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ECOLOGICAL AND BIOGEOCHEMICAL PROPERTIES OF LEAVES AND FRUITS OF FRUIT TREES OF THE MID-MOUNTAIN AGROLANDSCAPE OF THE VELVELA-CHAI-GUSARCHAI INTERFLUVE AREA (SOUTHERN SLOPE OF THE GREATER CAUCASUS)

Ilgar F. Guliyev

Baku State University, Baku, Azerbaijan

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Abstract

The article deals the ecological and biogeochemical properties of leaves and fruits of fruit trees developed in the mid-mountain agrolandscape of the Velvelachai-Gusarchai interfluve area of the southern slope of the Greater Caucasus. The statistical distribution parameters of the amounts of some trace elements in the natural leaves of fruit trees of the middle mountain agrolandscape were studied, and the clarke of concentration of the amounts determined in them was calculated. It was determined that, the concentrations of Zn (1.1-1.9 CC), Pb (1.4-1.7 CC) are characteristic for the leaves of fruit trees of the agrolandscape - with a higher concentration in pear leaves, and concentration of Cu (1.6 CC) is also observed in this plant. It was concluded that the fruits of fruit trees of the agrolandscape are characterized by a biogeochemical activity equal to 8.8 and the element complex studied with $R_6^- / R_6^+ = 2.7$ ratio indicates that it is mainly concentrated in the fruits of fruit trees. The results of the conducted biogeochemical data show that the signs and characteristics of biological absorption of elements in the leaves and fruits of fruit trees are well occurred in the analysis of biological absorption sequences: in apple leaves (Zn,Pb>Cu>Ni>Cr>Co), fruits of pear (Cu>Zn>Pb>Ni>Cr>Cu), apple (Cu>Zn>Ni>Pb>Co>Cr), pear (Cu>Zn>Pb>Ni>Cr>Co).

Keywords: Velvelachai-Gusarchai interfluve area, Southern slope of the Greater Caucasus, mid-mountain agrolandscape, leaves and fruits of fruit trees, biogeochemical properties

*Corresponding author.

E-mail address: ilgar.guliyev1@gmail.com (Ilgar Guliyev)

INTRODUCTION

The mid-mountain landscape of the Velvelachai-Gusarchai interfluve area (southern slope of the Greater Caucasus) is located at an altitude of 1000 to 2000-2000m above sea level. The relief of the mid-mountain landscape is denudation-erosion with a number of well-defined structural steps. Synclinal folds and plateaus with steep slopes predominate. Landslides and landslide-flood flows have developed widely on the slopes of valleys and heights due to the spread of clayey-marly rocks of the Cretaceous flysch. The landscape is characterized by deep V-shaped river valleys and slopes, the steepness and shape of which depend on the lithological composition of the rocks, the geological structure and also the exposure of the slopes. The general direction of the relief is directed towards the southeast. A network of valleys-ravines has developed in the same direction, their density reaches 1.2-1.5 km/km^2 and in some places even 2 km/km^2. The density of the river network varies within 0.2-0.4 km/km^2 [1-4].

The average annual air temperature is plus 5-100ºC. The temperature of the coldest month (January) is minus 5-80ºC, the temperature reaches 15-250ºC on the hottest (July) days. The temperature range from maximum (+350ºC) to minimum (-250ºC) is within 600ºC. Sunny hours per year are 1900-2000, and the total solar radiation value is 129 kcal/cm^2. The average amount of atmospheric precipitation reaches 900-1200 mm. An average of 200-700 mm of precipitation is recorded In winter, 700-900 mm and more in summer. Snow cover lasts for 80-120 days. Evaporation is slightly higher than atmospheric precipitation, and the landscape is characterized by moderate relative humidity. In general, the landscape is characterized by a humid type of climate, an even distribution of atmospheric precipitation and cold, dry winters [6-7].

The highlands of the landscape consist of Cretaceous sediments composed of marl and limestone. Paleogene, Neogene and Quaternary sediments are widespread in the lower parts, consisting of sandstones, limestones, conglomerates, clays, loam and gravels [7, 11, 12, 13, 14]. They are formed by soil-forming eluvial-diluvial layers on the fault products of parent rocks and directly on bed rocks. Their thickness and structure vary depending on the shape and steepness of the slopes [14,15]. Mountain-forest brown soils are formed under broad-leaved mountain forests on these sediments in the conditions of the washing water regime, mild warm and mild humid climate.

MATERIAL AND METHODS OF RESEARCH

30 trace elements were observed in the leaves and fruits of fruit trees developed in the mid-mountain agrolandscape of the Velvelachai-Gusarchai interfluve area of the southern slope of the Greater Caucasus. Spectral emission analysis was used to determine the content of these chemical elements in all samples. The article pays special attention to 6 heavy metals (Cr, Ni, Cu, Co, Pb, Zn), which are widely used and are characterized by stable detection in various plants of the region.

