

## The impact of vermicompost application on the yield parameters of maize (*Zea mays* L.) observed in selected phenological growth stages (BBCH-SCALE)

Mária Kmeťová\*, Peter Kováčik

Slovak University of Agriculture in Nitra, Slovak Republic

The impact of vermicompost application was assessed in one year pot experiment carried out in a vegetation cage located in the area of the SUA in Nitra. The model crop was grain maize. Treatment 1 was a non-fertilized treatment. In treatments 2 and 3, vermicompost was applied in autumn at the same dose of 8.26 t ha<sup>-1</sup> (170 kg ha<sup>-1</sup> N). In treatments 4 and 5, vermicompost was applied in spring at the same dose of 8.26 t ha<sup>-1</sup> (170 kg ha<sup>-1</sup> N). In treatments 3 and 5 was added nitrogen to vermicompost as the LAD (ammonium nitrate with dolomite) fertilizer at dose of 218.18 kg ha<sup>-1</sup> (60 kg ha<sup>-1</sup> N). During the vegetation was determined the height and stalk thickness of maize plants (growth stages BBCH 14, 16, 18), the yield of phytomass (growth stage BBCH 16), content of macro-elements (BBCH 16) and the total chlorophyll content (growth stage BBCH 18). The yield parameters were most positive influenced in treatment where vermicompost was applied in spring with the addition of the LAD. In the treatments, in which mineral nitrogen was added, yield parameters were affected more positively than in the treatments where only vermicompost was applied. Overall, the spring application affected yield parameters more positively than the autumn application. The highest N content in the phytomass was found in the same treatment, where was found highest observed parameters of plants. The addition of the LAD fertilizer had a depressing effect on the P and K content in phytomass. The autumn application of standalone vermicompost influenced the P and K content in plant phytomass more positively than the spring application. The addition of the LAD fertilizer had a positive effect on the Ca content in plant phytomass.

**Keywords:** vermicompost, maize, total chlorophyll, phytomass, macro-elements, phenological growth stages BBCH-scale

### 1. Introduction

In organic farming found use of a recovery of waste products with farming technology of earthworm in the genus *Eisenia foetida*, which in the gastrointestinal tract mixed digested organic matter with minerals, i.e. soil, thereby is created an organo-mineral complex secreted in the form of rollers i.e. casts, which having a positive impact on the physical, chemical and biological soil parameters. Compared to conventional compost contains vermicompost large amounts of total nutrients with larger percentage of available forms. Valuable is the high number of microorganisms and also considerable level of growth regulators such as auxins, gibberellins, cytokinins. Vermicompost application accelerates the ripening process of the crop of 1–2 weeks with improving the quality parameters of cultivated plants (Kováčik, 2005).

Vermicompost application positively affected the soil pH, reduces the hydrolytic acidity (Gutiérrez-Micely et al., 2007) and enhanced the enzyme activity of the soil (Lavelle and Martin, 1992). Easily available organic

residues and microorganisms coming from vermicompost stimulated in soil degradation of polycyclic aromatic hydrocarbons (PAHs) (Wilson and Jones, 1993; Banerje et al., 1997; Wilson and Bouwer, 1997; Namkoong et al., 2002). Vermicompost application had a positive effect on yield parameters of tomatoes (Gutiérrez-Micely et al., 2007; Szczech, 1999), strawberry (Singh et al., 2008), maize (Gutiérrez-Micely et al., 2008), peppers (Aracon et al., 2005) and cucumber (Edwards et al., 2010).

