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DYNAMICS OF NUTRIENT ELEMENTS IN THE SOIL IN THE CULTIVATION OF DIFFERENT RASPBERRY GENOTYPES

Stanislava ATANASOVA[1], Lubov PLESHKUTSA[1], Maria GEORGIEVA[2], Diyan GEORGIEV[2], Evlogi MARKOV[3]

[1]Trakia University, 6015 Stara Zagora, Bulgaria
[2]Research Institute of Mountain Stockbreeding and Agriculture Troyan, Agricultural Academy of Bulgaria, Sofia, Bulgaria
[3]Institute of Soil Science, Agrotechnologies and Plant Protection "Nikola Pushkarov", Sofia, Bulgaria

Corresponding author email: stanislava.atanasova@trakia-uni.bg

Abstract

The present study follows the dynamics of nutrient elements in the soil of a raspberry plantation during the period of blossoming and fruit harvesting. The scientific experiment was conducted in the period 2018-2020 in a collection plantation of the Research Institute of Mountain Stockbreeding and Agriculture in Troyan with four raspberry genotypes, such as Willamette, Meeker, Samodiva and Magdalena. The soils of the region are gray forest, moderately eroded, low in humus and prone to waterlogging.The content of basic nutrients (nitrogen, phosphorus, potassium), humus and pH in the 0-20 cm and 20-40 cm soil layers was analyzed. The results show that the highest nitrogen content was registered the surface soil layer with 89.77 mg/kg during the blossoming phenophase in 2019.The amount of phosphorus varied widely 2.60-6.20 mg/100 g. The highest potassium content (28.66 mg/100g) was found again in the surface soil layer during blossoming of the 2020 raspberry plants.

Key words: *raspberries, varieties, soils, agrotechnics, nutritional elements.*

INTRODUCTION

Raspberry (*Rubusidaeus* L.) is a fruit species that is widespread on almost all continents because of its plasticity and taste of the fruit. It is widely used in the foot-hill and mountain regions in Bulgaria, such as Troyan, Teteven, Berkovitsa, where soil and climate conditions are largely favorable for its development. In these places, the climate is cool, and soil and atmospheric humidity are higher.

The fruit agrocenosis suffers active anthropogenic impact, which is mainly aimed at increasing yield. At the same time, changes in soil fertility indicators (amount and content of organic matter, activity of accumulation and migration of substances, including nitrate compounds and water-soluble salts) determine soil sustainability as a biosphere component (Maliuk et al., 2020).

Every crop needs an optimal nutrient balance in the soil for good plant development. Obtaining economically justified yields is possible only by providing conditions for balanced nutrition and development of raspberry plantations (Kljajic, 2017). Determining the agrochemical composition of soil profiles is extremely important when growing fruit crops and providing them with nutrients, especially nitrogen, phosphorus and potassium, which is a major task in agriculture.

Until now, the research into the soil-plant system has been very limited in the Bulgarian raspberry production, and the literature lacks data on raspberry plantations on gray forest soils in mountaine regions (Petkova et al., 2013). The most important nutrients for raspberries are nitrogen and potassium (Fiedler, 1970; Bergman, 1988; Smolarz, 1999). Nitrogen stimulates vegetative growth, and potassium affects plant yield, increases drought tolerance and improves cold tolerance of raspberries (Motosugi et al., 1995; Németh et al., 2002).

Canadian scientists found that the content of nitrogen and potassium in ripe fruits is eight times greater than the content of phosphorus, calcium and magnesium (Kowalenko, 1994). This proves that raspberries need nitrogen and potassium more than phosphorus. Rempel et al.

(2004) and Kowalenko (2006) found that the optimal nitrogen amount in the soil stimulated the growth of raspberry shoots in length andthickness. In 2009, Zlatareva & Nikolov found that fertilizer rates higher than 12 kg N/da in a fruit-bearing plantation provide better nutrition for the raspberry plant.