RESULTS AND DISCUSSION

The leaves and fruits of fruit trees of the agrolandscape (apple, pear) are characterized by a 100% occurrence of Ni, Cu, Pb. Differences in the observing percentages of Zn, Cr, Co are found depending on the type and organ of the plant. For example, pear fruits are characterized by a high occurrence of Zn (1.7 times), Co (not found in leaves) and an equal occurrence of chromium compared to leaves. In turn, apple fruits are also characterized by a high occurrence of Zn (2.5 times), Co (not found in leaves), but a very low occurrence of chromium (4 times). Differences are also observed in the organs (limbs) of plant species. So, pear leaves are characterized by a greater occurrence of Zn (1.5 times) and an equal observing percentage of chromium compared to apple leaves. Fruits are characterized by a 100% occurrence of Zn. Pear fruit is distinguished by a large occurrence of Cr (5 times) and Co (2.3 times) (tables 1, 2). The analysis of the average amounts of elements in the leaves revealed higher amounts of Cr (1.25 times), Ni (1.8 times), Zn (1.8 times), Pb (1.2 times), Cu (2.4 times) in pear leaves. High amounts of Cr (5.1 times), Co (2.4 times), Pb (3.9 times) are also observed in pear fruit. Cu (1.34

times) differs in relatively large amounts in apples. No significant differences were observed in the amounts of Zn and Ni. In this case, higher amounts of Ni, Zn, Cu in leaves and Cr, Cu, Pb in fruits (pear) and copper in apples are statistically significant. The contrast in the quantitative distribution of elements in the leaves of fruit trees shows a moderate differentiation of Cu, Ni, Zn (Cr, Pb - weak), a strong biogeochemical differentiation of chromium in the fruits (Co, Pb - moderate and Ni, Zn, Cu - weak). In general, pear leaves differ in large amounts (1.8 times), apple fruits in large amounts (1.2 times) of the studied elements.

Compared to the leaves of woody plants of the natural landscape, the leaves of fruit trees of the agrolandscape are poor in Ni (1.2 times), Cr (1.4 times), Cu, Zn (1.6 times) and cobalt (1.2 times). No significant differences in Pb amounts were observed.

Zn (1.1-1.9 CC), Pb (1.4-1.7 CC) concentrations are typical for the leaves of fruit trees of the agrolandscape – higher concentrations are observed in pear leaves, and Cu (1.6 CC) concentrations are also observed in this plant. Ni content varies from low clarke level (1.8 CY) to clarke level (in pear leaves). Co (not found) and Cr (4.2-5.2 CY) are not observed in the leaves of fruit trees (table 1). These are characterized by moderate accumulation and strong retention of Ni, Cu, Zn, Pb (0.8-1.6) and moderate, weak and very weak retention of Co, Cr (up to 0.2 C). As a result, the biogeochemical activity of pear leaves (GCA=1.73) is 1.4 times higher than the biogeochemical activity of apple leaves (GCA=1.25). The ratios in apple ($R_6^- / R_6^+ = 1.7$) and ($R_6^- / R_6^+ = 1.2$) leaves also indicate a low concentration intensity of elements with apple leaves [9, 10]. In general, the leaves of fruit trees of the agrolandscape are characterized by a biogeochemical activity equal to 1.4, while $R_6^- / R_6^+ = 1.4$ reveals mainly deconcentration of elements in the leaves

Table 1

Statistical distribution parameters of the amounts of elements in natural leaves of fruit trees in the mid-mountain agrolandscape of the Velvelachai-Gusarchai interfluve area

$(x \cdot 10^{3}\%)$

Elements	**R, %**	**Fluctuation expanse**	**Distribution law**	$\overline{X}$	**Valid interval,** $\overline{X}$	**V, %**	**CC**	**CY**	**Ax**	**C_C**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Apple (N=10.0)										
Cr	80	0-3.0	N	1.6	0.96-2.4	65	0.2	5.2	0.2	-
Co	-	-	-	-	-	-	-	-	-	-
Ni	100	1.0-6.0	N	3.3	2.3-4.3	47	0.6	1.8	0.7	-
Cu	100	2.0-5.0	N	3.0	2.3-3.7	37	0.6	1.6	1.1	-
Zn	40	0-30.0	-	9.0	-	-	1.1	0.9	1.4	-
Pb	100	1.0-4.0	N	2.2	1.5-2.9	47	1.4	0.7	1.4	-