The application of vermicompost at dose of 10–12 t ha<sup>-1</sup> (170 kg ha<sup>-1</sup> N) gives average a 15–20 kg ha<sup>-1</sup> N in inorganic form and during the year released additionally 40–60 kg ha<sup>-1</sup> N<sub>an</sub> in mineralization process. From these reason is obvious that the only application of vermicompost in dose not higher than 170 kg ha<sup>-1</sup> N doesn't create conditions for achieving high yields. If vermicompost isn't apply in dose more than 170 kg ha<sup>-1</sup> N, then with aim to achieve high yield, agronomist must apply a mineral nitrogen fertilizers (Kováčik, 2014). The synergistic effect of combining farm and mineral fertilizers application has been confirmed many times

\*Correspondence: Mária Kmeťová, Slovak University of Agriculture in Nitra, Faculty of Agrobiolgy and Food Resources, Department of Agrochemistry and Plant Nutrition, Trieda Andreja Hlinku 2, 949 76 Nitra, e-mail: kmetova.maria0307@gmail.com

(Kováčik, 2009). The same results also reported Jeyabal and Kuppaswamy (2001) where the joint application of vermicompost and nitrogen fertilizer increased the rice crop of 15.6 % compared to the only application of nitrogen fertilizer.

To verify the nutritional status of the maize plants, it is recommended to carry out a sampling of plants 0.4 to 0.6 m corresponding to the growth stages BBCH 16 to BBCH 18. It is required to observe these terms, because the sampling at the lower growth stages is influenced by the lower content of dry matter and a higher nutrient content (Richter and Ryant, 2008). The verification of the nutritional status of the maize plants can be made by measuring the plant height, the thickness of the stalks or by determining of the nutrient and chlorophyll content in the plants.

From these reason the aim of experiment was to determine the impact of different term (autumn/spring) of vermicompost application and impact of addition of mineral nitrogen to vermicompost on selected yield parameters observed in phenological growth stages (BBCH-scale from 14 to 18).

## 2. Material and methods

The pot experiment was carried out in the vegetation cage at the Slovak University of Agriculture in Nitra (48° 18' S, 18° 06' V). Soil at dose of 22 kilograms was applied into pots of 0.38 m height and of 0.38 m diameter. The soil (Haplic Fluvisol) was taken from the fields of Agrokomplex Nitra from the topsoil (0–0.25 m).

The tested vermicompost was produced from cow dung (about 50 %), sheep manure (about 10 %), green

grass (about 10 %) and wood chips (about 30 %). After 3 to 4 months of fermentation (composting) was prepared a mixture of the new with the old vermicompost in a ratio of 1 : 1. In the old vermicompost were earthworms and cocoons. Viable cocoons were 10 times more than dead. In one litre of vermicompost were 65 pieces earthworms with an average weight of 0.45 grams per earthworm. The fodder for earthworms was mainly fruit and vegetables (food waste), and the fodder was mashed before the application. Basic agrochemical parameters of soil and vermicompost are presented in Table 1.

The experiment had 5 treatments with a threefold repetition. Treatment (tr.) 1 was a non-fertilized control treatment. In treatments 2 and 3 vermicompost was applied in autumn before the sowing of the maize at the same dose of 8.26 t ha<sup>-1</sup> (170 kg ha<sup>-1</sup> N). In treatments 3 was added nitrogen to vermicompost as the LAD (ammonium nitrate with dolomite) fertilizer at dose of 218.18 kg ha<sup>-1</sup> (60 kg ha<sup>-1</sup> N). In treatments 4 and 5, vermicompost was applied in spring, one month before the sowing of the maize at the same dose of 8.26 t ha<sup>-1</sup> (170 kg ha<sup>-1</sup> N). In treatments 5 was added mineral nitrogen to vermicompost as the LAD (ammonium nitrate with dolomite) fertilizer at dose of 218.18 kg ha<sup>-1</sup> (60 kg ha<sup>-1</sup> N). Nitrogen as the fertilizer LAD (ammonium nitrate with dolomite) was applied shallowly into the soil one week before the maize sowing. The experiment treatments are shown in Table 2.

