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Conditionally Essential Microelements in the Medicinal Herbs of Transbaikalia

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Abstract

Content of conventionally essential microelements (Li, B, Si, Ti, V, Ni) was studied in 21 species of medicinal herbs growing on different kinds of soil in Western Transbaikalia under the ecological phytocoenotic conditions of arid steppe, meadow with insufficient and normal wetting, and meadow bog. The species and ecological specificity of microelement accumulation in plants was determined. Different levels of microelement content in medicinal herbs and the concentrating plant species for Li, B, Si, Ti, V, Ni were established. According to the results of investigation, boron is attributed to the elements with intense absorption from soil, lithium to medium, nickel to weak, vanadium and titanium to the elements of very weak absorption.

Key words: lithium, boron, titanium, vanadium, nickel, medicinal herbs, phytocoenoses

INTRODUCTION

Microelements are essential components of the mineral nutrition of plants, animals and humans. Modern classification of microelements according to their importance in living organisms forms the following sequence: 1) vitally essential – Fe, Mn, I, Cu, Zn, Co, Cr, Mo, Se; 2) conditionally essential – Li, B, Ni, V, Si, F, Br, Ti; 3) toxic – Cd, Pb, Hg, Be, Tl, Bi *etc*. [1, 2]. However, incomplete knowledge of biochemical and physiological functions of the second group and especially the third group at this stage of science development does not mean the absence of these functions. Academician V. I. Vernadsky, the founder of biogeochemistry as science and the studies of microelements, wrote that "...the living matter embraces and controls all or almost all the chemical elements in the biosphere. All of them are necessary for life and get included into an organism not by chance. There are no special elements peculiar to life. There are predominant ones..." [3]. The optimal content of vitally and conventionally essential microelements and the minimal content of toxic ones bringing no danger to the adaptation mechanisms form one of the most important components of the normal functioning of an organism. Conventionally essential elements include those for which the vital importance for the vital activity of organisms has not been established yet in a reliable way but at the same time they have substantial effect on various processes involved in metabolism. Medicinal plants serve as one of the sources of microelements for humans and can provide correction of various kinds of microelementosis.

Under the conditions of Transbaikalia, no studies into the microelemental composition of medicinal plants have been carried out before our works. Meanwhile, this region is a territory of polyelemental endemias provided by the disturbance of natural biogeochemical cycles of a number of important microelements (deficit, excess or misbalance), which has a negative effect on the stability of functioning and on the productivity of ecosystems, as well as on human health. Previously [4] we reported the data on the concentrations of essential microelements in medicinal plants. In the present work we describe the data on the concentrations and specific features of the accumulation of conditionally essential microelements (Li, B, Si, Ti, V, Ni) in the top mass of some medicinal plants growing under different ecological and phytocoenotic conditions of Western Transbaikalia.

EXPERIMENTAL

Investigations were carried out in 12 most populated central and southern regions of Buryatia (Western Transbaikalia) under different ecological and phytocoenotic conditions. The objects of investigation were medicinal plants of 21 species growing in steppe, meadow and bog phytocoenoses on chestnut, alluvial sod, alluvial meadow and alluvial bog soil. The Latin names of plants are given according to Cherepanov [5], soil types are named according to [6] (Table 1). In order to study the microelement composition, the samples of the top parts of plants were taken in triple replication during the period of the highest productivity (flowering stage, because it is this stage that is connected with the maximal productivity and accumulation of biologically active compounds) at the sample areas (SA) 100×100 m in size according to the recommendations described in [7]. Ashing of crushed plant samples was performed in a muffle furnace at a temperature of 480 °C. The concentrations of Li, V, Ni were determined using atomic absorption, with a PerkinElmer spectrophotometer with atomization in the acetylene–air flame, the concentrations of Ti, Si were measured by means of atomic emission, B content was determined by means of colourimetry in the alcohol–acetic mixture of the plant ash residue with quinalizarin. Simultaneously with plant sampling, soil samples were collected at the same SA [8, 9]. The coefficient of biological accumulation (CBA) of microelements by plants from soil was calculated as a ratio of the content of an element in the ash of plants to its total concentration in soil. Mathematical processing of the results was carried out according to a standard procedure described in [10].

