The Open Agriculture Journal

Content list available at: https://openagriculturejournal.com

LETTER ARTICLE

Elemental Composition of *Dasiphora fruticosa* (L.) Rybd. Varieties

Olga V. Goryacha[1], Alla M. Kovaleva[1], Ain Raal[2,*], Tetiana V. Ilina[2], Oleh M. Koshovyi[2] and Zoia V. Shovkova[3]

[1]*Department of Pharmacognosy, National University of Pharmacy, 53 Pushkinska Street, Kharkiv, 61002, Ukraine*
[2]*Institute of Pharmacy, Faculty of Medicine, University of Tartu, Nooruse 1, Tartu, 50411, Estonia*
[3]*Department of Drug and Analytical Toxicology, National University of Pharmacy, 53 Pushkinska Street, Kharkiv, 61002, Ukraine*

Abstract:

Aim:

The aim of the study is to study the elemental composition of the leafy shoots, rhizomes, and roots of *D. fruticosa* varieties cultivated in Ukraine.

Background:

Dasiphora fruticosa (L.) Rybd. (*Rosaceae*) is a species native to Middle Asia and the Far East. More than 130 *D. fruticosa* varieties are known; plants have a significant raw material base and are promising objects for phytochemical research. Data only on the elemental composition of the aboveground parts of the wild-grown *D. fruticosa* is present. No information on the elemental composition of the raw materials of cultivated *D. fruticosa* varieties is available.

Objective:

A comprehensive analysis of the elemental composition of *Dasiphora fruticosa* varieties and identification of the features of macro- and microelements translocation.

Methods:

For all *D. fruticosa* varieties, raw materials were taken from two plants with five replicates per plant. The elemental composition was studied by atomic absorption spectroscopy. Using corresponding formulas, translocation factors of elements were determined, and a hygienic full-value of the raw materials was established.

Results:

In the studied raw materials, fourteen elements were identified and quantified. The translocation factors of potentially toxic elements Mo, Cu, Ni, and Sr indicate a capture of these elements in the root system and a presence of the barrier mechanisms preventing their accumulation in *D. fruticosa* varieties shoots.

Conclusion:

The results obtained show the presence of the barrier mechanisms preventing the accumulation of potentially toxic elements in aboveground parts of *D. fruticosa* varieties and justify a need for the study of those mechanisms.

Keywords: *Dasiphora fruticosa* (L.) Rybd., Atomic absorption spectroscopy, Macroelements, Microelements, Elemental composition, Rhizomes.

Article History	Received: July 22, 2021	Revised: November 30, 2021	Accepted: December 29, 2021

1. INTRODUCTION

Dasiphora Rafin. is a small genus of the subfamily *Rosoideae* of the family *Rosaceae*; as follows from different scientific sources, this genus comprises 5 or 6 species. *Dasiphora* plants are erect, less commonly prostrate shrubs growing mainly on rocks, rocky slopes, and along the banks of rivers. *Dasiphora* species are typical representatives of the flora of the Northern Hemisphere and the largest areas are characteristic of Siberia and Central Asia [1, 2].

Taxonomic independence of *Dasiphora* Rafin. genus species, as well as a generic name, are disputable. *Dasiphora* spp. are classified to *Potentilla* L. genus as shrubby cinquefoils [3]; S. K. Cherepanov classifies these plants to *Pentaphylloides* Hill genus [4]; some researchers support *Dasiphora* Rafin. genus as a separate taxonomic unit [5, 6]. By The Plant List, the name

* Address correspondence to this author at the Institute of Pharmacy, Faculty of Medicine, University of Tartu, Nooruse 1, Tartu, 50411, Estonia;
Tel: +372 5027574; E-mail: ain.raal@ut.ee

Dasiphora Rafin. is an accepted name, but *Dasiphora fruticosa* (L.) Rybd. is disputable, which is a synonym of *Potentilla fruticosa* L. [7].

