.43±0.09	7.04±1.76	0.94±0.34
MAC [18]	6	1	2	6	100	–	3	4

The roots, leaves and soil were collected in September 2021 during the autumn vegetation phase. The total sample of four replicates weighed from 500 to 1000 g, depending on the plant species and variety.

The raw plant material and soil were dried in a flow laboratory dryer at a temperature of 40 °C. The concentration of elements (Pb, Cd, As, Cr, Mn, Fe, Cu, Ni) was determined in dried and powdered materials (50 g of each sample). The content of nitrate nitrogen was estimated according to GOST R 53219-2008 [19], mobile phosphorus and potassium according to Chirikov [20], and exchangeable calcium and magnesium according to GOST 26487-85 [21]. Lead, cadmium, arsenic, chromium, manganese, iron, copper, nickel were estimated by atomic absorption spectrophotometry using Shimadzu AA-6300 with electrochemical atomizer GFA-EX-7. The analyses were carried out in triplicate.

Separately, leaf juice and root juice of the studied plants was obtained using a homogenizer, followed by filtration on Schott filters. The samples were mineralized using a Speedwave Xpert microwave digestion system (Berghof, Germany). Samples weighing about 2 g were placed in Teflon beakers with 8 ml of concentrated nitric acid and subjected to mineralization in accordance with the manufacturer's recommendations. Determination of metals in the juice was carried out according to the procedures [22–25] by atomic absorption spectrometry with flame atomization (nickel, chromium, manganese, copper, iron, arsenic) and with electrothermal atomization in a graphite furnace (lead, cadmium) (AA240F; AAS GTA 120, AA240Z, Varian, Australia). The analyses were carried out in triplicate.

The intensity of heavy metal absorption by the studied daylilies taxon was estimated using the biological absorption coefficient (hereinafter BAC) and root barrier coefficient (RBC). The BAC indicator was calculated as the ratio of the amount of the element in the ash of daylilies leaves and roots to its amount in the root-inhabited soil layer of the collection site of the SUBGI UFRC RAS [26]. RBC was calculated as the ratio of the element contents in the plant root and above-ground organs. RBC values greater than one indicate the presence of a barrier to the entry of elements into the above-ground parts of plants [27]. The results of the study were processed using generally accepted methods of variation statistics using SPSS 22.0 and Microsoft Excel 2007.

Results and discussion

The results of chemical analyses of selected species and varieties of the genus *Hemerocallis* L. ornamental plants are presented in Tables 2 and 3. The content and quantity of eight chemical elements belonging to the group of heavy metals (Pb, Cd, As, Cr, Mn, Fe, Cu, Ni) of aboveground and underground organs of *Hemerocallis* L. were examined. Table 2 presents the results on the study of dried raw materials elemental composition in leaves/roots comparison. Table 3 presents the results on juice elemental composition in leaves/roots comparison. The study of growing raw materials elemental composition was carried out on 14 daylily taxon (*H. citrina, H. fulva, H. lilioasphodelus, H. middendorfii, H. minor, H. dumortieri*, ‘Beverly Hillz’, ‘Buzz Bomb’, ‘Childrens Festival’, ‘Dr. Regel’, ‘Frans Hals’, ‘Golden Dust’, ‘Missouri Beauty’, ‘Red Sea’). These mineral elements play an important role in the vital activity of a human organism. The literature contains few data on the content of these elements in dried raw materials [14, 15], while data on elemental composition of *Hemerocallis* L. juices are not available.

The studied metals content in descending order of the daylily taxon dried leaves/roots was as follows Cu>Mn>Ni>Pb>Fe>Cr>As>Cd. The quantitative analysis of the research results revealed a pattern in the content of plant samples elements: in most of the studied taxon such elements as Cu and Mn predominated, while the As and Cd concentration was always minimal (Table 2).