The doses of vermicompost and nitrogen fertilizer were calculated based on content of total nitrogen in these materials. The content of total nitrogen, which was determined in vermicompost, is shown in Table 1. Dose of

**Table 1** Agrochemical characteristics of soil and vermicompost

Material	pH <sub>KCl</sub>	N <sub>an</sub>	P	K	Ca	Mg	N <sub>t</sub>	C <sub>ox</sub>	Org. s.
Soil	6.52	17.6	26.2	300.5	4670	1096	3234	2.29	9.59
VC (100% dry matter)	7.36	477.1	5642	14285	8535	4893	29400	20.51	48.53

VC – vermicompost, Org. s. – organic substances, C<sub>ox</sub> – total organic carbon, N<sub>an</sub> – inorganic nitrogen, N<sub>t</sub> – total nitrogen

**Table 2** Treatments of the experiment

Treatments	labelling	Dose of N			Dose of VC		Dose of LAD		Term of application	
		in VC	in LAD	total	t ha <sup>-1</sup>	g pot <sup>-1</sup>	kg ha <sup>-1</sup>	g pot <sup>-1</sup>	VC	LAD
No.		kg ha <sup>-1</sup>			t ha <sup>-1</sup>	g pot <sup>-1</sup>	kg ha <sup>-1</sup>	g pot <sup>-1</sup>	VC	LAD
1	control	0	0	0	0	0	0	0	-	-
2	VC <sub>aut170</sub>	170	-	170	8.26	202	-	-	autumn	-
3	VC <sub>aut170</sub> + N <sub>spr60</sub>	170	60	230	8.26	202	218.18	5.33	autumn	spring
4	VC <sub>spr170</sub>	170	-	170	8.26	202	-	-	spring	-
5	VC <sub>spr170</sub> + N <sub>spr60</sub>	170	60	230	8.26	202	218.18	5.33	spring	spring

no. – number, VC – vermicompost, N – nitrogen, LAD – ammonium nitrate with dolomite, VC<sub>aut</sub> – autumn application of vermicompost, VC<sub>spr</sub> – spring application of vermicompost, N<sub>spr</sub> – spring application of LAD fertilizer

LAD fertilizer was determined based on the knowledge that the nitrogen content in the LAD fertilizer is 27 %. In LAD fertilizer is half of nitrogen in ammoniacal form and half is in nitrate form.

Through application doses were applied 170 kg ha<sup>-1</sup> N by vermicompost and 60 kg ha<sup>-1</sup> N by LAD, which was in accordance with the nitrates Directive (Directive 91/676/EEC, 1991). The doses of vermicompost and nitrogen fertilizer were calculated from per hectare application doses to the application doses for the pot. In accordance with the principles of nutritionist pot experiments, the doses were increased fivefold (Ivanič et al., 1984).

The sowing of the Pioneer (PR38V91, FAO 310) type of maize was carried out in the third decade of April. It was seeded in a rate of 10 seeds per pot. The sowing depth was 0.03 m. By the beginning of July, the number of plants kept in the pot was 3 specimens per pot. Before the sowing of the seeds (24 April 2013), washed perlite was applied to the soil surface in the pot up to 0.05 m, in which the maize seeds were sown. The maize was protected against the detrimental effects of diseases and pests using standard production practice.

In the phenological growth stages (BBCH-scale) 14 (4 leaves are developed), 16 (6 leaves are developed) and 18 (8 leaves are developed), the plant height and stalks thickness was measured with a measuring tape. In the maize plants taken at growth stage BBCH 16, the content of macroelements (N, P, K, Ca, Mg and S) was determined. The content of total nitrogen was determined via distillation, using the Kjeldahl method after the mineralization in concentrated H<sub>2</sub>SO<sub>4</sub> (Cohen, 1910). The content of phosphorus, potassium, calcium, magnesium and sulphur was determined after the mineralization of the plant phytomass using HNO<sub>3</sub> and HClO<sub>4</sub> in the ratio 2 : 1. After mineralization, the phosphorus content was determined by colorimetrically. The potassium content was determined directly in the mineralize using a flame photometer (Koppová et al., 1955), the calcium and magnesium content was determined by the method AAS (atomic absorption spectrophotometry). The content of sulphur was determined spectrophotometrically. In the growth stage BBCH 18, the total chlorophyll content was determined from the last developed leaf by spectrophotometry, using 80 % acetone as the extracting method, along with MgCO<sub>3</sub> (Šesták and Čatský, 1966). The yield of phytomass taken in the growth stage BBCH 16 was determined by weighing.