The aim of the present study is to trace the content of the main nutrients (nitrogen, phosphorus, potassium), humus and pH in the soil of a raspberry plantation at different plant phenophases.

MATERIALS AND METHODS

The scientific experiment was conducted in the period 2018-2020 in a collection plantation of the Research Institute of Mountain Stockbreeding and Agriculture in Troyan. The objective of the study are four raspberry genotypes, such as Willamette, Meeker, Samodiva and the candidate cultivar Magdalena, that has been selected in RIMSA - Troyan. The area is maintained in black fallow in the intra-row spacing, whereas the inter-row spacings are naturally grassed, with the application of the appropriate mowing of the grass. Fertilizing is carried out in the intra-row area to achieve optimal values of the individual nutrients for the raspberry crop.The following fertilizing was applied for the three experimental years: 20 kg/da ammonium nitrate (annually), 15 kg/da triple superphosphate and 7.5 kg/da potassium chloride (first and third year). The plants are grown under irrigated conditions with drip irrigation.

The soils in the region are gray forest, medium to heavy sandy-clay, moderately eroded with low humus content (Mihailova et al., 2008), poor in digestible phosphorus and potassium and with a high absorption capacity in relation to phosphorus (Nikolov, 1969; Nikolov, 1985; Mihailova et al., 2006). Gray forest soils are distinguished by a low content of total nitrogen, which slightly varies under the influence of fertilizing with both nitrogen and phosphorus mineral fertilizers (Petkova et al., 2013) and poor in humus (about 2% in plowed areas). Most of the organic matter is concentrated in the uppermost part of the humus horizon, where there is also the greatest concentration of soil microflora and fauna (Valchovski, 2010).

The stock of soil with the main nutrients was determined:

Soil reaction (pH) - determined potentiometrically.

Nitrogen (mg/kg) - according to the Bremner and Keeney method in 2018 and according to the Kjeldahl method, BDS - EN ISO 5983, in 2019 and 2020.

Phosphorus (mg/100 g) - according to the method of P. Ivanov

Potassium (mg/100 g) - according to the method of P. Ivanov

Humus (%) - according to Tyurin

The mechanical composition of the soil was determined by Rutkowski method.

The data were processed according to the methods of two-factor variance (ANOVA) and descriptive analysis (Lidanski, 1988), the software product MS Excel - 2010 was used.

RESULTS AND DISCUSSIONS

As a result of the performed analyzes it was established that the variety of the soil by mechanical composition is heavily sandy-clayey to clayey (with physical clay content from 30 to 90%), moderately eroded with low humus content (Table 1).

Table 1. Mechanical composition of the soil, determined by the method of Rutkowski (1972)

Cultivars	Soil layers / Soil type / Physical clay content, %		
	0-20 cm	20-40 cm	40-60 cm
Willamette - 0.50 m	Clay (60)	Clay (60)	Clay (90)
Willamette - 0.30 m	Clay (48)	Clay (42)	Clay (78)
Meeker - 0.50 m	Clay (60)	Heavy sandy-clay (30)	Clay (36)
Meeker - 0.30 m	Clay (54)	Clay (48)	Clay (60)
Samodiva - 0.50 m	Clay (60)	Clay (66)	Clay (80)
Samodiva - 0.30 m	Clay (78)	Clay (60)	Heavy sandy-clay (30)
candidate cultivar Magralena - 0.50 m	Clay (36)	Clay (60)	Clay (54)
candidate cultivar Magralena - 0.30 m	Clay (54)	Clay (54)	Heavy sandy-clay (30)

The agrochemical analysis for the content of basic nutrients (N, P, K), humus and pH was reported during the period of blossoming and fruit harvesting in two soil layers from the intra-row spacing of the plantation.