RESULTS AND DISCUSSION

Lithium (^{3}Li)

Lithium deficiency in human organism promotes bipolar disorder, schizophrenia and other mental diseases. Lithium possesses a clearly pronounced therapeutic effect. Medicinal herbs that concentrate lithium have been determined; they find application in psychiatry and neurology [11]. It was established in experiments with the introduction of optimal lithium salt doses into soil with different plants growing on it that the maximal positive effect of lithium was manifested for the plants of Solanum family – potato, tomato, pepper, aubergine [12].

Lithium content of the studied medicinal plants varied within the range 1.3–22.2 mg/kg of dry matter (see Table 1). The difference between the maximal and minimal content was 17.1 times. These results correspond to the published data on lithium content (0.16–24.8 mg/kg) in 15 species of medicinal plants growing at the territory of the European part of Russia [11]. The minimal lithium content was revealed in daylily (*Hemerocallis minor* Miller.) in the meadow phytocoenoses with normal wetting and in wormwood sage in the steppe arid phytocoenoses, while the maximal content was detected in the medicinal plants of different phytocoenoses in the Gusinoozerskaya depression: in common yarrow (*Achillea millefoluim* L.) (22.2 mg/kg), Daurian thyme (*Thymus dahuricus* Serg.) (14.7 mg/kg), common plantain (13.3 mg/kg), *Panzerina lanata* (7.3 mg/kg), as well as in fleawort growing in the meadow phytocoenoses with insufficient wetting in the Mukhorshibir and Bichur districts (15.0 and 13.6 mg/kg, respectively). These plant species can be regarded as intense concentrators of lithium. In the opinion of the authors of [11], lithium concentrators are plants accumulating it in the amount of 1.5–2.4 mg/kg. Increased accumulation of lithium in the plants of the Gusinoozerskaya depression of Selenginsk district is likely to be due to higher biological availability of the element in soil because its overall content (27–33 mg/kg) only insignificantly differed from its content in soil in other districts (18–27 mg/kg in steppe phytocenoses, 20–33 mg/kg in meadow phytocoenoses).

TABLE 1

Concentrations of conventionally essential microelements in medicinal plants in Transbaikalia, mg/kg of dry matter