The achieved results were evaluated by analysis of variance (One-Way ANOVA). Averages of treatments were tested by LSD test at significance level 95 % (P < 0.05) using the computer program Statgraphics Plus, version 4.0. The significance of correlations was assessed using the correlation coefficient.

### 3. Results and discussion

The data presented in Table 3 shows that the application of vermicompost alone or with LAD fertilizer has statistically significantly influenced the height and stalks thickness of the maize plant in the growth stages BBCH 14, 16 and 18. Gutiérrez and Miceli et al. (2007) reported similar results, where the application of vermicompost significantly positively impacted the height of the tomato plants in a greenhouse experiment, in comparison to a control treatment.

The statistically significant lowest plants in all of the taken measurements (BBCH-scale 14, 16, 18) were formed in the control treatment (Table 3). The application of vermicompost alone or together with mineral nitrogen affected the increase of the height of the plants positively. The addition of mineral nitrogen in treatments 3 and 5 had a more positive effect on the plants height in comparison with standalone application of vermicompost (tr. 2 and 4). Similar results were also reported by Koul (1997), Omer (1998), Gasim (2001) and Sawi (1993) where plants positively responded to the addition of nitrogen fertilizers, which led to an increase in their height. In the observed growth stages, the statistically significant highest plants were formed in the treatment 5, where vermicompost (170 kg ha<sup>-1</sup> N) was applied in spring, along with mineral nitrogen (60 kg ha<sup>-1</sup> N). A surprising find was that in terms of application date (autumn / spring) of vermicompost, either alone (tr. 2 and 4) or with mineral nitrogen (tr. 3 and 5), the spring application influenced plant height in all observed phenological growth stages significantly more positively than the autumn application.

The impact of treatments on the increase of maize stalk thickness (Table 4) was identical as the impact on plant height. Statistically significant thinnest plants in all of the measurements taken (BBCH-scale 14, 16, 18) were formed in the control treatment (tr. 1). The application of vermicompost alone or together with the mineral nitrogen affected the increase of plants stalk thickness positively. The addition of mineral nitrogen (tr. 3 and 5) influenced the stalk thickness of the plants more positively than just a standalone application of vermicompost (tr. 2 and 4). John and Warren (1967) noted same results when the addition of nitrogen increased stalk diameter. In observed growth stages (14, 16, 18 BBCH-scale), the statistically significant coarsest plant stalks were formed in the treatment 5, where vermicompost (170 kg ha<sup>-1</sup> N) was applied in spring along with mineral nitrogen (60 kg ha<sup>-1</sup> N). In this treatment, the highest plants were created. Similarly as in case of plant height, the spring application of either only vermicompost (tr. 2, 4) or together with the addition of the LAD fertilizer (tr. 3, 5) influenced the thickness of the stalks significantly more positively than the autumn application. This effect could

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**Table 3** The impact of treatments on the height of maize plants in different growth stages (BBCH-scale)

Treatment		Date / phenological growing stage		
		13. 6. / BBCH 14	21. 6. / BBCH 16	28. 6. / BBCH 18
No.	labelling	cm		
1	control	15.72 a	31.78 a	43.00 a
2	VC <sub>aut170</sub>	19.89 b	36.00 b	45.17 b
3	VC <sub>aut170</sub> + N <sub>spr60</sub>	27.17 d	51.06 d	51.44 d
4	VC <sub>spr170</sub>	25.56 c	45.33 c	45.78 c
5	VC <sub>spr170</sub> + N <sub>spr60</sub>	31.06 e	56.17 e	68.06 e
LSD <sub>0.05</sub>		0.388	0.553	0.414

no. – number, VC<sub>aut</sub> – autumn application of vermicompost, VC<sub>spr</sub> – spring application of vermicompost, N<sub>spr</sub> – spring application of LAD fertilizer

Different letters (a, b, c, d, and e) between the factors show statistically significant differences ( $P < 0.05$ ) – LSD test

**Table 4** The impact of treatments on the stalk thickness of the maize plants in different phenological growth stages (BBCH-scale)

