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THE MINERAL COMPOSITION OF CHERRY (*PRUNUS CERASUS* MILL.) FRUITS DEPENDING ON THE SCION-STOCK COMBINATION

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ABSTRACT

Cherry is a stone fruit crop that is valued for its early fruiting, productivity, and high taste and diet properties. The researches in the sphere of compatible scion-stock combinations selection of cherry crops with high winter hardiness and fruits quality were held in Federal Horticultural Research Center for Breeding, Agrotechnology and Nursery for these crops introduction in industrial gardening of the Central region of Russia. The mineral composition of four cherry cultivars of FHRCBAN selection (Apuchtinskaya, Rusinka, Volochaevka, and Molodezhnaya) grown on rooted and grafted plants (stocks AVCH-2, Izmaylovskiy, and Moskoviya) was studied for the first time. The influence of scion-stock combinations on 11 elements (Na, P, K, Mn, Fe, Mg, Ca, Co, Zn, Se, Mo) accumulation in the fruits was determined. The greatest proportion of mineral substances in cherry fruits belongs to K. Depending on the scion-stock combination its amount is varied from 13.89 mass % (Apuchtinskaya/Moskoviya) to 30.52 mass % (Molodezhnaya/Izmaylovskiy). For all cultivars fruits, the amount of K is 1.1 – 1.3 times higher on stock Izmaylovskiy than on rooted plants. The variation coefficient of K is low (V %) 1.37 – 6.91 for the majority of scion-stock combinations that indicate the stable entry of this element inside the fruit. The most content of all the elements under study was found in the fruits ash of Rusinka, Molodezhnaya, and Volochaevka on stock Izmaylovskiy that indicates the stable physiological state of the plants on these stocks. Results show that the cherry fruits analyzed could be an alternative to the supplementing of a mineral diet.

Keywords: *Prunus cerasus* (Mill.); scion-stock combinations; fruit; ash content; EDS analysis

INTRODUCTION

Stone crops fruits grown in the gardens of the Central region of Russia play an important role in the quality functional nutrition of the population. Most unit weight belongs to cherry fruits. They contain macro and microelements, fiber, minerals, vitamins, bioactive phenolic compounds such as anthocyanins, coumarins, and others. Their consumption has a preventive and curative effect **(McCune et al., 2011; Robinson, Hoying and Dominguez, 2017)**.

The traditional growing of cherry trees in extensive gardens is connected with the growing of large-sized trees with extensional crowns **(Kiprijanovski et al., 2018).** For intensive gardens it is necessary to use scion-stock combinations suitable for close planting and which are characterized by early entry into fruiting and high quality of fruits **(Eremin, 2000; Upadysheva, 2009; Bujdoso, Magyar and Hrotko, 2019; Balducci, Capriotti and Mazzoni, 2019).** The influence of the stock on physiologic, biochemical, and molecular processes in the scion plants is not studied enough till the present time and is an actual subject of researches **(Nimbolkar et al., 2016)**. In the works of some researchers **(Gonçalves et al., 2005; Landi et al., 2014)** the influence of the stock on the physiological-biochemical parameters of the grafted trees leaves (photosynthetic pigments and metabolites composition), biological peculiarities of growth and fruiting was determined **(Jiméneza et al., 2007)**. The stock influences the intake of water, nutrients, and minerals from the soil to determine the intensity of above-ground system growth and photosynthesis, regulation and signalization, growth hormones, gene expression, and phloem proteins transportation. This, in its turn, causes the influence on fruits ripening, the profile formation of carbohydrates, phenolic compounds, and other biologically active substances in the grafted plant fruits **(Spinardi, Visai, Bertazza, 2005; Upadysheva, 2009; Usenik et al., 2010; Prasad et al., 2017; Upadysheva et al., 2018)**.

Literature data point out that some fresh fruits could be a supplementary source for the daily-recommended intake of minerals **(Gogoaşă et al., 2014; Mehari et al., 2015)**.

The important indicator of stonecrops fruits' nutritional value is micronutrients, the content of which also depends on the using stock. However, similar data about cherry trees are extremely few.

Figure 1 The garden general view in the fruiting period.

Figure 2 The fruiting of Molodezhnaya on stock Izmaylovskiy.