In the present study, heavy metals content in the dried leaves and roots did not have significant deviation. In accordance with the State Pharmacopoeia of the Russian Federation (SP RF) [28] and the World Health Organization (WHO) for medicinal plants [29], the maximum allowable concentration (MAC) of Pb in medicinal plant materials is 6 mg/kg, which corresponds in terms of safety to the data obtained. The Pb content in the organs of the studied plants varied from 0.10 mg/kg (*H. fulva*) in the roots to 1.55 mg/kg (*H. dumortieri*) in the leaves. Depending on the average values of Pb, the highest accumulation was observed in leaves (0.93 mg/kg) than in roots (0.78 mg/kg). The maximum allowable content of Cd in accordance with the SP RF and WHO MAC is 1 mg/kg [28, 29], which corresponds in terms of safety to the data obtained. The Cd content in the studied plants organs varied from 0.01 mg/kg (*H. dumortieri*) to 0.04 mg/kg in roots ('Missouri Beauty', 'Buzz Bomb', *H. minor*) and leaves ('Red Sea'). Depending on the average values of Cd, the highest accumulation was observed in the leaves (0.03 mg/kg) than in the roots (0.02 mg/kg). The As content analysis in the studied plants showed that its concentration in daylily roots varies from 0.18 mg/kg (*H. middendorfii*) to 0.81 mg/kg (*H. lilioasphodelus*). In the leaves As was observed within the average values of 0.27–0.76 mg/kg. According to the SP RF and WHO MAC for As is 0.50 mg/kg. It was found that the As content in some taxon exceeds the norms specified in the SP RF. A slight increase in As concentration is observed in leaves (0.76 mg/kg ('Dr. Regel') and roots (0.81 mg/kg) (*H. lilioasphodelus*), which is most likely due to individual growth characteristics of these representatives.

The roots of *H. dumortieri* showed the lowest concentration of Cr (0.07 mg/kg) and Mn (0.93 mg/kg), while their greatest accumulation was observed in the root varieties 'Missouri Beauty' (Cr 0.95 mg/kg) and 'Frans Hals' (Mn 2.65 mg/kg). The average content of Cr in daylilies organs decreased in the series: roots (0.58 mg/kg) > leaves (0.53 mg/kg), while an inverse relationship was observed for Mn: leaves (1.69 mg/kg) > roots (1.54 mg/kg). The *H. middendorfii* representative accumulates the least amount of Fe 0.40 mg/kg (leaves), Cu 6.24 mg/kg, and Ni 0.50 mg/kg (roots). The highest content of these elements at a level of 0.80 mg/kg Fe (*H. lilioasphodelus*), 11.55 mg/kg Cu ('Buzz Bomb'), and 1.70 mg/kg Ni (*H. fulva*) is found in the roots. The average content of Fe, Cu, and Ni was consistent for all three elements and decreased in the series roots > leaves, for Fe (0.71 > 0.65), Cu (9.91 > 9.81), and Ni (1.15 > 1.08 mg/kg). Thus, analyzing the average values for the accumulation of heavy metals in dried samples of *Hemerocallis* L., the predominance of Pb, Cd, Mn in the leaves and As, Cr, Fe, Cu and Ni in the roots of the studied samples is observed.

The content of elements in descending order in the leaf/root juice of daylily taxon was as follows: Fe>Mn>Ni>Cu>Pb>Cr>As>Cd / Fe>Mn>Ni>Cu>Cr>Pb>As>Cd (Table 4). The quantitative analysis of juice elemental composition revealed the following pattern - Fe and Mn predominate in most of the studied taxon, while As and Cd concentration is always minimal.

