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The influence of nitrogen and potassium fertilizers on the growth and yield of raspberries cv. 'Polana'

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Abstract. The experiment was carried out from 1998–2001 at the Lithuanian Institute of Horticulture, according to the scheme: N_{60} (control); $N_{60}K_{90}$; N_{90}; $N_{90}K_{130}$; N_{120}; $N_{120}K_{180}$; N_{150}; $N_{150}K_{240}$. The soil was Epicalcari – Endohypogleic cambisol, clay loam, containing 7.2% of organic matter, 140 mg kg^{-1} P_2O_5, 125 mg kg^{-1} K_2O, 11900 mg kg^{-1} CaO, 3040 mg kg^{-1} MgO, pH_{KCl} –7.3.

Primocane raspberries cv. 'Polana' fertilized with the largest amount of nitrogen fertilizers (N_{150}) produced 20% more primocanes in comparison with the control (N_{60}). Potassium fertilizers increased the diameter of raspberry stems – fertilizing them with $N_{120}K_{180}$ stem diameter resulted in an increase of 5.3%, with $N_{90}K_{130}$ and by 4.2% with $N_{150}K_{240}$ in comparison with the control.

Primocane raspberries cv. 'Polana' fertilized with $N_{120}K_{180}$ gave the highest yield increment – 2.5 t ha^{-1}, and, with $N_{60}K_{90}$ – 2.4 t ha^{-1} - in comparison with those fertilized only with nitrogen fertilizers (N_{60}).

When the rate of nitrogen fertilizers was increased from 60 to 90–150 kg ha^{-1}, the nitrogen content in the soil increased by approximately 25%. When the rate of potassium fertilizers was increased from 90 to 240 kg ha^{-1}, potassium content in the soil increased to 33%. The content of potassium in raspberry cv. 'Polana' leaves significantly increased when fertilizing only with the highest rates of potassium fertilizers ($N_{120}K_{180}$ – $N_{150}K_{240}$) – by 12.1–19.7% - in comparison with control (N_{60}).

Key words: fertilization, nitrogen, nutrient content, potassium, raspberry, yield

INTRODUCTION

Raspberries require a soil rich in nutrients. With the same yield, nutrient uptake by raspberries is fivefold that of gooseberries (Kazakov, 1994). It was established that raspberries with 8 t ha^{-1} berry yield, with the stems cut away, uptake approximately 50 kg ha^{-1} N, 15 kg ha^{-1} P_2O_5 and 65 kg ha^{-1} K_2O (Jaroslavcev, 1987) from the soil. Moreover, nutrients are used for primocane growth; some are washed out to the deeper soil layers.

The rates of fertilizers to be applied depend on the natural soil fertility, climate conditions, management means, peculiarities of cultivars, etc. The soil may contain large amounts of nutrients but with unfavorable conditions (acid or alkaline soil, improper ratio of chemical elements, insoluble forms of elements, lack of humidity) plants are unable to utilize them (Balobin & Shkurko, 1972).

The most important nutrients for raspberries are nitrogen and potassium (Fiedler, 1970; Bergman, 1988; Smolarz, 1999). Nitrogen stimulates vegetative growth; potassium affects plant yield, increases resistance to drought, and improves winter hardiness. Canadian scientists established that the content of nitrogen and potassium in mature berries is similar and is eightfold greater than the content of phosphorus, calcium and magnesium (Kowalenko, 1994). This proves that raspberries demand nitrogen and potassium, but not phosphorus fertilizers. The phosphorus content of natural soil usually supplies raspberries with this nutrient.

The scientists from various countries have different and often conflicting opinions about raspberry fertilization, generally determined by different soil and climate conditions. French scientists recommend fertilizing the yielding raspberries with $N_{40-50}K_{150}$ (Pierre, 1977), Polish – with $N_{60-80}K_{40-80}$ (Smolarz, 1999), German – with N_{80} (Quast, 1982), former Yugoslavian – with $N_{100}K_{75}$ (Džamić et al., 1989), Ukrainian – N_{120} (Shumeiko, 1987), Byelorussian – with $N_{120}K_{120}$ (Korneva, 1985).

Primocane raspberries are becoming increasingly more important in Lithuanian commercial berry plantations. The objective of the experiment was to investigate the influence of the different nitrogen and potassium fertilizer rates on the growth vigour and productivity of primocane raspberries cv. 'Polana' and to establish the effect of fertilizers on the content of these elements in the soil and in plant leaves.