The researches of cherry scion-stock combinations which are characterized with high technological value and suitable for intensive plantation formation in the Central region of Russia are held in Federal Horticultural Research Center for Breeding, Agrotechnology and Nursery. The clonal rootstocks used are interspecific cherry hybrids: Izmaylovskiy (*Prunus cerasus* x *Prunus fructicosa* x *Prunus maackii*), AVCh-2 (*Prunus fructicosa* x *Prunus maackii*), and Moskoviya (*Prunus cerasus* x *Prunus maackii*). Trees grafted on the Izmaylovskiy and AVCH-2 rootstocks do not form root growth. Trees grafted on the Moskoviya rootstock give many root suckers, which complicates the technology of garden care. Own-rooted trees of the Apuchtinskaya variety are distinguished by low growth, high yield, and are recommended for laying intensive plantings **(Upadysheva and Belikova, 2020)**. Considering all this, the authors of this paper considered it would be worth assessing research was to study the mineral composition of cherry fruits received from scion-rooted and grafted plants depending on the scion-stock combination.

The authors measured the concentration of some essential microelements such as Na, P, K, Mn, Fe, Mg, Ca, Co, Zn, Se, and Mo, eventually assessed the mineral supply of cherry fruits.

Scientific hypothesis

Cherry fruits guarantee the intake of biologically active micronutrients in the human organism. The ash composition of cherry fruits depending on the scion-stock combination is not studied.

We checked the influence of the stock on the formation of mineral composition of cherry fruits grown in the conditions of the Moscow region. We suppose that the stock will influence the formation of cherry fruit mineral composition. Our work is devoted to this question studying.

MATERIAL AND METHODOLOGY

The objects of the research were the fruits of 4 cherry cultivars of Federal Horticultural Research Center for Breeding, Agrotechnology and Nursery selection - Apuchtinskaya, Rusinka, Volochaevka, and Molodezhnaya from scion-rooted and grafted on stocks AVCH-2, Izmaylovskiy, and Moskoviya plants. The cherry trees were grown on the selection plant of FHRCBAN in the Leninskiy district of the Moscow region. The plantation's overall area is 0.6 ha. The garden of intensive type is set out using a 5 x 2.5 m scheme. The soil in the row spacing is under perennial grassing (Figure 1).

The fruits were picked up at the ripeness stage (Figure 2).

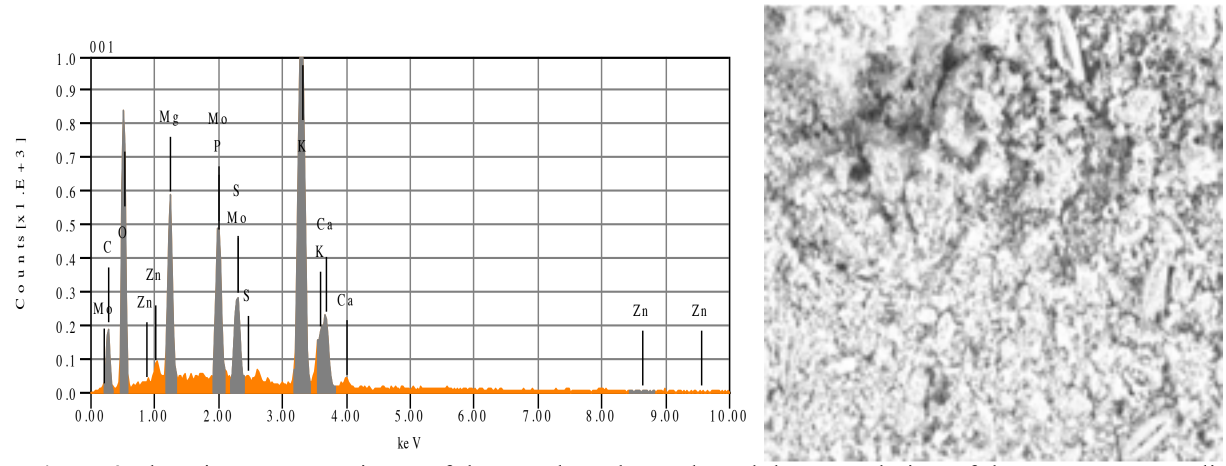

Figure 3 The microstructure picture of the sample under study and the general view of the X-ray spectrum lines that show the elements presence in the analyzing area. Note: Mg – 6.39; P – 5.73; S – 2.20; K – 26.77; Ca – 5.49 and Zn – 0.13 mass % respectively.