$R_6^+(BGF) = 1.25\ R_6^- = 2.15$										
Pear (N=10.0)										
Cr	90	0-4.0	N	2.0	1.1-3.0	63	0.2	4.2	0.2	-
Co	-	-	-	-	-	-	-	-	-	-
Ni	100	1.0-10.0	N	6.0	3.4-8.5	57	1.0	1.0	1.3	1.1
Cu	100	2.0-20.0	N	7.3	2.4-12.2	90	1.6	0.6	2.6	-
Zn	60	0-40.0	N	16.0	6.0-27.0	85	1.9	0.5	2.4	-
Pb	100	1.0-4.0	N	2.7	1.8-3.6	51	1.7	0.6	1.7	-
$R_6^+(BGF) = 1.73\ R_6^- = 2.1$										
Woody plants as a whole (N=20.0)										
Cr	85	0-4.0	-	1.8	-	-	0.2	4.6	0.2	-
Co	-	-	-	-	-	-	-	-	-	-
Ni	100	1.0-10.0	-	4.7	-	-	0.8	1.2	1.0	-
Cu	100	2.0-20.0	-	5.2	-	-	1.1	0.9	1.9	-
Zn	50	0-40.0	-	12.5	-	-	1.5	0.7	1.9	-
Pb	100	1.0-4.0	-	2.5	-	-	1.6	0.6	1.6	-
$R_6^+(BGF) = 1/4\ R_6^- = 1.93$										

CC - high clarke level, CY - low clarke level, A_x- biological absorption coefficient, V-variability, C_C - anomaly coefficient, BGF - biogeochemical activity, N - normal distribution

Fruits of fruit trees is characterized by concentrations of Cu (15.5-20.9 CC), Zn (5.9-6.5 CC) – with higher concentrations in apple trees, Cr (1.6-8.3 CI), Co (4.1-10.0 KI), Ni (1.3 CI) are not observed in fruits (table 2) [5, 8]. In general, the fruits of fruit trees are characterized by intensive and moderate accumulation of Cu (18.2 CC), moderate accumulation and strong retention of Ni, Pb, Zn (0.8-6.2 CC) and moderate, weak and very weak retention of Co, Cr (0.2-0.4 CC). Biogeochemical activity fluctuates within the limits of 8.1 (pear) – 13.7 (apple). However, the differences in apple ($R_6^- / R_6^+ = 2.6$) and pear ($R_6^- / R_6^+ = 3.5$) reveal a more intensive concentration of elements in fruits of pear tree.

In general, the fruits of fruit trees of the agrolandscape are characterized by a biogeochemical activity equal to 8.8 [8, 9, 10], which indicates that the element complex studied with the $R_6^- / R_6^+ = 2.7$ ratio is mainly concentrated in the fruits of fruit trees (table 2). So, fruit trees (leaves, fruits) of agrolandscape are characterized by intensive and moderate accumulation of Cu, moderate accumulation and weak retention of Ni, Zn, Pb, and moderate, weak and very weak retention of Cr, Co. These ranks correspond to the order of accumulation of elements in terrestrial vegetation (with the exception of Zn), the latter moves from the order of intensive and moderate accumulation in terrestrial vegetation to the order of moderate accumulation and strong retention in fruit trees, while Cu moves from the order of moderate accumulation and strong retention in terrestrial vegetation to the order of intensive and moderate accumulation in fruit trees. At the same time, differences in the concentrations of elements are observed depending on the plant organ (limb). The concentration of elements in the leaves and fruit of fruit trees is generally similar to the concentration distribution in terrestrial vegetation, but at a much lower level and with the exception of fruits, where the concentration of Cu is 3.7-5.0 times higher. Differences are also observed in the concentrations of Pb and Cr: Pb and Cr concentrations are lower than Cu and Co concentrations (respectively), while the concentration of these elements is correspondingly higher in the leaves of fruit trees. Fruit trees also differ in biogeochemical activity: the biogeochemical activity in leaves is weak in comparison with terrestrial vegetation (5.2 times) and with woody vegetation of the natural landscape (1.5). The biogeochemical activity in fruits is higher than in the terrestrial vegetation (1.2 times) and in the leaves of woody plants of the natural landscape.

Depending on the species and organ (root) of fruit trees, the biological absorption intensity of elements varies significantly (tables 3.6, 3.7, figure 3.5). So, apple fruits, unlike leaves, contain Cu (3.2 times), Zn (6 times), Cu (2 times), Ni (1.4 times), Cr, and Pb with lower absorption intensity (2 times). Analogous situations are observed in pears - the fruits are distinguished by a large accumulation of Cu (10 times), Zn (3 times), Cr (3 times). Unlike apples, pear leaves have a higher concentration of Pb (1.7 times) and a lower absorption intensity of Ni (1.3 times). So, the fruits of fruit trees are characterized by a greater absorption intensity of Cu (10-32 times), Zn (3-6 times), Cr (2-3 times) and Co (not found in the leaves) compared to the leaves. Thus, apples are characterized by a large accumulation of Cr, Zn, and pears by Cr. Differences are observed in the intensity of biological absorption of Pb and Ni: fruits of apple tree absorb Ni more intensively and Pb less intensively, while fruits of pear tree show the opposite picture - Pb is absorbed with great intensity and Ni is absorbed weakly.