MATERIALS AND METHODS

The investigations were carried out at the Lithuanian Institute of Horticulture in the years 1998–2001 according to the following scheme: N_{60} (control); $N_{60}K_{90}$; N_{90}; $N_{90}K_{130}$; N_{120}; $N_{120}K_{180}$; N_{150}; $N_{150}K_{240}$.

The soil was Epicalcari – Endohypogleic cambisol, clay loam, containing 7.2% organic matter, 140 mg kg^{-1} P_2O_5, 125 mg kg^{-1} K_2O, 11900 mg kg^{-1} CaO, 3040 mg kg^{-1} MgO, pH_{KCl} – 7.3.

Primocane raspberries cv. 'Polana' were planted in the spring of 1998 at a spacing of 3.0x0.5 m. The width of plant belts, 0.5 m; the number of canes wasn't controlled. The length of the accounting plot was 3 m, width, 3 m, area, 9 m^2. The experiment was designed in four randomized blocks.

Raspberry canes were kept for one yield, then, in October, cut at the ground and removed. Nitrogen fertilizers (ammonium nitrate) at the rate N_{60} were applied in early spring. The balance of nitrogen fertilizers was broadcast two weeks later. Potassium fertilizers (potassium chloride) were applied in autumn, when the primocanes were cut away.

Meteorological conditions varied during the years of investigation. The hydrothermal coefficient (HTC) (Chomiakov, 1989) presented in Table 1 shows that the plants suffered primarily from drought in 1999. During the period of vegetation, July was the driest, June was not sufficiently humid, and September, droughty. All Septembers, when primocane raspberries yield abundantly, distinguished themselves.

September 2000 was especially dry. The year 2001 was notable for the excess of humidity - July and September were the most humid.

Summer 1999 was not only dry but also hot; Summer 2001, rainy and hot. There were no strong early frosts in autumn, when raspberries yield, during the years of investigation. A frost of –2.6°C, which occurred on May 3, 2000, damaged the shoots.

The following data were recorded: yield, berry weight, cane height, diameter and density; nutrient content in soil and leaves; prevalence and intensity of *Didymella applanata* Sacc. and *Gloesporium venetum* Speg. Data were subjected to analysis of variance and statistically processed using 'ANOVA' computer program.

RESULTS AND DISCUSSION

The growth vigour. During three years of the experiment the largest number of raspberry primocanes (by 20% more in comparison with the control) was produced by fertilizing them with the highest rate of nitrogen – 150 kg ha^{-1} (Table 2).

Nitrogen and potassium fertilizers had no effect on primocane height (Table 2). Primocane diameter of raspberries fertilized with $N_{150}K_{180}$ increased by 5.3% and with $N_{150}K_{240}$ – by 4.2% in comparison to those fertilized with N_{60} (Table 2). Throughout the experimental years, the tendency of raspberry primocane to increase in diameter, when fertilized not only with nitrogen but also with potassium fertilizers, was established.

It was also established that different rates of nitrogen and potassium fertilizers had no essential influence on the prevalence and intensity of fungal stem diseases.

The productivity. R aspberry cv. 'Polana' formed the longest yielding part of primocane when they were fertilized with $N_{90}K_{130}$ and $N_{120}K_{180}$ (by 3.0–3.4% longer than those fertilized with N_{60}) (Table 3).

In 1998 the longest yielding part of primocane formed in the plants which were fertilized with $N_{120}K_{180}$ (by 8% longer in comparison with the control), and in 1999, in those fertilized with $N_{90}K_{130}$ (by 11.2% longer).

The length of the yielding primocane part depended not only on the rate of fertilizers, but also on the meteorological conditions of the year. When humidity was sufficient, the cropping stem part comprised about 40% of all stem length; in the dry year (1999), only 26.7%: i.e. the drought decreased not only the stem height, but its cropping part as well.

According to the average data, raspberries cv. 'Polana' formed most fruiting laterals when they were fertilized with $N_{90}K_{130}$ – by 8% more in comparison with the control (Table 3).

Berry weight of primocane raspberries cv. 'Polana' fertilized with $N_{90}K_{130}$ and N_{120} increased on average by 5.0–5.4% (Table 3). In 2000, when shoots grew smaller due to spring frost damage, nitrogen and potassium fertilizers significantly increased the average berry weight.