Dasiphora fruticosa (L.) Rybd. (*Potentilla fruticosa* L., *Pentaphylloides fruticosa* (L.) O. Schwarz) is an erect, less commonly prostrate branchy silky-pubescent ornamental shrub of 20-150 cm height. Branches covered with brown or gray bark; leaves more or less large, pinnate, 5 less frequently 7 leaflets each, leaflets oblong in shape, entire with pointed ends. Flowers yellow, up to 3 cm in diameter, solitary or in small apical inflorescence. The plant grows along the banks of rivers, in bushes, floodplains, on the rocky slopes, and outcrops. The species is common to Central and Atlantic Europe, Scandinavia, the Caucasus, Siberia, Central Asia, and the Far East [1]. In Tibetan medicine, *D. fruticosa* is used in the treatment of gastrointestinal tract diseases, pulmonary tuberculosis, and lobar pneumonia; the species is the nectariferous plant and is used as a tea substitute [8]. *D. fruticosa* is a valuable shrub with more than 130 varieties distinguished by flowers colour and size [9].

The whole plants of *D. fruticosa* have several pharmacological activities, such as antimicrobial and anti-viral activities. They contain immune-boosting properties as well as the ability to lower cholesterol and blood sugar levels. Due the high amounts of hyperoside, ellagic acid, and (+)-catechin, the leaf extract from *D. fruticosa* may display significant antioxidant activity *in vitro* and protective effects on *Escherichia coli* under peroxide stress [10].

Due to the undemanding cultivation requirements, resistance against environmental factors and a significant raw material base, we consider *D. fruticosa* as a promising object for phytochemical research.

A number of articles have shown the elemental composition of the aboveground parts of the wild-grown *D. fruticosa* [11, 12] and a generalized model of the distribution of some elements in the taxon has been proposed [13]. However, in the available scientific primary sources, there are no data on the elemental composition of the aboveground parts of *D. fruticosa* varieties, as well as underground organs of both wild-grown plants and cultivated varieties.

We believe that the analysis of plant elemental composition should be comprehensive and include the study of the elemental composition of both aboveground parts and underground organs since such information helps understand the features of macro- and microelements translocation, and hence, show the presence of the barrier mechanisms preventing the accumulation of certain elements in plant aboveground parts, as well as justify the need for the study of those mechanisms.

The present article aims to study the elemental composition of shoots and rhizomes and roots of *Dasiphora fruticosa* (L.) Rybd. varieties cultivated in Ukraine, and identify the features of the translocation of macro- and microelements. It was also reasonable to determine the total ash of the raw materials.

2. MATERIALS AND METHODS

2.1. Plant Samples

The objects of the study were the raw materials (RMs), namely leafy shoots, rhizomes, and roots of three *D. fruticosa* varieties, namely 'Primrose Beauty', the compact shrub, crown diameter up to 1.2 m; flowers light yellow, small, numerous, blooming time: mid-June – mid-September; 'Goldfinger', the shrub 1 – 1.5 m high, up to 1.5 m wide; leaves dark green; flowers numerous, intensely yellow, up to 5 cm in diameter, blooming time: June – October; 'Princess/Pink Queen', the shrub up to 80 cm high; crown pulvinate, up to 1.2 m in diameter; leaves dark green; flowers pink, 3-3.5 cm in diameter; blooming time: May – October.

All *D. fruticosa* varieties were purchased in spring 2019 from plant nurseries at the age of approx. 3 years. Plants were transplanted and grew for approx. 1.5 year before sampling. For each *D. fruticosa* variety, all RMs were taken from two plants with five replicates per plant and mixed to obtain corresponding combined samples.

The leafy shoots (app. 25 g per each plant) were harvested in the flowering and early fruiting phase in August-September 2020 (Kyiv region, Petropavlivska Borshchahivka village, (Table **1**); immediately after harvesting, shoots were rinsed and then dried in an oven at 40-45° C. Rhizomes and roots were harvested in November 2020, and immediately after harvesting, were washed thoroughly with running water and dried in the oven at 45-50° C. The oven-dried RMs were stored in paper bags in a dry place protected from light.