Treatment		Date / phenological growing stage		
		13. 6. / BBCH 14	21. 6. / BBCH 16	28. 6. / BBCH 18
No.	labelling	cm		
1	control	2.81 a	3.19 a	4.11 a
2	VC <sub>aut170</sub>	3.17 b	4.17 b	4.80 b
3	VC <sub>aut170</sub> + N <sub>spr60</sub>	4.11 d	4.42 c	5.21 d
4	VC <sub>spr170</sub>	3.69 c	4.41 c	5.02 c
5	VC <sub>spr170</sub> + N <sub>spr60</sub>	4.14 d	5.56 d	6.19 e
LSD <sub>0.05</sub>		0.066	0.103	0.070

no. – number, VC<sub>aut</sub> – autumn application of vermicompost, VC<sub>spr</sub> – spring application of vermicompost, N<sub>spr</sub> – spring application of LAD fertilizer

Different letters (a, b, c, d, and e) between the factors show statistically significant differences ( $P < 0.05$ ) – LSD test

be causes due to the fact that the addition of mineral fertilizer accelerated mineralization processes in the soil and, therefore, was able to release enough easily available nutrients of vermicompost, even though it was applied in the spring and had significantly less time to make available organically fixed nutrients compared with treatment where vermicompost was applied in the autumn, along with the spring addition of LAD fertilizer.

In terms of established practices of organic fertilizers use in the autumn, was expected that autumn application of vermicompost will have on the observe parameters better effect than spring application. The results of our experiment have not confirmed it, because that under

field conditions the spring plowing of farm fertilizers often leads to lack of water for germinating seeds and subsequent growth retardation. For these reasons, Kováčik (2014) recommends for spring applications use only mature friable compost to shallow incorporation into the soil, in a maximum depth of 0.12 m.

Above mentioned data it is obvious that the treatments influenced the height of the plants and the thickness of the stalks identically. This is confirmed by the correlation coefficients between the thickness of the stalk and the plant heights measured in the individual phenological growth stages (Table 5). This find does not correspond with the knowledge of Kováčik et al. (2010), who found

**Table 5** The relationships between plant height and thickness of the maize stalks expressed as a correlation coefficient (r)

Parameter		Date / phenological growing stage		
		13. 6. / BBCH 14	21. 6. / BBCH 16	28. 6. / BBCH 18
Dependent	Independent	r		
Plant height	thickness of stalks	0.9733**	0.9007**	0.9310**

\* $P < 0.05$ , \*\* $P < 0.01$

that sunflower plants due to inadequate nutrition were higher than well-fertilized plants and their stalks were thinner than the stalks of the plants sufficiently fertilized.

From the data in Table 6, is obvious that the application of vermicompost, either alone or together with mineral fertilizer, had a significant influence on phytomass yield taken in growth stage BBCH 16 and on the total chlorophyll content ( $Chl a + b$ ).

The statistically significant lowest phytomass yield taken at the phenological growth stage BBCH 16 was created in the control, non-fertilized treatment (tr. 1), i.e. in the treatment, where the lowest plants with the thinnest stalks were created and the lowest content of total chlorophyll was found (Table 6). The highest yield of phytomass was achieved in the treatment 5, in which vermicompost (170 kg ha<sup>-1</sup> N) was applied in spring along with the addition of LAD (60 kg ha<sup>-1</sup> N). In this treatment in the all observed phenological growth stages, the highest plants with the thickest stalks were created and the highest content of total chlorophyll was achieved. The obtained results are in accordance with the knowledge of Tognetti et al. (2006), who reports that plants positively respond to rational nitrogen fertilization.

The common application of vermicompost and LAD fertilizer (tr. 3, 5) affected the phytomass yield significantly more positively than a standalone application of vermicompost (tr. 2, 4). The spring application of vermicompost, either alone or with the addition of mineral nitrogen, influenced the phytomass yield taken at the phenological growth stage BBCH 16 significantly more positively than the autumn application (tr. 4 versus tr. 2 and tr. 5 versus tr. 3).