The laboratory research was performed in 2017-2019 at the Laboratory of Physiology and Biochemistry of FHRCBAN.

Sample preparation

Cherry fruits were washed in distilled water, dried, separated from stones, selected average samples weighing 10 g, put in porcelain crucibles, dried in drying oven Snol (Russia) at T = 80 °C. The dried samples were mineralized in a muffle furnace Naberterm LVT15/11/B180 (Germany) with a temperature increase of 10 °C/15 min at T = 450 °C 5 hours. The received ash was pounded with a pestle, homogenized in the ultrasound unit, applied on the object table covered with carbonic scotch Agar (Germany), and put in the camera of the electron microscope.

EDS - analysis

The chemical composition of the basic ash components (Na, P, K, Mn, Fe, Mg, Ca, Co, Zn, Se, Mo) was determined by the method of energy dispersive spectrometry (ESD) on the analytical raster electron microscope JEOL JSM 6090 LA. The microscope solution is 4 nm at accelerating voltage 20 kV (secondary electrons image), zooming is from x 10 till x 10 000. While performing the elemental analysis the working distance (WD) is 10mm. An energy-dispersive spectrometer allows to carry out the quantitative X-ray microanalysis with the desired analyzing area: in a point or areally. and to receive the maps of elements allocation. X-ray microanalysis data are presented in the form of standard protocols that contain the microstructure picture of the sample under study, the table of the data in weighting and atomic correlation, spectra, and histograms. The spectrum example is shown in Figure 3.

Taking into consideration the spectrum line intensity the concentration of the desired element can be determined. The fractional accuracy of the chemical analysis is spread in the following way: at the element concentration from 1 till 5% the accuracy is less than 10%: from 5 till 10% the accuracy is less than 5%; at the element concentration more than 10% the accuracy is less than 2%. 100 ash areas of each sample were studied. The local analysis is 3 mm. the scanned area is not less than 12 um.

Statistical analysis

All analyses were **quadruple**-time repetition. Results were expressed as mean values (n = 4) in standard deviation (*SD*). Used the Statistics, version 6 program.

To determine the differences - significance between the data one-way and two-factor experience ANOVA test was used (p <0.05) via the program Statgraphics Centurion.

RESULTS AND DISCUSSION

The most proportion of mineral substances in cherry fruit belongs to K. Its content depending on cultivar and scion-stock combination varies from 13.89 mass % (Apuchtinskaya/Moskoviya) to 30.52 mass % (Molodezhnaya/Izmaylovskiy), Table 1. In the fruits of all cultivars received from rooted trees the content of K varies insignificantly (21.75 – 24.81) mass %. On stock AVCH-2 the content of K showed a 1.1 times increase in the fruits of Molodezhnaya, 1.2 times in the fruits of Rusinka, and 1.3 times in the fruits of Volochaevka respectively. On stock Moskoviya the content of this element increased insignificantly in Rusinka and Volochaevka, and in the fruits of Molodezhnaya and Apuchtinskaya decreased on 22 and 37% respectively. The variation coefficient of K for the majority of scion-stock combinations is low (V %) 1.37 – 6.91, which shows a stable intake of this element inside the fruits. According to the data of **Heghedűş-Mîndru et al. (2013)**, the content of K in cherry fruits is not only higher than in sweet cherry and plum fruits, but this element is also taken up better. K is a macroelement that is responsible for the regulation of the majority of metabolic reactions that flow in living organisms. The very special role in controlling the homeostasis belongs to K. It controls osmotic pressure transmembrane potential, charges equilibrium, cathode-anion balance, and pH – everything that the homeostasis of cells and tissues consists of. In the ionic form, K can be found in all the organs, tissues, and cell structures in concentrations that exceed the concentration of other ions **(Meathnis et al., 1997)**.

The content of P, Mo, Mg Ca in the fruits of the combinations under study is given in Figure 4.

Table 1 The pecularities of K accumulation in the cherry fruits depending on stock.