2.2. Determination of Elemental Composition

The elemental composition of RMs was determined using a DFC-8 atomic emission spectrophotometer at the premises of the State Scientific Institution "Institute for Single Crystals" of the NAS of Ukraine. Accurately weighted grounded raw material samples (passed through a 2 mm sieve) were treated with sulfuric acid and carefully ashed in a muffle furnace (temperature was not more than 500 °C) for 1 hour. The samples were evaporated from the craters of graphite electrodes. There were the following conditions of spectra photographing: the amperage of the arc AC – 16 A, the ignition phase – 60°, the frequency of the pulses ignited – 100 discharges per second; the analytical interval – 2 mm; the width of the spectrograph slit – 0.015 mm; exposure – 60 s; as a source of spectra excitation IBC-28 was used. The spectra were recorded on photographic plates using a DFC-8 spectrophotometer with a three-lens system of the slit illumination and diffraction screen of 600 lines/mm. Measurement of the line intensities in the spectra of the samples analyzed was performed using an MF-4 microphotometer at a wavelength from 240 to 347 nm compared to the standard samples of elements – calibration samples [14, 15].

The translocation factor (T_F) was calculated as the ratio of the element's concentration in the shoots to that in the rhizomes and roots (Formula 1) [16, 17]:

$$\mathbf{T_F = C_{Shoots} / C_{Rhizomes\ and\ roots}}\ \textbf{(Formula 1)}$$

Hygienic full-value (H_{FV}) was calculated as the ratio of Ca concentration to Sr concentration in RM (Formula 2) [18]:

$H_{FV} = C_{Ca} / C_{Sr}$ (Formula 2)

The total ash of RMs was determined according to the procedure given in the State Pharmacopoeia of Ukraine [19].

2.3. Statistical Analysis

All measurements were performed five times for each combined sample. The mean and standard deviation (SD) for each combined sample were calculated according to the State Pharmacopoeia of Ukraine [20].

3. RESULTS

3.1. The Elemental Profile of *Dasiphora Fruticosa* Varieties

In the studied RMs of *D. fruticosa* varieties, 19 elements were identified and quantified, namely 9 microelements (Si, Fe, Al, Mn, Mo, Cu, Zn, Sr, Ni) and 5 macroelements (K, Na, Ca, Mg, P); the translocation factors of elements from the root system to the shoots were determined (Table **2**). The elements were ranked in the descending order of their concentration: 'Goldfinger', shoots: K>Ca>Mg>Si=P>Al>Fe>Na>Mn>Zn>Sr>Cu>Mo>Ni; rhizomes and roots: K>Ca>P>Mg>Na>Si=Fe>Mn>Al>Sr>Zn>Cu>Mo>Ni; 'Primrose Beauty', shoots: K>Ca>Mg>Si>P>Al> Na=Fe>Mn>Zn>Sr>Cu>Mo>Ni; rhizomes and roots: Ca>K>Mg>P>Na>Si>Fe=Al>Sr>Mn=Zn>Cu>Mo>Ni; 'Princess/Pink Queen', shoots: K>Ca>Mg>P>Si>Na>Al> Mn>Fe>Zn>Sr>Cu>Mo>Ni; rhizomes and roots: K>Ca>P>Mg>Si>Na>Fe=Mn> Zn>Al>Sr>Cu>Mo>Ni.

The highest content of macroelements was determined in *D. fruticosa* var. 'Princess/Pink Queen' shoots (185.98±5.88 mg/kg). Of all the RMs, the content of microelements was the highest in *D. fruticosa* var. 'Primrose Beauty' shoots (27.27±1.11mg/kg).

In RMs, the composition of the prevailing elements was similar, but their content differed. In *D. fruticosa* var. 'Goldfinger' shoots macroelements K, Ca, and Mg prevailed; K and Ca prevailed in rhizomes and roots. K, Ca, Mg, and Si were the prevailing macroelements in *D. fruticosa* var. 'Primrose Beauty' shoots, in rhizomes and roots Ca, K, and Mg prevailed. The prevailing macroelements of *D. fruticosa* var. 'Princess/Pink Queen' shoots were K, Ca, and Mg, in rhizomes and roots K and Ca prevailed. The obtained profiles of the prevailing macroelements are comparable with the corresponding profiles of the representatives of the family *Rosaceae* Juss. [21 - 23].

Table 1. The studied *Dasiphora fruticosa* (L.) Rybd. varieties.

Dasiphora Fruticosa (L.) Rybd. Variety	Geographical Coordinates
'Goldfinger'	50°26'04.1"N 30°19'23.4"E
'Primrose Beauty'	50°26'04.0"N 30°19'22.3"E
'Princess/Pink Queen'	50°26'05.8"N 30°19'22.7"E

Table 2. The elemental profile of *Dasiphora fruticosa* varieties raw materials and translocation factors of elements.

