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Potassium dynamics in orchard soil and potassium status of sour cherry trees affected by soil nutritional conditions

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ABSTRACT

The influence of mineral fertilizers on the seasonal dynamics of exchangeable potassium in the soil, potash status and productivity of trees was studied in field experiment with sour cherry trees cv. 'Turgenevka' in soil-climatic condition of Central Russian upland in 2018-2019. The urea and potassium sulfate were applied annually in early spring at doses of N30K40, N60K80, N90K120, and N120K160 kg/ha. The potassium level in soil-plant system depended on weather conditions, the doses of fertilizers and uptake of the element by trees. The reserves of exchangeable potassium in loamy Haplic Luvisol at the level of 100-200 mg/kg were sufficient to ensure the sour cherry yield in the start of fruiting. Fertilization by doses of N60K80 and higher increased the content of exchangeable potassium in root zone (more than 200 mg/kg), but the features of potassium seasonal dynamics were similar to unfertilized plots. With increase in the average fruit load from 4.6 (2018) to 8.3 (2019) kg/tree, the uptake of potassium by young trees increased, which led to a significant decrease in the concentration of potassium in the soil and leaves during the fruit development period (June and July). Fertilization reduced this effect but did not significantly influence on the productivity of trees and fruit potassium status.

Keywords: sour cherry, Haplic Luvisol, exchangeable potassium, leaf and fruit potassium content, tree productivity

INTRODUCTION

Among the nutrients, that fruit trees absorb from the soil, potassium is the second most important element after nitrogen in terms of nutrition and fertilization of orchards. Potassium is involved in vital physiological processes and has a positive impact on various aspects of fruit quality and productivity of fruit trees (Szűcs, 2003; Shen et al., 2018; Rather et al., 2019; Yener and Altuntaş, 2020; Kuzin et al., 2020). According to modern concepts, the uptake of potassium by plants and potassium transport within the tree are complex processes that are strictly regulated by large groups of specific genes (Shin, 2014).

Both deficiency and excess of potassium can lead to an imbalance of physiological processes in fruit trees and reduce their productivity. Potassium is removed from orchards with fruits and pruned shoots. As a result, the potash reserves in the soil are depleted and must be replenished in order for trees to maintain sufficient potash status. A significant decrease of exchangeable potassium reserves in the soil and the yield of fruit trees can occur after 6-8 years of growing without fertilization (Gomand, 2018; Haberman et al., 2019). On the other hand, the doses of potash fertilizers are often many times higher than the need of plants. In addition, various forms of potassium in the soil are in dynamic equilibrium, and its exchangeable forms can be released from non-exchangeable fractions and make a significant contribution to the soil balance of potassium (Zörb, 2014; Balík et al., 2019). Unused potash is adsorbed by the soil exchange complex or moved below the root zone, especially in soils with low cation exchange capacity (Öborn et al., 2005).

The rates of potassium fertilizers application depend on the needs of trees and the efficiency of potassium uptake by plants. Soil analysis alone does not provide information about the nutritional needs of fruit trees.

Fruit trees may have visible symptoms of potassium deficiency even with a high content of exchangeable potassium in the soil (Debnath et al., 2017). Therefore, it is necessary to combine the soil tests with leaf chemical analysis (Milošević and Milošević, 2020).

Stone trees, including cherries, have variable nutrient requirements throughout the growing season. Knowledge of this dynamics is important for improving the diagnosis of potash nutrition and improving the effectiveness of potash fertilizers in site-specific conditions.

Currently, there is not enough information about the application of potash fertilizers in sour cherry orchards in soil-climatic condition of East European Plain. The purpose of the research was to study the influence of soil applied mineral fertilizers on the seasonal dynamics of exchangeable potassium in the soil, potash status of leaves and fruits and productivity of sour cherry trees.

MATERIAL AND METHODS

Experimental site and design

The field experiment was conducted at the experimental site of the Russian Research Institute of Fruit Crop Breeding, located in the forest-steppe zone of the Central Russian upland (Orel region), Russia (53°00'09.5"N, 36°04'19.1"E) in 2018-2019. The climate is moderately continental with an average annual temperature of 5.5 °C and an average annual precipitation of 450-550 mm. Soil is classified as Haplic Luvisol (IUSS Working Group WRB, 2015). Agrochemical characteristics of the soil before planting the orchard are presented in Table 1.

The experiment was conducted with sour cherry trees cv. 'Turgenevka' on *Prunus mahaleb* rootstock. The trees were planted in 2015 at a distance of 3 m in rows and 5 m between the rows. The experimental treatments: 1. Without fertilizers (control); 2. N30K40; 3. N60K80; 4. N90K120; 5. N120K160 kg/ha. The experiment was laid out in three repetitions with a randomized arrangement of plots with 4 accounting trees in each plot. The soil management: in the rows of trees – treatments by herbicides, but in the interrows ploughing was applied. Fertilizers in the form of urea (46% N) and potassium sulfate (52% K_2O) were used in experiment since 2017. The fertilization carried out annually in early spring (April) to a depth of 10-15 cm in a 2.2 m wide strip with the center in a row of trees.