Scion-stock combination	Defined parameters				
	K (mass %)	max	min	S	V (%)
Apuchtinskaya own rooted	21.99	22.31	21.19	0.538	2.45
Rusinka own rooted	21.75	22.14	21.42	0.298	1.37
Volochaevka own rooted	22.47	22.97	21.84	0.496	2.21
Molodezhnaya own rooted	24.84	25.46	24.05	0.299	2.41
Apuchtinskaya /AVCH-2	19.39	19.82	18.76	0.500	2.58
Rusinka/AVCH-2	25.92	26.17	25.33	0.395	1.52
Volochaevka/AVCH-2	30.03	31.24	29.08	1.01	3.35
Molodezhnaya/ AVCH-2	27.17	29.14	22.11	3.392	15.33
Apuchtinskaya /Izmaylovskiy	24.46	26.41	21.34	2.281	9.34
Rusinka/ Izmaylovskiy	26.23	34.12	23.31	5.273	20.10
Volochaevka/ Izmaylovskiy	30.24	31.13	29.94	0.534	1.76
Molodezhnaya / Izmaylovskiy	30.52	32.14	29.87	1.041	3.52
Apuchtinskaya /Moskoviya	13.86	14.28	13.19	0.511	3.64
Rusinka/Moskoviya	23.76	24.19	23.24	0.494	2.10
Volochaevka/Moskoviya	23.18	25.14	21.22	1.602	6.91
Molodezhnaya/Moskoviya	19.49	23.22	14.25	2.043	20.89

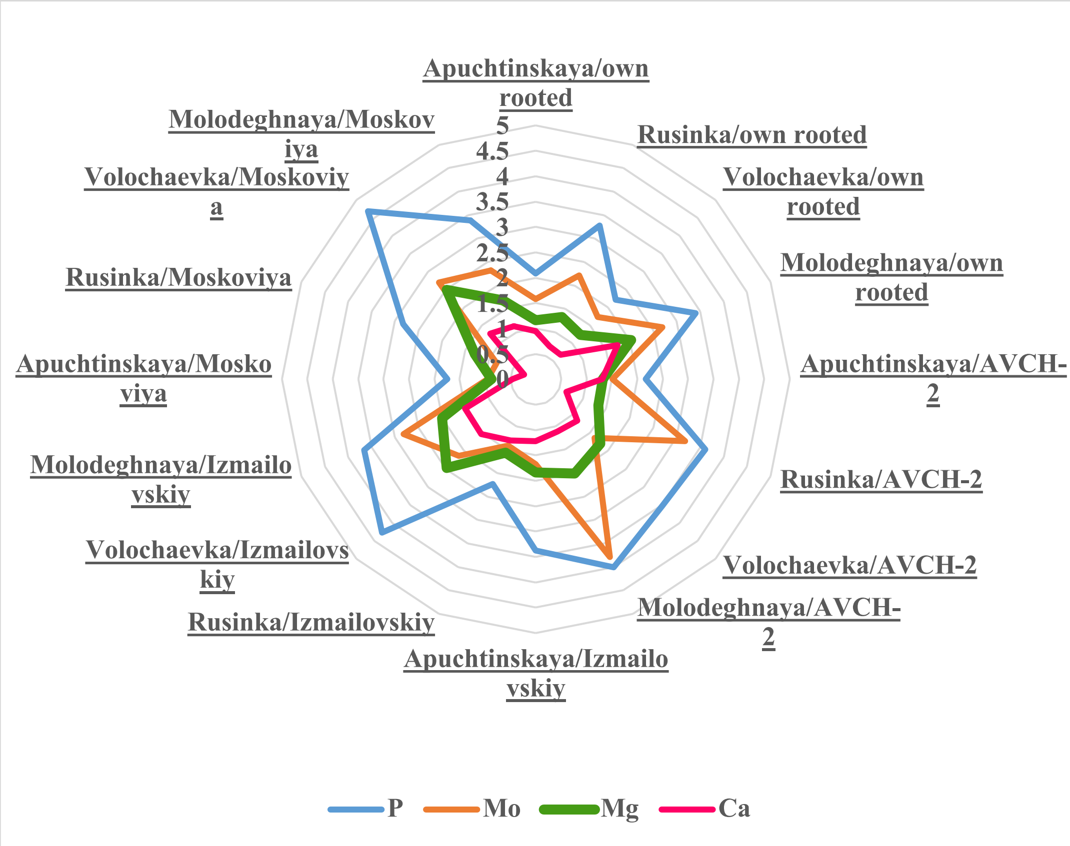

Figure 4 The content of P, Mo, Mg and Ca in the cherry fruits on different stocks, mass %.

The most content of P is determined in the fruits of scion-stock combinations Volochaevka/Moskoviya, Molodezhnaya/Izmaylovskiy, Volochaevka/Izmaylovskiy, Rusinka/AVCH-2, Volochaevka/AVCH-2, and Molodezhnaya/AVCH-2. The proportion of Mo in cherry fruits is 0.5 – 2 times lower than P.