Plants	Sampling site (village)	Li	B	Si	Ti	V	Ni	Ash, %
	Steppe arid phytocoenoses							
Thoroughwax	Belozersk	–	6.9	1380	23	0.46	0.14	4.9
(*Bupleurum*	Petropavlovka	–	5.8	1160	25	0.59	0.19	5.8
scorzonerifolium Willd.)	Unegetey	–	2.3	1140	9	0.57	0.17	5.7
Panzerina lanata (L.) Sojak	Yagondoe	7.30	3.7	7300	73	7.28	2.19	7.3
Wormwood sage	Belozersk	–	7.7	2040	31	0.51	0.26	5.1
(*Artemisia frigida* Willd.)	Petropavlovka	1.68	11.2	2240	45	1.12	0.45	4.8
	Ust'-Kyakhta	–	–	6480	23	3.80	1.62	7.7
	Udinsk	–	5.2	3900	65	1.30	0.24	6.5
Daurian thyme (*Thymus dahuricus* Serg.)	Yagodnoe	14.7	9.8	9800	10	2.94	1.96	9.8
	Meadow phytocoenoses with insufficient wetting (alluvial sod soil)							
Heterochromous dianthus (*Dianthus versicolor* Fisch.)	Ust'-Kyakhta	–	–	1830	49	0.61	3.66	6.1
Barbate gentian (*Gentiana barbata* Froel.)	Kizhinga	–	5.2	1560	16	0.78	0.26	5.2
Greater burnet	V. Taltsy	–	12.0	6000	18	1.20	0.30	8.1
(*Sanguisyrba officinālis* L.)	Kizhinga	–	6.5	5200	20	1.30	0.33	6.4
	Petropavlovsk	1.95	9.8	3250	13	0.65	0.20	6.5
	Tugnuy	–	–	7200	22	0.72	7.20	7.2
	Ust'-Kyakhta	1.77	–	4720	12	0.63	8.85	5.9
Fleawort	M. Kunaley	13.6	–	6800	14	0.70	1.36	6.8
(*Galium verum* L.)	Sharalday	15.0	–	7500	22	0.75	6.00	7.5
	Tugnuy	2.30	–	6080	23	1.52	3.80	7.6
	Nadeeno	2.68	–	6700	33	0.67	1.18	6.7
	Ust'-Kyakhta	1.72	–	6440	56	1.70	4.50	5.6
Tarragon	Il'inka	2.43	24	1620	65	2.43	2.40	8.1
(*Artemisia dracunculus* L.)	Talovka	2.01	67	2100	34	3.35	2.01	6.7
Caraway (*Carum carvi* L.)	Nadeeno	–	–	1380	27	0.70	0.34	6.9
Pyramidal sorrel (*Rumex thyrsiflorus* Fingerh.)	Nadeeno	2.00	–	1340	26	1.34	4.00	6.7
	Meadow phytocoenoses with normal wetting (alluvial meadow soil)							
British inula (*Inula Britannica* L.)	Kizhinga	–	5.7	3420	14	1.14	0.34	11.4
Aromatic melilot	M. Kunaley	–	–	1520	23	0.76	1.14	6.7
(*Melilotus suaveolens* Led.)	V. Taltsy	2.10	5.6	1050	11	0.70	0.21	7.0
	Unegetey	–	3.7	1860	19	0.62	0.25	6.2
Meadow clover	Nadeeno	–	–	1280	19	0.64	3.20	6.4
(*Trifolium pretense* L.)	Tugnuy	3.20	–	2140	64	1.10	5.10	7.7
Small daylily (*Hemerocallis minor* Miller.)	Tarbagatay	1.30	2.2	880	9	0.42	0.44	4.4
Silverweed (*Potentilla anserine* L.)	Unegetey	–	5.3	–	44	0.89	0.27	8.9
Common plantain	Yagodnoye	13.3	13.6	13300	40	3.98	3.95	13.3
(*Plantago major* L.)	Tugnuy	–	–	–	–	–	–	8.9
Common yarrow (*Achillea millefolium* L.)	Yagodnoye	22.2	7.4	7400	22	2.20	0.74	6.6
Horsetail	Il'iinka	2.07	20.7	7590	21	3.45	0.69	6.9
(*Equisetum arvense L.*)	M. Kunaley	–	–	8700	26	0.90	0.43	8.7
	Tarbagatay	–	–	10 800	21	1.10	1.08	10.8
	Meadow-bog phytocoenoses (alluvial bog soil)							
Bean trefoil (*Menyanthes trifoliate* L.)	Posolsk	–	28.4	1500	22	1.42	0.73	12.1
Cowberry Posolsk (*Comarum palustre* L.)	Posolsk	–	70.0	700	28	1.40	0.70	7.8

Note. Dash means that the concentration was not determined.

The analysis of the data presented in Table 1 showed that 30 % of determinations of the studied medicinal plants in Transbaikalia revealed lithium concentrations 4.9–14.8 times higher than the average (clarke) value in plants which is equal to 1.5 mg/kg [13]. In other 70 % of cases lithium content in plants corresponded to the clarke or exceeded it only slightly accounting for 1.3–2.5 mg/kg (average value 2.0 mg/kg).

One and the same plant species growing in different places accumulated lithium in essentially different amounts. This difference is especially significant for fleawort in meadow phytocoenoses with insufficient wetting: 15.0 mg/kg (Sharalday village), 13.6 mg/kg (Maly Kunaley village), 1.7 mg/kg (Ust'-Kyakhta village). So, the difference between the maximal and minimal content was 8.8 times. The ecological features of the accumulation of one or another element in the same species growing in different biotopes can be due to the differences in biological availability of elements, which is determined by soil geochemical factors.

The intensity of lithium accumulation by meadow plants estimated on the basis of CBA is higher than 1.0 (Table 2) and varies within the range 1.1–2.3. As far as the dependence between lithium content in plants and its overall content in soil, a medium positive correlation was established for meadow phytocenoses in the system plant–soil ($r = 0.55$ for $t_{fact} = 1.3$, $t_{theor} = 2.8$).