Table 2. Composition of agrochemical indicators from the soil layers of the raspberry plantation for 2018

Soil layers cm		pH		∑ N- NH_4+NO_3	P_2O_5	K_2O	Humus
		H_2O	KCl	mg/kg	mg/100 g		%
	During blossoming						
0-20 cm	Minimum	5.00	4.40	14.40	2.60	10.00	0.81
	Maximum	5.00	4.50	34.60	8.30	16.90	1.44
	Mean	5.00	4.47	27.67	5.37	12.63	1.15
	St error	0.00	0.03	6.64	1.65	2.15	0.18
	St Dev	0.00	0.06	11.49	2.85	3.73	0.32
	CV%	0.00	1.34	41.53	53.07	29.53	27.83
20-40 cm	Minimum	4.90	4.30	15.00	1.70	8.00	0.26
	Maximum	5.00	4.50	31.70	10.00	18.20	1.71
	Mean	4.97	4.37	21.90	6.20	12.87	0.92
	St error	0.03	0.07	5.03	2.42	2.95	0.42
	St Dev	0.06	0.12	8.72	4.19	5.12	0.73
	CV%	1.21	2.75	39.82	67.58	39.78	79.35
	During fruit harvesting						
0-20 cm	Minimum	4.40	3.80	34.60	1.40	6.20	0.90
	Maximum	5.20	4.60	49.50	7.60	14.80	1.64
	Mean	4.76	4.20	43.64	3.26	10.16	1.20
	St error	0.17	0.17	3.09	1.12	1.42	0.14
	St Dev	0.38	0.38	6.91	2.51	3.17	0.32
	CV%	7.98	9.04	15.83	76.99	31.20	26.67
20-40 cm	Minimum	4.60	3.90	31.70	0.50	5.30	1.06
	Maximum	4.90	4.40	69.10	4.40	10.40	1.37
	Mean	4.78	4.12	41.80	2.60	8.00	1.18
	St error	0.05	0.09	6.89	0.83	0.96	0.05
	St Dev	0.11	0.19	15.40	1.85	2.15	0.11
	CV%	2.30	4.61	36.84	71.15	26.88	9.32

In 2018, during the raspberry blossoming phenophase, the soil acidity was defined as highly acidic, with a pH range of 4.97 (20-40 cm) to 5.0 (0-20 cm) (Table 2). The average nitrogen content recorded in the surface layer (0-20 cm) was 27.67 mg/kg, and at a depth of 20-40 cm it was slightly lower at 21.90 mg/kg, values indicating low stocking. The average values of phosphorus during the phenophase of full blossoming of raspberries in the upper soil layer are respectively 5.37 mg/100g. The phosphorus content is significantly higher in the next soil layer (20-40 cm), where it reaches values of 6.2 mg/100 g, which is defined as an average stock. The concentration of potassium at the two soil depths is 12.63 and 12.87 mg/100 g, respectively. The reported results for the humus content show that its values from the soil profiles are low - 1.15% at 0-20 cm and 0.92% at 20-40 cm (Table 2).

During the 2018 raspberry harvest, the soil reaction at the 0-20 cm soil layer was 4.76, and at the 20-40 cm depth it was 4.78 and was characterized as highly acidic (Table 2). The average nitrogen content recorded in the surface layer is 43.64 mg/kg., and in the lower layer 41.8 mg/kg, which defines the soil as moderately stocked with the element. Phosphorus values during the phenophase of raspberry harvesting in the upper soil layer are respectively 3.26 mg/100 g, in the next it significantly decreases to reach an average value of 2.60 mg/100 g. During the phenophase of fruit harvesting, a low potassium content ranging from 10.16 mg/100 g (0-20 cm) to 8.0 mg/100 g (20-40 cm) was recorded.The content of humus in the upper soil layers is low - 1.2% and 1.18%

Table 3. Composition of agrochemical indicators from the soil layers of the raspberry plantation in 2019