Element	*D. fruticosa* Variety, Content*, mg/kg, mean ± SD (n=5).								
	'Goldfinger'			'Primrose Beauty'			'Princess/Pink Queen'		
	Shoots	Rhizomes and Roots	T_F	Shoots	Rhizomes and Roots	T_F	Shoots	Rhizomes and Roots	T_F
Macroelements									
K	98.16±2.49	37.54±1.57	2.61	59.06±1.81	26.04±0.83	2.27	125.46±3.38	55.2±2.08	2.27
Na	2.80±0.09	4.05±0.11	0.69	3.36±0.17	4.34±0.17	0.77	2.88±0.11	2.76±0.08	1.04
Ca	28.16±1.40	19.98±0.89	1.41	53.96±1.55	34.72±1.13	1.55	33.46±1.81	15.24±0.83	2.20
Mg	14.26±0.65	8.05±0.40	1.77	22.10±1.07	10.16±0.56	2.18	14.58±0.54	6.56±0.29	2.22
P	9.60±0.47	9.31±0.33	1.03	9.96±0.55	6.41±0.30	1.55	9.60±0.55	7.06±0.37	1.36
Sum of macroelements	152.98±2.29	78.94±2.29	-	148.4±2.59	81.67±0.42	-	185.98±5.88	86.82±2.21	-
Microelements									
Si	9.92±0.33	3.51±0.18	2.83	14.84±0.70	4.24±0.19	3.50	7.54±0.33	3.46±0.13	2.18
Fe	3.56±0.17	3.59±0.13	0.99	3.35±0.18	3.43±0.15	0.98	1.92±0.08	1.38±0.05	1.39
Al	4.18±0.20	0.81±0.03	5.16	5.05±0.20	3.51±0.11	1.44	2.82±0.08	0.92±0.04	3.07
Mn	2.61±0.08	1.36±0.07	1.92	2.39±0.11	0.87±0.03	2.75	2.40±0.09	1.38±0.04	1.74
Mo	<0.03	0.010±0.001		0.0040±0.0001	0.0100±0.0004	0.40	0.0042±0.0001	0.016±0.001	0.26
Cu	0.040±0.002	0.080±0.040	0.50	0.02±0.001	0.030±0.001	0.67	0.024±0.401	0.050±0.002	0.48
Zn	0.87±0.03	0.48±0.02	1.81	1.22±0.04	0.87±0.03	1.40	0.96±0.05	1.15±0.05	0.83
Sr	0.35±0.02	0.67±0.03	0.52	0.39±0.02	1.11±0.05	0.35	0.340±0.011	0.31±0.01	1.10
Ni	<0.03	<0.03	-	<0.03	0.0033±0.0001		<0.03	<0.03	

(Table 2) contd.....

Element	*D. fruticosa* Variety, Content*, mg/kg, mean ± SD (n=5).								
	'Goldfinger'			'Primrose Beauty'			'Princess/Pink Queen'		
	Shoots	Rhizomes and Roots	T_F	Shoots	Rhizomes and Roots	T_F	Shoots	Rhizomes and Roots	T_F
Sum of microelements	21.53±0.49	10.5±0.23		27.27±1.11	14.07±0.30		15.69±0.43	8.66±0.17	
Total	**174.51±2.38**	**89.43±2.23**		**175.71±3.05**	**95.74±0.71**		**201.68±4.94**	**95.48±2.29**	

Note: Pb<0.003; Co<0.003; Cd<0.001; As<0.001; Hg<0.001; T_F – translocation factor;
«-» – the value was not determined; * – mg/kg in the oven-dried RMs

Table 3. The hygienic full-value of *Dasiphora fruticosa* varieties.

D. fruticosa Variety	[Ca], mg/kg	[Sr], mg/kg	[Ca]/[Sr] Ratio
Shoots			
'Goldfinger'	28.16±1.40	0.35±0.02	80.45
'Primrose Beauty'	53.96±1.55	0.39±0.02	137.66
'Princess/Pink Queen'	33.46±1.81	0.340±0.011	98.42
Rhizomes and Roots			
'Goldfinger'	19.98±0.89	0.67±0.03	29.82
'Primrose Beauty'	34.72±1.13	1.11±0.05	31.28
'Princess/Pink Queen'	15.24±0.83	0.31±0.01	49.16

Table 4. The total ash of raw material of the *Dasiphora fruticosa* varieties.

