Original Research

Weight of Carrot Phytomass and Content of Vitamin C 100 Days after Seeding in Dependence of Vermicompost Quantity and Earthworms (Eisenia fetida) in Soil Substrate

Peter Kováčik¹, Jadwiga Wierzbowska²*, Sylwester Smoleń³, Nora Polláková⁴, Zafarjon Jabbarov⁵

¹Slovak University of Agriculture in Nitra, Department of Agrochemistry and Plant Nutrition, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia
²University of Warmia and Mazury in Olsztyn, Department of Agricultural and Environmental Chemistry, Oczapowskiego 8, 10-719 Olsztyn, Poland
³University of Agriculture in Krakow, Unit of Plant Nutrition, Department of Plant Biology and Biotechnology, Al. 29 Listopada 54, 31-425 Krakow, Poland
⁴Slovak University of Agriculture in Nitra, Department of Pedology and Geology, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia
⁵National University of Uzbekistan, Department of Soil Science, University Street 4, 100174 Tashkent, Uzbekistan

Received: 5 May 2021
Accepted: 23 June 2021

Abstract

The aim of the study was to evaluate the effect of various amounts of vermicompost (0, 10, 20, 25 and 50%) and Eisenia fetida earthworms (0, 10, 20 individuals per pot) on the weight of carrot roots and leaves and their vitamin C content on the 100th day after seeding. The achieved results indicate that along with the increasing content of vermicompost in the soil substrate the weight of roots and leaves was rising and the content of vitamin C was decreasing. The weight of roots was increasing more dynamically than the weight of leaves. The high proportion—even 50% of Vc-in the soil substrate did not have a negative impact on the formation of aboveground and underground phytomass. The earthworms had a positive influence on the formation of carrot roots and leaves. The impact on the roots was stronger. The impact of earthworms on the formation of phytomass depended on the interactive impact of the vermicompost quantity in the substrate and number of earthworms. The smallest percentage increase of roots and leaves yields with both numbers of earthworms was achieved if the earthworms were put into the substrate of the highest 50% proportion of vermicompost.

Keywords: roots, leaves, vitamin C, red earthworms, soil substrates

*e-mail: jadwiga.wierzbowska@uwm.edu.pl
**Introduction**

Carrot (*Daucus carota* L.) is grown successfully around the whole temperate climatic zone. It is an important component of human nutrition. Carrot has a high nutritional value [1], it is rich in antioxidants [2-5] and its consumption acts preventively against several diseases [6-9]. Therefore, its growing is being increased in the whole world. China is the significant world carrot producer. In spite of the positive effects of carrot consumption and also other vegetables in the fresh or processed form on the human health, the area of fields assigned for the vegetables growing represents less than 1% of the area of arable soils in Slovakia.

In the whole world carrots is being grown conventionally and ecologically [10, 11]. Both the commercial and organic fertilizers are used in its cultivation [12-14]. The Slovak farmers have a shortage of organic fertilizers, predominantly manure. The availability of composts is better. However, farmers’ confidence in compost is low, especially in compost from municipal solid waste, but also in industrial and domestic compost, in compost produced by cities. In the country, the trust in vermicomposts is significant, which is related to the fact that the components of vermicompost mean the fodder and living place and also reproduction of earthworms. In the case when the vermicompost contains the components unsuitable for earthworms’ life, they either escape from the vermicompost or die [15]. The vermicompost full of earthworms and cocoons indicates its biological appropriateness for agricultural purposes.

The majority of the European population believes that the fertilization by the organic fertilizers is the guarantee of a higher quality of the cultivated products and lower threat for the environment in comparison with the mineral fertilizers. But many scientific publications state that the impact of the organic fertilizers on the yield quantity and quality of the cultivated crops can be positive, neutral, and also negative [16-21]. Similarly, their effect on the soil parameters and environment can be either positive or negative [22-24]. The organic fertilizers are the source of the organic substances, from which soil humus is being formed [25], they increase the sorption capacity and buffering ability of soils [26, 27]. The organic fertilizers decrease the bulk density of soils [28], they have a positive impact on the heat capacity [29] and air regime in soils. The organic fertilizers increase the water infiltration into soil and water capacity, improve the water management of soil [30, 31]. They provide the growth stimulants [32], macro- and microelements, improve the nutrient uptake [33]. They effect the formation of soil aggregates [34, 35] and they increase the soil stability [27]. After their usage there occurs a faster decomposition of the crop residues [36]. They inhibit the intake of heavy metals into the food chain [37]. They vitalize biologically soil [38]. They accelerate the biodegradation of undesirable matters in soil [39]. They increase pH of soil, and also the number of bacteria genus *Azotobacter chroococcum* in soil, which has the positive impact on the health condition of crops, on the formation of aboveground and underground phytomass of plants [15].

The positive impact of organic fertilizers on the biological, chemical and physical soil parameters [40], it determines positively the quantititative and qualitative parameters of the cultivated crops. Blouin et al [41] claims that vermicompost brings about average increases of 26% in commercial yield, 13% in total biomass, 78% in shoot biomass, and 57% in root biomass. After the application of vermicompost the content of the total antioxidants, content of carotenones, lycopene, crude fibre, saccharides, Ca, Mg, P, Fe, Zn and other elements was increased in the crops like tomato, pepper, apple, pears, spinach, lettuce, cabbage, turnip, carrots, beetroots, celery, potato lentil [42-44]. The utilization of vermicompost increased the content of proteins and fat in the wheat grains [45]. The yields harvested from plants receiving vermicompost were firmer, characterized as ascorbic acid content and lower acidity, and have attractive colour [46] and better taste [47]. The substitution of mineral fertilizers by vermicompost reduced drastically the incidence of physiological disorders like albinism, fruit malformation and occurrence of grey mould in strawberry, indicating that vermicompost played a significant role in reducing nutrient-related disorders and diseases like Botrytis rot, and thereby increasing the marketable fruit yield up to 58.6% with better quality parameters [46, 48].

The negative impact of organic fertilizers on soil, environment and a man is associated predominantly with their improper usage, when they can lead to the increased content of nitrates in the ground water and surface water and plants [49]. The utilization of organic fertilizers raises the risk of leakage NH₃ into the atmosphere [50]. The threat of organic fertilizers consists also in the fact that they can contain pathogenes harmful for both people and plants [51].