Boron (^{5}B)

Boron relates to conventionally essential microelements for human and animal organisms, while it is essential for plants. It participates in the mineral exchange of bone tissue and in carbohy-

TABLE 2

Averaged variation-statistical parameters of microelement content and the intensity of their absorption by medicinal plants in different phytocoenoses of Transbaikalia

Parameters	Li	B	Si	Ti	V	Ni
		Steppe arid phytocoenoses (n = 9)				
Range, mg/kg	1.68–14.7	2.3–11.2	1140–9800	9–73	0.46–7.28	0.14–2.19
$M \pm m$, mg/kg	7.89±3.77	6.6±1.1	3938±1058	34±8	2.06±0.76	0.80±0.29
V, %	83	45	81	67	111	107
r	–	0.67	–	0.82	–0.04	0.76
CBA	–	7.5±0.7	–	0.09±0.01	0.16±0.027	0.20±0.028
		Meadow phytocoenoses with insufficient wetting (n = 16)				
Range, mg/kg	1.72–15.0	5.2–67.0	1340–7500	12–65	0.61–3.35	0.26–8.85
$M \pm m$, mg/kg	4.31±1.50	18.1±8.6	4358±600	28±4	1.23±0.18	2.80±0.64
V, %	115	125	55	54	62	94
r	0.55	0.58	–	–0.29	–0.23	–0.08
CBA	1.32±0.24	6.0±0.6	–	0.09±0.02	0.18±0.028	0.31±0.068
		Meadow phytocenoses with normal wetting (n = 14)				
Range, mg/kg	1.30–22.2	2.2–20.7	880–13300	9–44	0.42–3.98	0.21–5.10
$M \pm m$, mg/kg	7.36±3.49	8.0±2.2	4995±1254	26±4	1.38±0.31	1.37±0.45
V, %	116	76	87	60	82	118
r	0.38	–0.04	–	–0.42	0.11	0.17
CBA	1.97±0.68	3.0±0.4	–	0.09±0.03	0.16±0.03	0.47±0.10
		Meadow-bog phytocoenoses (n = 2)				
Range, mg/kg	–	28.4–70.0	700–1500	21–28	1.40–1.42	0.70–0.73
$M \pm m$, mg/kg	–	49.2±20.8	1100±400	24.5±3.5	1.41±0.01	0.72±0.02
V, %	–	60	51	20	1	3
CBA	–	–	–	0.73±0.10	1.10±0.05	2.20±0.2

Notes. 1. Parameters: limits of variation, $M \pm m$, variation coefficient (V) are given as calculated for the dry matter; correlation coefficient (r) in the system plant (for ash)–soil; CBA is the coefficient of biological accumulation. 2. Dash means that the content was not determined.

drate exchange interacting with enzymes, vitamins, hormones, catecholamines, and also in membrane transport and energy exchange, affects metabolism of calcium, phosphorus and magnesium [1].

Boron content of medicinal plants in different phytocoenoses of Transbaikalia varies from 2.1 to 70.0 mg/kg. These data correspond to boron content in 52 species of medicinal plants in the European part of Russia, which is 0.8–97.0 mg/kg [14]. Boron content in plants from different phytocoenoses varied within the limits, mg/kg: steppe phytocoenoses – 2.3–11.2, meadow insufficiently wetted ones – 2.1–67.0, meadow normally wetted ones – 2.2–20.7, meadow-bog – 28.4–70.0. The minimal boron content was detected in caraway and in small daylily in meadow phytocoenoses (2.1–2.2 mg/kg), while the maximal content was observed in cowberry, bean trefoil from meadow-bog phytocoenoses (28.4 –70.0 mg/kg), tarragon from meadow phytocoenoses with insufficient wetting (24.0–67.0 mg/kg), horsetail from meadow phytocoenoses with normal wetting (20.7 mg/kg). It should be noted that in the European part the boron content in the top parts of cowberry and horsetail (5.6 and 2.0 mg/kg, respectively) [14] turned out to be substantially lower than the values for the conditions of Transbaikalia.

The same species in different places exhibited differences in boron content from 1.5 times (aromatic melilot, 3.7–5.6 mg/kg) and 1.8 times (greater burnet, 6.5–12.0 mg/kg) to 2.8 times (tarragon, 24.0–67.0 mg/kg) and 3.0 times (thoroughwax, 2.3–6.9 mg/kg). Differences between different species growing in the same places fall within the same ranges: common yarrow and common plantain – 1.8 times (7.4–13.6 mg/kg), bean trefoil and cowberry – 2.5 times (28.4–70.0 mg/kg).