Comparative analysis of elements A_x in the leaves of fruit trees revealed a more intensive absorption of Pb (1.2 times), Zn (17 times), Ni (1.9 times) and Co (2.4 times) in pear leaves. No differences are observed in the absorption of Cr, Co in the leaves of fruit trees (table 1). Pears are distinguished by a large intensive absorption of Co (25 times), Pb (3.6 times), Cr (6 times). Cu is more concentrated (1.3 times) in apples. No significant differences in the intensive biological absorption of Zn and Ni in the fruits of fruit trees were observed (Table 2).

Table 2

Statistical distribution parameters of the amount of elements in fruits of fruit trees in the agrolandscape of the Middle Jurassic landscape of the Velvelachai-Gusarchai interfluves area

$(x \bullet 10^{3}\%)$

Elements	R, %	Fluctuation expanse	$\overline{X}$	CC	CY	Ax	C_C	From dry matter mg/kg
1		2	3	4	5	6	7	8
Apple (N=10.0)								
Cr	20	0-5.0	1.0	0.12	8.3	0.1	-	0.27
Co	30	a/0-0.6	0.18	0.1	10.0	0.2	1.2	0.05
Ni	100	1.0-10.0	4.5	0.8	1.3	1.0	-	1.2
Cu	100	10.0-200.0	98.0	20.9	0.05	35.0	11.7	26.8
Zn	100	6.0-160.0	54.0	6.5	0.2	8.2	2.6	14.6
Pb	100	0.4-3.0	1.2	0.8	1.3	0.8	-	0.3
$R_6^{+}(BGF) = 13.7 \; R_6^{-} = 5.2$								
Pear (N=10.0)								
Cr	100	2.5-10.0	5.1	-	1.6	0.6	22.0	0.7
Co	70	a/0-1.2	0.44	-	4.1	0.5	3.0	0.1
Ni	100	2.0-8.0	4.4	-	1.3	1.0	-	1.1
Cu	100	30.0-200.0	73	15.5	0.1	26.1	8.7	17.0
Zn	100	16.0-100.0	49.3	5.9	0.2	7.5	2.4	11.8
Pb	100	1.6-10.0	4.7	2.9	0.3	2.9	1.7	1.1
$R_6^{+}(BGF) = 8.1 \; R_6^{-} = 2.3$								
Whole fruits (N=20.0)								
Cr	60.0	a/o-10.0	3.1	0.4	2.7	0.4	-	0.49
Co	50.0	a/o-1.2	031	0.2	5.8	0.3	-	0.08
Ni	100.0	1.0-10.0	4.5	0.8	1.3	1.0	-	1.2
Cu	100.0	10.0-200.0	85.5	18.2	0.1	30.5	-	21.9

Zn	100.0	6.0-160.0	51.7	6.2	0.2	7.8	-	13.2
Pb	100.0	0.4-10.0	3.0	1.9	0.5	1.2	-	0.7
$R_6^+(BGF) = 8.8$ $R_6^- = 3.3$								

CONCLUSİON

The results of the conducted biogeochemical data show that the signs and characteristics of biological absorption of elements in the leaves and fruits of fruit trees are well occurred when analyzing the biological absorption series: in apple leaves (Zn,Pb>Cu>Ni>Cr>Co), pear (Cu>Zn>Pb>Ni>Cr>Cu), fruits of apple (Cu>Zn>Ni>Pb>Co>Cr), fruits of pear (Cu>Zn>Pb>Ni>Cr>Co). According to these rows, the leaves of fruit trees absorb the first 3 elements (Zn, Pb, Cu) with great intensity, but Zn, Pb are replaced by copper depending on the species. Alterations in the minimum absorption of Ni, Cr, Co are not observed. Cu, Zn are also characterized by the greatest absorption intensity in the fruits, Cr, Co are minimal. But depending on the species, Ni and Pb, as well as Cr and Co change their places.

So, selective absorption of elements occurs in fruit trees, which is associated with different physiological responses to the amounts of certain elements. In this case, Cu is distinguished with the greatest intensity of biological absorption - this element is involved in photosynthesis, biosynthesis of proteins and complex phosphorus-organic compounds.

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