A considerable part of the European population also supposes that the more earthworms are in soil the higher yield and quality of the cultivated crops is. However, the impact of earthworms on the quantity and quality of the cultivated crops depends on several factors, as a result there were recorded the positive effects on plant [52-54], also ambiguous, i. e. positive and negative [55, 56]. The statistically insignificant but also positive and negative plant reactions to the earthworms occurrence were presented by [57, 58].

Individual countries focus the different attention to the study of the impact of the particular species of earthworms on the quantity and quality of yields of the particular plant species. As far any facts have been presented about the number of earthworms of the particular species which can be beneficial for the individual crops and when they are harmful. The utility and harmfulness of earthworms should be evaluated not only form the aspect of the yield quantity, but also from...
the viewpoint of the yield quality, or the impact on the environment.

The objective of the submitted article is to answer the questions (I) how the different quantities of vermicompost in soil and (II) the presence of earthworms (Eisenia fetida) in the soil substrates can influence the carrot root and leaves weight and the content of vitamin C on the 100th day after its seeding.

Material and Methods

Experimental Design and Field Management

The two-year pot experiment (2017 and 2018) was carried out in the vegetation cage located in the campus of the Slovak University of Agriculture in Nitra (48°18'N, 18°05'E). In the experiment, the impact of two factors (I. amount of vermicompost and II. number of red earthworms) were studied on the carrot phytomass production and vitamin C content on the 100th day after carrot sowing.

The total number of treatments was 13. The weighed soil (treatment 1) and the mixture of soil and vermicompost (treatments 2 to 13) were placed in 35 cm high cylindrical pots with a diameter of 35 cm. The treatment 1 was the control one (soil without vermicompost). In the treatments 2-5 the impact of vermicompost quantity in the soil substrates was detected and in the treatments 6-13 the impact of the number of earthworms added to the soil substrates was studied, tested in the treatments 1-5.

20 kg of soil (Haplic Luvisol) was applied into the pots in the treatment 1 and 20 kg of the mixture consisting of soil and vermicompost (treatments 2 to 13) were placed in 35 cm high cylindrical pots with a diameter of 35 cm. The treatment 1 was the control one (soil without vermicompost). In the treatments 2-5 the impact of vermicompost quantity in the soil substrates was detected and in the treatments 6-13 the impact of the number of earthworms added to the soil substrates was studied, tested in the treatments 1-5.

20 kg of soil (Haplic Luvisol) was applied into the pots in the treatment 1 and 20 kg of the mixture consisting of soil and vermicompost (treatments 2 to 13) were placed in 35 cm high cylindrical pots with a diameter of 35 cm. The treatment 1 was the control one (soil without vermicompost). In the treatments 2-5 the impact of vermicompost quantity in the soil substrates was detected and in the treatments 6-13 the impact of the number of earthworms added to the soil substrates was studied, tested in the treatments 1-5.

Before putting the soil substrates into the pots, the plastic net was placed at the bottom of all pots to prevent the earthworms (EW) to escape. The pots with the weighted substrate were located on the saucers which were able to capture 1,000 ml of the leaked soil solution in the period of precipitation. The leaked solution was returned back to the pots.

The experiment was established according to the method of random arrangement of pots in four repetitions. The model crop was carrot (Daucus carota L. ssp. sativus) cultivar Nantes 3. In both years the sowing took place on 16 March. Subsequently, the experiment was irrigated to the level of 75% FWC (field or full water capacity). In the following 70 days all the pots were irrigated by the same dose of water containing the minimal quantity of nutrients. During the last 30 days of experiment the treatments 2 to 13 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. Twenty days after emergence of plants, they were thinned down their number to ensure the same number per pot (repetition). During the growth season (24 June on the 100th day after sowing) sampling of plant material was accomplished. 10 average individuals were taken from each treatment and repetition, which served for the evaluation of the root and leaves weight. The contents of vitamin C were determined in roots and leaves.

Analysis of Soil and Vermicompost

Were used the following analytical methods for the induction of the agrochemicals parameters of used soil

Table 1. Parameters of the soil and vermicompost used in the experiment.

| Subs. | N | P  | K  | Ca | Mg | S  | N<sub>int</sub> | C<sub>int</sub> | C:N | EC | pH<sub>KCl</sub> |
|-------|---|----|----|----|----|----|-------------|-------------|-----|----|---------------|
| So    | 9.20 | 17.80 | 173 | 3,100 | 452 | 4.40 | 0.70 | 9.00 | 11.88 | 0.12 | 6.35          |
| Vc    | 310.1 | 3,085 | 8,763 | 5,135 | 3,252 | 2,068 | 29.70 | 198.9 | 5.53 | 4.98 | 7.33          |

Subs. – substrate, So - soil, Vc – vermicompost
and vermicompost. N-NH$_4^+$ by Nessler’s colorimetric method; N-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$_2$SO$_4$. Nin was calculated as a sum of N-NH$_4^+$ + N-NO$_3^-$ (Nin = N–NH$_4^+$ + N–NO$_3^-$). The contents of available P, K, Ca, Mg were determined by Mehlich 3 extraction procedure [59]. The content of P was determined by colorimetric method, K by flame photometry, Ca and Mg by atomic absorption spectrophotometry, S spectrophotometrically (in the leachate of ammonium acetate), Nt by distillation after the mineralization of strong H$_2$SO$_4$ (Kjeldahl method) [60], C$_{ox}$ spectrophotometrically after the oxidation according to Tiurin [61], EC by the method of specific electrical conductivity and pH/KCl (in solution of 1.0 mol/dm$^3$ KCl) potentiometrically.

### Determination of L-ascorbic Acid

Three grams of homogenized fresh samples were stabilized with 10 mL of acid solution prepared as follows: 10% perchloric acid and 1% orthophosphoric acid in ultra pure water. The mixture was thoroughly vortexed for 1 minute. This solution was diluted to 50 mL with HPLC mobile phase. The sample was filtered with 0.45 μm filter.