Soil sampling and analysis

Soil samples were collected in a row between trees in the subcronal zone at a distance of 1.0-1.2 m from the tree trunk in layers from a depth of 0-20, 20-40 and 40-60 cm five times during the growing season, i.e. in May, June, July, August and September. The average soil samples were made of three-point samples. Exchangeable potassium was extracted from air-dried soil samples by 0.2 mol/dm^3 HCl solution at 1:5 soil:solution ratio (Mineyev, 2001). The suspension was shaken for 1 min on a horizontal shaker and was filtered in 15 min after shaking. Potassium content in extracts was measured by Sherwood 410 flame photometer.

Plant sampling and analysis

Fruit samples were taken at harvest, and leaf samples were taken 3 times during the growing season in June,

Table 1. Soils chemical properties

Soil depth (cm)	pH_{KCl}	Organic matter (%)	Easily Hydrolysable N	Available P	Exchange K	Exchange Ca	Exchange Mg
			mg/kg			mmol/100g	
0-20	5.8±0.11	2.8±0.10	108±1.6	383±9.4	120±7.8	15.0±0.12	4.4±0.08
20-40	5.7±0.07	2.6±0.05	98±3.9	308±16.2	86±8.1	15.5±0.10	4.6±0.10
40-60	5.7±0.11	2.0±0.08	76±17.1	118±15.9	54±14.8	14.7±0.20	4.8±0.10

July, and August. From each plot around the trees, 40 fully developed leaves were collected from the middle part of the annual shoots. Leaves were dried at room temperature for a week and then in a drying chamber for 6 hours at 40 °C. Then all the plant material was homogenized. The dry leaf material was burned to ash in a muffle furnace at a temperature of 450 °C. The ash was dissolved in 20% HCl and the potassium content was determined in the resulting solution. The mixed fruit samples (~1000 g) were taken from each plot. From these samples, small portions of whole fruits (22-26 g each) were randomly weighed and dried at a temperature of 70 °C in a drying chamber for about 96 hours. Then the analysis was performed similarly to the leaf samples. The determination of potassium in ash solution was performed by Sherwood 410 flame photometer.

Fruit weight and yield

The weight of a single fruit was estimated from a sample of 200 randomly selected fruits. The accounting of fruit harvest was carried out in the first decade of July by weight method considering fruits weight from each experimental tree.

Statistical analysis

Data were subjected to dispersion analysis with Microsoft Office Excel 2007. The means were compared with the LSD test. To determine the relationship between the content of potassium in soil and plants, a Pearson correlation analysis was performed, the statistical significance of which was evaluated by the Student's t-criterion. The confidence interval was calculated using the standard deviation. The significance level for all statistical analyses was 95% ($P<0.05$).

Meteorological conditions

In 2018, the average temperature for May-September period was 17.3 °C, which is 1.9 °C higher than the average annual values. That year, June and August were the driest, while July was very wet. The total amount of precipitation during this period was 226.2 mm, which was 72.2 mm less than the annual average. In 2019, the average temperature was 16.6 °C, i.e. 1.2 °C higher than the average annual level. The total amount of precipitation during five months was 260 mm. In May, the largest amount of precipitation fell (85 mm), and June was the driest (Table 2).

RESULTS AND DISCUSSION

Soil potassium content

The reserves of exchangeable potassium compounds are the main source for stabilizing the potassium level in the soil solution when the element is uptaken by plants (Yakimenko, 2019). The content of exchangeable potassium in the soil of control plots (without fertilizers) during two periods of research vary within 118.6 - 183.6, 81.1-113.9, 46.0-87.1 mg/kg in layers 0-20, 20-40 and 40-60 cm, respectively (Table 3).

Table 2. Monthly and growing season precipitation and temperature in 2018 and 2019

Months	Air temperature (°C)			Precipitation (mm)		
	2018	2019	Normal*	2018	2019	Normal*
May	16.4	15.6	13.0	31.4	85.0	36.4
June	17.0	20.5	16.9	18.2	20.7	65.1
July	19.9	17.4	18.5	119.9	49.8	88.0
August	18.4	17.1	17.1	11.2	54.7	65.7
September	14.9	12.5	11.7	45.5	50.2	43.2
Mean or total	17.3	16.6	15.4	226.2	260.4	298.4

*Normal refers to the long-term average (40-year average, i.e. 1961–2000 period)

Table 3. Seasonal changes of the soil exchangeable potassium content, mg/kg in 2018