Soil layers cm		Active reaction pH	Total mineral nitrogen	P_2O_5	K_2O	Humus
		H_2O	mg/kg	mg/100 g		%
0-20 cm	**During blossoming**					
	Minimum	4.56	83.81	2.62	22.09	2.17
	Maximum	5.36	96.06	4.73	34.15	2.77
	Mean	5.03	89.77	3.34	28.53	2.39
	St error	0.09	1.53	0.23	1.30	0.07
	St Dev	0.25	4.33	0.66	3.69	0.19
	CV%	5.03	4.83	19.70	12.93	7.82
20-40 cm	Minimum	4.69	77.35	2.18	21.9	2.03
	Maximum	5.2	94.97	3.98	31.88	2.86
	Mean	4.99	83.53	2.86	27.13	2.36
	St error	0.07	2.28	0.23	1.15	0.09
	St Dev	0.20	6.46	0.66	3.24	0.27
	CV%	3.93	7.73	22.97	11.95	11.25
0-20 cm	**During fruit harvesting**					
	Minimum	5.51	60.97	4.78	20.67	1.86
	Maximum	5.88	69.05	7.16	22.91	2.01
	Mean	5.67	64.47	6.06	21.95	1.96
	St error	0.08	1.71	0.49	0.52	0.03
	St Dev	0.17	3.42	0.98	1.04	0.07
	CV%	2.94	5.31	16.23	4.76	3.51
20-40 cm	Minimum	5.59	59.73	4.22	19.78	1.79
	Maximum	5.98	62.32	6.5	20.46	1.94
	Mean	5.74	60.98	5.19	20.07	1.87
	St error	0.09	0.55	0.48	0.15	0.04
	St Dev	0.17	1.10	0.96	0.29	0.07
	CV%	2.99	1.81	18.56	1.46	3.94

In 2019, in the blossoming phenophase, both investigated soil layers had a pH of 5.03 (0-20 cm) and 4.69 (20-40 cm) (Table 3), which are defined as - highly acidic. The reported amount of total nitrogen averaged 89.77 mg/kg (0-20 cm) and 83.53 mg/kg (20-40 cm).

The analysis shows that the nitrogen content is significantly higher than the previous year, recorded in the same phenophase and soil layers.

The average values of phosphorus during the blossoming phenophase of raspberries in the upper soil layer are respectively 3.34 mg/100 g, and in the next layer they are 2.86 mg/100 g, which is defined as low stocking. The results regarding potassium content show that both soil depths are well stocked with the nutrient, 28.53 mg/100 g at 0-20 cm and 27.13 mg/100 g at 20-40 cm, respectively. The content of humus in the two soil layers is almost equal (2.36-2.39%), but it is not satisfactory for the needs of the plants.

During the raspberry harvest (2019), the soil reaction ranges between 5.67-5.74, which characterizes it as moderately acidic (Table 3). The nitrogen content in the soil ranges from 60.98-64.47 mg/kg, which is medium to good stocking, although the nitrogen content decreases with depth. During fruit harvesting, the phosphorus content increased almost twice and was within the limits of 6.06 mg/100 g (0-20 cm) and 5.19 mg/100 g (20-40 cm).

The results regarding potassium content show that both soil depths are well stocked. At 0-20 cm it was 21.95 mg/100 g and at 20-40 cm it was 20.07 mg/100 g, but a slight decrease of the element was observed compared to the blossoming phenophase. The humus content varies slightly, with 1.96% in the top soil layer and 1.87% in the next soil layer.

