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Original paper

IMPACT OF VERMICOMPOST AS COMPONENT OF GROWING MEDIUM ON PHYTOMASS FORMATION OF RADISH (*RAPHANUS SATIVUS* L.)

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In Slovakia more than a half of the landfill's waste consist of the biodegradable waste (BDW). Therefore the BDW composting can decrease significantly the production of the landfill gas as well as the financial and space requirements for landfills. However, the composts production have to be solved comprehensively, including their rational usage. In Slovakia the use of composts is ineffective if the location of their production is farther than 50 km, because of the high tranportation costs. The objective of the experiments was to determine the ratio of vermicompost in the soil growing medium in order not to decrease the yield quantity and quality of radish – the most commonly grown vegetable in the gardens in Slovakia. Five shares of vermicompost were tested in the soil substrate (0%, 10%, 20%, 25% and 50%). The results show that 50% share of vermicompost in the soil substrate, i.e. the ratio of vermicompost to soil 1:1, was not the optimal solution of the vermicompost usage. However, even this quantity of vermicompost did not have a negative impact on the weight of the aboveground and underground phytomass in comparison with the treatment without vermicompost. 50% share of vermicompost in the growing medium had the negative impact on the qualitative parameters of radish. It decreased the content of vitamin C and increased the content of nitrates in radish roots and leaves. Along with the higher share of vermicompost in the growing medium, the content of vitamin C was decreased in radish roots and leaves, and the content of nitrates in radish roots was increased. The roots of the biggest diameter, and consequently the highest yield of radish roots and leaves was formed in the treatment where the soil substrate consisted of four portions of soil and one portion of vermicompost (20% proportion of vermicompost).

Key words: vermicompost, radish, vitamin C, nitrates

Vermicompost is a product of the biological degradation and the consequent stabilization of the organic substance by the activity of microorganisms and earthworms.

The following species of earthworms *Eisenia eugeniae, Eisenia foetida*, *Eisenia Andrei, Eudrilus eugeniae and Lumbricus rubellus* are most frequently used for the vermicomposting (Amossé *et al.* 2013; Soobhany *et al.* 2015; Saha *et al.* 2018). In comparison with the common composts the vermicompost contain predominantly higher quantities of nutrients in the total and also in available forms (Van Groenigen *et al.* 2014; Vos *et al.* 2014; Goswami *et al.* 2017). The content of the plant-growth regulators in

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vermicomposts is 5 even 6 times higher than in the classical composts (Pathma & Sakthivel 2012).

The vermicomposts have the positive impact on the plant growth (Lazcano & Domínguez 2011; Gholami *et al.* 2018), they accelerate the process of crop ripening along with the improvement of several qualitative parameters of the grown crops (Gutiérrez-Micely *et al.* 2007; Singh *et al.* 2008; Sinha *et al.* 2011). However, like the other organic fertilisers, can have not only the positive impact but also negative impact on soil, plants and the environment. The effect of impact is determined by the vermicompost quality and the level of rationality of its usage. The application of low-quality organic fertilisers in the incorrect terms and doses causes the retardation of plant germination, lagging behind in growth, yield decline and it can have the negative impact on the quality of environment (Kováčik *et al.* 2016).

At the end of the last century in the Slovak Republic the changes have begun in the way of usage gardens in the neighbourhood of the private houses (decorative gardens instead of vegetable gardens) and also the legislation restricting burning of the plant residues and supporting the composting of the biodegradable waste. These changes arose the question for the Slovak population about the compost management. On the one hand, every year more and more compost is produced, on the other hand, the number of the gardens where it can be used is decreasing. The utilization of composts, including industrial ones, is limited also by the carriage costs. Therefore, the objective of our experiments was to determine what quantity of compost, in our case vermicompost, is possible to apply into soil in order not to decrease the quantity and quality of radish, which is the most common vegetable grown in the Slovak gardens. Radish is also the popular crop of the bio-vegetable producers in the whole world (Gruver *et al.* 2016).

For this reason, the goal of experiments was to find out which quantity of compost (vermicompost) it is possible to put into soil, or which ratio can the vermicompost have in the soil growing medium not to decrease the quantity and quality of the most common vegetable grown in the gardens of Slovakia (radish).