Sampling time	Treatments					Mean
	Control	N30K40	N60K80	N90K120	N120K160	
			Depth 0-20 cm			
May	123.6±2.6[a]	175.9±13.4[ab]	228.7±62.6[ab]	270.0±61.3[b]	180.6±18.2[ab]	195.8±27.6
June	171.0±7.3[a]	143.6±2.8[a]	232.8±19.2[ab]	281.9±130.4[b]	212.0±6.4[ab]	208.3±31.9
July	182.3±13.1[a]	178.4±54.3[a]	232.5±12.2[ab]	303.6±100.3[b]	227.1±17.5[ab]	224.8±28.8
August	125.8±4.0[a]	129.1±4.9[a]	191.2±11.6[ab]	236.2±34.6[b]	162.3±14.9[ab]	168.9±20.1
September	142.0±19.9[a]	149.1±16.7[a]	211.3±22.04[a]	210.4±29.0[a]	202.0±58.8[a]	182.9±19.1
Mean	148.9±11.6[a]	155.9±13.7[ab]	219.3±14.6[bc]	260.4±35.5[c]	196.8±15.6[b]	–
LSD_{05}			Treatments = 43.7 Sampling time × treatments = 106.7			Sampling time 43.7
			Depth 20-40 cm			
May	84.6±15.8[a]	96.1±19.7[a]	111.4±26.7[a]	123.7±51.8[a]	91.0±4.7[a]	101.2±13.0
June	91.6±7.0[a]	93.8±11.6[a]	134.2±24.2[a]	126.6±31.1[a]	120.1±9.0[a]	117.0±10.9
July	99.8±17.7[a]	93.6±12.9[a]	147.6±8.8[b]	133.2±22.8[ab]	109.5±15.5[ab]	114.1±11.2
August	113.9±37.4[a]	81.0±8.2[a]	121.6±18.5[a]	114.8±2.8[a]	120.4±4.9[a]	110.3±10.2
September	97.9±0.5[a]	114.3±8.0[ab]	146.9±14.3[b]	91.3±13.5[a]	95.0±14.5[a]	109.1±10.3
Mean	97.0±9.1[a]	96.9±7.0[a]	132.8±10.0[bc]	117.9±13.4[b]	107.2±7.0[ab]	–
LSD_{05}			Treatments = 20.5 Sampling time × treatments = 45.9			Sampling time NS
			Depth 40-60 cm			
May	46.0±15.5[a]	50.3±9.2[a]	50.6±15.2[a]	98.6±45.4[b]	60.5±6.9[ab]	61.2±12.6
June	70.6±17.3[a]	73.8±6.7[a]	63.8±3.3[a]	72.9±11.5[a]	78.1±4.9[a]	71.8±4.6
July	87.1±1.0[a]	74.5±6.5[a]	68.4±8.3[a]	87.5±4.2[a]	79.6±3.8[a]	79.4±3.9
August	53.5±1.2[a]	47.1±8.8[a]	60.4±3.5[a]	66.6±2.1[a]	68.0±3.4[a]	59.1±4.0
September	71.9±1.3[a]	78.7±32.2[a]	97.0±50.5[a]	54.5±3.0[a]	75.2±14.9[a]	75.5±12.7
Mean	65.8±7.7[a]	64.9±8.8[a]	68.0±11.8[a]	76.0±10.9[a]	72.3±4.8[a]	–
LSD_{05}			Treatments = NS Sampling time × treatments = 44.5			Sampling time 19.9

NS - non significant. In rows, values followed by different letters are significantly different, *P*<0.05, LSD test

According to the gradation for fruit trees (Kondakov, 2006), these values correspond to the medium range (100-200 mg/kg) of potassium concentrations in the soil layer of 0-40 cm and low range (<100 mg/kg) - in the layer of 40-60 cm.

Although the uptake of potassium by sour cherry trees is a continuous process, its maximum occurs during the most important stages of fruit growth and maturation (from mid-May to mid-July).

In 2018, the evaluation of changes in exchangeable potassium content due to plant uptake was difficult because of the low yield of young trees. Regardless of fertilizers, the potassium level in topsoil (0-20 cm) increased from May to July and decreased in August (1.2-1.4 times less than the July level). This may be due to both the uptake of potassium by trees and the increase fixation by the soil after wetting-drying cycles (Shakeri and Abtahi, 2020).

With a higher fruit load in 2019, the lowest content of exchangeable potassium in the soil layer of 0-20 cm was observed in June and July (1.3-1.6 times less than in May). In August and September, the indicator returned to the May level (Table 4). Seasonal dynamics of exchangeable potassium was similar in fertilized and unfertilized plots.

Brunetto et al. (2015) report that the exchangeable potassium content in the topsoil of the pear orchard increased in proportion to the applied doses of potassium fertilizers (40-160 kg/ha). In the experimental sour cherry orchard the level of exchangeable potassium in the soil layer of 0-20 cm was significantly higher, compared with the control, when applying fertilizers in doses of N60K80 or more during two years. However, the indicator values at N60K80, N90K120 and N120K160 treatments did not differ significantly from each other. Signs of potassium migration to deeper soil layers were observed in 2018 in N60K80 and N90K120 treatments, but in 2019 these signs were observed only when N90K120 was applied. When fertilizing with N120K160, there was a tendency to increase the concentration of exchangeable potassium in the layer of 20-60 cm, but the differences with the control were not significant. Perhaps, in this variant, the potassium moved below the root zone. Other researchers also have found an increase of potassium supply in 60 cm soil layer of orchards when applying potash fertilizers in doses 250-300 kg/ha (Ruiz, 2006; Gao et al., 2012; Haberman et al., 2019).

The seasonal fluctuations of potassium level were more evident in upper soil layer, but the changes of potassium content were also observed in deeper layers. In the dry August 2018, the content of exchangeable potassium in the layer of 40-60 cm was significantly lower than in July. This decrease could be related to the increasing of element uptake by roots, because the potassium in parched topsoil became unavailable. In 2019 the lowest potassium content in 20-60 cm layer was at fruiting period (July), when the potassium requirement of trees was the highest.

Leaf and fruit potassium concentration

The content of potassium in sour cherry leaves during 2 years varied within 0.70-1.09% DW (Table 5). The values of the indicator were below the range of optimal potassium concentration in leaves, which for fruit-bearing cherry trees is 1.1-1.8% (Semenyuk, 1983).