L-ascorbic acid was determined by HPLC Agilent 1260 with quaternary solvent manager coupled with degasser, sample manager, column manager and DAD detector. All analyses were performed on C18 end capped column. Mobile phases consisted of methanol (B) and 0.1% H$_3$PO$_4$ (C). The isocratic elution was as follows: 0-6 min (20% B and 80% C) and 3 minutes post-run. The mobile phase flow was 1 mL/min and the sample injection was 20 µL. Column thermostat was set to 30 °C and the samples were kept at 4 °C the sampler manager. The detection wavelength was set at 256 nm. The spectral data were collected and processed using Agilent OpenLab ChemStation software for LC 3D Systems.

### Statistical Analysis

The acquired results were processed by the mathematical and statistical method, by the multifactorial analysis of variance (ANOVA). The differences between the treatments were evaluated by LSD test (Tukey’s test) at the significance level $\alpha = 0.05$. 

| Treatment | Designation | (g/10 individuals) | (%) |
|-----------|-------------|---------------------|-----|
| n.        | So          | 31.53               | 100.0 |
| 2         | SoVc$_{9:1}$ | 109.48              | 347.22 100.00 |
| 3         | SoVc$_{6:1}$ | 189.45              | 600.86 173.05 100.00 |
| 4         | SoVc$_{3:1}$ | 207.85              | 691.81 199.24 115.14 104.95 100.00 |
| 5         | SoVc$_{1:1}$ | 218.13              | 659.21 189.85 109.71 100.00 |
| 6         | SoVc$_{9:1}$+EW$_{10}$ | 135.03              | 428.26 123.34 71.27 64.97 61.90 |
| 7         | SoVc$_{9:1}$+EW$_{20}$ | 160.97              | 610.53 147.03 84.97 77.45 73.80 |
| 8         | SoVc$_{4:1}$+EW$_{10}$ | 208.38              | 660.89 190.34 109.99 100.26 95.53 |
| 9         | SoVc$_{4:1}$+EW$_{20}$ | 219.05              | 694.74 200.08 116.62 105.39 100.42 |
| 10        | SoVc$_{3:1}$+EW$_{10}$ | 221.44              | 702.32 202.73 116.89 106.54 101.52 |
| 11        | SoVc$_{3:1}$+EW$_{20}$ | 223.06              | 707.45 203.75 117.74 107.32 102.26 |
| 12        | SoVc$_{1:1}$+EW$_{10}$ | 231.02              | 732.70 211.02 121.94 111.15 105.91 |
| 13        | SoVc$_{1:1}$+EW$_{20}$ | 234.32              | 743.17 214.03 123.68 112.74 107.42 |

LSD$_{0.05}$ 3.296

1-13 183.82 - -

2-5 181.23 100.00 -

6-13 204.16 112.65 -

6,8,10,12 198.97 109.79 100.00

7,9,11,13 209.35 115.52 108.46

n. – number, So - soil, Vc – vermicompost, EW – earthworms, LSD$_{0.05}$ – least significant difference at the level $\alpha = 0.05$; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%
Results and Discussion

Weight of Underground Phytomass

Along with increasing the content of vermicompost in the soil substrate (tr. 2-5) the weight of carrot roots was rising (Table 2) as a result of the increasing content \( N_a \) but also other macroelements in the substrate, because Vc contained severalfold higher contents of macroelements in the available form than soil (Table 1). The increasing contents Vc in the soil substrate (10, 20, 25 and 50%) increased the yield of carrot roots compared with the treatment without Vc 3.47, 6.00, 6.59 and 6.92 times (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].

The differences in the roots weight (weight growth) between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were being decreased gradually. The biggest weight increase 3.47 times was detected between the treatments 1 and 2, and the lowest one only 1.05 times occurred between the treatments 4 and 5 (Table 2). This finding did not correspond with the facts of [62], who monitored the rise of roots weight in radish cultivation only up to the level 20% of proportions Vc in the soil substrate. The contents Vc in the soil substrate above the level 20% (25 and 50%) resulted in the fall of roots weight. The different reaction of the carrot plant and radish plants to the quantity of vermicompost in the substrate depends probably on the different duration of the experiment. The experiment with radish took 52 days and the experiment with carrot 100 days. The weight increase of carrot roots in consequence of the increasing quantity Vc the soil substrate approved the fact that the crop yields depend on the quantity of available nutrients in soil [63].
in soil - Table 1), in particular, in the areas where there is not risk of deterioration of quality of ground water and worsening of the parameters of environment.

The earthworms had the positive impact on the formation of carrot roots. When comparing the average roots weight of all treatments with earthworms and the average roots weight in the treatments without earthworms, it is obvious that the earthworms increased the roots weight by 12.65% (tr. 6 - 13 vs tr. 2 - 5). The positive effect of earthworms (different genera) on the phytomass formation of the grown crops was recorded by Brown et al. and Nweke [52, 54]. Based on the meta-analysis [64] claim that the presence of earthworms elevated significantly the underground biomass by 29%.

The average difference in carrot root yield between the treatments with 20 and 10 earthworms in the substrate (tr. 7, 9, 11, 13 vs. tr. 6, 8, 10, 12-Table 2) was 8.46% in favour of a higher number of earthworms. In the majority of cases the increases of roots weight as a result of a higher number of earthworms were statistically significant. Nurhidayati et al. [55] detected that along with the increasing number of earthworms genus *Pontoscolex corethrurus* in the growing medium there occurs the increase as well as decrease of cabbage yield. On the contrary, the opposite results were presented by Kováčik et al. [56], who recorded the decrease of radish root yield with the rising number of earthworms in the soil substrate. The presented different effect of earthworms on the carrot roots in comparison with the impact on the radish roots is the consequence of the fact that carrot has a longer growing season than radish. A longer growing season allows the carrot plants to cope with the initial attack of earthworms of root hairs better, and at the same time it allows carrot plants to use better the positive effect of earthworms on several soil parameters [56].