The most content of Mo was marked in the fruits of the following combinations: Molodezhnaya/Izmaylovskiy (3.2 mass %), Molodezhnaya/AVCH-2, and Volochaevka/AVCH-2 (3.6 mass %).

The content of Mg is at 1.2 – 2.5 mass % level in the cherry fruits. In the cherry fruits on stocks Moskoviya and Izmaylovskiy, the proportion of Mg is 2 – 2.5 mass %.

The most proportion of Ca (1.5 – 1.7 mass %) was stated in the cherry fruits of rooted plants of Molodezhnaya, combinations Molodezhnaya/Izmaylovskiy and Volochaevka/Izmaylovskiy. Scion-stock combinations Apuchtinskaya/AVCH-2 and Apuchtinskaya/Izmaylovskiy are also specific in the content of Ca. The minimal content of P, Mo, Mg, and Ca was marked in the fruits of Apuchtinskaya and Volochaevka roots, Apuchtinskaya/Moskoviya combination.

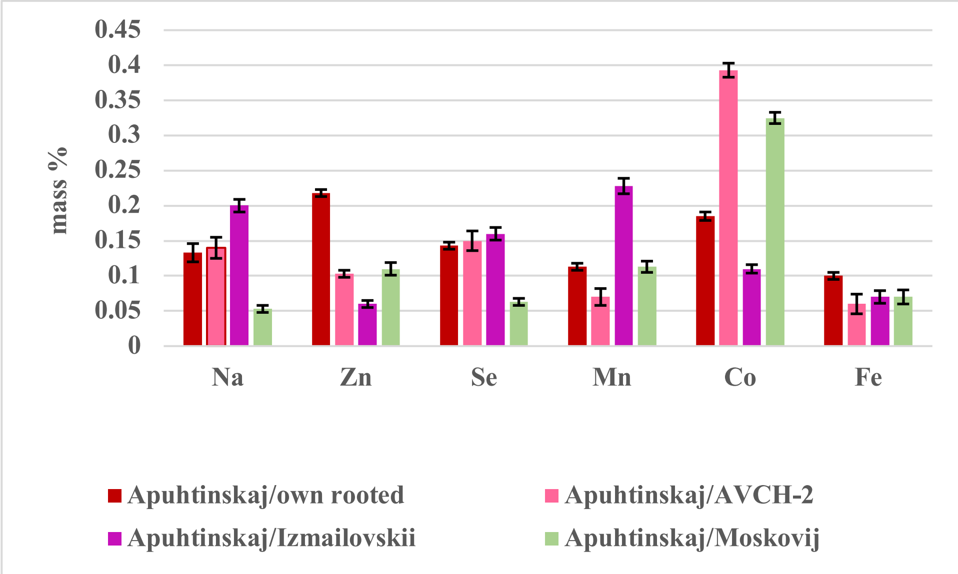

Figure 5 The content of Na, Zn, Se, Mn, Co and Fe in the cherry fruits of Apuchtinskaya on different stocks.

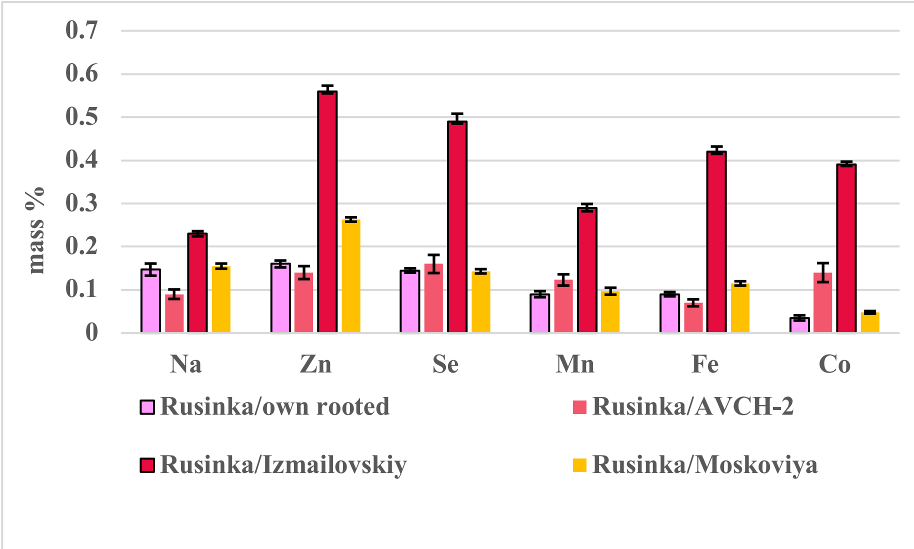

Figure 6 The content of Na, Zn, Se, Mn, Co, and Fe in the cherry fruits of Rusinka on different stocks.