There was a small amount of nitrates in berries (19.2–21.7 mg kg^{-1}); this amount was not influenced by the rates of fertilizers.

From the first year of the experiment it was established that by increasing the rates of potassium fertilizers, the yield of raspberries cv. 'Polana' increased as well (4.9–13.2%) (Table 4). The positive effect of potassium fertilizers on the yield during the later years of investigation became even more evident. In 2001 the hghest raspberry yield was obtained fertilizing with $N_{120}K_{180}$ (43.9% higher than the control). Yield increment of 41.2% was fixed after fertilization with $N_{60}K_{90}$; 38.4% – using $N_{90}K_{130}$.

By contrast, all investigated rates of nitrogen fertilizers used without potassium had no significant effect on raspberry yield.

During four years of the experiment the largest yield increase (30.5%) in comparison with the control was obtained fertilizing with $N_{120}K_{180}$ (Fig.1). Raspberries fertilized with $N_{60}K_{90}$ yield increased by 25.6%.

Nutrient content in soil and leaves. Fertilizing the primocane raspberries cv. 'Polana' with 90–150 kg ha^{-1} of nitrogen increased the amount of nitrogen in the soil by approximately 25% (Table 5).

In the treatments where nitrogen and potassium fertilizers were applied, the content of potassium increased in the soil only with the largest potassium rate. The most evident influence of potassium fertilizers on its content in the soil was fixed in the third year of the experiment. According to the average data of three years, when the potassium fertilizer rate was raised from 90 to 240 kg/ha (the norm of nitrogen fertilizers was increased as well), potassium content in the soil increased by 33%. With increasing rates of potassium fertilizers, calcium content in the soil decreased by 36–39%. Content of magnesium in the soil in most cases was significantly decreased by the higher rates of potassium fertilizers as well. With equal rates of nitrogen fertilizer (N_{90-120}), using potassium fertilizers ($K_{130-180}$), the amount of magnesium in the soil decreased by approximately 45%, in comparison with fertilization only with nitrogen fertilizers.

It was established that in the first year of investigation the rates of nitrogen fertilizers - 120–150 kg ha^{-1} - significantly increased nitrogen content in plant leaves. According to the average data of three years, raspberries cv. 'Polana' had the highest content of nitrogen in leaves (2.57–2.58%) when fertilized with $N_{120}K_{180}$ and N_{120}, even though significant differences among treatments were not established (Table 6). In all treatments nitrogen content in the leaves of raspberries slightly exceeded the minimal limit of the optimal range and did not increase further.

Raspberries accumulated sufficient content of phosphorus in their leaves; the variations did not depend on the rates of nitrogen and potassium fertilizers.

The content of potassium in raspberry leaves was deficient. The fertilization of raspberries with 90–120 kg ha^{-1} of nitrogen fertilizers did not influence absorption of potassium, but the highest rate (N_{150}) of fertilizers decreased the content of potassium in the leaves. According to the average data of three years, when primocane raspberries cv. 'Polana' were fertilized with nitrogen and potassium fertilizers, the content of potassium in plant leaves increased. A significant increment was obtained after fertilization with the biggest rates of fertilizers. When raspberries were fertilized with $N_{120}K_{180}$ and $N_{150}K_{240}$ potassium content in the leaves increased correspondingly by 12.1 and 19.7% in comparison with the control (N_{60}).

Alkaline soils negatively affect nutrition of some orchard and berry plants: the balance of nutritional elements is violated, and the absorption of manganese, iron, boron and the other elements is broken down (Balobin & Shkurko, 1972). The optimal soil reaction pH for raspberries is 5.5–6.5.

Table 1. Hydrothermal coefficients of vegetation period. LIH, 1998–2001.

Years	Hydrothermal coefficient					
	May	June	July	August	September	The average of V–IX months
1998	0.9	1.2	2.3	1.8	0.6	1.4
1999	1.	0.9	0.5	1.6	0.7	0.9
2000	1.	1.4	2.2	1.1	0.5	1.2
2001	1.	1.1	2.2	1.0	2.0	1.6

Table 2. Growth parameters of differently fertilized raspberries cv. 'Polana'. LIH, 1998–2000.