The intensity of earthworms` impact on the weight of roots depended on the interactive effect of the quantity of vermicompost in the substrate and number of earthworms. The root weight was increased by 23.34% with quantity 10% of Vc in the soil substrate under the influence of 10 pieces of earthworms per a pot, and by 47.03% under the influence of 20 pieces (tr. 6 and 7 vs. tr. 2). The weight of roots was increased by 9.99% with the quantity 20% Vc in the substrate under the influence of 10 pieces of earthworms, and by 15.62% under the influence of 20 pieces (tr. 8 and 9 vs. tr. 3). The root weight was increased by 6.54% with

---

**Table 4. Impact of vermicompost and earthworms on the content of vitamin C in fresh carrot roots.**

| Treatment        | (mg/100 g) | (%)    |
|------------------|------------|--------|
| n. Designation   | (mg/100 g) | (%)    |
| 1 So             | 14.94 ^c   | 100.00 |
| 2 SoVc<sub>9:1</sub> | 13.42 ^bc  | 89.83  | 100.00 |
| 3 SoVc<sub>4:1</sub> | 12.00 ^ab  | 80.32  | 89.42  | 100.00 |
| 4 SoVc<sub>3:1</sub> | 11.73 ^ab  | 78.51  | 87.41  | 97.75  | 100.00 |
| 5 SoVc<sub>9:1+EW</sub> | 10.67 ^a   | 71.42  | 79.51  | 88.92  | 90.96  | 100.00 |
| 6 SoVc<sub>9:1+EW</sub> | 12.69 ^abc | 84.94  | 94.56  | 105.75 | 108.18 | 118.93 |
| 7 SoVc<sub>4:1+EW</sub> | 12.22 ^ab  | 81.79  | 91.06  | 101.83 | 104.18 | 114.53 |
| 8 SoVc<sub>4:1+EW</sub> | 10.67 ^a   | 71.42  | 79.51  | 88.92  | 90.96  | 100.00 |
| 9 SoVc<sub>1:1+EW</sub> | 10.52 ^a   | 70.41  | 78.39  | 87.67  | 89.68  | 98.59 |
| 10 SoVc<sub>3:1+EW</sub> | 10.58 ^a   | 70.82  | 78.84  | 88.17  | 90.20  | 99.16 |
| 11 SoVc<sub>3:1+EW</sub> | 10.48 ^a   | 70.15  | 78.09  | 87.33  | 89.34  | 98.22 |
| 12 SoVc<sub>2:1+EW</sub> | 10.53 ^a   | 70.48  | 78.46  | 87.75  | 89.77  | 98.69 |
| 13 SoVc<sub>1:1+EW</sub> | 10.39 ^a   | 69.54  | 77.42  | 86.58  | 88.58  | 97.38 |

LSD<sub>0.05</sub> 2.424

1-13 11.60 - -

2-5 11.96 100.00 -

6-13 11.01 92.06 -

6,8,10,12 11.12 92.98 100.00

7,9,11,13 10.90 91.14 98.02

n. – number, So - soil, Vc – vermicompost, EW – earthworms, LSD<sub>0.05</sub> – least significant difference at the level α = 0.05; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%
Weight of Carrot Phytomass and Content...

Table 5. Impact of vermicompost and earthworms on the content of vitamin C in fresh carrot leaves.

| Treatment | Designation | (mg/100 g) | (%) | L-R |
|-----------|-------------|------------|-----|-----|
| n. | So 32.24 | 100.00 | 2.16 |
| 2 | SoVc 41.35 | 128.26 | 3.08 |
| 3 | SoVc 41.03 | 99.23 | 3.42 |
| 4 | SoVc 39.73 | 96.08 | 3.39 |
| 5 | SoVc 34.54 | 83.53 | 3.24 |
| 6 | SoVc 42.73 | 103.34 | 3.37 |
| 7 | SoVc 47.43 | 114.71 | 3.88 |
| 8 | SoVc 42.25 | 102.18 | 3.96 |
| 9 | SoVc 46.59 | 112.67 | 4.43 |
| 10 | SoVc 40.04 | 96.83 | 3.78 |
| 11 | SoVc 41.88 | 101.28 | 4.00 |
| 12 | SoVc 37.93 | 91.73 | 3.60 |
| 13 | SoVc 39.14 | 94.66 | 3.77 |
| LSD<sub>0.05</sub> | 3.508 | - | - |
| 1-13 | 40.53 | - | - |
| 2-5 | 39.16 | 100.00 | - |
| 6-13 | 42.25 | 107.89 | - |
| 6,8,10,12 | 40.74 | 104.03 | 100.00 |
| 7,9,11,13 | 43.76 | 111.75 | 107.41 |

n. – number, So - soil, Vc – vermicompost, EW – earthworms, LSD<sub>0.05</sub> – least significant difference at the level α = 0.05; different letter behind a numerical value respond to the statistically significant difference at the level 95.0%

quantity 25% of Vc under the influence of 10 pieces of earthworms, and by 7.32% under the influence of 20 pieces (tr. 10 and 11 vs. tr. 4). The weight of roots rose by 5.91% with quantity 50% of Vc in the soil substrate under the influence of 10 pieces of earthworms, and by 7.42% under the influence of 20 pieces (tr. 12 and 13 vs. tr. 5). These facts prove that the highest percentage yield increase was achieved if earthworms were put into the substrate with the lowest quantity of vermicompost. This finding is related to the fact that the positive impact of earthworms on the bulk density of soil and consequently on the rise of roots yield is falling along with the decreasing bulk density of soil, the increasing content of organic matter in soil [15].

Weight of Aboveground Phytomass

The carrot leaves reacted to the presence of vermicompost and red worms in the substrate similarly like the roots, however less markedly. Along with the increasing content of vermicompost in the soil substrate (tr. 2 - 5) the leaves weight was being increased (Table 2). With 10, 20, 25 and 50% of Vc content in the soil substrate the leaves weight was increased compared to the treatment without VC 2.72, 4.02, 4.31 and 4.71 times (Table 2). The registered more dynamic growth of the roots weight than leaves in the treatments with vermicompost approved the fact that the fertilization by nitrogen usually determines more considerably the growth of roots than leaves [65].

The growths of leaves weight between the treatments 1 and 2, 2 and 3, 3 and 4, 4 and 5 were as following: 2.73, 1.47, 1.07 and 1.09 times (Table 3). This result proves that along with the increasing quantity of vermicompost in soil the effect of Vc on the leaves growth was falling. The curves, expressing the impact of N fertilizers on the plant growth, have the different shape depending on the growing conditions. Their course has usually the sigmoid shape. Along with the growth of dose N first the phytomass rises dynamically, later the growth is being slowed down, and it can even result in the decrease of the phytomass formation.