The received data about the content of Ca, Mg, and P in cherry fruits correlate with the data published in the works **(Papp et al., 2008; Kalyoncu, Ersoy and Yılmaz, 2009)**.

High concentrations of K, Mg, and Ca in the fruits of *Laurocerasus officinalis* Roem. and the content of Mn, Fe, and Zn, comparable with our data, are noted in the work **(Kolayli et al., 2003; Mahmood et al., 2012)**.

Usenik et al., (2005) the effects of rootstock on sweet cherry mineral composition (N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Mo, and Zn) was studied in 'Lapins' grafted on ten different rootstocks. The highest influence of rootstock was observed concerning P, K, Mg, and Fe.

P plays a very important role in cell energetics. Mg is necessary for the processes of regeneration and renewal of cells, tissues, and organs. It activates a large number of enzymes that take part in the processes of $CO_2$and N assimilation. In cytosol Mg counter-balances organic compounds (sugars groups, nucleotides, organic and amino acids). Mg is necessary for the keeping up of the cathode-anion balance and pH regulation **(Avtsyn et al., 1991)**.

The content of Na, Zn, Se, Mn, Co, and Fe in the fruits of Apuchtinskaya is given in Figure 5.

Scion-stock combination Apuchtinskaya/Izmaylovskiy is specific in the high content of Na, Se, and Mn. In the fruits of Apuchtinskaya/Moskoviya and Apuchtinskaya/AVCH-2 combinations, the proportion of Co is 0.32 mass %, that shows twice the increase than in the fruits of rooted plants. The content of Fe in the fruits of Apuchtinskaya grafted trees is lower than at roots and does not exceed 0.1 mass %.

The fruits of Rusinka picked up from grafted trees have a richer mineral composition in comparison with rooted plants (Figure 6). Thus, the content of Na is 1.5 – 2 times, Zn – 1.5 times, and Fe – 0.6 times higher. Cherry of the Rusinka variety on the Izmailovsky rootstock has the highest trace element content. The Zn content is 3.2, Se in 2.8, Mn in 2.5, Fe in 3.8, and Co in 8 times higher in comparison with the fruits of rooted trees.

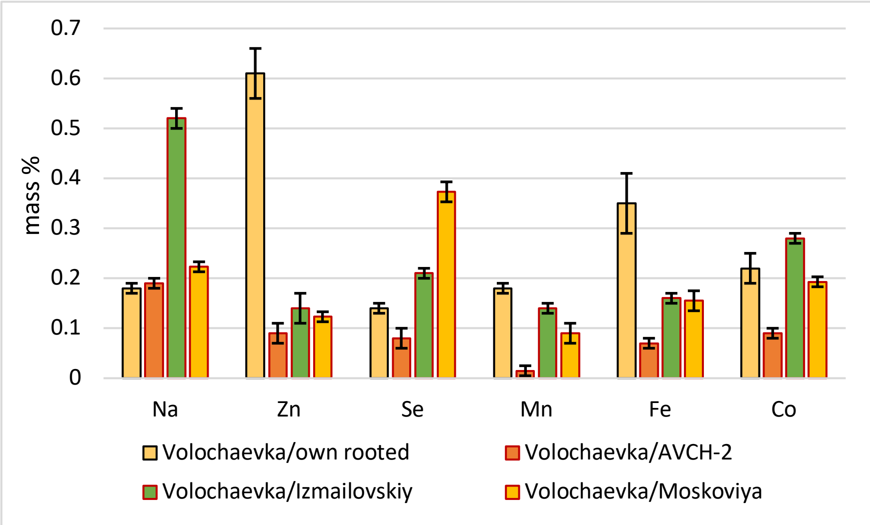

Figure 7 The content of Na, Zn, Se, Mn, Co and Fe in the cherry fruits of Volochaevka on different stocks.