The seasonal dynamics of potassium accumulation in leaves depended on fruit load and weather conditions. For 2 years the highest potassium content in leaves was in June. Apparently, in the early stages of fruit development, the intake of potassium from the soil and storage organs was sufficient to meet the needs of growing fruits, so the leaves contained more potassium. In 2018, under contrasting humidification conditions and a lower fruit load, the potassium content in the leaves was stable both during fruit maturation and after harvesting. The lack of moisture in August could limit the uptake of potassium by the roots, but the content of the element in the leaves this month was at the level of June and July. It is possible that potassium was transferred to the leaves from the root reserve (Ferreira, 2018). The supply of potassium during this period is important for fruiting in following year, since after fruit harvest cherry trees begin to differentiate fruit buds, which require a sufficient amount of nutrients.

Table 4. Seasonal changes of the soil exchangeable potassium content, mg/kg in 2019

Sampling time	Treatments					Mean
	Control	N30K40	N60K80	N90K120	N120K160	
			Depth 0-20 cm			
May	182.8±6.20[a]	205.1±26.7[a]	243.5±36.7[a]	244.0±58.7[a]	205.5±34.0[a]	216.2±18.2
June	136.5±38.5[a]	138.8±2.6[a]	185.3±29.9[a]	212.1±32.7[a]	151.5±36.6[a]	164.8±18.0
July	118.6±22.3[a]	172.0±12.2[a]	198.9±53.9[a]	182.4±8.8[a]	175.8±10.8[a]	169.5±16.3
August	183.6±22.6[a]	207.0±37.7[a]	214.9±59.8[a]	230.6±55.8[a]	248.5±60.7[a]	216.9±22.0
September	171.2±21.2[a]	234.5±30.3[a]	222.5±68.3[a]	222.9±16.5[a]	207.3±4.6[a]	211.7±17.2
Mean	158.5±15.3[a]	191.5±17.9[ab]	212.7±22.4[b]	218.4±18.5[b]	198.3±20.2[b]	–
LSD_{05}			Treatments = 39.6			Sampling
			Sampling time × treatments = NS			time
						39.6
			Depth 20-40 cm			
May	93.8±12.9[a]	113.6±10.6[ab]	139.1±15.0[ab]	176.5±69.8[b]	109.4±9.4[ab]	126.5±18.6
June	98.6±14.3[a]	142.3±3.4[a]	137.8±51.8[a]	164.4±92.6[a]	153.8±39.2[a]	139.4±22.6
July	81.1±12.7[a]	104.8±9.1[a]	104.4±26.2[a]	112.8±16.1[a]	91.5±10.3[a]	98.9±8.1
August	99.8±15.7[a]	111.4±1.3[a]	101.4±44.1[a]	143.5±5.3[a]	109.4±24.6[a]	113.1±11.8
September	97.0±2.80[a]	102.2±11.0[a]	116.0±27.7[a]	119.9±21.7[a]	108.0±12.6[a]	108.6±9.0
Mean	94.1±5.8[a]	114.9±7.2[ab]	119.7±15.8[ab]	143.4±22.4[b]	114.4±14.0[ab]	–
LSD_{05}			Treatments = 33.9			Sampling
			Sampling time × treatments = 75.9			time
						33.9
			Depth 40-60 cm			
May	77.3±20.7[a]	101.9±2.7[a]	87.5±4.8[a]	83.6±38.6[a]	92.9±4.7[a]	88.6±8.7
June	66.2±18.1[a]	95.2±21.9[a]	79.9±27.5[a]	115.3±74.1[a]	129.7±71.1[a]	97.3±22.1
July	58.4±12.3[a]	65.0±7.0[a]	81.3±14.7[a]	71.8±4.8[a]	70.7±6.5[a]	69.4±5.2
August	79.1±17.5[a]	73.6±3.7[a]	78.5±15.4[a]	81.4±16.4[a]	87.4±25.8[a]	80.0±6.8
September	61.9±17.7[a]	79.7±4.1[a]	74.9±20.3[a]	86.2±17.0[a]	76.3±3.0[a]	75.8±6.2
Mean	68.6±7.7[a]	83.1±7.5[a]	80.4±7.4[a]	87.7±16.8[a]	91,4±21.8[a]	–
LSD_{05}			Treatments = NS			Sampling
			Sampling time × treatments = NS			time
						NS

NS - non significant. In rows, values followed by different letters are significantly different, *P*<0.05, LSD test

Table 5. Seasonal changes of leaf potassium content (% DW) (2018-2019)