D. fruticosa Variety	Total Ash, %, Mean ± SD (n=5)
Shoots	
'Goldfinger'	3.52 ± 0.14
'Primrose Beauty'	4.83 ± 0.24
'Princess/Pink Queen'	4.75 ± 0.22
Rhizomes and Roots	
'Goldfinger'	2.66 ± 0.14
'Primrose Beauty'	2.89 ± 0.12
'Princess/Pink Queen'	2.09 ± 0.10

Since an excessive accumulation of Sr in bone tissue occurs only with a lack of body Ca, we believe it is important to use in pharmaceutical production only herbal medicinal materials meeting requirements to the ratio between the concentrations of Ca and Sr (hygienic full-value requirement). Considering relatively high concentrations of Sr in the *D. fruticosa* RMs, we studied the conformity of all RMs with hygienic full-value requirements and established that shoots of the studied *D. fruticosa* varieties conform with those requirements (Table **3**).

The highest content of total ash was in *D. fruticosa* var. 'Primrose Beauty' shoots (4.83 ± 0.24%); the lowest – in *D. fruticosa* var. 'Princess /Pink Queen' rhizomes and roots (2.09 ± 0.10%), (Table **4**).

4. DISCUSSION

The results obtained (Table **2**) are generally consistent with the data on the composition and content of macro- and microelements in *D. fruticosa* from natural areas. E. V. Andysheva *et al*. [11] and E.P. Khramova *et al*. [12] studied the elemental composition of leaves and shoots of wild-growing *D. fruticosa* by the method of X-ray fluorescence analysis using synchrotron radiation. According to their findings, only K and Ca represented macroelements. However, in our study, Na, Mg and P were additionally identified and quantified in leafy shoots, giving a more detailed macroelement pattern of *D. fruticosa* aboveground organs. We also first characterized the composition of macroelements in *D. fruticosa* roots and rhizomes. The content of K in aboveground organs of wild-grown *D. fruticosa* and cultivated varieties was comparable, but Ca concentration was 2-fold higher in RMs of wild-grown *D. fruticosa*.

As relating to microelements, previous studies [11, 12] revealed the presence of 19 microelements in leaves and shoots of wild-growing *D. fruticosa*. Here we report only 9 microelements in leafy shoots of *D. fruticosa* varieties. Both in the above ground organs of wild-grown and cultivated *D. fruticosa* plants, the following microelements were identified and quantified: Fe, Mn, Mo, Cu, Ni, Sr, and Zn.

Concentrations of Ni, Cu, Zn, Sr, and Mo in all the studied RM samples were less than 0.01%. However, the content of Fe in leafy shoots of cultivated varieties exceeded that in leaves and shoots of wild-growing *D. fruticosa* by 2.2-2.7 times; as well as Mn concentration was 2-fold higher in leafy shoots of

cultivated varieties.

The following heavy metals were absent in the studied RMs or were beyond the device's determination capabilities: Pb (<0.003), Co (<0.003), Cd (<0.001), As (<0.001), and Hg (<0.001). Previously we studied the content of toxic elements in the branches of *Salix* spp. and found that fortunately, Cd and Pb (both <0.003 mg/kg), Cd, As, and Hg (all <0.001 mg/kg) were absent or not within the range of determination by the method of emission spectrometry. According to The Commission of the European Communities (2006), the maximum allowed concentrations for Cd and Pb are 0.05 and 0.2 mg/kg/bw for vegetables, berries, and fruits, which are much more than detected in *Salix* species and *D. fruticosa* varieties by us [15].

In *D. fruticosa* aboveground organs, we first reported Si and Al, the presence of which may result from environmental and cultivation conditions.

Microelements in *D. fruticosa* roots and rhizomes were first studied.