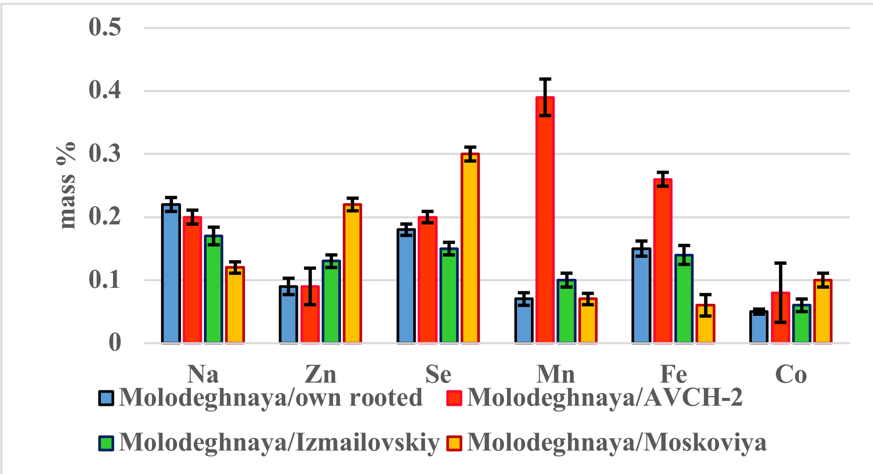

Figure 8 The content of Na, Zn, Se, Mn, Co, and Fe in the cherry fruits of Molodezhnaya on different stocks.

In the cherry fruits of Volochaevka (Figure 7) on stock Izmaylovskiy, the content of Na is 2.5 times and Se and Co – 0.8 times higher; on stock Moskoviya in the fruits, the content of Se is 2.6 times higher than in cherry roots.

Researchers **(Jurikova et al., 2012)** provide data on the low Na content in *Prunus tomentosa* fruits as compared to the Mg and Ca content.

In the fruits of Molodezhnaya (Figure 8) on stock AVCH-2, the content of Mn is 3 times, Fe – 1.5 times higher and the content of Se and Co is insignificant. In the cherry fruits of the scion-stock combination, Molodezhnaya/Moskoviya Zn is accumulated 2 times and Se – 1.5 times higher in comparison with the fruits of rooted trees. Se is one of the most important trace elements. Interest in selenium is mainly due to its powerful antioxidant activity. In the human body, selenium plays an important role in the functioning of the immune system. The work **(Serradilla et al., 2016)** indicates that cherry is a source of Se.

Fe is an essential microelement: it has a respiratory function and makes up hemoglobin and certain enzymes. It plays a role in cell energy, in the processes of oxi-reduction, and the synthesis of nucleic acids; it supports the human body's defense system against the aggressiveness of infectious factors. Assimilating iron is linked to the presence of copper, cobalt, and manganese, as well as to that of vitamins C **(Ismail et al., 2011; Naeem et al., 2017)**.

Mn a microelement that enhances the activity of many enzymes and vitamins of Complex B has beneficial effects on the nervous system reducing irritability and increasing the ability to memorize. Zincum, a microelement essential mainly in the maintenance of reproduction and immune system health **(Slavin and Lloyd, 2012)**. Mn an essential microelement involved, together with Zincum and copper, in some enzymatic processes. Cu, an essential microelement, is involved, together with Zincum and manganese, in numerous enzymatic systems; Co, a microelement that makes up vitamin B12, playing an essential role in the making up of blood red cells and being also known for its vasodilating properties **(Avtsyn et al., 1991; Ishida, 2004)**, was determined in much smaller amounts than Fe, Zn, Mn.

The order of accumulation of elements in fruits according to average data for the same for varieties Rusinka and Apuchtinskaya and has the form: K > P > Mo > Mg > Ca > Mn > Zn > Se > Co > Na > Fe. In the fruits of varieties Molodezhnaya and Volochaevka, the order is different.

In the fruits Molodezhnaya – K > P > Mo > Mg > Ca > Na > Se > Fe > Zn > Mn > Co.

Table 2 Table 2: Correlation coefficient between 11 trace elements matrix for the 11 elements in the ash pollen of cherry fruits.