Treatments	Sampling time			Mean
	June	July	August	
		2018		
Control	0.89±0.14^{a}	0.94±0.10^{a}	0.86±0.07^{a}	0.90±0.06^{a}
N30K40	1.04±0.13^{ab}	1.04±0.18^{a}	0.94±0.16^{a}	1.01±0.09^{b}
N60K80	1.03±0.21^{ab}	1.03±0.20^{a}	0.90±0.16^{a}	0.99±0.11^{ab}
N90K120	1.07±0.09^{b}	1.03±0.08^{a}	0.94±0.09^{a}	1.01±0.05^{b}
N120K160	1.00±0.03^{ab}	0.99±0.03^{a}	0.92±0.03^{a}	0.97±0.02^{ab}
Mean	0.95±0.06^{ab}	0.96±0.06	0.89±0.05	–
LSD_{05}		Sampling time = 0.07		Treatments
		Sampling time × treatments = 0.17		0.10
		2019		
Control	0.93±0.12^{a}	0.70±0.06^{a}	0.70±0.06^{a}	0.77±0.07^{a}
N30K40	1.09±0.21^{a}	0.94±0.19^{b}	0.83±0.15^{a}	0.95±0.11^{bc}
N60K80	1.06±0.24^{a}	0.82±0.28^{ab}	0.80±0.24^{a}	0.89±0.15^{b}
N90K120	1.04±0.13^{a}	0.81±0.05^{ab}	0.73±0.14^{a}	0.86±0.09^{ab}
N120K160	1.02±0.14^{a}	0.78±0.06^{ab}	0.65±0.08^{a}	0.82±0.09^{ab}
Mean	1.03±0.07	0.81±0.07	0.74±0.06	–
LSD_{05}		Sampling time = 0.08		Treatments
		Sampling time × treatments = 0.18		0.11

In columns, values followed by different letters are significantly different, *P*<0.05, LSD test

In 2019, when the fruit load was 1.4-2.2 times higher than in 2018, there was a significant decrease (1.16-1.33 times on average) in the potassium concentration in leaves in July, which was especially noticeable for non-fertilized trees (Table 5). The decrease foliar potassium with increasing yield was also found for pear and apple (Brunetto et al., 2015; Kuzin et al., 2020). This is due to the redistribution of potassium between leaves and fruits with intensive growth of the latter and the accumulation of sugars. In 2019, there was a significant correlation between the potassium content in June leaves and fruits (R^2=0.338 at $P<0.05$) (Figure 1A). This may be connected to the important role of potassium in the processes of sugar synthesis and transport from leaves to fruits (Shen et al., 2018). In August, leaf potassium concentration decreased even more compared to June (by 1.32-1.55 times).

The potassium content in leaves does not depend solely on its content in the soil, since potassium can migrate through the plant and redistribute between different organs (Ferreira, 2018). Only in 2018, a significant correlation between the May content of exchangeable potassium in the soil (average in 0-40 cm layer) and leaf potassium content in June was observed (R^2=0.448 at $P<0.05$) (Figure 1B).

It was found that the potassium content in cherry leaves increases significantly when potassium fertilizers are applied to the soil with the low potassium content (Callan and Westcot, 1996). In experimental orchard a significant increase of leaf potassium content was observed each year as a function of fertilization. In 2018, the treatments by N30K40 and N90K120 lead to rise of potassium status (by 0.11% dry matter), and in 2019 similar effect occurred as a result of treatments with N30K40 and N60K80 (by 0.18 and 0.12% DW, respectively).

Fertilization did not significantly affect the potassium content of the fruit, with the exception of the treatment with N90K120 in 2018, where the potassium content was 12% higher than in the control (Table 6), which is consistent with the results by Uçgun (2019). In 2018, when fruit load was lower, a statistically significant correlation was found between the fruit potassium content and the soil potassium content at 20-40 cm layer in June (R^2=0.647 at P<0.05) (Figure 1C).

Fruit weight and yield

Fruit weight varied in the range from 4.79-5.31 g in 2018 to 4.38-4.61 g in 2019 (Table 7). The values of the indicator were lower in the year with higher productivity (in 2019), which is consistent with the results of other studies (Neilsen and Neilsen, 2014). Also in 2019, there was a correlation between the weight of the single fruit and the June level of potassium in 0-60 cm soil layer (R^2=0.594 at P<0.05) (Figure 1D).

Table 6. Fruit potassium content (mg/100g FW) (2018-2019)

Treatments	2018	2019	Mean
Control	172.03±4.56[a]	189.35±5.70[a]	180.69±5.61[a]
N30K40	175.76±10.50[ab]	190.01±8.56[a]	182.88±7.85[a]
N60K80	180.55±6.64[ab]	181.87±15.05[a]	181.21±6.90[a]
N90K120	193.01±11.91[b]	174.06±14.73[a]	183.53±10.64[a]
N120K160	172.05±8.09[a]	178.78±8.30[a]	175.41±5.94[a]
Mean	178.70±4.30	182.80±5.13	–
LSD_{05}	Years= NS		Treatments
	Years × treatments =19.04		NS

NS - non significant. In columns, values followed by different letters are significantly different, P<0.05, LSD test

Table 7. Fruit weight and fruit yield of cv. 'Turgenevka' sour cherry trees (2018-2019)

Treatments	Fruit weight, g		Fruit yield, kg/tree	
	2018	2019	2018	2019
Control	5.15±0.10[a]	4.38±0.31[a]	4.38±0.55[a]	8.24±1.60[a]
N30K40	4.98±0.36[a]	4.49±0.18[a]	4.26±0.70[a]	8.46±3.52[a]
N60K80	5.07±0.08[a]	4.61±0.10[a]	3.90±1.25[a]	8.67±2.17[a]
N90K120	4.79±0.06[a]	4.58±0.13[a]	5.12±1.68[a]	7.01±1.72[a]
N120K160	5.31±0.26[a]	4.53±0.42[a]	5.38±0.64[a]	9.33±2.41[a]

NS - non significant. In columns, values followed by different letters are significantly different, P<0.05, LSD test