The translocation factors of potentially toxic elements Mo, Cu, Ni, and Sr (Table **2**) indicate a capture of these elements in the root system (T_F<1), as well as the presence of the barrier mechanisms that prevent the accumulation of these elements in shoots of the studied *D. fruticosa* varieties [24, 25]. All the studied varieties were capable of capturing Mo and Cu; roots and rhizomes of *D. fruticosa* var. 'Goldfinger' and *D. fruticosa* var. 'Primrose Beauty' captured Sr; only *D. fruticosa* var. 'Primrose Beauty' roots and rhizomes were capable of capturing Ni.

Whereas Al, Si, and K were actively transported to the shoots. The maximum T_F values of Al were established for *D. fruticosa* var. 'Goldfinger' and *D. fruticosa* var. 'Princess/Pink Queen' (5.16 and 3.07, respectively); *D. fruticosa* var. 'Primrose Beauty' is characterized by the highest T_F of Si (3.49) and Mn (2.76).

Potentially toxic elements Fe, Al, Mn, Mo, Cu, Sr, Ni, and Zn were present in the RMs of the studied *D. fruticosa* varieties. Only in *D. fruticosa* var. 'Goldfinger' rhizomes and roots Cu content slightly exceeded the MPC (1.62 MPC); however, in all RMs, Zn content significantly exceeded the MPC [26]. For instance, in the shoots of three varieties, Zn content was 8.6-12.2-folds higher than the MPC; in rhizomes and roots, the MPC for Zn was exceeded by 4.8-11.5 times.

Due to the absence of the regulatory requirements for the content of Sr in RM, we considered it would be reasonable to determine the hygienic full-value of the studied plant objects (Table **3**). Hygienic full-value is the ratio between the concentrations of Ca and Sr; the minimum permissible value is "80" [18]. Hygienic full-value is an important parameter of feed and food crop quality, but we considered it would be reasonable to determine this parameter for studied RMs. We found that only shoots of the studied *D. fruticosa* varieties meet the requirements for hygienic full-value ([Ca]/[Sr]>80).

Considering the absence of the relevant information on the permissible levels of Fe, Al, Ni, Mn, and Mo in plants and substances of herbal origin, as well as taking into account the significant excess of Zn MPC in RMs, in the future, we propose to control the safety of the developed herbal drug preparations taking into account the maximum permissible daily doses of microelements [27, 28], as well as to determine the compliance of the herbal drug preparations with the requirements of ICH Q3D (R1) [29] and to monitor their hygienic full-value.

D. fruticosa varieties are not pretentious to cultivation conditions, are resistant against environmental factors, and potentially have barrier mechanisms preventing translocation of potentially toxic elements to aboveground parts of *D. fruticosa* varieties. The results obtained emphasize the need for the increase in the number of the subject *D. fruticosa* varieties, as well as the need for the comprehensive study of the features of macro- and microelements accumulation in order to justify the prospects for the use of *D. fruticosa* varieties as phytoremediants [30 - 33].

CONCLUSION

The elemental composition of the shoots and rhizomes and roots of *Dasiphora fruticosa* (L.) Rybd. varieties cultivated in Ukraine, namely 'Goldfinger', 'Primrose Beauty' and 'Princess/Pink Queen' was first studied. For three *D. fruticosa* varieties, translocation factors of macro- and microelements were calculated. The barrier functions of the root system of *D. fruticosa* varieties in relation to potentially toxic elements Mo and Cu (all varieties), Ni (*D. fruticosa* var. 'Goldfinger' and *D. fruticosa* var. 'Primrose Beauty') and Sr (*D. fruticosa* var. 'Primrose Beauty') were shown, justifying a need for the study of possible barrier mechanisms. The obtained data on the elemental composition and hygienic full-value of raw materials will be used in the development, as well as during the control of the safety of medicinal products from the studied raw materials.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this study are available within the article.

FUNDING

The research was funded by the Ministry of Health Care of Ukraine at the expense of the State Budget in the framework # 2301020 "Scientific and scientific-technical activity in the field of health protection" on the topic "Modern approaches to the creation of new medicines for a correction of metabolic syndrome".

CONFLICT OF INTEREST

Dr. Ain Raal is the Editorial Board Member of The Open Agriculture Journal..

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] Yuzepchuk SV, Ed. Flora of the USSR. Moscow, Leningrad: Publishing house of academy of sciences of the USSR 1941; 10.