Treatment	Number of canes		Cane height		Cane diameter	
	units / m	%	m	%	mm	%
N_{60} (control)	34.1	100	1.13	100	9.4	100
$N_{60}K_{90}$	37.4	109.7	1.16	102.7	9.4	100
N_{90}	36.2	106.2	1.15	101.8	9.5	101.1
$N_{90}K_{130}$	36.0	105.6	1.10	97.3	9.8	104.2
N_{120}	34.1	100	1.08	95.6	9.3	98.9
$N_{120}K_{180}$	33.6	98.5	1.14	100.9	9.9	105.3
N_{150}	40.9	119.9	1.10	97.3	9.7	103.2
$N_{150}K_{240}$	36.8	107.9	1.11	98.2	9.8	104.2
LSD_{05}	*7.6*		*0.13*		*0.80*	

Table 3. Productivity parameters of differently fertilized raspberries cv. 'Polana'.
LIH, 1998–2000.

Treatment	Length of the fruiting cane		Number of fruiting laterals		Berry weight	
	cm	%	units / cane	%	g	%
N_{60} (control)	40.6	100	20.1	100	2.78	100
$N_{60}K_{90}$	39.6	97.5	18.1	90.0	2.87	103.2
N_{90}	40.9	100.7	19.6	97.5	2.88	102.9
$N_{90}K_{130}$	41.8	103.0	21.7	108.0	2.92	105.0
N_{120}	41.0	101.0	19.4	96.5	2.93	105.4
$N_{120}K_{180}$	42.0	103.4	19.5	97.0	2.86	102.9
N_{150}	39.2	96.6	21.0	104.5	2.83	101.8
$N_{150}K_{240}$	41.1	101.2	20.3	101.0	2.87	103.2
LSD_{05}	*3.32*		*2.71*		*0.204*	

Table 4. The yield of differently fertilized raspberries cv. 'Polana'. LIH, 1998–2001.

Treatment	1998	1999	2000	2001
N_{60} (control)	8.39	6.26	9.42	8.41
$N_{60}K_{90}$	8.48	7.62	12.81	11.87
N_{90}	9.54	7.10	11.24	10.09
$N_{90}K_{130}$	9.95	7.14	11.30	11.64
N_{120}	9.18	6.46	11.06	8.81
$N_{120}K_{180}$	10.10	7.96	12.26	12.1
N_{150}	8.70	6.92	11.0	9.93
$N_{150}K_{240}$	9.81	9.28	10.1	11.03
LSD_{05}	*2.838*	*1.822*	*2.316*	*2.824*

Table 5. Agrochemical characteristics of soil (in the depth of 0–20 cm) depending on the different fertilization of raspberries cv. 'Polana'.LIH, 1998–2000

Treatment	N_{min}*, mg kg^{-1}	P_2O_5, mg kg^{-1}	K_2O, mg kg^{-1}	CaO, mg kg^{-1}	MgO, mg kg^{-1}
N_{60} (control)	9.3	126	131	12900	3300
$N_{60}K_{90}$	9.1	114	141	12100	3600
N_{90}	11.7	130	134	13700	3400
$N_{90}K_{130}$	8.2	99	144	8300	1900
N_{120}	11.1	128	136	13800	3700
$N_{120}K_{180}$	9.8	111	154	8600	2000
N_{150}	11.6	135	131	13100	3400
$N_{150}K_{240}$	10.9	127	188	12300	2900
LSD_{05}	*3.84*	*38.1*	*31.4*	*4901.7*	*1594.8*

*the average data of 1999–2000

Table 6. Nutrient content in leaves of raspberries cv. 'Polana' . LIH, 1998–2000.

Treatment	N	P	K	Ca	Mg	Fe	B	Cu	Zn	Mn
	% of dry weight					mg kg^{-1} of dry weight				
N_{60} (control)	2.49	0.16	0.66	1.88	0.77	194	24.2	8.99	16.4	12.9
$N_{60}K_{90}$	2.53	0.14	0.73	1.71	0.73	177	22.2	7.79	16.2	20.2
N_{90}	2.48	0.16	0.64	1.90	0.76	172	23.7	8.28	14.3	12.5
$N_{90}K_{130}$	2.52	0.16	0.66	1.79	0.72	161	26.2	7.26	16.6	16.4
N_{120}	2.57	0.17	0.65	2.02	0.77	177	21.6	7.33	14.2	12.3
$N_{120}K_{180}$	2.58	0.16	0.74	1.78	0.76	149	26.0	7.16	15.9	18.9
N_{150}	2.54	0.16	0.56	1.90	0.75	147	22.3	7.44	13.8	11.4
$N_{150}K_{240}$	2.53	0.16	0.79	1.80	0.69	157	23.1	6.58	14.2	15.1
LSD_{05}	*0.127*	*0.021*	*0.084*	*0.221*	*0.094*	*44.9*	*3.31*	*2.12*	*2.70*	*8.56*
Optimal content	2.4-3.3	0.15-0.25	1.6-2	1-1.5	0.4-0.6	200-300	25-80	7-15	20-70	20-70