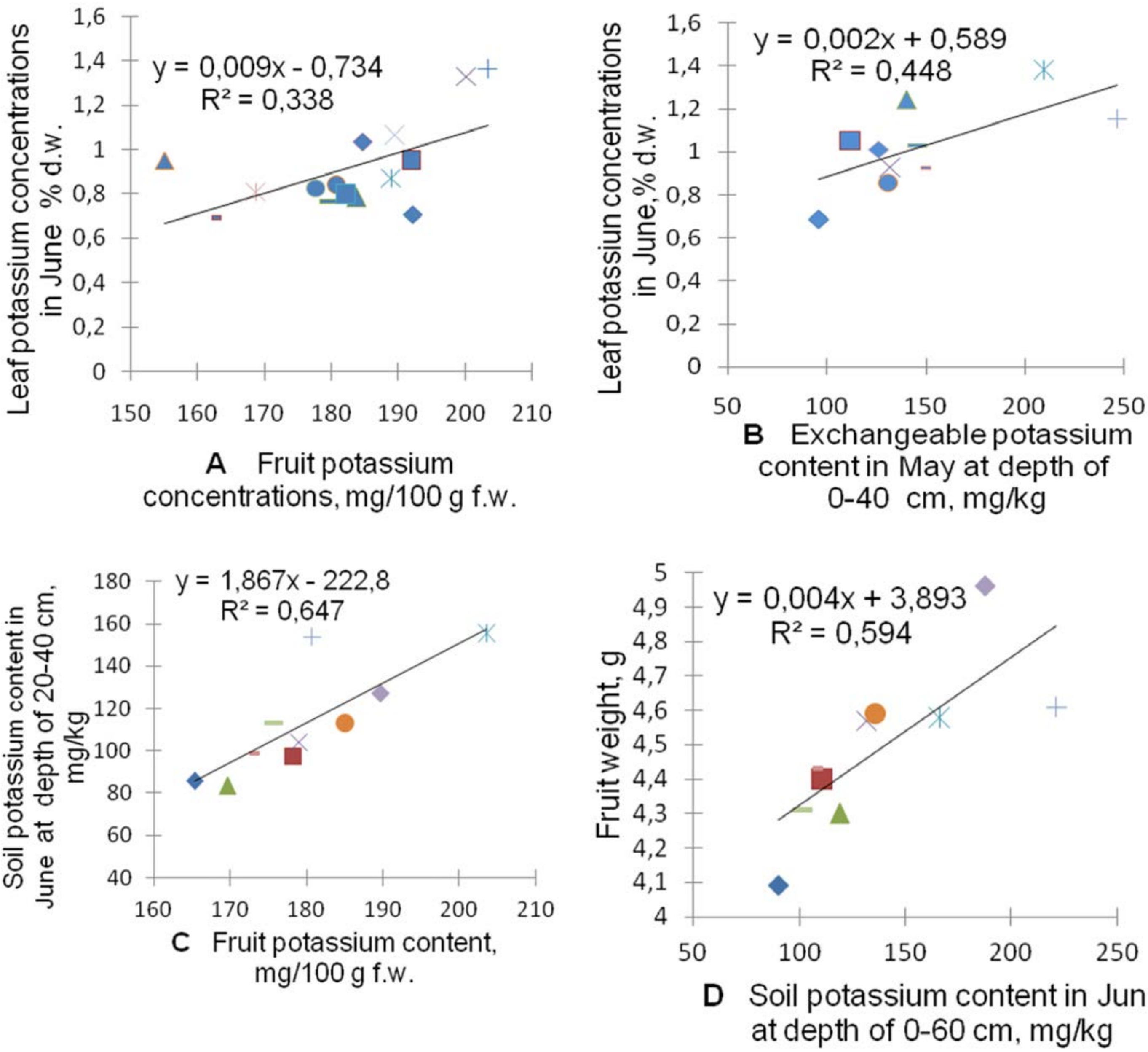

Figure 1. Relationship between the content of: (A) - potassium in leaves and fruits in June (2019); (B) - exchangeable potassium in the soil at depth 0-40 cm in May and potassium in leaves in June (2018); (C) - exchangeable potassium in the soil at depth 20-40 cm in June and potassium in fruits (2018); (D) - exchangeable potassium in the soil at depth 0-60 cm in June and fruit weight (2019)

Sour cherry productivity varied between 3.9-5.38 in 2018 and 7.01-9.33 kg/tree in 2019 (Table 7). When fertilizer was applied in doses of N120K160, the productivity was 22% and 13% higher than the control in 2018 and 2019, respectively, but these differences were not statistically significant.

The insignificant influence of potash fertilizers on the productivity of sour cherry trees and the potash status of fruits and leaves may be connected to the sufficient content of exchangeable potassium in the soil. Annual potassium uptake by 13-year-old cherry trees may be 16-47 kg/ha (Roversi and Monteforte, 2006). In the soil of the experimental site, the reserves of exchangeable potassium in the 0-20 cm layer of non-fertilized plots during vegetation periods varied from 295 to 439 kg/ha, which is significantly more than the needs of 3-4-year-old cherry trees. With increasing age of the trees, the efficiency of potassium fertilizer may rise. Information about increase in the yield of the cherry trees (Szűcs, 2003; Podsiadlo and Jaroszewska, 2013) and other fruit crops (Nava and Dechen, 2009; Rather et al., 2019; Sete et al., 2020) under the influence of potassium fertilization relate to the trees at the age of 10-20 years, grown on low potassium soils (Dbara et al., 2016; Shen et al., 2018).