MATERIAL AND METHODS

The pot experiment was carried out in the vegetation cage located in the area of the Slovak University of Agriculture in Nitra. On cage sides and ceiling there was the metal mesh with the size of a mesh 15 mm × 15 mm, which protected the experiment against birds.

The experiment was established on March 13, 2017. The weighted soil (treatment 1) and mixture of soil and vermicompost (treatments 2–5) were put into the cylindrical pots 35 cm high with the diameter 35 cm. In the treatment 1, twenty (20) kg of soil (Haplic Luvisol) was used and in the treatments 2, 3, 4 and 5 was put into the pots of 20 kg of mixture of soil and vermicompost. In the treatment 2, the mixture was created by 18 kg of soil (S) and 2 kg of vermicompost (V), which was the ratio S:V = 9:1, (10% proportion V). In the treatment 3, the mixture was created by 16 kg of soil and 4 kg of vermicompost, which was the ratio S:V = 4:1 (20% proportion V). In the treatment 4 the mixture was created by 15 kg of soil and 5 kg of vermicompost, which was the ratio S:V = 3:1 (25% proportion V). In the treeatment 5 the mixture was created by 10 kg of soil and 10 kg of vermicompost, which was the ratio S:V = 1:1 (50% proportion V). In the treatments 2–5 the same soil was used like in the treatment 1 (Haplic Luvisol). The used soil was taken from the field located in Párovské Háje, (cadaster Nitra), in particular, from the upper horizon of soil 0.0–0.3 m. The weighed out pots were placed into the dishes, which were able to keep 1,000 ml of the leaked soil solution during the period of precipitation. The leaked through solution was returned back to the pots. The agrochemical parameters of the used soil and the vermicompost are indicated in the Table 1. We used the following analytical methods for the indication of the given parameters: $N\text{-}NH_4^+$ by Nessler's colorimetric method; $N\text{-}NO_3^-$ by colorimetric method with phenol – 2,4 disulphonic acid, where the extract from soil was achieved by using the water solution 1% K_2SO_4. $N_{min} = N–NH_4^+ + N–NO_3^-$. The contents of available P, K, Ca, Mg were determined by Mehlich 3 extraction procedure (Mehlich 1984). Content of P was determined by colorimetric method, K by flame photometry, Ca and Mg by atomic absorption spectrophotometry, S by spectrophoto-

T a b l e 1

Parameters of the soil substrates used in the experiment

Substrate	N_{min}	P	K	Ca	Mg	S	N_t	C_{ox}	C:N	EC	pH_{KCl}
	[mg/kg]						[%]			[mS/cm]	
Soil	13.2	21.9	156	4,250	444	1.3	0.077	0.915	11.88	0.14	6.97
VC	313.8	351.3	19,000	4,350	3,052	4,688	3.775	20.880	5.53	5.58	7.06

VC – vermicompost

metrically (in the leachate of ammonium acetate), N_t by distillation after the mineralization of strong H_2SO_4 (Kjeldahl - Bremner 1960), C_{ox} by spectrophotometrically after the oxidation (Tyurin 1966), EC by method of specific electrical conductivity and pH/KCl (in solution of 1.0 mol/dm^3 KCl) potentiometrically.

The experiment was established according to the method of random arrangement of pots in four repetitions. The model crop was radish (*Raphanus sativus*, L.) cultivar Granát. The sowing was carried out on March 16. Subsequently, the experiment was irrigated to the level of 75% FWC (field or full water capacity). In the following three weeks all pots were irrigated by the same dose of water containing the minimal quantity of nutrients. During the last 14 days the treatments 2, 3, 4 and 5 were irrigated by a higher dose of water, because the plants in these treatments evaporated more water as a result of the significantly larger leaf area. During growing season (April 24, May 3 and May 9 i.e. in 27/39, 36/48 and 42/54 days after emerge/sowing) three samplings of plant material were accomplished (The plants of radish, emerged after 12 days from sowing). 10 average individuals were taken from each treatment and repetition, which served for the evaluation of the roots and leaves weight.