In accordance with the Technical Regulations of the Customs Union "On Food Safety" (TR CU) MPC of Pb is 0.50 mg/kg, of Cd 0.03 mg/kg, of As 0.20 mg/kg, which corresponds in terms of safety to the data obtained [30]. According to the study, the quantitative content of heavy metals in leaves and roots juices did not have significant deviations in accordance with the recommended MAC of metals in drinking water provided by WHO [31]. Depending on the average values, the greatest accumulation of Pb and Cd was observed in leaf juice than in roots. For As, on the contrary, the opposite picture was observed: the accumulation in the root juice was more intense than in the leaf juice. The Pb content in the studied plants juice in most cases was less than 0.02 mg/kg, except for leaf juice of *H. dumortieri* (0.02 mg/kg), Buzz Bomb and Red Sea (0.03 mg/kg), Frans Hals (0.04), and root juice of *H. dumortieri* and 'Red Sea' (0.03 mg/kg). The following pattern was observed for the other studied elements: the Mn and Ni average content was higher in leaf juices, whereas, the Cr, Fe and Cu predominated in daylily root juices. It is obvious that the Fe and Mn prevailed in the juices of most of the studied taxon, while the As and Cd concentration was always minimal.

Taking into account some results of the previous researchers [3], the flowers of the *Hemerocallis* L. plant can be considered as a possible source of Cu (0.29 mg/kg), Mn (0.88 mg/kg) and Zn (1.15 mg/kg), which coincides with the results of our studies. As a result, these mineral elements can be taken into account in the recommendations on the daily diet for adults. For example, according to researchers, when consumed with food, 100 g of fresh *Hemerocallis* L. will provide the need for 29.3% of copper, 43.8% of manganese, and 11.5% of zinc [32]. Studies have shown that plant raw materials and juices of *Hemerocallis* L. can be regarded as a possible source of mineral elements in the human diet [14].

It is known that the concentration of chemical elements in plants is determined by their biological characteristics, the presence of functional barriers at the boundaries of root - stem, stem - leaf, stem - reproductive organs, and also depends on the concentration of their mobile forms in the soil [33]. Calculation of RBC (Table 4) showed that Mn and Cd in most plants enter above-ground organs without barriers. For the remaining metals (Pb, Cr, Fe, Ni) of most of the plants studied, the barrier type of accumulation was characteristic, with the exception of As and Cu. With regard to these elements, barrier accumulation was observed in one half of the plants, and barrier-free accumulation in the other half.

Table 2. The content of heavy metals in leaves and roots (dry material) of some representatives of the genus *Hemerocallis* L. (leaves/roots)