CONCLUSION

The purpose of the research was to study the influence of soil applied mineral fertilizers on the seasonal dynamics of exchangeable potassium in the soil, potash status of leaves and fruits and productivity of sour cherry trees. The results showed that the reserves of exchangeable potassium in loamy Haplic Luvisol at the level of 100-200 mg/kg were sufficient to ensure the sour cherry yield in the start of fruiting. Fertilization by doses of N60K80 and higher increased the content of exchangeable potassium in the soil but had little effect on the potash status of trees. With a twofold increase in the fruit load, the uptake of potassium by plants increased, which led to a significant decrease in the concentration of potassium in the soil and leaves during the fruit development. Fertilization reduced this effect but did not significantly influence on the productivity of trees.

REFERENCES

Balík, J., Černý, J., Kulhánek, M., Sedlář, O., Suran, P. (2019) Balance of potassium in two long-term field experiments with different fertilization treatments. Plant Soil Environment, 65, 225-232. DOI: https://doi.org/10.17221/109/2019-PSE

Brunetto, G., Nava, G., Ambrosini, V.G., Comin, J.J., Kaminski, J. (2015) The pear tree response to phosphorus and potassium fertilization. Revista Brasileira de Fruticultura, 37 (2), 507-516. DOI: https://doi.org/10.1590/0100-2945-027/14

Callan, N.W., Westcott, M.P. (1996) Drip irrigation for application of potassium to tart cherry. Journal of Plant Nutrition, 19 (1), 163–172. DOI: https://doi.org/10.1080/01904169609365114

Dbara, S., Gader, T., Mimoun, M. B. (2016) Improving yield and fruit quality of peach cv. 'Flordastar' by potassium foliar spray associated to regulated deficit irrigation. Journal of New Sciences, 28 (10), 1631-1637. Available at: https://www.jnsciences.org/component/content/article.html?id=157:improving-yield-and-fruit-quality-of-peach-cv-flordastar-by-potassium-foliar-spray-associated-to-regulated-deficit-irrigation [Accessed 5 April 2021]

Debnath, S., Attri, B.L., Kumar, A., Bhat, S.C., Kishor, A., Narayan, R., Singh, D.B. (2017) Relationship among different forms of soil potassium and availability as influenced by the contrasting management practices in apple (*Malus domestica* Borkh.) orchards of Kumaon region. All Interentional Quarterly Journal of life sciences, 12 (1), 477-484. Available at: http://krishi.icar.gov.in/jspui/handle/123456789/14142 [Accessed 5 April 2021]

Ferreira, I.Q., Arrobas, M., Moutinho-Pereira, J., Correia, C., & Rodrigues, M.Â. (2018) Olive response to potassium applications under different water regimes and cultivars. Nutrient Cycling in Agroecosystems, 112 (3), 387-401. DOI: https://doi.org/10.1007/s10705-018-9954-2123456789

Gao, Y., Tong, Y., Lu, Y., Ma, H. (2012) Effect of long-term application of nitrogen, phosphorus and potassium on apple yield and soil nutrient accumulation and distribution in orchard soil of Loess Plateau. Journal of Fruit Science, 29 (3), 322-327. (in Chinese)

Gomand, A., Vercammen, J., Siongers, V., Bylemans, D. (2018) Multiyear field trials to balance the nutrition of nitrogen and potassium for 'Conference' pear. Acta Horticulture, 1217, 239-246. DOI: https://doi.org/10.17660/ActaHortic.2018.1217.30

Haberman, A., Dag, A., Shtern, N., Zipori, I., Erel, R., Ben-Gal, A., Yermiyahu, U. (2019) Long-term impact of potassium fertilization on soil and productivity in intensive olive cultivation. Agronomy, 9 (9), 525. DOI: https://doi.org/10.3390/agronomy9090525

IUSS Working Group WRB (2015) World Reference Base for Soil Resources 2014 (update 2015). International Soil Classification System for Naming Soils and Creating Legends for Soil Maps. World Soil Resources Reports No. 106. Rome: Food and Agriculture Organisation. Available at: http://www.fao.org/soils-portal/soil-survey/soil-classification/world-reference-base/en/ [Accessed 10 April 2021]

Kondakov, A.K. (2006) Fertilizing Fruit Trees, Berry-Fields, Nurseries and Flower Crops. Michurinsk, Russia (In Russian)

Kuzin, A.I., Kashirskaya, N.Y., Kochkina, A.M., Kushner, A.V. (2020) Correction of Potassium Fertigation Rate of Apple Tree (*Malus domestica* Borkh.) in Central Russia during the Growing Season. Plants, 9 (10), 1366. DOI: https://doi.org/10.3390/plants9101366

Milošević T., Milošević N. (2020) Chapter 41 - Soil fertility: Plant nutrition vis-à-vis fruit yield and quality of stone fruits. In: Srivastava, A.K., Chengxiao, Hu (eds.). Fruit Crops. Diagnosis and Management of Nutrient Constraints. Elsevier, 583-606. DOI: https://doi.org/10.1016/B978-0-12-818732-6.00041-1