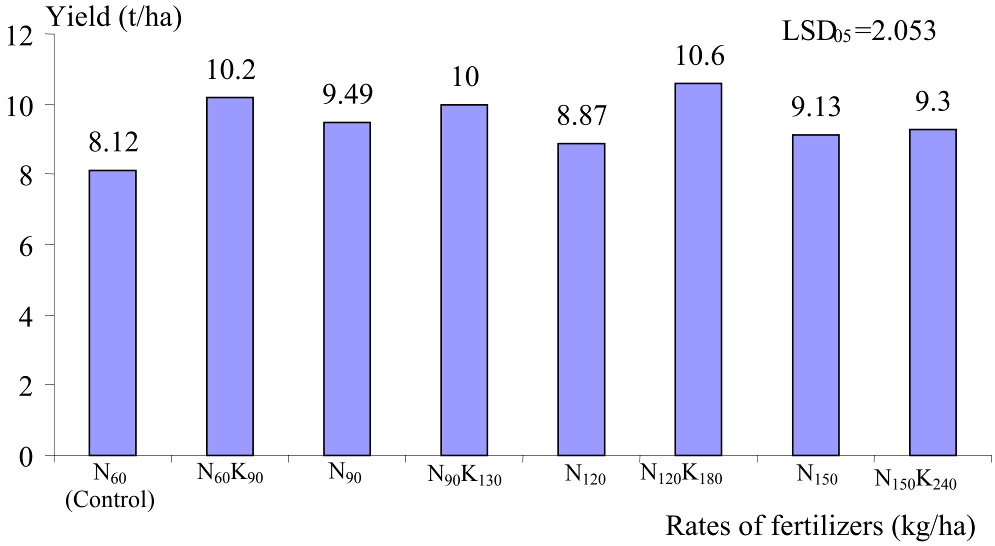

Fig 1. Average yield of differently fertilized raspberries cv. 'Polana'. LIH, 1998–2001.

Our investigations showed that in slightly alkaline soil the highest rates of fertilizers ($N_{150}K_{240}$) did not produce the desirable results due to the high amount of calcium (CaO – 8900–13800 mg kg^{-1}) and magnesium (MgO – 1900–3700 mg kg^{-1}). Calcium and magnesium are antagonists to potassium and nitrogen: the high content of calcium and magnesium in the soil and in plant leaves prevented raspberries from absorbing potassium and nitrogen.

In order to optimize apple tree nutrition with potassium, Fiedler's (1970) investigations used up to 360 kg ha^{-1} of K_2O, but the content of potassium in plant leaves was low. A possible explanation could be that the high content of magnesium accumulated in the leaves prevented plants from absorbing potassium. Investigating nitrogen fertilization of orchard plants, Fiedler established that excess calcium and magnesium in plant leaves block the absorption of potassium and nitrogen. Probably for analogical reasons, Polish scientists Zmarlicka & Smolarz (2000) did not establish the essential differences, investigating the influence of different rates of nitrogen fertilizers (N_{50}; N_{100}; N_{150}) on growth vigour and productivity of primocane raspberries cv. 'Polana' in naturally fertile soil of acid reaction (pH 4.3–4.5). Moreover, as Russian scientists proved, it is important to take into account that raspberries readily absorb nutrients which are in the soil. According to their data, only mineral fertilizers with microelements increase plant productivity (Jelsakov, 1999).

Kentworthy (1960) and the other scientists affirm that the ratio of the different nutritional elements is much more important than their content. It is not easy to increase the content of one nutrient in plant leaves, because increasing the rate of one particular monomial fertilizer can violate the balance of chemical elements and prevent the desirable result.

Our investigations showed that by fertilizing primocane raspberries of cv. 'Polana' in slightly alkaline soil not only with nitrogen but also with potassium fertilizers, the harmful excess of calcium and magnesium decreases in plant leaves, therefore the nutrition of plants improves and the raspberry yield essentially increases.