Taxon	Amount of heavy metals leaves/roots, mg/kg							
	Pb	Cd	As	Cr	Mn	Fe	Cu	Ni
H. citrina	1.07 / 0.11	0.03 / 0.02	0.58 / 0.46	0.46 / 0.67	1.71 / 1.45	0.69 / 0.75	10.88 / 10.59	1.16 / 1.45
H. dumortieri	1.55 / 0.88	0.03 / 0.01	0.46 / 0.68	0.59 / 0.07	1.62 / 0.93	0.68 / 0.59	7.94 / 8.94	1.04 / 0.89
H. fulva	0.90 / 0.10	0.02 / 0.02	0.53 / 0.43	0.64 / 0.71	1.61 / 1.08	0.67 / 0.71	10.50 / 9.67	1.10 / 1.70
H. lilioasphodelus	0.89 / 0.11	0.03 / 0.02	0.65 / 0.81	0.68 / 0.63	2.12 / 1.37	0.68 / 0.80	11.20 / 10.25	0.92 / 1.62
H. middendorfii	1.05 / 0.11	0.02 / 0.02	0.57 / 0.18	0.44 / 0.52	1.69 / 1.36	0.40 / 0.74	11.41 / 6.24	0.84 / 0.50
H. minor	0.84 / 0.93	0.02 / 0.04	0.55 / 0.50	0.37 / 0.51	1.68 / 1.36	0.66 / 0.72	7.37 / 8.80	0.98 / 1.20
Beverly Hillz	0.62 / 1.14	0.02 / 0.01	0.46 / 0.46	0.50 / 0.43	1.73 / 2.18	0.63 / 0.52	10.57 / 9.62	1.25 / 0.99
Buzz Bomb	0.98 / 1.02	0.02 / 0.04	0.51 / 0.58	0.61 / 0.68	1.71 / 2.20	0.68 / 0.71	9.54 / 11.55	0.92 / 1.03
Childrens Festival	0.89 / 1.08	0.03 / 0.01	0.35 / 0.63	0.41 / 0.12	1.62 / 1.20	0.63 / 0.64	10.72 / 10.50	1.00 / 1.06
Dr. Regel	0.91 / 1.04	0.03 / 0.01	0.76 / 0.63	0.59 / 0.80	1.69 / 1.30	0.68 / 0.79	7.73 / 10.46	1.04 / 1.25
Frans Hals	0.92 / 1.20	0.02 / 0.03	0.56 / 0.51	0.45 / 0.74	1.70 / 2.65	0.70 / 0.75	9.78 / 11.36	1.28 / 1.11
Golden Dust	0.79 / 1.04	0.03 / 0.01	0.27 / 0.38	0.42 / 0.94	1.61 / 1.00	0.67 / 0.65	10.61 / 10.69	0.97 / 1.30
Missouri Beauty	0.84 / 0.91	0.01 / 0.04	0.50 / 0.66	0.67 / 0.95	1.61 / 2.23	0.63 / 0.77	9.47 / 10.75	1.05 / 0.90
Red Sea	0.76 / 1.18	0.04 / 0.02	0.66 / 0.60	0.59 / 0.41	1.58 / 1.30	0.64 / 0.79	9.66 / 9.30	1.51 / 1.04
Mean	0.93 / 0.78	0.03 / 0.02	0.53 / 0.54	0.53 / 0.58	1.69 / 1.54	0.65 / 0.71	9.81 / 9.91	1.08 / 1.15
MAC	6	1	0.5	–	–	–	–	–

Table 3. The content of heavy metals in leaf and root juice of some representatives of the genus *Hemerocallis* L. (leaf juice / root juice)

Taxon	Amount of heavy metals leaf /root juice, mg/dm^3							
	Pb	Cd	As	Cr	Mn	Fe	Cu	Ni
H. citrina	0.005 / 0.001	0.0020 / 0.0001	0.001 / 0.001	0.001 / 0.001	0.78 / 1.76	4.1 / 33.6	0.23 / 0.32	0.91 / 0.55
H. dumortieri	0.023 / 0.025	0.0003 / 0.0001	0.002 / 0.001	0.001 / 0.002	0.88 / 1.61	2.8 / 8.1	0.19 / 0.55	0.73 / 0.44
H. fulva	0.001 / 0.001	0.0001 / 0.0001	0.001 / 0.001	0.016 / 0.001	1.45 / 1.30	7.7 / 12.9	0.05 / 0.25	0.68 / 0.67
H. lilioasphodelus	0.010 / 0.001	0.0006 / 0.0001	0.002 / 0.001	0.001 / 0.020	2.82 / 1.23	13.6 / 13.8	0.26 / 0.39	0.89 / 0.60
H. middendorfii	0.018 / 0.003	0.0001 / 0.0001	0.001 / 0.001	0.001 / 0.001	3.55 / 0.70	12.9 / 11.6	0.26 / 0.28	1.21 / 0.91
H. minor	0.019 / 0.004	0.0002 / 0.0002	0.001 / 0.005	0.001 / 0.058	1.59 / 1.77	7.3 / 31.0	0.10 / 0.32	0.39 / 0.49
Beverly Hillz	0.010 / 0.001	0.0001 / 0.0001	0.001 / 0.001	0.024 / 0.001	4.59 / 1.14	11.4 / 10.6	0.34 / 0.52	0.85 / 0.63
Buzz Bomb	0.030 / 0.001	0.0008 / 0.0001	0.001 / 0.002	0.001 / 0.001	3.39 / 1.52	12.3 / 12.7	0.45 / 0.14	1.09 / 0.60
Childrens Festival	0.001 / 0.001	0.0008 / 0.0001	0.001 / 0.001	0.001 / 0.001	2.69 / 0.95	5.8 / 6.4	0.91 / 0.40	0.83 / 0.64
Dr. Regel	0.007 / 0.009	0.0001 / 0.0001	0.001 / 0.004	0.001 / 0.019	3.00 / 2.56	7.2 / 45.2	0.17 / 0.55	0.51 / 1.00
Frans Hals	0.041 / 0.008	0.0001 / 0.0002	0.001 / 0.001	0.001 / 0.001	2.47 / 1.36	9.5 / 22.7	0.26 / 0.39	1.00 / 0.76
Golden Dust	0.001 / 0.001	0.0001 / 0.0001	0.001 / 0.001	0.001 / 0.001	1.69 / 1.25	5.2 / 4.6	0.30 / 0.28	0.43 / 0.55
Missouri Beauty	0.001 / 0.019	0.0001 / 0.0001	0.002 / 0.001	0.001 / 0.001	4.62 / 1.57	5.9 / 26.3	0.38 / 0.65	0.69 / 0.90
Red Sea	0.027 / 0.026	0.0001 / 0.0005	0.001 / 0.005	0.001 / 0.001	2.55 / 1.13	4.8 / 12.1	0.34 / 0.40	0.92 / 1.08
Mean	0.010 / 0.007	0.0004 / 0.0001	0.001 / 0.002	0.004 / 0.008	2.58 / 1.42	7.89 / 18.0	0.30 / 0.39	0.80 / 0.70
MAC	0.5	0.03	0.2	–	–	–	–	–