Boron can be related to intensively accumulated elements: its CBA in medicinal herbs from steppe phytocoenoses varied from 6.2 to 8.3 (7.5 as the average value), meadow phytocoenoses with insufficient wetting – 4.2 to 6.7 (average – 6.0), meadow with normal wetting – 2.0 to 4.2 (average – 3.0). In meadow phytocoenoses with insufficient wetting, the correlation between boron content in plants and in soil is medium (r = 0.58), while in meadow phytocoenoses with normal wetting it is absent (r = –0.04).

Silicon (^{14}Si)

Silicon plays important part in the formation of bone system participating in the formation of the organic matrix of bones at the initial stages of ossification. In the case of the lack of plant fibre and silicon, skin ageing shows itself more rapidly due to a decrease in the synthesis of protein–glucosamine complexes with silicon, which denudes the skin of the back-up collagen layer. In plants silicon gets accumulated mainly in cell walls providing their strength [1].

Silicon content of the plants in steppe phytocoenoses varied within the range 1140–7300 mg/kg, in meadow phytocenoses with insufficient wetting within 1340–7500 mg/kg, meadow with normal wetting – 880–13300 mg/kg, meadow-bog – 700–1500 mg/kg. The highest contrast in silicon content was detected in the plants of meadow phytocoenoses (15.1 times), while the lowest one was observed for the plants of the meadow-bog phytocoenoses (2.1 times). According to the data of different authors, silicon content in grass varies within the range 400–12 000 mg/kg (in meadow clover 400–1300 mg/kg) [15]. According to our data, silicon content in meadow clover was 1280–1340 mg/kg.

The minimal silicon content was revealed in cowberry and in small daylily (700 and 880 mg/kg, respectively), while the maximal one was detected in common plantain (13 300 mg/kg), horsetail (10 800 mg/kg), Daurian thyme (9800 mg/kg), fleawort (7500 mg/kg), *Panzerina lanata* (7300 mg/kg) and greater burnet (7200 mg/kg). These species are intense concentrators of silicon.

Differences in silicon content for the same species growing under different conditions varied from 1.2 times (thoroughwax, 1140–1380 mg/kg, fleawort, 6080–7500 mg/kg), 1.4 times (horsetail, 7590–10 800 mg/kg) to 2.2 times (greater burnet, 3250–7200 mg/kg), 3.2 times (wormwood sage, 2040–6480 mg/kg). Different species growing in the same place exhibited much more substantial differences in silicon content: from 3,5 times (fleawort, 6440 mg/kg; heterochromous dianthus, 1830 mg/kg) in meadow phytocoenoses with insufficient wetting to 11.5 times (horsetail, 10 800 mg/kg; small daylily, 880 mg/kg) in meadow phytocoenoses with normal wetting.

Titanium (^{21}Ti)

Experiments with titanium application revealed its positive action on animal organisms (activation of erythropoiesis, increase in hemoglobin) and on plants (enhancement of growth processes, increase in crop yield) [16]. Titanium had stimulating effect on plant metabolism through enhancement of the activity of peroxidase and catalase and an increase in iron concentration in leaves and in chloroplasts [17].

Titanium content in medicinal plants of different phytocoenoses varied within the limits, mg/kg: for steppe phytocenoses – 8.6–73, meadow with insufficient wetting – 12–65, meadow with normal wetting – 8.8–64, meadow-bog – 21–28. The highest contrast in titanium content was detected for the plants of steppe phytocoenoses (8.5 times), the lowest one was observed for the plants of meadow-bog phytocoenoses (1.2 times). Titanium content in the top parts of seven medicinal plant species of Far East varied within the range 10–142 mg/kg, CBA within 0.2–0.4 [18].

The minimal titanium content is characteristic of thoroughwax (8.6 mg/kg), small daylily (8.8 mg/kg), Daurian thyme (10.0 mg/kg) and aromatic melilot (11.0 mg/kg), while the maximal content was detected in *Panzerina lanata* (73 mg/kg), wormwood sage (65 mg/kg), tarragon (65 mg/kg), and fleawort (56 mg/kg).