4.71 times higher weight of carrot leaves in the treatment with 50% proportion of Vc in comparison with the control treatment without Vc does not indicate the depressive impact of the high proportion of Vc in the soil substrate on the carrot plants, which is often
evident with high application doses of the fertilizers containing nitrogen [66, 67].

In the treatments 6-13 the earthworms increased the leaves weight on average only by 5.95% (tr. 6 - 13 vs tr. 2 - 5), which is the considerably lower effect compared with the impact on the roots weight (Table 2 and 3). The rate of increase was significantly lower also in comparison with the data presented by van Groenigen [53], who state that earthworms in the different ecosystems increase the formation of the aboveground phytomass by 23%.

The number of earthworms did not influence considerably the carrot leaves weight, nevertheless, it tended to increase it. The average growth of the carrot leaves weight between the treatments with 20 and 10 earthworms in the substrate (tr. 7, 9, 11, 13 vs. tr. 6, 8, 10, 12) was at the level of 2.59% in favour of a higher number of earthworms.

The impact of earthworms on the leaves weight determined the interactive effect of the quantity of vermicompost in the substrate and number of earthworms. The quantity 10% Vc in the soil substrate under the influence of 10 pieces of earthworms per a pot increased the leaves weight by 6.97% and under the influence of 20 pieces by 8.66% (tr. 6 and 7 vs. tr. 2). The quantity 20% Vc in the substrate under the influence of 10 pieces of earthworms increased leaves weight by 5.57% under the influence of 20 pieces by 11.47% (tr. 8 and 9 vs. tr. 3). The quantity 25% Vc under the influence of 10 pieces of earthworms increased the roots weight by 4.58% and under the influence of 20 pieces by 6.00% (tr. 10 and 11 vs. tr. 4). The quantity 50% Vc under the influence of 10 pieces of earthworms increased the roots weight by 4.58% and under the influence of 20 pieces by 6.00% (tr. 10 and 11 vs. tr. 4). The quantity 50% Vc under the influence of 10 pieces of earthworms increased the roots weight by 4.58% and under the influence of 20 pieces by 6.00% (tr. 10 and 11 vs. tr. 4). The positive interactive effect of earthworms and vermicompost on the formation of phytomass of the cultivated crops was presented by Brown et al. [52].

The lowest percentage growths of leaves weight with both numbers of earthworms were detected in the treatments where was the highest - 50% proportion Vc in the soil substrate. This information corresponds with already presented interactive effect between the quantity of vermicompost in the substrate and the number of earthworms on the roots weight (Table 2). But the impact on the leaves was less strong.

Vitamin C Content

In all treatments of the experiment the average value of vitamin C (11.6 mg/kg) was considerably higher than [68, 9] claim and lower than [69, 70] state. The highest content of vitamin C in the carrot roots (14.94 mg/kg) was detected in the control treatment, where the soil substrate did not involve Vc. Along with the increasing quantity Vc in the soil substrate (tr. 2 - 5) the content of vitamin C was falling (Table 4). The reason was the generally known negative correlation between the content N in soil and the content of vitamin C in a plant, because with the rising content Vc in the substrate the content N in the substrate was increasing. Under some growing conditions the increase of quantity Vc in soil does not lead to the decrease of the content of vitamin C in plants [55]. The differences in contents of vitamin C between 1 and tr. 2-5 varied in the interval from 1.52 to 4.27 mg/100g, whereby the differences between tr. 1 and tr. 3-5 were significant.

The earthworms did not determine the content of vitamin C in roots statistically significantly. On average in the treatments 6-13 they decreased the content of vitamin C only by 0.95 mg/kg (tr. 6 - 13 vs tr. 2 - 5). The differences in the contents of vitamin C between the relevant treatments (tr. 2 and tr. 6, 7, tr. 3 and tr. 7 and 8, tr 4 and tr. 9 and 10, tr. 5 and tr. 11 and 12) were minimal, statistically insignificant. The insignificant impact of earthworms on the content of vitamin C in the fruits of papaya (Carica papaya L.) was presented by [71].

The rise of number of earthworms from 10 individuals to 20 ones per a pot did not have a considerable impact on the content of vitamin C in carrot roots. In spite of this fact, it is possible to state that the increase of the number of earthworms tended to increase the content of vitamin C in roots. The average decrease of the content of vitamin C in the treatments 7, 9, 11 and 13 compared with the treatments 6, 8, 10 and 12 achieved cca 2% (Table 4).

The content of vitamin C in carrot leaves was 2.16 even 4.00 times higher than in the roots (Table 5). The effect of vermicompost on the content of vitamin C in the leaves was partially different from the impact on the roots. In all treatments with vermicompost the content of vitamin C was higher than in the control treatment, however, this content was diminishing with the rising quantity of Vc in the soil substrate. The lowest content of vitamin C detected in the treatment without Vc (tr.1) was the consequence of the fact that the plants react to the insufficiency of nutrients by more rapid ageing of leaves and the faster degradation of vitamin C.

The earthworms influenced the content of vitamin C in leaves more significantly than the content in roots, thanks to predominantly the treatments with a higher number of earthworms in the substrate. The effect of earthworms on the content of vitamin C was positive. On average in the treatments 6-13 the increased the content of vitamin C in leaves by 7.89% (tr. 6 - 13 vs tr. 2 - 5). 10% quantity of Vc in the soil substrate with 10 pieces Ew per a pot increased the content of vitamin C in leaves by 3.34% and by the impact of 20 pieces Ew by 14.71% (tr. 6 and 7 vs. tr. 2). The quantity 20% Vc in the substrate with 10 pieces of earthworms increased the content of vitamin C in leaves by 2.97% and by the influence of 20 pieces by 13.57% (tr. 8 and 9 vs. tr. 3). The quantity 25% Vc in the substrate with 10 pieces of earthworms increased the content of vitamin C in leaves by 0.78% and by the influence of
20 pieces by 5.41% (tr. 10 and 11 vs. tr. 4). The quantity 50% Vc in the substrate determined the increases at the level of 9.81% and 13.32% (tr. 12 and 13 vs. tr. 5). 20 pieces of earthworms in comparison with 10 pieces of earthworms (tr. 7, 9, 11, 13 vs. tr. 6, 8, 10, 12) increased the content of vitamin C on average by 7.41%. The rise of the content of vitamin C in carrot roots after the inoculation of earthworms into soil was recorded by Kovácík et al. [72].