The diameter of the root thickness was measured by the slide calliper. The nitrate content and vitamin C content in the roots and leaves of the second and third sampling was detected. The quantity of vitamin C was determined by titration with 2,6-dichlorophenolindophenol. In order to determine nitrates we used ion-selective electrode of the type 07-35 and reference electrode of the type RCE 101 (Monokrystaly Turnov, Czech republic). The second and third samplings were carried out in six days interval because radish is usually harvested two or more terms.

The acquired results were processed by mathematical and statistical method, by analysis of variance (ANOVA) and linear regression analysis using Statgraphics PC program, version 5.0. The differences between the treatments were evaluated subsequently by *LSD* test at the significance level $a = 0.05$.

RESULTS AND DISCUSSION

Along with the change of the ratio of soil to vermicompost also the formation (weight) of the aboveground and underground radish phytomass was changed (Table 2 and 3). Regardless of the ratio of soil (S) and vermicompost (V) more phytomass was formed in the treatments 2–5, compared to the treatment without vermicompost (Trt. 1). The weight of the aboveground and underground phytomass was increased in all those samplings where the ratio of soil to vermicompost was lower or equal 4:1 (Trt. 2 and 3). The addition of compost above this ratio (Trt. 4 and 5) resulted in the gradual decrease of the formation of radish phytomass. As a result, the highest yield of roots and leaves was formed in the treatment 3 with the ratio S:V = 4:1. A higher quantity of vermicompost in the substrate, i.e. a lower ratio of soil to vermicompost than 4:1, resulted in the gradual decline of the phytomass formation. In spite of that, on the last days before the harvest of radish plants in the treatment with the lowest ratio of soil to vermicompost (1:1) five times more root phytomass was formed and about six times more leaves phytomass than in the control treatment without vermicompost. It was clear that the ratio of vermicompost and soil at the level of 1:1 was not optimal. However, even this high quantity of vermicompost in the growing medium did not have the negative impact on the weight of the aboveground and underground phytomass in comparison with the control treatment.

The positive impact of all tested quantities of vermicompost in the substrate on the radish phytomass was measurable on 24 April, i.e. 27 days from the radish emergence (Table 2). The highest phytomass weight was recorded on the 42[th] day after emergence (May 9).

If we assess the percentage of the phytomass growth in the treatments with vermicompost and the control treatment (in the individual samplings), we can claim that mostly roots reacted by more significant weight growth than leaves weight. The contrary results were recorded by Kováčik (1999a), when the leaves grew more dynamically than radish roots after the application of fertilisers containing nitrogen.

On the 27[th] day after the plant emergence the weight ratio of leaves and roots was on average 7.42:1 in all treatments. In the later growth phases, i. e. on 36[th] and 42[nd] day after emergence the ratio was lower than 1:1 (Table 4). The dynamic changes in the ratio of leaves and root weight indicated that in the initial vegetation period leaves were predominantly formed. The roots, as a reserve organ into which photosynthates are transfered, increased their weight in the last third of radish vegetation (before harvest).

If we evaluate the ratios of leaves weight (L) and roots weight (R), it can be stated that the ratio L:R in the treatments with the vermicompost was

T a b l e 2

Impact of vermicompost on the changes of the radish roots weight

Treatment		24. IV. (27 days after emergence of plants)		3. V. (36 days after emergence of plants)		9. V. (42 days after emergence of plants)	
number	mark	[g/10 ind.]	[%]	[g/10 ind.]	[%]	[g/10 ind.]	[%]
1	S	1.95[a]	100.00	20.03[a]	100.00	27.83[a]	100.00
2	$SV_{9:1}$	2.83[b]	145.13	148.71[cd]	742.39	185.80[c]	667.62
3	$SV_{4:1}$	3.58[c]	183.59	153.83[d]	768.00	219.15[e]	787.46
4	$SV_{3:1}$	2.70[b]	138.46	145.82[c]	728.00	214.23[d]	769,78
5	$SV_{1:1}$	2.08[a]	106.67	101.07[b]	504.59	140.38[b]	504.42
$LSD_{0.05}$		0.333		6.376		2.832	