Elements	K	P	Mo	Mg	Ca	Na	Mn	Fe	Si	Zn	Co
K	1	0.53	0.55	0.63	0.29	0.01	-0.41	-0.01	-0.01	-0.04	0.05
P		1	0.84	0.54	0.32	-0.09	-0.46	-0.48	-0.51	-0.55	-0.42
Mo			1	0.59	0.39	-0.52	1	-0.22	-0.50	-0.25	-0.19
Mg				1	0.78	0.09	-0.05	-0.3	-0.08	-0.42	-0.11
Ca					1	-0.42	0.14	-0.03	0.29	-0.34	0.18
Na						1	0.23	-0.14	0.15	-0.19	-0.02
Mn							1	0.61	0.56	0.17	0.75
Fe								1	0.38	0.73	0.53
Si									1	-0.01	0.58
Zn										1	0.12
Co											1

In the fruits Volochaevka – K > P > Mo > Mg > Ca > Zn > Na > Se > Fe > Co > Mn. The genotypes we studied to be important sources of nutritive minerals. Thus, cornelian cherry consumption can contribute to a well-balanced diet. The varietal differences in the accumulation of mineral elements in fruits of different cherry varieties on different rootstocks that we established are consistent with the data available in the scientific literature, for example, research by **(Gozlekci et al., 2017)**, have found that the order of accumulation of nutritive minerals depending cherry genotypes. In the article, they give the following series of accumulation of elements K > Ca > P > Mg > Na > Fe > Mn > Zn > Cu. In the article **(Mitić et al., 2012)** cherry cultivars were analyzed using inductively coupled plasma optical emission spectrometry. The four elements are very abundant (K, Na, Ca, and Mg), and four are not abundant (Cu, Fe, Mn, and Zn). The order of the content of these elements in fruits of two cherry varieties is K > Mg > Ca > Na > Fe > Zn > Mn.

Calculated correlation coefficients between elements (Table 2).

There is a high correlation between elements, for example, P and Mo (r = 0.84); Mg and Ca (r = 0.78) and Mo and Mn (r = 1).

The mean correlation is between K and Mg (r = 0.63); Mn and Fe (r = 0.61); Mo and Mg (r = 0.59); Si and Co (r = 0.58); Mn and Si (r = 0.56); K and Mo (r = 0.55); P and Mg (r = 0.54); K and P and Fe and Co (r = 0.53); Mo and Na (r = 0.52).

Weak correlation found between Mo and Ca (r = 0.39); P and Ca (r = 0.32); K and Ca and Ca and Si (r = 0.29); Na and Si (r = 0.25); Na and Mn (r = 0.23); Ca and Mn (r = 0.14).

CONCLUSION

The results of 11 mineral element accumulation that characterizes the micronutrient composition of cherry (*Prunus cerasus* Mill.) fruits depending on the used scion-stock combination and on rooted plants are presented in the present paper. As a result of the researches, the influence of a cultivar and a stock on micro- and macroelements accumulation was determined and the limits of their content change depending on the used stock were stated. The most proportion of mineral elements in cherry fruits belongs to K. The variation coefficient of K is low (V %) 1.37 – 6.91 for the majority of scion-stock combinations that show a stable intake of this element in the fruits. Descending series of the content of the elements under study is the following: K > P > Mo > Mg > Ca > Na > Zn > Se > Mg > Zn > Se > Mn > Fe > Co.

Stocks Izmaylovskiy and AVCH-2 conduced high accumulation of P and Mo in Molodezhnaya, Volochaevka, and Rusinka and higher accumulation of Zn, Se, Mn, and Fe in the fruits of Rusinka and Molodezhnaya in comparison with the content of these elements in the fruits of rooted plants and on other stocks. The fruits of Apuchtinskaya on stock Izmaylovskiy are specific in a higher content of Na and Mn in comparison with rooted trees fruits and Co, Zn, and Se on stocks AVCH-2 and Moskoviya. Using the data of laboratory researches it can be stated that the optimal stocks that conduce mineral elements accumulation in the fruits of Rusinka, Volochaevka, and Molodezhnaya are Izmaylovskiy and AVCH-2. In the fruits of roots trees, the content of elements is minimal. In the fruits of Apuchtinskaya on rooted plants, macro- and microelement composition of all elements under study is richer than on scion-stock combinations. In the fruits of Apuchtinskaya on rooted plants, macro- and microelement composition of all elements under study is richer than on scion-stock combinations. The results give new information about the influence of a stock on the formation of cherry fruits mineral composition and confirm that fresh cherry fruits can be additional sources of macro and micronutrients.

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