CONCLUSIONS

1. Primocane raspberries cv. 'Polana' fertilized with the highest rate of nitrogen fertilizers (150 kg ha^{-1} a.m.) produced 20% more primocanes in comparison with the control (N_{60}).

Potassium fertilizers increased the diameter of raspberry stems: fertilizing with $N_{120}K_{180}$ led to increased stem diameter by 5.3%; with $N_{90}K_{130}$ and $N_{150}K_{240}$ – by 4.2% as compared to the control.

2. Primocane raspberries cv. 'Polana' fertilized with $N_{120}K_{180}$ gave the highest yield increment – 2.5 t ha^{-1}, and with $N_{60}K_{90}$ – 2.4 t ha^{-1} - in comparison with those fertilized only with nitrogen fertilizers (N_{60}). To optimize the nutrition of raspberries in soil rich with calcium and magnesium it is recommended to apply nitrogen and potassium fertilizers at the same time.

3. When the rate of nitrogen fertilizers was increased from 60 to 90–150 kg ha^{-1}, the nitrogen content in the soil increased by approximately 25%. When the rate of potassium fertilizers was increased from 90 to 240 kg ha^{-1}, potassium content in the soil increased to 33%. The content of potassium in raspberry cv. 'Polana' leaves significantly increased fertilizing only with the highest rates of potassium fertilizers ($N_{120}K_{180}$ – $N_{150}K_{240}$) – by 12.1–19.7% in comparison with the control (N_{60}).

REFERENCES

Balobin, V.N. & Shkurko, T.I. 1972. *Orchard fertilizations*. Uradzai, Minsk, 70 pp. (in Russian).

Bergman, W. 1988. *Ernahrungsstorungen bei Kulturpflanzen*. 762 s.

Džamić, R., Jovanović, M., Veličković, M., Oparnica, C. & Dźopalić, M. 1989. Proućavanje vaźnijih biolośkih osobina maline ´Willamette´ pri razlicitm uslovima ishrane. *Jugoslaven. Vocar*. **23**(1-2), 497–505.

Jelsakov, G.V. 1999. Optimizations of small fruit nutrition in the North of Kola penin suls. *Plodovodstvo*. Samochvalovici **12**, 78–80 (in Russian).

Kazakov, J.V. 1994. *Raspberry and blackberry*. Kolos, Moskva, 141 pp. (in Russian).

Kenworthy, A.L. 1960. Nutrient element composition of leaves from fruit trees. *Proceedings Amer. Soc. Horticult. Sci*. **55**, 41–46.

Kowalenko, C.G. 1994. Growing season chantes in the concentration and distribution of macroelements in Willamette red raspberry plant parts. *Canadian Journal of Plant Science*. **74**(4), 833–839.

Pierre, C. 1977. Framboisiers: ravail du soil et fertilisation: deux facteurs de reussite. *Agri sept*. **6**, 22–23.

Quast, P. 1982. Untersuchungsergebnisse zur Höhe der erforderlichen Stickstoffdüngung in Himbeeranlagen. *Mitt. Obstbauversuchspinges Alten Landes*. **37**(4), 126–129.

Smolarz, K. 1999. Racjonalne nawożenie plantacji krzewow jagodowych. *Intensyfikacja produkcji owocow z krzewow jagodowych*. Skierniewice, 43–51.

Zmarlicka, A.L. & Smolarz, K. 2000. Wstępne wyniki badan nad wpływem nawożenia azotowego na owocowanie maliny powtarzającej odmiany Polana. *Zeszyty naukowe institutu sadownictwa i kwiaciarstwa*. **8**, 239–242.

Korneva, N.J. 1985. The role of cultivar and fertilization on the increase of raspberry productivity. *Progressive management means in vegetable and fruit growing*. 37–43 (in Russian).

Fiedler, V. 1970. *Leaf analysis in fruit growing*. Kolos, Moskva, 75 pp. (in Russian).

Shumeiko, L.J. 1987. Effect of nitrogen nutrition an productivity of raspberries. *Biul. of Soil Institute. Vaschnil*. №44. 62–63, (in Russian).

Jaroslavcev, J.V. 1987. *Raspberry*. Agropromizdat, Moskva, 207 pp. (in Russian).

Chomiakov V. N. 1989. Objective evaluation of state of agroassociation. *Agrometeorologitcheskij aspekt. Leningrad*, 126–130 (in Russian).