[g/10 ind.] – g/10 individuals; S – soil; $SV_{9:1}$ – soil + vermicompost in ratio 9:1; $SV_{4:1}$ – soil + vermicompost in ratio 4:1; $SV_{3:1}$ – soil + vermicompost in ratio 3:1; $SV_{1:1}$ – soil + vermicompost in ratio 1:1; $LSD_{0.05}$ – least significant difference at the level *a* = 0.05; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

T a b l e 3

Impact of vermicompost on the changes of the radish leaves weight

Treatment		24. IV. (27 days after emergence of plants)		3. V. (36 days after emergence of plants)		9. V. (42 days after emergence of plants)	
number	mark	[g/10 ind.]	[%]	[g/10 ind.]	[%]	[g/10 ind.]	[%]
1	S	14.53[a]	100.00	15.70[a]	100.00	18.23[a]	100.00
2	$SV_{9:1}$	20.88[c]	143.70	83.60[b]	532.48	104.20[b]	571.59
3	$SV_{4:1}$	22.30[c]	153.48	95.63[c]	609.11	147.38[e]	808.45
4	$SV_{3:1}$	20.10[bc]	138.33	85.65[b]	545.54	135.95[d]	745.75
5	$SV_{1:1}$	17.08[ab]	117.55	84.53[b]	538.41	112.83[c]	618.92
$LSD_{0.05}$		3.035		6.880		3.520	

[g/10 ind.] – g/10 individuals; S – soil; $SV_{9:1}$ – soil + vermicompost in ratio 9:1; $SV_{4:1}$ – soil + vermicompost in ratio 4:1; $SV_{3:1}$ – soil + vermicompost in ratio 3:1; $SV_{1:1}$ – soil + vermicompost in ratio 1:1; $LSD_{0.05}$ – least significant difference at the level *a* = 0.05; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

lower than in the control treatment, apart from the treatment 5 and partially the treatment 3 (only in the last sampling). This finding approved our statement that the roots reacted to vermicompost mostly by more significant weight growth than leaves. The highest ratio L:R was recorded in the treatment with the highest proportion of vermicompost in the substrate (Trt. 5), which according to Kováčik (1999b) indicated the excessive supply of nutrients in the particular treatment.

Along with the change of treatments the root weight was changing (Table 2), similarly the diameters of radish roots were changing (Table 5). The biggest root diameter was achieved in the ratio S:V = 4:1 (Trt. 3) and the smallest one was in the control treatment. In the treatment 1 the root diameter was lower than 2.0 cm, therefore those roots were not suitable for market according to the Slovak Technical Standard 46 31 20. 50% proportion of vermicompost in the growing medium (Trt. 5) compared with 20% proportion (Trt. 3) resulted in the significant decrease of the root diameter. However, 50% proportion of vermicompost in the growing medium (Trt. 5) in comparison with the control treatment 1 (without vermicompost) increased considerably the radish root diameter, and the radish became tradable.

The highest content of vitamin C was detected in the control treatment (Table 5). Along with the growth of vermicompost share in the substrate the content of vitamin C decreased. The differences in

T a b l e 4

Impact of vermicompost on dymnamics of changes in weight ratio of leaves and roots of radish

Treatment		24. IV. (27 days after emerge of plants)	3. V. (36 days after emerge of plants)	9. V. (42 days after emerge of plants)
number	mark	L:R	L:R	L:R
1	S	7.45	0.78	0.66
2	$SV_{9:1}$	7.38	0.56	0.56
3	$SV_{4:1}$	6.63	0.62	0.67
4	$SV_{3:1}$	7.44	0.59	0.63
5	$SV_{1:1}$	8.21	0.84	0.80
Average		7.42	0.68	0.66

S – soil; $SV_{9:1}$ – soil + vermicompost in ratio 9:1; $SV_{4:1}$ – soil + vermicompost in ratio 4:1; $SV_{3:1}$ – soil + vermicompost in ratio 3:1; $SV_{1:1}$ – soil + vermicompost in ratio 1:1

T a b l e 5

Impact of vermicompost on change of diameters of radish roots and qualitative parameters of roots