[2] Baikov KS, Ed. Check-list of flora of Asian Russia: Vascular plants. Novosibirsk: Publishing House of SO RAN 2012. [in Russian]

[3] Flora of China. Available from: efloras.org/florataxon.aspx?flora_id=2&taxon_id=304106 [Accessed April 05, 2021].

[4] Vascular plants of Russia and the adjacent states (within the former USSR). Cherepanov SK, Mir i Sem'ya , Eds. Saint-Peterburg 1995. [in Russian]

[5] Chen X, Li J, Cheng T, *et al.* Molecular systematics of *Rosoideae* (Rosaceae). Plant Syst Evol 2020; 306(9): 9. [http://dx.doi.org/10.1007/s00606-020-01629-z]

[6] Eriksson T, Hibbs MS, Yoder AD, Delwiche CF, Donoghue MJ. The phylogeny of *Rosoideae* (Rosaceae) based on sequences of the internal transcribed spacers (ITS) of nuclear ribosomal DNA and the Trnl/F region of chloroplast DNA. Int J Plant Sci 2003; 164(2): 197-211. [http://dx.doi.org/10.1086/346163]

[7] The Plant List. A working list of all plant species. Available from: theplantlist.org/tpl1.1/record/rjp-8070 [Accessed June 06, 2021].

[8] Sokolov PD, Ed. The plant resources of the USSR: Flowering plants, their chemical composition, use; Hydrangeaceae-Haloragaceae families 1987.

[9] Miller DM. RHS pant trials and awards: Shrubby Potentilla. Available from: rhs.org.uk/plants/pdfs/plant-trials-and-awards/plant-bulletins /potentilla.pdf [Accessed April 09, 2021].

[10] Zeng Y, Sun Y-X, Meng X-H, Yu T, Zhu H-T, Zhang Y-J. A new methylene bisflavan-3-ol from the branches and leaves of *Potentilla fruticosa*. Nat Prod Res 2020; 34(9): 1238-45. [http://dx.doi.org/10.1080/14786419.2018.1557169] [PMID: 30663382]

[11] Andysheva EV, Chankina OV, Khramova EP, Krestov PV, Rakshun YaV, Sorokoletov DS. Comparative study of element composition of species of the genus *Dasiphora* (Rosaceae) in the Primorsky region and Republic of Buryatia. Siberian J Physics 2019; 14(4): 105-17. [http://dx.doi.org/10.25205/2541-9447-2019-14-4-103-117]

[12] Khramova EP, Chankina OV, Syeva SYa, Kostikova VA. Features of the accumulation of mineral elements of the mountain Altai shrubs. Plant Life of Asian Russia 2019; 3(35): 62-9. [http://dx.doi.org/10.21782/RMAR1995-2449-2019-3(62-69)]

[13] Pavlov VE, Khramova EP, Khvostov IV, *et al.* A generalized model of the distribution of some elements in *Pentaphylloides fruticosa*. Chem Plant Raw Mat 2008; 3: 163-8.

[14] Osmachko AP, Kovaleva AM, Ili'ina TV, Koshovyi ON, Komisarenko AM, Akhmedov EYu. Study of macro- and microelements composition of *Veronica longifolia* L. herb and *Veronica teucrium* L. herb and rhizomes, and extracts obtained from these species. AZƏRBAYCAN ƏCZAÇILIQ və FARMAKOTERAPİYA JURNALI 2017; 1: 24-8.

[15] Borodina N, Ain R, Kovalyov V, Koshovyi O, Ilina T. Macro- and microelements in the branches of some *Salix genus* species in the flora of Ukraine. Int J Med Res Prof 2020; 9(3): 71-80.

[16] Nworie OE, Qin J, Lin C. Trace element uptake by *Herbaceous* plants from the soils at a multiple trace element-contaminated site. Toxics 2019; 7(1): 3. [http://dx.doi.org/10.3390/toxics7010003] [PMID: 30658443]

[17] Galal TM, Shehata HS. Bioaccumulation and translocation of heavy metals by *Plantago major* L. grown in contaminated soils under the effect of traffic pollution. Ecol Indic 2015; 48: 244-51. [http://dx.doi.org/10.1016/j.ecolind.2014.08.013]

[18] Lavrishchev AV. *Studying the behaviour of stable strontium in agroecosystems of the north-west of Russia*. Doctoral Thesis. St. Petersburg: St. Petersburg State Agrarian University 2016.