The same plant species growing in different places accumulated different amounts of titanium. For greater burnet, the difference reached 1.8 times (12–22 mg/kg), for thoroughwax – 2.9 times (8.6–25 mg/kg), for fleawort – 4.0 times (14–56 mg/kg). Different species growing in the same place differed in titanium content by a factor of 4.7: greater burnet (12 mg/kg) and fleawort (56 mg/kg).

On the basis of accumulation by plants from soil, titanium belongs to the elements with very low absorption intensity: its CBA for the plants of steppe phytocoenoses varied from 0.07 to 0.12 (average value: 0.9), for the plants of meadow phytocenoses with insufficient wetting – from 0.03 to 0.25 (average: 0.09), meadow phytocenoses with normal wetting – from 0.02 to 0.25. For the meadow-bog phytocoenoses, the CBA of titanium turned out to be much higher (0.63–0.83 with the average value equal to 0.73) because titanium content of the peat-bog soil is much lower than its content in mineral soil (480 and 2015–6020 mg/kg, respectively). A high positive correlation between titanium accumulation in plants and its overall content in soil was revealed for steppe phytocoenoses (r = 0.82), and negative for meadow phytocenoses (r = –0.29 and –0.42).

Vanadium (^{23}V)

Vanadium is an important element for bone tissue; it promotes calcification, enhances the stability of teeth against caries and increases the action of insulin [1].

Vanadium content in medicinal plants of steppe phytocoenoses varied within the range 0.46–7.28 mg/kg, in meadow phytocoenoses with insufficient wetting – 0.61–3.35 mg/kg, meadow with normal wetting – 0.42–3.98 mg/kg, meadow-bog – 1.40–1.42 mg/kg. The largest difference in vanadium content was detected for the plants of steppe phytocoenoses (15.8 times), which is due to its high concentration in *Panzerina lanata*; the smallest differences were observed for the plants of the meadow-bog phytocoenoses (1.1 times). Vanadium content in medicinal plants of Transbaikalia mainly corresponds to that in medicinal plants of the European part, which varies from 0.1 to 3.6 mg/kg [14].

The minimal vanadium content was detected in thoroughwax (0.46 mg/kg), wormwood sage (0.51 mg/kg) and aromatic melilot (0.62 mg/kg), while its maximal content was detected in *Panzerina lanata* (7.28 mg/kg), tarragon (3.35 mg/kg), common plantain (3.98 mg/kg).

The same species growing in different places differed in vanadium content from 1.3 times for thoroughwax (0.46–0.59 mg/kg), 2.1 times for greater burnet (0.62-1.3 mg/kg), 2.5 times for fleawort (0.67–1.7 mg/kg) and wormwood sage (0.51–1.3 mg/kg) to 3.8 times – for horsetail (0.90–3.45 mg/kg). Different species in the same place – fleawort and heterochromous dianthus – differed in vanadium content by a factor of 2.8 (1.7 and 0.61 mg/kg, respectively).

Vanadium can be related to the elements with low intensity of absorption: its CBA varied from 0.11 to 0.26 in steppe phytocoenoses (average value: 0.16), meadow phytocoenoses with insufficient wetting – 0.07–0.31 (0.18), meadow with normal wetting – 0.07–0.20 (0.16).

Correlation between vanadium accumulation in plants and its content in soil is almost completely absent: for steppe phytocoenoses $r = -0.04$, for meadow phytocoenoses with insufficient wetting $r = -0.23$, for meadow phytocoenoses with normal wetting.

Nickel (^{28}Ni)

Nickel participates in carbohydrate, lipid, mineral and hormonal metabolism, stimulates erythropoiesis and immune system [1]. In plants, nickel is a component of urease enzyme which catalyzes the decomposition of urea [2].

Nickel content in medicinal plants of steppe phytocoenoses varied within the range 0.14–2.19 mg/kg, in meadow phytocoenoses with insufficient wetting within 0.20–8.85 mg/kg, meadow with normal wetting – 0.21–5.10 mg/kg, meadow-bog – 0.70–0.73 mg/kg. The largest difference in nickel content was detected for the plants of meadow phytocoenoses with insufficient wetting (44.3 times), while the smallest one for meadow-bog phytocoenoses (1.1 times). Nickel content in medicinal plants of Transbaikalia in general corresponds to its concentration in medicinal plants of the European part (0.4 to 10.0 mg/kg) [14].