Treatment		Roots diameter		Viatamin C		$NaNO_3$	
		3. V.	9. V.	3. V.	9. V.	3. V.	9. V.
number	mark	[cm]		[mg/kg]			
1	S	1.44[a]	1.68[a]	114.88[b]	161.84[c]	738[a]	570[a]
2	$SV_{9:1}$	3.13[c]	3.29[c]	101.08[a]	115.00[b]	1,649[b]	1,480[b]
3	$SV_{4:1}$	3.33[c]	3.69[d]	94.20[a]	105.00[a]	2,762[d]	2,516[d]
4	$SV_{3:1}$	3.21[c]	3.64[d]	94.12[a]	105.00[a]	2,633[c]	2,234[c]
5	$SV_{1:1}$	2.71[b]	2.96[b]	91.92[a]	102.70[a]	3,247[e]	2,896e
$LSD_{0.05}$		0.313	0.294	9.473	7.418	104.153	109.587

S – soil; $SV_{9:1}$ – soil + vermicompost in ratio 9:1; $SV_{4:1}$ – soil + vermicompost in ratio 4:1; $SV_{3:1}$ – soil + vermicompost in ratio 3:1; $SV_{1:1}$ – soil + vermicompost in ratio 1:1; $LSD_{0.05}$ – least significant difference at the level $a = 0.05$; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

the contents of vitamin C between the treatments with vermicompost were insignificant. Enhancing share of vermicompost in the substrate (Trt. 2–5), compared to the control treatment, decreased significantly the content of vitamin C in the radish roots, at the same time it increased substantially the content of nitrates. This negative impact of vermicompost on the qualitative parameters of radish roots was the consequence of the fact that it contained 23.77 times more mineral nitrogen than soil (Table 1). The negative correlation between the mineral nitrogen in the growing substrate and the content of vitamin C in vegetables, or the positive correlation between the content N_{an} in soil and the content of nitrates in vegetables is well-known (Citak & Sonmez 2010; Čekey *et al.* 2011; Lošák *et al.* 2016). Liao *et al.* (2009) claims that small application doses of nitrogen can result in the increase of vitamin C content in radish roots and leaves.

The objective of the crop growers is a marketable product. The goal of a Slovak radish grower is well root. In many Asian countries radish is grown not only for its roots but also for its leaves, and in some countries predominantly for its leaves (Bhatnagar & Azhar 2016). The analysis of the leaves studying the content of nitrates and vitamin C (Table 6 and 7) indicated that the vitamin C content is 1.94 even 2.56 times higher in leaves than in roots. On the contrary, the nitrates content is 1.37 až 1. 47 times lower in leaves than in roots. It is evident that leaves are of a higher quality than roots (Table 6) from the aspect of two monitored qualitative parameters (content of vitamin C and content of nitrates). This finding explains the reason why some Slovak citizens coming from the Orient do not throw the leaves away, unlike the domestic inhabitants. The salutariness of vitamin C consumption, not only in vegetables but also as the significant antioxidant with the

Table 6

Impact of vermicompost on qualitative parameters of radish leaves

Treatment		Viatamin C		$NaNO_3$	
		3. V.	9. V.	3. V.	9. V.
number	mark	[mg/kg]			
1	S	352.70[e]	295.84[d]	1,206[a]	1,138[a]
2	$SV_{9:1}$	258.80[d]	239.05[c]	1,400[b]	1,262[b]
3	$SV_{4:1}$	241.25[c]	219.40[b]	1,472[c]	1,472[d]
4	$SV_{3:1}$	218.30[b]	200.65[a]	1,438[bc]	1,360[c]
5	$SV_{1:1}$	201.05[a]	188.15[a]	1,973[d]	1,821[e]
$LSD_{0.05}$		11.685	13.667	53.546	69.853

S – soil; $SV_{9:1}$ – soil + vermicompost in ratio 9:1; $SV_{4:1}$ – soil + vermicompost in ratio 4:1; $SV_{3:1}$ – soil + vermicompost in ratio 3:1; $SV_{1:1}$ – soil + vermicompost in ratio 1:1; $LSD_{0.05}$ – least significant difference at the level *a* = 0.05; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

Table 7

Contents of vitamin C and nitrates in radish leaves and roots (average of all experiment treatments)

Evaluated organ	Vitamin C		$NaNO_3$		$NaNO_3$: Vitamin C	
	3. V.	9. V.	3. V.	9. V.	3. V.	9. V.
	[mg/kg]					
Leaf (L)	254.42	228.62	1,497.80	1,410.60	5.89	6.17
Root (R)	99.24	117.87	2,205.80	1,939.20	22.23	16.45
Ratio L:R	2.56	1.94	0.70	0.73	–	–

chemopreventive effects, is well-known (Zieliński *et al.* 2007; Uher *et al.* 2014; Mostafavi-Pour 2017).