Conclusions
Along with the increase of the content of vermicompost in the soil substrate the weight of roots and leaves was increased and the content of vitamin C was falling. The roots weight was rising more dynamically than the leaves weight. A high-50% proportion of Vc in the soil substrate did not have the negative effect on the formation of the aboveground and underground phytomass. The use of Vc in soils with a low content of available nutrients in high doses (25 and 50% in the substrate) does not pose a risk of reduced yields. This finding creates a precondition for the use of year-on-year growing compost production in European countries.

The earthworms (10 and 20 individuals/pot) have the positive impact on the formation of carrot roots and leaves. The impact on roots was stronger. A higher yield of roots was achieved in the treatments with 20 earthworms than in the treatments with 10 earthworms per a pot. The highest percentage increases of the roots yield with both numbers of earthworms were achieved if the earthworms were placed into the substrate with the lowest quantity of vermicompost. The earthworms did not determine the content of vitamin C in carrot roots.

Acknowledgements
This article was supported by the national granted project VEGA of the Ministry of education of Slovak Republic under the No. 1/0378/20.

Conflict of Interest
The authors declare no conflict of interest.

References
1. HEINONEN M. Carotenoids and provitamin A activity of carrot (Daucus carota L.) cultivars. J. Agric. Food Chem. 38 (3), 1990.
2. ARSCOTT S.A., TANUMIHARDJO S.A. Carrots of many colors provide basic nutrition and bioavailable phytochemicals acting as a functional food. Compr. Rev. Food Sci. Food Saf. 9, 223, 2010
3. SINGH D.P., BELOY J., McINERNEY J.K., DAY L. Impact of boron, calcium and genetic factors on vitamin C, carotenoids, phenolic acids, anthocyanins and antioxidant capacity of carrots (Daucus carota). Food Chemistry. 132, 1161, 2012.
4. BYSTRICKA J., KAVALCOVÁ P., MUSILOVÁ J., VOLLMANNOVÁ A., TÓTH T., LENKOVÁ M. Carrot (Daucus carota L. ssp. sativus (Hofm.) Arcang) as source of antioxidants. Acta Agric. Slov. 105 (2), 303, 2015.
5. QUE F., HOU X.L., WANG G.L., XU Z.S., TAN G.F., LI TONG, WANG Y.H.-KHADRA A., XIONG, A.S. Advances in research on the carrot, an important root vegetable in the Apiaceae family. Horticulture Research. 6, 69, 2019.
6. GALLICHLIO L., BOYD K., MATANOSKI G., TAO XG., CHEN L., LAM T.K., SHIELS M., HAMMOND E., ROBINSON K.A., CAULFIELD L.E., HERMAN J.G., GUALLAR E., ALBERG A.J. Carotenoids and risk of developing lung cancer: a systematic review. Am. J. Clin. Nutr. 88, 372, 2008.
7. ZHANG C.X., HO S.C., CHEN Y.M., FU J.H., CHENG S.Z., LIN F.Y. Greater vegetable and fruit intake is associated with a lower risk of breast cancer among Chinese women. Int. J. Cancer. 125, 181, 2009.
8. SILVA DIAS J.C. Nutritional and Health Benefits of Carrots and Their Seed Extracts. Food and Nutrition Sciences, 5, 2147, 2014.
9. SHARMA K.D., KARKI S., THAKUR N.S., ATTRI S. Chemical composition, functional properties and processing of carrot - a review. J. Food Sci. Technol. 49 (1), 22, 2012.
10. MAGDAS D.A., FEHER I., DEHELEAN A., CRISTEA G., MAGDAS T.M., PUSCAS R., MARINCAȘ O. Isotopic and elemental markers for geographical origin and organically grown carrots discrimination. Food Chemistry. 267, 231, 2018.
11. WIERZBOWSKA J., CWALINA-AMBROZIAK B., ZALEWSKA M., ŚWIATŁY A. Cultivation system versus the content of minerals in carrot (Daucus carota L.) roots. Acta Sci. Pol. Hortorum Cultus. 16 (6), 111, 2017.
12. SMOLEN S., SADY W. The effect of various nitrogen fertilization and foliar nutrition regimes on the concentrations of sugars, carotenoids and phenolic compounds in carrot (Daucus carota L.). Scientia Horticuluctiae, 120, 315, 2009.
13. MBATHA A.N., CERONIO G.M., COETZER G.M. Response of carrot (Daucus carota L.) yield and quality to organic fertilizer. S. Afr. J. Plant Soil. 31 (1), 1, 2014.
14. ASSUNÇÃO N.S., CLEMENTE J.M., DE AQUINO L.A., DEZORDI L.R., DOS SANTOS L.P.D. Carrot yield and recovery efficiency of nitrogen, phosphorus and potassium. Revista Caatinga. 29 (4), 859, 2016.
15. KOVÁČIK P. Principles and methods of plant nutrition. Nitra: SPU in Nitra, 278, 2014. ISBN 978-80-552-1193-0.
16. LEÓN A.P., MARTÍN J.P., CHIESA A. Vermicompost application and growth patterns of lettuce (L.). Agricultura Tropica et Subtropica. 29 (2), 45, 2016.
17. ZAYED M.S., HASSANEIN M.K.K., ESA N.H., ABDALLAH M.M.F. Productivity of pepper crop (Capsicum annuum L.) as affected by organic fertilizer, soil solarization, and endomycorrhizae. Ann. Agric. Sci. 58, 131, 2013.
18. CHAKRABORTY B., KUNDU M., CHATTOPADHYAY R.N. Organic Farming with Bio-mulching – A New Paradigm for Sustainable Leaf Yield & Quality of Mulberry (Morus alba L.) under Rainfed Lateritic Soil Condition. Agric. Agric. Sci. Procedia. 11, 31, 2016.
19. Gholami H., Fard F.R., Saharkhiz M.J., Ghani A. Yield and physicochemical properties of inulin obtained from Iranian chicory roots under vermicompost and humic acid treatments. Industrial crops. Ind. Crops Prod. 123, 610, 2018.