[19] State Pharmacopoeia of Ukraine; RIREG. Kharkiv 2001.

[20] State Pharmacopoeia of Ukraine. 2nd. 2 supp.Kharkiv: Ukrainian scientific pharmacopoeial center for quality of medicines 2018.

[21] Imbrea I, Radulov I, Nicolin A, Imbrea F. Analysis of macroelements content of some medicinal and aromatic plants using flame atomic absorption spectrometry (FAAS). Rom Biotechnol Lett 2016; 21(4): 11642-51.

[22] Shohayeb M, Arida H, Abdel-Hameed E-SS, Bazaid S. Abdel-Hameed, El-S. S., Bazaid, S. Effects of macro- and microelements in soil of rose farms in taif on essential oil production by *Rosa damascena* Mill. J Chem 2015; 2015: 1-7. [http://dx.doi.org/10.1155/2015/935235]

[23] Van der Ent A, Mulligan DR, Repin R, Erskine PD. Foliar elemental profiles in the ultramafic flora of Kinabalu Park (Sabah, Malaysia). Ecol Res 2018; 33(3): 659-74. [http://dx.doi.org/10.1007/s11284-018-1563-7]

[24] Yan A, Wang Y, Tan SN, Mohd Yusof ML, Ghosh S, Chen Z. Phytoremediation: A promising approach for revegetation of heavy metal-polluted land. Front Plant Sci 2020; 11: 359. [http://dx.doi.org/10.3389/fpls.2020.00359] [PMID: 32425957]

[25] De-Jesús-García R, Rosas U, Dubrovsky JG. The barrier function of plant roots: Biological bases for selective uptake and avoidance of soil compounds. Funct Plant Biol 2020; 47(5): 383-97. [http://dx.doi.org/10.1071/FP19144] [PMID: 32213271]

[26] Kukhniuk OV. Research of heavy metal accumulation by agricultural products of Cherkasy region. Available from: tnv-agro.ksauniv.ks.ua/archives/115_2020/15.pdf (Accessed April 20, 2021) [in Ukrainian]

[27] Institute of Medicine. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.Washington, DC: The National Academies Press 2001. [http://dx.doi.org/10.17226/10026]

[28] Joint FAO/WHO expert committee on food additives. Available from: fao.org/3/ca5270en/ca5270en.pdf (Accessed April 20, 2021).

[29] International Council for Harmonization of Technical Requirements for Pharmaceuticals for Human Use. Guideline for Elemental Impurities Q3D(R1) Available from: ema.europa.eu/en/documents/scientific-guideline/international-conference-harmonisation-technical-requirements-registration-pharmaceuticals-human-use_en-21.pdf (Accessed April 20, 2021)

[30] Asgari Lajayer B, Khadem Moghadam N, Maghsoodi MR, Ghorbanpour M, Kariman K. Phytoextraction of heavy metals from contaminated soil, water and atmosphere using ornamental plants: Mechanisms and efficiency improvement strategies. Environ Sci Pollut Res Int 2019; 26(9): 8468-84. [http://dx.doi.org/10.1007/s11356-019-04241-y] [PMID: 30712209]

[31] Gajić G, Djurdjević L, Kostić O, Jarić S, Mitrović M, Pavlović P. Ecological potential of plants for phytoremediation and ecorestoration of fly ash deposits and mine wastes. Front Environ Sci 2018; 6: 124. [http://dx.doi.org/10.3389/fenvs.2018.00124]

[32] Wu B, Peng H, Sheng M, *et al.* Evaluation of phytoremediation potential of native dominant plants and spatial distribution of heavy metals in abandoned mining area in Southwest China. Ecotoxicol Environ Saf 2021; 220112368 [http://dx.doi.org/10.1016/j.ecoenv.2021.112368] [PMID: 34082243]

[33] Pasricha S, Mathur V, Garg A, Lenka S, Verma K, Agarwal S. Molecular mechanisms underlying heavy metal uptake, translocation and tolerance in hyperaccumulators-an analysis: Heavy metal tolerance in hyperaccumulators. Environment Challeng 2021; 4100197 [http://dx.doi.org/10.1016/j.envc.2021.100197]