The dependence between the root size and weight and the content of nitrates in roots, or between the root size and weight and the content of vitamin C in roots was evaluated. There has been found out that the larger the root is the larger weight, the more nitrates and less vitamin C it has (Table 8). The found dependences were more striking with the older plants. It is not always the rule that the higher root size resulted in higher nitrates content. Kováčik (1998) recorded the growth of radish roots by the foliar application of saccharose, in this case, the higher root size lower the nitrates content.

The similar dependence, like it was detected between the root weight and the qualitative parameters of roots, was also determined in leaves. The older leaves were, the less vitamin C and more nitrates were in them (Table 8).

The qualitative parameter of radish can be considered also by the content of nutrients in roots and in leaves in some countries (Lu *et al.* 2011; Karmakar *et al.* 2013).

The increased share of vermicompost in the substrate, increased the contents of N, K, Mg and S in radish roots. On the contrary, the contents of P and

T a b l e 8

Correlation coefficient r expressing the relationship between the radish qualitative yield parameters (nitrates, vitamin C) and the quantitative yield parameters (diameter of roots, weight of roots and leaves)

Parameter		Date of sampling		n
		3. V. (36 days after emerge of plants)	9. V. (42 days after emerge of plants)	
dependent	independent	correlation coefficient (r)		
$NaNO_3$ in roots	root diameter	$+0.6510^{++}$	$+0.7281^{++}$	20
vitamin C in roots		-0.6033^{++}	-0.9041^{++}	
$NaNO_3$ in roots	root weight	$+0.6172^{++}$	$+0.6848^{++}$	
vitamin C in roots		-0.7216^{++}	-0.8783^{++}	
$NaNO_3$ in leaves	leaves weight	$+0.5274^{+}$	$+0.5262^{+}$	
vitamin C in leaves		-0.8894^{++}	-0.8435^{++}	

$^{+}$ statistically significant ($P < 0.05$); $^{++}$statistically high significant ($P < 0.01$); n – number of measurements

T a b l e 9

Impact of vermicompost on macroelement contents in radish roots (100% dry matter)

Treatment		Roots					
		N	P	K	Ca	Mg	S
number	mark	[mg/kg]					
1	S	11,440^{a}	3,925^{c}	43,800^{a}	6,950^{d}	4,005^{a}	1,640^{a}
2	$SV_{9:1}$	12,420^{b}	3,700^{b}	44,400^{b}	5,125^{c}	4,069^{a}	1,700^{a}
3	$SV_{4:1}$	14,520^{c}	3,575^{b}	52,400^{c}	3,100^{b}	4,288^{b}	2,230^{b}
4	$SV_{3:1}$	15,510^{d}	3,500^{ab}	53,200^{d}	2,450^{a}	4,687^{c}	2,400^{b}
5	$SV_{1:1}$	22,600^{e}	3,300^{a}	82,400^{e}	2,200^{a}	4,853^{c}	2,640^{c}
Average		15,698	3,600	55,240	3,965	4,380	2,122
LSD 0.05		324.281	207.705	583.555	309.377	183.326	191.281

S – soil; $SV_{9:1}$ – soil + vermicompost in ratio 9:1; $SV_{4:1}$ – soil + vermicompost in ratio 4:1; $SV_{3:1}$ – soil + vermicompost in ratio 3:1; $SV_{1:1}$ – soil + vermicompost in ratio 1:1; $LSD_{0.05}$ – least significant difference at the level $a = 0.05$; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

Ca decreased. The decline of phosphorus content in roots was related to the growth of nitrogen content. Similarly, the decrease of calcium content was related to the growth of magnesium content. Gill & Lavender (1983) noticed the negative correlation between the contents of nitrogen and phosphorus, but also calcium and magnesium in the plant organs.