20. Gholami H., Saharkhiz M.J., Fard F.R., Ghani A., Nadaf F. Humic acid and vermicompost increased bioactive components, antioxidant activity and herb yield of Chicory (Cichorium intybus L.). Biocatal. Agric. Biotechnol. 14, 286, 2018.

21. Najjari F., Ghasemi S. Changes in chemical properties of sawdust and blood powder mixture during vermicomposting and the effects on the growth and chemical composition of cucumber. Scientia Horticulturae. 232, 250, 2018.

22. Kong X.B., Lai B., Liu H.B., Li K.J., Feng G.L., Zhang Q.P., Zhang B.B. Chapter four - Fertilizer intensification and its impacts in China’s HHH plains. Advances in Agronomy. 125, 135, 2014.

23. Wu D., Feng Y., Xue L., Liu M., Yang B., Hu F., Yang L. Biochar combined with vermicompost increases crop production while reducing ammonia and nitrous oxide emissions from a paddy soil. Pedosphere. 29, 82, 2019.

24. Makova J., Javorekova S., Elbl J., Medo J., Hricakova N., Kovácik P. Impact of vermicompost on biological indicators of the quality of soil under maize in a greenhouse experiment. J. Elem. 24 (1), 319, 2019.

25. Mensik L., Hlinskirovsky L., Pospisilova E., Kunzova E. The effect of application of organic manures and mineral fertilizers on the state of soil organic matter and nutrients in the long-term field experiment. J. Soils Sediments. 18, 283, 2018.

26. Vagi P., Ferreira M.C., Pessoa da Cruz M.C., Barboza J.C. Organic matter fractions and soil fertility under the influence of liming, vermicompost and cattle manure. Sci. Agric. 60 (3), 549, 2003.

27. Pernes-Debuysier A., Tessier D. Soil physical properties affected by long-term fertilization. Eur. J. Soil Sci. 55 (3), 505, 2004.

28. Mahmod F., Khan I., Ashraf U., Shahzad T., Hussain S., Shahid M., Abid M., Ullah S. Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. J. Plant. Nutr. Soil Sci. 17 (1), 22, 2017.

29. Usowicz B., Lipiec J. The effect of exogenous organic matter on thermal properties of tilled soils in Poland and the Czech Republic. J. Soils Sediments. 20, 365, 2020.

30. Liu C.-A., Li F.-R., Zhou L.-M., Zhang R.-H., Yu J., Lin S.-L., Wang L.-J., Siddique K.H.M., Li F.-M. Effect of organic manure and fertilizer on soil water and crop yields in newly-built terraces with loess soils in a semi-arid environment. Agric. Water Manag. 117, 123, 2013.

31. Doan T.T., Henry-des-Tureaux T., Rumple C., Janeau J.L., Jouquet P. Impact of compost, vermicompost and biochar on soil fertility, maize yield and soil erosion in Northern Vietnam: A three year mesocosm experiment. Sci. Total Environ. 514, 147, 2015.

32. Murmu K., Swain D.K., Ghosh B.C. Comparative assessment of conventional and organic nutrient management on crop growth and yield and soil fertility in tomato-sweet corn production system. Aust. J. Crop Sci. 7 (11), 1617, 2013.

33. Wang X., Yan J., Zhang X., Zhang S., Chen Y. Organic manure input improves soil water and nutrients use for sustainable maize (Zea mays L.) productivity on the Loess Plateau. PLoS ONE. 15 (8), e0238042, 2020.

34. Wortmann C.S., Shapiro C.A. The effects of manure application on soil aggregation. Nutr. Cycling Agroecosyst. 80, 173, 2007.

35. Guo Z., Zhang L., Yang W., Hua L., Cai C. Aggregate Stability under Long-Term Fertilization Practices: The Case of Eroded Ultisols of South-Central China. Sustainability. 11 (4), 1169, 2019.

36. Kovácik P., Kozánek M., Takač P., Galliková M., Varga L. The effect of pig manure fermented by larvae of house flies on the yield parameters of sunflowers (Helianthus annuus L.). Acta Univ. Agric. et Silvic. Mendelaeiana Brno. 58 (2), 147, 2010.

37. Zaniewicz-Bajkowska A., Rosa R., Franczuk J., Kosterna E. Direct and secondary effect of liming and organic fertilization on cadmium content in soil and in vegetables. Plant Soil Environ. 53 (11), 473, 2007.

38. Zaller J.G., Köpke U. Effects of traditional and biodynamic farmyard manure amendment on yields, soil chemical, biochemical and biological properties in a long-term field experiment. Biol. Fertil. Soils. 40 (4), 222, 2004.

39. Han S.H., An J.Y., Hwang J., Kim S.B., Park B.B. The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera Lin.) in a nursery system. Forest Sci. Technol. 12 (3), 137, 2016.

40. Loss A., DA ROSA Couto R., Brunetto G., DA Veiga M., Tozelli M., Balidi E. Animal manure as fertilizer: changes in soil attributes, productivity and food composition. Int. J. Res. Granthaalayah. 7 (9), 307, 2019.

41. Blouin M., Barrere J., Meyer N., Lartigue S., Barot S., Mathieu J. Vermicompost significantly affects plant growth. A meta-analysis. Agron. Sustain. Dev. 39, 34, 2019.

42. Worthington V. Nutritional Quality of Organic Versus Conventional Fruits, Vegetables and Grains. J. Altern. Complement. Med. 7 (2), 161, 2001.

43. Gutiérrez-Miceli F.A., Santiago-Borraz J., Montes Molina J.A., Nafate C.C., Abud-Aricha M., Oliva Llaven M.A., Rincon-Rosales R., Dendooven L. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (Lycopersicon esculentum). Bioresour. Technol. 98, 2781, 2007.

44. Demir Z., Kiran S. Effect of vermicompost on macro and micro nutrients of lettuce (Lactuca Sativa Var. Crispa) under salt stress conditions. KSU J. Agric. Nat. 23 (1), 33, 2020.

45. Joshi R., VIG A.P., Singh J. Vermicompost as soil supplement to enhance growth, yield and quality of Triticum aestivum L.: A field study. Int. J. Recycl. Org. Waste Agric. 2, 16, 2013.