Table 6 shows that the fertilization influenced the total content of chlorophyll ( $Chl a + b$ ) in the same way as the parameters of phytomass formation (plant height, stalk thickness – Table 3 and 4) and as a yield of phytomass. The statistically significant lowest total chlorophyll content was determined in the controlled non-fertilized

treatment (tr. 1). The application of vermicompost alone or together with mineral nitrogen had positive influence on the total chlorophyll content. As is the case in plant height and thickness of the stalks, the addition of mineral nitrogen influenced the total chlorophyll content more positively than the alone application of vermicompost. A strong positive correlation between the nitrogen content in the plants and the chlorophyll content was also proven by the several authors (Baret et al., 2007; Oppelt, 2002; Oppelt and Mauser, 2004; Vos and Bom, 1993; Yoder and Pettigrew-Crosby, 1995). Nitrogen is involved in the development of the leaf area and affected the efficiency of photosynthesis (Arduini et al., 2006; Muchow, 1988). The statistically significantly highest content of total chlorophyll (BBCH 18) was formed in the treatment 5, where vermicompost was applied in spring (170 kg ha<sup>-1</sup> N) together with mineral nitrogen (60 kg ha<sup>-1</sup> N). It is the same treatment, where up to the growth stage BBCH 18 the highest plants with the thickest stalks were created. Similar results were reported also by the authors Anderson et al. (1985), Dwyer and Anderson (1995), Earl and Tollenaar (1997), Tóth et al., (2002) that through the increase in nitrogen fertilizer increased the photosynthetic activity, increased the leaf area index, the index of leaf density and increased the chlorophyll content. The spring application of either alone vermicompost (tr. 2, 4) or together with the addition of fertilizer LAD (tr. 3, 5) influenced the total chlorophyll content significantly more positively than the autumn application.

The data in Table 7 shows that the plant height, stalk thickness of the plants and the phytomass yield in all measurements has reported a very strong positive correlation. In both cases, with the increasing growth phase, the value of the correlation coefficient has been increased. Between the plant height and the phytomass of the yield, a closer correlation was recorded, as well as between the thickness of the stalks and the phytomass yield.

**Table 6** The impact of the treatments on the phytomass yield taken in the phenological growing stage BBCH 16 and on the total chlorophyll content in the maize leaves in the phenological growing stage BBCH 18

Treatment		Phytomass yield (BBCH 16) (100 % dry matter)		Total chlorophyll ( $Chl a + b$ ) (BBCH18)
No.	labelling	g pot <sup>-1</sup> (1 piece)	rel.%	mg m <sup>-2</sup>
1	control	5.59 a	100.0	164.03 a
2	VC <sub>aut170</sub>	8.05 b	144.0	168.53 b
3	VC <sub>aut170</sub> + N <sub>spr60</sub>	13.67 d	146.9	204.41 d
4	VC <sub>spr170</sub>	8.21 c	244.6	188.16 c
5	VC <sub>spr170</sub> + N <sub>spr60</sub>	19.81 e	354.5	244.80 e
LSD <sub>0.05</sub>		0.153		1.964

no. – number, VC<sub>aut</sub> – autumn application of vermicompost, VC<sub>spr</sub> – spring application of vermicompost, N<sub>spr</sub> – spring application of LAD fertilizer

Different letters (a, b, c, d, and e) between the factors show statistically significant differences ( $P < 0.05$ ) – LSD test

**Table 7** The relationships between the yield of phytomass and the plant height, thickness of the maize stalks and total chlorophyll content expressed as a correlation coefficient (r)

Parameter		Date / growing stage		
Dependent	Independent	13. 6. / BBCH 14	21. 6. / BBCH 16	28. 6. / BBCH 18
		r		
Yield of phytomass (BBCH 16) 100 % dry matter	plant height	0.8876**	0.9130**	0.9726**
	thickness of stalks	0.8549**	0.9059**	0.9495**
	total chlorophyll (Chl a + b)	1. 7. / BBCH 18		
		r		
		0.9762**		

\* $P < 0.05$ , \*\* $P < 0.01$ 

The present level of relationship between the phytomass yield and the total chlorophyll content in Table 7 shows a highly statistically significant positive correlation. With the increase of the total chlorophyll content, the phytomass yield was also increased.