Table 4. Agrochemical indicators from the soil layers of the raspberry plantation in 2020

Soil layers cm		Active reaction pH	Total mineral nitrogen	P_2O_5	K_2O	Humus
		H_2O	mg/kg	mg/100 g		%
0-20 cm	**During blossoming**					
	Minimum	4.07	76.39	3.88	25.42	1.98
	Maximum	5.02	96.11	5.95	32.62	2.44
	Mean	4.52	88.03	4.56	28.66	2.20
	St error	0.13	2.33	0.25	0.79	0.05
	St Dev	0.37	6.58	0.70	2.24	0.15
	CV%	8.12	7.48	15.29	7.81	7.05
20-40 cm	Minimum	3.91	74.59	3.35	23.79	1.94
	Maximum	4.91	93.34	4.98	31.09	2.51
	Mean	4.34	85.03	4.19	27.68	2.22
	St error	0.13	2.25	0.20	0.74	0.07
	St Dev	0.38	6.37	0.56	2.08	0.18
	CV%	8.69	7.50	13.35	7.52	8.31
0-20 cm	**During fruit harvesting**					
	Minimum	4.77	61.61	3.86	25.86	1.98
	Maximum	5.51	74.00	5.18	26.73	2.06
	Mean	5.14	67.81	4.52	26.30	2.02
	St error	0.37	6.20	0.66	0.44	0.04
	St Dev	0.52	8.76	0.93	0.62	0.06
	CV%	10.18	12.92	20.65	2.34	2.80
20-40 cm	Minimum	4.45	59.41	3.75	24.8	1.75
	Maximum	5.35	72.09	4.25	25.42	2.00
	Mean	4.9	65.75	4.00	25.11	1.88
	St error	0.45	6.34	0.25	0.31	0.13
	St Dev	0.64	8.97	0.35	0.44	0.18
	CV%	12.99	13.64	8.84	1.75	9.43

The analysis of the results of the study of the agrochemical status of the soil in the 2020 experimental year during the full blossoming phenophase show that the soil reaction is strongly acidic - 4.52 at 0-20 cm and 4.34 at 20-40 cm (Table 4).

Total mineral nitrogen is high at both depths. In the first (0-20 cm) it is 88.03 mg/kg and in the second (20-40 cm) it is 85.03 mg/kg. The phosphorus content is higher in the first soil layer - 4.56 mg/100 g, with a tendency to decrease in depth. The results regarding potassium content show that both soil depths are well stocked. At 0-20 cm it is respectively 28.66 mg/100 g and at 20-40 cm it is 27.68 mg/100 g.

The content of organic matter in both soil layers is low (from 2.20% to 2.22%). The analysis of the results during fruit harvesting show that the active reaction of the soil is from highly acidic - 4.9 at 20-40 cm, to moderately acidic 5.14 from 20-40 cm (Table 4).

The reported total mineral nitrogen has lower values compared to the full blossoming phenophase. At the first depth, the element is within the limits - 67.81 mg/kg, and at the second depth - 65.75 mg/kg. These values show that the soil is well stocked with nitrogen and can satisfy the plants' needs. During the fruit harvesting, the phosphorus content was kept within close limits of 4.52 mg/100 g (0-20 cm) and 4.00 mg/100 g (20-40cm). The results regarding potassium content show that both soil depths are well stocked, but a slight decrease in the element was observed compared to the blossoming phenophase. The degree of variation is very low CV% - 2.34% (0-20 cm), CV% - 1.75% (20-40 cm). The content of humus is again very low - 2.02% in the upper soil layer and 1.88% in the lower soil layer. This content of organic matter is unsatisfactory for plants.

CONCLUSIONS

Based on the analyzes of the soil profiles from different depths and periods (blossoming period and fruit harvesting period), it was established that they have different reserves of nitrogen, phosphorus and potassium.

The studied soil layers of 0-20 cm and 20-40 cm of the intra-row spacing show a strongly to moderately acidic reaction in aqueous solution.

Nitrogen content in the first year varies from low during the blossoming period to moderate during the fruit harvesting period. Over the next two years, nitrogen values ranged from good during the blossoming phenophase to very well stocked during the fruiting period.
The amount of phosphorus is in the range from low to medium stock in the soil depths.
The analyzed soil layers in 2018 are poorly stocked with potassium. In the following two years, a good supply of the element was registered with values above 20 mg/100 g.
The organic matter in all three years of the experiment was low in quantities unsatisfactory for the needs of the raspberry plants.

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