46. Singh R., Sharma R.R., Kumar S., Gupta R.K., Patil R.T. Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (Fragaria x ananassa Duch.). Bioresour. Technol. 99 (17), 8507, 2008.

47. Sarjoltia V. Use of Vermicompost in Apple Orchards in Himachal Pradesh, India. Agricultural Science, 1, 17, 2012.

48. Adhikary S. Vermicompost, the story of organic gold: A review. Agricultural Sciences. 3 (7), 9, 2012.

49. Li S., Li J., Zhang B., Li D., Li G., Li Y. Effect of different organic fertilizers application on growth and environmental risk of nitrate under a vegetable field. Scientific Reports. 7, 17020, 2017.
50. van der STELT B., TEMMINGHOFF E.J.M., van VLIEET P.C.J., van RIEMSDIJK W.H. Volatilization of ammonia from manure as affected by manure additives, temperature and mixing. Bioresour. Technol. 98 (18), 3449, 2007.
51. BHATT M.K., LABANYA R., JOSHI H.C. Influence of Long-term Chemical fertilizers and Organic Manures on Soil Fertility-A Review. Univers. J. Agric. Res. 7 (5), 177, 2019.
52. BROWN G.G., EDWARDS C.A., BRUSSAARD L. How earthworms effect plant growth: Burrowing into the mechanisms. In: Edwards C.A. et al. Earthworm ecology. 2nd Edition. CRC Press, Boca Raton. 13, 2004, ISBN 9780849318191.
53. VAN GROENIGEN J.W., LUBBERS I.M., VOS H.M.J., KOVÁČIK P., Šalamúň P., ŠIMANŠKÝ V., MORAVČÍK E. Earthworms increase plant production: a meta-analysis. Scientific Reports. 4 (6365), 1, 2014.
54. NWEKE I.A. Effect of compost and earthworm production on soil properties, growth and dry matter yield of maize in crude oil degraded soil. J. Soil Sci. Environ. 8, 1, 2017.
55. NURHIDAYATI N., ALI U., MURWANI I. Yield and quality of cabbage (Brassica oleracea L. var. capitata) under organic growing media using vermicompost and earthworm Pontoscolex corethrurus inoculation. Agric. Sci. Procedia. 11, 5, 2016.
56. KOVÁČIK P., ŠALAMÚŇ P., WIERZBOWSKA J. Vermicompost and Eisenia foetida as factors influencing the formation of radish phytomass. Agriculture (Polnohospodársťo). 64, 49, 2018.
57. DOAN T.T., NGO P.T., RUMPEL C., NGUYEN B.V. Interactions between compost, vermicompost and earthworms influence plant growth and yield: A one-year greenhouse experiment. Scientia Horticulturae. 160, 148, 2013.
58. ELMER W.H. Effect of leaf mold mulch, biochar, and earthworms on mycorrhizal colonization and yield of asparagus affected by Fusarium crown and root rot. Plant Disease. 100, 2507, 2016.
59. MEHLICH A. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. Commun. Soil Sci. Plant Anal. 15, 1409, 1984.
60. BREMNER J.M. Determination of nitrogen in soil by the Kjeldahl method. J. Agric. Sci., 55, 11, 1960.
61. DZIADOWIEC H., GONET S.S. A guide to the methods for determination of soil organic matter. Prace Komisji Naukowej. PTG, Warszawa. 65, 1999.
62. KOVÁČIK P., ŠALAMÚŇ P., SMOLEŇ S., RENČO M. Impact of vermicompost as component of growing medium on phytomass formation of radish (Raphanus sativus L.). Agriculture (Polnohospodársťo), 64 (3), 106, 2018.
63. CONG W.-F., CHRISTENSEN B.T., ERIKSEN J. Soil nutrient levels define herbage yield but not root biomass in a multispecies grass-legume ley. Agric. Ecosyst. Environ. 276, 47, 2019.
64. XIAO Z., WANG X., KORICHEVA J., KERGUNTEUIL A., LE BAYON R-C., LIU M., HU F., RASMASS N. Earthworms affect plant growth and resistance against herbivores: A meta-analysis. Functional Ecology. 32, 150, 2018.
65. SUQUIRA D., TATENO M. Optimal leaf-to-root ratio and leaf nitrogen content determined by light and nitrogen availabilities. PloS One. 6, e22236, 2011.
66. WANG D., XU Z., ZHAO J., WANG Y., YU Z. Excessive nitrogen application decreases grain yield and increases nitrogen loss in a wheat-soil system. Acta Agr. Scand. B-S. P. 61, 681692, 2011.
67. MOJID M.A., WYSEURE G.C.L., BISWAS S.K. Requirement of nitrogen, phosphorus and potassium fertilizers for wheat cultivation under irrigation by municipal wastewater. J. Plant. Nutr. Soil Sci. 12 (4), 655, 2012.
68. NICOLLE C., SIMON G., ROCK E., AMOUROUX P., RÉMÉSY CH. Genetic Variability Influences Carotenoid, Vitamin, Phenolic, and Mineral Content in White, Yellow, Purple, Orange, and Dark-orange Carrot Cultivars. J. Am. Soc. Hortic. Sc. 129 (4), 523, 2004.
69. LEONG S.Y., OYE I. Effect of endogenous ascorbic acid oxidase activity and stability on vitamin C in carrots (Daucus carota subsp. sativus) during thermal treatment. Food Chemistry. 134, 2075, 2012.
70. GAMBOA-SANTOS J., SORIA A.C., PEREZ-MATEOS M., CARRASCO J.A., MONTILLA A., VILLAMIEL M. Vitamin C content and sensorial properties of dehydrated carrots blanched conventionally or by ultrasound. Food Chemistry. 136, 782, 2013.
71. XIANG H., ZHANG J., GUO L., ZHAO B. In situ earthworm breeding in orchards significantly improves the growth, quality and yield of papaya (Carica papaya L.). PeerJ, 4, e2752, 2016.
72. KOVÁČIK P., ŠALAMÚŇ P., SMOLEŇ S., ŠKARPA P., ŠIMANSKÝ V., MORAVČÍK E. Determination of the carrot (Daucus Carota L.) yields parameters by vermicompost and earthworms (Eisenia Foetida). Slovak J. Food Sci. 12, 520, 2018.