Table 8 shows that the treatments of the experiment had a significant influence on the content of macroelements (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) determined in the plant phytomass taken at the phenological growth stage BBCH 16.

The data presented in Table 8 shows that fertilization, either with only vermicompost or together with the LAD fertilizer, had a positive effect on the increase of N in plants (except tr. 4), as was confirmed via the conclusions of Dordas (2009). The higher increase of the nitrogen content in the phytomass occurred before flowering because the nitrogen is involved in formation of an inflorescence (up to 80 % of total N) (Papakosta and Gagianas, 1991). The nitrogen content in the maize plants was oscillated in the range from 1.12 to 1.33%. Well-grown maize plants should contain from 3.5 to 5.0 % of nitrogen at the phenological growth stage BBCH 16 (crops height from 0.4 to 0.6 m) (Bergmann, 1986). It's obvious that, in a given growing stage, the nitrogen content was deep under the optimal value and point out the knowledge of Kováčik (2012), that the application dose at 170 kg ha<sup>-1</sup> N in compost and cattle manure cannot saturate the need of nitrogen for maize. The lowest nitrogen content in the plants taken at the phenological growing stage BBCH 16 was recorded in the treatment, where vermicompost was applied in spring at a dose of 170 kg ha<sup>-1</sup> N (tr. 4). The significantly highest nitrogen content was detected in the plants in treatment 5, where vermicompost was applied in spring along with nitrogen fertilizer. In this treatment were the highest plants with the thickest stalks created, the highest content of total chlorophyll and highest yield of phytomass was achieved.

Dordas (2009) notes, that with the increasing dose of phosphorus an increased intake of nitrogen by plants

occurs as a result of the expanded root system. On the contrary, Ranjit et al. (1983) argues, that the increase of nitrogen application dose often decreases phosphorus content, as was also confirmed by our results (Table 8), when the application of mineral nitrogen in the form of LAD resulted in a significant reduction of the content of phosphorus in plants, taken at the phenological growth stage BBCH 16. The significantly lowest content of phosphorus in the plants was found in the treatments, where vermicompost was applied along with the fertilizer LAD (tr. 3 and 5). The autumn application of vermicompost influenced the phosphorus significantly more positively than the spring application (tr. 2 versus tr. 4). The significantly highest phosphorus content was found in the plants grown on the treatment, where vermicompost was applied in autumn (170 kg ha<sup>-1</sup> N, tr. 2). The phosphorus content in the maize plants oscillated in the range from 0.27 to 0.40 %. According to Bergmann (1986), the phosphorus content in the maize plants (BBCH 16 – BBCH 18) should be in the range from 0.35 to 0.60 %.

The potassium content in the maize plants of crop height from 0.4 to 0.6 m should fluctuate in the range from 3.0–4.5 % (Bergmann, 1986). In our experiment, the potassium content in the plants ranged from 2.70 to 3.35 %. The significantly lowest content of potassium in the plants was recorded in the treatments 3 and 5, i.e. in the treatments, where vermicompost was applied along with industrial nitrogen. In these treatments, were also the lowest recorded contents of phosphorus in the plants. Similar to the phosphorus, the autumn application of vermicompost influenced the potassium content significantly more positively than the spring application (tr. 2 versus tr. 4).

The calcium content oscillated in a range from 0.18 to 0.31 %. The well-grown plants of maize in the phenological growth stage BBCH 16–18 should contain from 0.3 to 1.0 % of calcium (Bergmann, 1986). From these numbers, it is obvious that the maize plants contain not only insufficient amounts of N, but also of Ca.