Table 4. Root barrier coefficient of some representatives of the genus *Hemerocallis* L.

Taxon	Root barrier coefficient							
	Pb	Cd	As	Cr	Mn	Fe	Cu	Ni
H. citrina	0.10	0.67	0.79	1.46	0.85	1.09	0.97	1.25
H. dumortieri	0.57	0.33	1.48	0.12	0.57	0.87	1.13	0.86
H. fulva	0.11	1	0.81	1.11	0.67	1.06	0.92	1.55
H. lilioasphodelus	0.12	0.67	1.25	0.93	0.65	1.18	0.92	1.76
H. middendorfii	0.10	1	0.32	1.18	0.80	1.85	0.55	0.60
H. minor	1.11	2	0.91	1.38	0.81	1.09	1.19	1.22
Beverly Hillz	1.84	0.50	1	0.86	1.26	0.83	0.91	0.79
Buzz Bomb	1.04	2	1.14	2.41	1.29	1.04	1.21	1.12
Childrens Festival	1.21	0.33	1.80	0.29	0.74	1.02	0.98	1.06
Dr. Regel	1.14	0.33	0.83	1.36	0.77	1.16	1.35	1.20
Frans Hals	1.30	1.50	0.90	1.64	1.56	1.07	1.16	0.87
Golden Dust	1.32	0.33	1.41	2.24	0.62	0.97	1.01	1.34
Missouri Beauty	1.08	4	1.32	1.42	1.39	1.22	1.14	0.86
Red Sea	1.55	0.50	0.91	0.69	0.82	1.23	0.96	0.69

A certain level of heavy metal content in plants depends on such factors as enrichment with soil elements, forms bioavailability, plant age, mineralogical composition of elements, depth of the root system, etc. [33]. Accordingly, the chemical composition of plant tissues reflects the composition of the soil in which this plant grows. The biological absorption coefficient (BAC) is used to determine the relationship between the concentration of chemical elements in soil and in plants. BAC > 1 corresponds to the biological accumulation, while BAC < 1 testifies to biological capture. According to the intensity of biological absorption, all elements are divided into five groups: very weak capture (BAC = 0.001–0.01), weak capture (BAC = 0.01–0.1), weak absorption and medium capture (BAC = 0.1–1), strong absorption (BAC = 1–10), energetic absorption (BAC = 10–100) [33]. BAC increases when the availability of chemical elements from the soil increases; as a rule, such elements are present in the soil either as soluble salts or in a finely dispersed form [34]. The BAC was assessed in pairs of soil-leaf and soil-root samples (Table 5).