The minimal nickel content was detected in thoroughwax (0.14 mg/kg), wormwood sage and aromatic melilot (0.24 mg/kg), while its maximal content was observed in greater burnet (8.85 mg/kg), fleawort (4.5 mg/kg), heterochromous dianthus (3.66 mg/kg), common plantain (3.95 mg/kg) and *Panzerina lanata* (2.19 mg/kg).

The same species in different places differed in nickel content from 1.4 times (thoroughwax, 0.14–0.19 mg/kg), 1.9 times (wormwood sage, 0.24–0.45 mg/kg) to 2.5 times (horsetail, 0.43–1.08 mg/kg) and 3.8 times (fleawort, 1.18–4.5 mg/kg). Different species in the same place – fleawort and heterochromous dianthus – differed in nickel content by a factor of 1.2 (4.5 and 3.66 mg/kg, respectively).

Nickel belongs to the elements with low intensity of absorption: its CBA in steppe phytocoenoses varied from 0.13 to 0.30 (average: 0.20), in meadow phytocoenoses with insufficient wetting – 0.08–0.54 (0.31), in meadow phytocenoses with normal wetting – 0.14–0.71 (0.41). Nickel in the meadow-bog landscape is characterized by medium accumulation intensity: its CBA for two plant species was 2.0–2.4. This is due to the fact that nickel content in meadow-bog soil is much lower (5.0 mg/kg) than in mineral soil of steppe and meadow phytocoenoses (14–39 mg/kg).

A medium correlation was revealed between nickel accumulation in plants and its content in soil for steppe phytocoenoses ($r = 0.76$) and the absence of correlation for meadow phytocoenoses with insufficient ($r = -0.08$) and normal wetting ($r = -0.17$).

CONCLUSIONS

Substantial non-uniformity was revealed in the accumulation of conventionally essential microelements in medicinal plants, which is due to their physiological significance, biological features of plants and the selectivity of absorption of microelements from the nutrition medium, as well as due to the ecological and geochemical factors determining biological availability of elements. Microelement content of 21 studied species of medicinal plants varied within the limits, mg/kg of the dry matter: Si 700–13 300 (average: 4326±512), Ti 8.8–73 (28±2.6), B 2.1–70 (13.7±3.6), Li 1.3–22.2 (5.76±1.40), Ni 0.14–8.85 (1.81±0.33), V 0.42–7.28 (1.47±0.21). The smallest variation coefficient (59 %) was detected for titanium, while the largest one (130 %) was detected for boron. On the basis of the intensity of biological accumulation, boron relates to the group of intense accumulation (CBA = 6.2–8.3), lithium – to the group of medium accumulation (CBA = 1.1–2.3), nickel – to weak (0.13–1.30), titanium and vanadium – very weak accumulation (0.02-0.39). Ambiguous correlation dependencies between microelement content in medicinal plants and microelement concentrations in soil were established: for steppe arid landscapes – a strong positive correlation for Ti, Ni, a weak negative correlation for V; for meadow landscapes with insufficient wetting – a medium positive correlation for Li, B, a weak negative one for Ti, V; for meadow landscapes with normal wetting – a weak positive correlation for V, Ni, and negative for Ti.

Plants concentrating microelements in increased amounts were revealed: Li – common yarrow, *Panzerina lanata*, common plantain; B – cowberry, tarragon, horsetail, common plantain, *Panzerina lanata*; Ti – *Panzerina lanata*, tarragon; V – common plantain, *Panzerina lanata*, tarragon; Ni – *Panzerina lanata*, common plantain, greater burnet. According to the ability to concentrate a group of elements, the following plants are distinguished: *Panzerina lanata* – five of six studied microelements (Li, Si, Ti, V, Ni), common plantain – four elements (Li, Si, V, Ni), tarragon – three elements (B, Ti, V). The minimal microelement content is characteristic of thoroughwax (Si, Ti, V, Ni) and small daylily (Li, B, Si, Ti).

It was established that the same plant species under different ecological conditions substantially differ in microelement content, while different species in the same biotope accumulate different amounts of microelements.

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