Mineev, V.G., Sychev, V.G., Amelyanchik, O.A., Bolycheva, T.N., Gomonova, N.F., Durynina, E.P., Yegorov, V.S., Yegorova, E.V., Edemskaya, N. L., Karpova, E.A., Prygukova, V.G. (2001) Educational Aid on Agricultural Chemistry. 2nd Edition. Moscow: Publishing House of Lomonosov Moscow State University, pp. 168-171, 356-357, 410-411. (In Russian)

Nava, G., Dechen, A.R. (2009) Long-term annual fertilization with nitrogen and potassium affect yield and mineral composition of 'Fuji' apple. Scientia Agricola, 66 (3), 377-385. DOI: http://dx.doi.org/10.1590/S0103-90162009000300013

Neilsen, G.H., Neilsen, D., Kappel, F., Forge, T. (2014) Interaction of irrigation and soil management on sweet cherry productivity and fruit quality at different crop loads that simulate those occurring by environmental extremes. HortScience, 49 (2), 215-220. DOI: https://doi.org/10.21273/HORTSCI.49.2.215

Öborn, I., Andrist-Rangel, Y., Askekaard, M., Grant, C.A., Watson, C.A., Edwards, A.C. (2005) Critical aspects of potassium management in agricultural systems. Soil Use and Management, 21 (1), 102-112. DOI: https://doi.org/10.1111/j.1475-2743.2005.tb00114.x

Podsiadlo, C., Jaroszewska, A. (2013) Effect of irrigation and fertilization of nitrogen and potassium on photosynthetic activity of cherry. Infrastructure and ecology of rural areas, 2 (I), 93-101. (in Polish)

Rather, G.H., Bansal, S.K., Bashir, O., Waida, U. (2019) Impact of potassium nutrition on fruit yield and physico-chemical characteristics of apple cultivar Red Delicious. Indian Journal of Fertilisers, 15 (7), 790-797. Available at: https://www.ipipotash.org/uploads/abstracts/pdf/impact-potassium-nutrition-on-fruit-yield-and-characteristics-of-apple-ijf2019.pdf [Accessed 10 April 2021]

Roversi, A., Monteforte, A. (2006) Preliminary results on the mineral uptake of six sweet cherry varieties. Acta Horticulture, 721, 123-128. DOI: https://doi.org/10.17660/ActaHortic.2006.721.15

Ruiz, R. (2006) Effects of different potassium fertilizers on yield, fruit quality and nutritional status of Fairlane nectarine trees and on soil fertility. Acta Horticulture, 721, 185-190. DOI: https://doi.org/10.17660/ActaHortic.2006.721.24

Semenuk, G.M. (1983) Diagnostics of mineral nutrition of stone fruit crops with the use of information retrieval systems (2nd Edition). Stiinza, Kishinev, 323 p. (in Russian)

Sete, P.B., Ciotta, M.N., Nava, G., Stefanello, L.D.O., Brackmann, A., Berghetti, M.R.P., Cadoná, E.A., Brunetto, G. (2020) Potassium fertilization effects on quality, economics, and yield in a pear orchard. Agronomy Journal, 112 (4), 3065-3075. DOI: https://doi.org/10.1002/agj2.20235

Shakeri, S., Abtahi A. (2020) Potassium fixation capacity of some highly calcareous soils as a function of clay minerals and alternately wetting-drying. Archives of Agronomy and Soil Science, 66 (4), 445-457. DOI: https://doi.org/10.1080/03650340.2019.1619176

Shen, C., Li, Y., Wang, J., Al Shoffe, Y., Dong, C., Shen, Q., Xu, Y. (2018) Potassium influences expression of key genes involved in sorbitol metabolism and its assimilation in pear leaf and fruit. Journal of Plant Growth Regulation, 37, 883–895. DOI: https://doi.org/10.1007/s00344-018-9783-1

Shin, R. (2014) Strategies for improving potassium use efficiency in plants. Molecules and cells, 37 (8), 575-584. DOI: https://dx.doi.org/10.14348%2Fmolcells.2014.0141

Szűcs, E. (2003) Nutrient demand of stone fruits. International Journal of Horticultural Science, 9 (2), 19-23. DOI: https://doi.org/10.31421/IJHS/9/2/385

Uçgun, K. (2019) Effects of nitrogen and potassium fertilization on nutrient content and quality attributes of sweet cherry fruits. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 47 (1), 114-118. DOI: https://dx.doi.org/10.15835/nbha47111225

Yakimenko, V.N. (2019) Balance of potassium, yield and potash status of the soil in long-term field experiments in forest-steppe of western Siberia. Agricultural Chemistry, 10, 16-24. DOI: https://doi.org/10.1134/S0002188119100156

Yener, H., Altuntaş, Ö. (2020) Effects of potassium fertilization on leaf nutrient content and quality attributes of sweet cherry fruits (*Prunus Avium* L.). Journal of Plant Nutrition, 44 (7), 946-957. DOI: https://doi.org/10.1080/01904167.2020.1862203

Zörb, C., Senbayram, M., Peiter, E. (2014) Potassium in agriculture-status and perspectives. Journal of Plant Physiology, 171 (9), 656–669. DOI: https://doi.org/10.1016/j.jplph.2013.08.008