All studied samples showed the BAC values of Pb, Cd, As, Cr, Mn, Fe, Cu, Ni > 1, which indicates the biological accumulation of these elements for most taxon. With the exception of the 'Beverly Hills' leaves and the roots of *H. citrina*, *H. fulva*, *H. lilioasphodelus*, *H. middendorfii* with BAC (Pb) < 1, in these taxon lead is an element of biological capture. The minimum BAC of Pb is established for the roots of *H. fulva* (0.14), the maximum for the leaves of *H. dumortieri* (2.21). The minimum BAC of Cd is established for the roots of *H. dumortieri* (1), the maximum is for the roots of 'Missouri Beauty' (4). The leaves of the varieties 'Childrens Festival' and 'Golden Dust', as well as the roots of the species *H. middendorffii*, have BAC of As < 1; for them, it is an element of biological capture. The minimum BAC for As was obtained for the roots of *H. middendorfii* (0.49), the maximum for the roots of *H. lilioasphodelus* (2.19). The chromium was found to be a biological capture element for the roots of the taxon *H. dumortieri* and 'Childrens Festival'. The minimum BAC of Cr was established for the roots of *H. dumortieri* (0.24) and the maximum for the roots of 'Missouri Beauty' (3.28). Biological capture elements are also BAC < 1: Mn for the roots of taxon *H. dumortieri*, *H. fulva*, and 'Golden Dust'; Fe in leaves of *H. middendorfii*; Cu in *H. middendorfii* roots; Ni for leaves of taxon *H. lilioasphodelus*, *H. middendorfii*, 'Buzz Bomb' and roots of *H. dumortieri*, *H. middendorfii* and 'Missouri Beauty'.

Thus, all the studied elements in the leaves and roots of the investigated plants can be characterized as elements of strong accumulation, and with a BAC value of more than 1, we can already speak about the accumulation of a particular element by the plant and the formation of a biogeochemical barrier. All the studied elements of *Hemerocallis* L. representatives are accumulative elements with an average BAC value of 1.11–3.00. Cd and Cr are characterized by the maximum BAC, while Pb and Ni by the minimum. An analysis of empirical accumulation series showed that the coefficient of biological absorption of the studied elements by leaves is generally 1.1 times higher than by roots. A more intense accumulation of Pb, Cd, Mn is observed in the leaves, and of As, Cr, Fe, Cu, Ni in the roots.

Table 5. BAC in soil-leaf / soil-root pairs of some representatives of the genus *Hemerocallis* L.