Kováčik and Jančovič (2001) reported the contents of N, P, K, Ca, Mg, S and Na in radish roots with the sufficient and insufficient nutrition. Comparing the data in the Table 9 with the data of these authors, it is apparent that the contents of P, Ca and S are insufficient in all treatments. The contents of N and K, apart from treatment 5 ($SV_{1:1}$) were also insufficient. Mg content was at the appropriate level. According to the data of Scaife and Turner (1983) only potassium was at the appropriate level, out of the monitored nutrients, in radish roots. This fact proves that the quantity of vermicompost used for the formation of the growing medium did not result in the excessive uptake of nutrients.

The impact of treatments of experiment on the contents of nutrients in leaves did not correspond with the impact on the contents in roots (Table 10). The N, P, Mg and S contents in the particular treatments changed along with the change of the leaves weight (Table 3). The contents of the monitored macroelements were higher, independently on the ratio of soil and vermicompost in the treatments with vermicompost (Trt. 2–5) in comparison with the control treatment (Table 10). The exception was only the content of potassium. The contents of N, P, Mg and S were increased in all samplings by the addition of vermicompost into soil with the ratio – one proportion of vermicompost and four proportions of soil (Trt. 2 and 3). The addition of compost above this ratio (Trt. 4 and 5) resulted in the gradual decline of the contents of N, P, Mg and S. In spite of this fact, in the treatment with the narrowest ratio of soil and vermicompost (1:1), higher contents of all macroelements were recorded than in the control treatment. The vermicompost in the growing me-

T a b l e 10

Impact of vermicompost on macroelement contents in radish leaves (100% dry matter)

Treatment		Leaves					
		N	P	K	Ca	Mg	S
number	mark	[mg/kg]					
1	S	29,780[a]	2,400[a]	48,800[c]	24,650[a]	9,247[a]	5,510[a]
2	$SV_{9:1}$	30,410[a]	2,763[b]	47,400[b]	25,450[b]	9,507[b]	7,410[b]
3	$SV_{4:1}$	34,050[c]	3,388[c]	46,800[a]	27,275[c]	11,887[e]	8,510[d]
4	$SV_{3:1}$	31,600[b]	3,275[c]	48,500[c]	31,040[d]	10,682[d]	8,400[d]
5	$SV_{1:1}$	29,980[a]	2,500[a]	64,000[d]	37,150[e]	10,355[c]	8,000[c]
Average		31,164	2,865	51,100	29,113	10,336	7,566
$LSD_{0.05}$		647.975	145.681	512.300	317.534	88.172	295.559

Num. – number; S – soil; $SV_{9:1}$ – soil + vermicompost in ratio 9:1, $SV_{4:1}$ – soil + vermicompost in ratio 4:1, $SV_{3:1}$ – soil + vermicompost in ratio 3:1, $SV_{1:1}$ – soil + vermicompost in ratio 1:1; $LSD_{0.05}$ – least significant difference at the level $a = 0.05$; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

T a b l e 11

Impact of vermicompost on ratios of nutrient contents in radish leaves and roots

Treatment	N	P	K	Ca	Mg	S
1	2.60	0.61	1.11	3.55	2.31	3.36
from 2 to 5	1.99	0.80	0.93	5.83	2.36	3.57

dium decreased the content of N and K in leaves, and vice versa, increased the contents of Ca, P, S and also Mg (Table 11).

CONCLUSIONS

The roots of the highest diameter and consequently the highest yield of radish roots and leaves were formed in the treatment where the growing substrate consisted of four proportions of soil and one proportion of vermicompost (20% of vermicompost).

50% share of vermicompost in the growing substrate, i. e. the ratio of vermicompost and soil at the level of 1:1 was not an optimal solution of the vermicompost usage, however, this high quantity of vermicompost did not have the negative impact on the weight of aboveground and underground phytomass, compared to the control treatment. 50% share of vermicompost in the growing medium had the negative impact on the qualitative parameters of radish. It decreased the content of vitamin C and increased the content of nitrates in both radish roots and leaves.

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