**Table 8** The content of macro-elements in the plants taken in the phenological growth stage BBCH 16

Treatment		N	P	K	Ca	Mg	S
No.	labelling	mg kg <sup>-1</sup> 100 % dry matter					
1	control	12515 b	3981 c	32387 c	3090 e	3730 c	405 d
2	VC <sub>aut170</sub>	12894 c	4048 d	33466 d	1876 b	5174 e	337 c
3	VC <sub>aut170</sub> + N <sub>spr60</sub>	12515 b	2699 a	26989 a	2645 d	2791 a	270 b
4	VC <sub>spr170</sub>	11187 a	3913 b	30228 b	1808 a	3519 b	337 c
5	VC <sub>spr170</sub> + N <sub>spr60</sub>	13273 d	2699 a	26989 a	2146 c	3780 d	169 a
LSD <sub>0.05</sub>		250.24	38.555	103.83	24.460	15.819	5.0593

no. – number, V<sub>aut</sub> – autumn application of vermicompost, VC<sub>spr</sub> – spring application of vermicompost, N<sub>spr</sub> – spring application of LAD fertilizer

Different letters (a, b, c, d, and e) between the factors show statistically significant differences ( $P < 0.05$ ) – LSD test

**Table 9** The relationships between the yield of phytomass and the content of macroelements expressed as a correlation coefficient (r)

Parameter		Correlation coefficient (r)
Dependent	Independent	
Yield of phytomass BBCH 16 (100% dry matter)	N	0.5096
	P	-0.9051**
	K	-0.8525**
	Ca	-0.1682
	Mg	-0.2916
	S	-0.9902**

\* $P < 0.05$ , \*\* $P < 0.01$

The significantly highest calcium content was found in the non-fertilized treatment, which was associated with the poor mobility of Ca in the plant. Fertilization supported an increase of phytomass, while the growth was faster than the movement of calcium, which caused its lower concentration in the plants in the treatments 2 to 5 in comparison to treatment 1.

The magnesium content oscillated in the range from 0.28 to 0.52 %. Bergmann (1986) reported that the magnesium content in the maize plants (growth stages BBCH 16 – BBCH 18) was in the range from 0.25 to 0.60 %. The statistically significant lowest magnesium content in phytomass of the plants was found in the treatment, where vermicompost was applied in autumn and LAD fertilizer was applied in spring (tr. 3). The significantly highest magnesium content in the phytomass was found in the treatment, where vermicompost was applied in autumn at dose of 170 kg ha<sup>-1</sup> N.

The sulphur content in the plants oscillated in the range from 0.02 to 0.04 %. The significantly lowest sulphur content in the plants was found in the treatment 5, which is the treatment where the highest yield of phytomass was achieved and the highest plants with the thickest stalks and with the highest chlorophyll content were grown. On the contrary, the highest sulphur content in the plants was found in the control treatment, where the

lowest yield of phytomass in the phenological growth stage BBCH 16 was achieved. With the increasing yield of phytomass the sulphur content in the plants decreased, which is shown in Table 9 via the correlation coefficient.

From the data presented in Table 9 we can conclude, that we have found a highly significant negative correlation between the yield of phytomass taken at the phenological growing stage BBCH 16 and the content of phosphorus, potassium and sulphur in the plant phytomass taken at the growing stage BBCH 16. With the increasing of the phytomass yield, the concentration of these macronutrients in dry matter has decreased. Between other observed macronutrients and the yield of phytomass taken at the phenological growth stage BBCH 16, significant correlations were not found.

These findings clearly point to the fact that in assessing the nutritional status of crops is also necessary to take into account the weight of created phytomass.

#### 4. Conclusions

The results show that the application of vermicompost, either alone or together with LAD fertilizer, positively influenced observed parameters (height and stalk thickness of plants, the total chlorophyll, the yield of phytomass and the content of macro-elements) assessed in selected phenological growth stages (BBCH-scale),

while the addition of mineral nitrogen influenced observed parameters more positively than standalone application of vermicompost.

The spring application of vermicompost, either alone or together with LAD fertilizer affected the plant height, thickness of stalks, total chlorophyll content and the phytomass yield more positively than the autumn application.

From the observed parameters (height and stalk thickness of plants, the total chlorophyll content, the yield of phytomass) the highest values were found in the treatment, where vermicompost was applied in spring (170 kg ha<sup>-1</sup> N) with the addition of fertilizer LAD (60 kg ha<sup>-1</sup> N).

In the phenological growth stage BBCH 16 was found a higher correlation between weight of aboveground phytomass and total chlorophyll content as between the aboveground phytomass weight and height, respectively thickness of plants.

The rationality of organic-mineral fertilization was confirmed.

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