Taxon	BAC							
	Pb	Cd	As	Cr	Mn	Fe	Cu	Ni
H. citrina	1.53 / 0.16	3 / 2	1.57 / 1.24	1.59 / 2.31	1.55 / 1.30	1.60 / 1.74	1.55 / 1.50	1.23 / 1.54
H. dumortieri	2.21 / 1.26	3 / 1	1.24 / 1.83	2.03 / 0.24	1.47 / 0.85	1.58 / 1.37	1.13 / 1.27	1.11 / 0.95
H. fulva	1.29 / 0.14	2 / 2	1.43 / 1.16	2.21 / 2.45	1.46 / 0.98	1.56 / 1.65	1.49 / 1.37	1.17 / 1.81
H. lilioasphodelus	1.27 / 0.16	3 / 2	1.76 / 2.19	2.34 / 2.17	1.93 / 1.25	1.58 / 1.86	1.59 / 1.46	0.98 / 1.72
H. middendorfii	1.50 / 0.16	2 / 2	1.54 / 0.49	1.52 / 1.79	1.54 / 1.24	0.93 / 1.72	1.62 / 0.89	0.89 / 0.53
H. minor	1.20 / 1.33	2 / 4	1.49 / 1.35	1.28 / 1.76	1.53 / 1.24	1.53 / 1.67	1.05 / 1.25	1.04 / 1.28
Beverly Hillz	0.89 / 1.63	2 / 1	1.24 / 1.24	1.72 / 1.48	1.57 / 1.98	1.47 / 1.21	1.50 / 1.37	1.33 / 1.05
Buzz Bomb	1.40 / 1.46	2 / 4	1.38 / 1.57	2.10 / 2.34	1.55 / 2.00	1.58 / 1.65	1.36 / 1.64	0.98 / 1.10
Childrens Festival	1.27 / 1.54	3 / 1	0.95 / 1.70	1.41 / 0.41	1.47 / 1.09	1.47 / 1.49	1.52 / 1.49	1.06 / 1.13
Dr. Regel	1.30 / 1.49	3 / 1	2.05 / 1.70	2.03 / 2.76	1.54 / 1.18	1.58 / 1.84	1.10 / 1.49	1.11 / 1.33
Frans Hals	1.31 / 1.71	2 / 3	1.51 / 1.38	1.55 / 2.55	1.55 / 2.41	1.63 / 1.74	1.39 / 1.61	1.36 / 1.18
Golden Dust	1.13 / 1.49	3 / 1	0.73 / 1.02	1.45 / 3.24	1.46 / 0.91	1.56 / 1.51	1.51 / 1.52	1.03 / 1.38
Missouri Beauty	1.20 / 1.30	1 / 4	1.35 / 1.78	2.31 / 3.28	1.46 / 2.03	1.47 / 1.79	1.35 / 1.53	1.12 / 0.96
Red Sea	1.09 / 1.69	4 / 2	1.78 / 1.62	2.03 / 1.41	1.44 / 1.18	1.49 / 1.84	1.37 / 1.32	1.61 / 1.11
Mean	1.33 / 1.11	3 / 2	1.43 / 1.45	1.83 / 2.01	1.54 / 1.40	1.50 / 1.65	1.40 / 1.41	1.14 / 1.22

Conclusion

The data obtained allow getting additional information on the quantitative and qualitative mineral composition of ornamental plants of the genus *Hemerocallis* L. The accumulation of the studied metals in descending order in the dried raw materials of the studied daylilies taxon leaves/roots was as follows Fe>Mn>Ni>Cu>Pb>Cr> As>Cd / Fe>Mn>Ni>Cu>Cr>Pb>As>Cd, while the order of distribution of heavy elements in the leaf/root juice turned out to be approximately the same Fe>Mn>Ni>Cu>Pb>Cr>As>Cd / Fe>Mn>Ni>Cu>Cr>Pb>As>Cd, which indicates the commonality of metabolic processes in plants of related species. The quantitative analysis revealed a pattern in the content of elements in plant samples: Cu and Mn predominated in the dried material, Fe and Mn in the juices, while the concentration of As and Cd was always minimal. Species and variety specificity in the accumulation of heavy metals in the leaves and roots of the studied daylilies taxon was noted. The analysis of empirical accumulation series showed that the coefficient of biological absorption of the studied elements by leaves is generally 1.1 times higher than by roots. In the leaves a more intensive accumulation of Pb, Cd, Mn is observed, while in the roots of As, Cr, Fe, Cu, Ni. Cd and Cr are characterized by the maximum CBP, Pb and Ni by the minimum. Thus, the analyzed samples of leaves and roots had a wide variety of mineral composition. In the future, plants of the genus *Hemerocallis* L. can serve as a natural source of nutritional supplements containing valuable mineral elements in a form accessible to the human body.

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Conflict of Interest

The authors of this work declare that they have no conflicts of interest.

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