The impact of vermicompost application on the maize (*Zea mays* l.) phytomass creation at the growth stage 16 (BBCH-scale) and on the selected yield parameters of maize

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Abstract: 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 170 kg ha^{-1} N. In treatments 4 and 5, vermicompost was applied in spring at the same dose of 170 kg ha^{-1} N. In treatments 3 and 5 was added nitrogen in spring to vermicompost as the AND (ammonium nitrate with dolomite) fertilizer at dose of 60 kg ha^{-1} N. The observed parameters (phytomass taken at growth stage 16 (BBCH-scale), yield of phytomass, grain yield, starch content) were most positive influenced in treatment where vermicompost was applied in spring with the addition of the AND. In the treatments, in which mineral nitrogen was added, observed parameters were affected more positively than in the treatments where only vermicompost was applied. Overall, the spring application affected observed parameters more positively than the autumn application.

Key-Words: vermicompost, maize, yield parameters, mineral nitrogen

Introduction

Low livestock numbers are the cause of the lack of cattle manure and slurry, which in many cases causes the reduction of soil fertility [1]. One of the possible alternatives for these fertilizers is vermicompost. Vermicompost is an improved compost (fermented compost mass is biodegraded with help of earthworms, *Eisenia foetida* is the most common genus). Earthworms through their enzymes and hormones transform the nutrients in compost to available forms and they enrich the compost with growth promoters such as auxins, cytokinins and gibberellins, through their secretions (also called "casts").

Vermicompost application positively affects the soil reaction, reduces the hydrolytic acidity [2] and enhances the enzyme activity of the soil [3]. Easily available organic residues and microorganisms coming from vermicompost stimulate in soil degradation of polycyclic aromatic hydrocarbons (PAHs) [4, 5, 6]. Valuable part of vermicompost are humic substances, which make an important contribution to increases yield of crops such as maize, oats, tobacco, soybeans, peanuts, clover and cucumber [7, 8, 9]. Vermicompost application has a positive effect on yield parameters of tomatoes [10, 2], strawberry [11], maize [12], peppers [13] and cucumber [9].

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 the phytomass taken at growth stage 16 (BBCH-scale) and on selected yield parameters observed after harvest (yield of phytomass, grain yield, starch content).

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). 22 kg of soil were placed into pots of 0.38 m height and of 0.38 m diameter. The soil (Haplic Fluvisol) was taken from the growing areas of Agrokomplex Nitra from the upper 0.25 m of the humus horizon.

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 - 4 months fermentation, earthworms were introduced into the compost produced from these materials. Earthworms were left in the compost for two months and were fed through an amount of 400 kg per ton of compost fodder per month. The fodder was mainly fruit and vegetables, and the fodder was mashed before the application. Basic agrochemical parameters of soil and vermicompost are presented in Table 1.

Table 1 Agrochemical characteristics of soil and vermicompost

Material	pH_{KCl}	N_{an}	P	K	Ca	Mg	N_t	C_{ox}	Org. s.
		[mg.kg^{-1}]						%	
Soil (100% drymass)	6.52	17.6	26.2	300.5	4670	1096	3234	2.29	9.59
VC (100% drymass)	7.36	477.1	5642	14285	8535	4893	29400	20.51	48.53

VC – vermicompost, Org. s. – organic substances, P, K, Mg, - available nutrients, C_{ox} - total organic carbon, N_{an} – inorganic nitrogen, N_t – total nitrogen

The experiment consisted of 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^{-1} (170 kg ha^{-1} N). In treatments 3 was added nitrogen to vermicompost as the AND (ammonium nitrate with dolomite) fertilizer at dose of 218.18 kg ha^{-1} (60 kg ha^{-1} 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^{-1} (170 kg ha^{-1} N). In treatments 5 was added mineral nitrogen to vermicompost as the AND fertilizer at dose of 218.18 kg ha^{-1} (60 kg ha^{-1} N). Nitrogen as the fertilizer AND was applied shallowly into the soil one week before the maize sowing. The experiment treatments are shown in Table 2.

Table 2 Treatments of the experiment

Treatments		Dose of N			Dose of VC		Dose of AND		Term of application	
		in VC	in AND	Total						
no.	labelling	kg ha^{-1}			t ha^{-1}	g pot^{-1}	kg ha^{-1}	g pot^{-1}	VC	AND
1	control	0	0	0	0	0	0	0	-	-
2	VC_{aut170}	170	-	170	8.26	202	-	-	autumn	-
3	$VC_{aut170} + N_{spr60}$	170	60	230	8.26	202	218.18	5,33	autumn	spring
4	VC_{spr170}	170	-	170	8.26	202	-	-	spring	-
5	$VC_{spr170} + N_{spr60}$	170	60	230	8.26	202	218.18	5,33	spring	spring

VC – vermicompost, Org. s. – organic substances, P, K, Mg, - available nutrients, C_{ox} - total organic carbon, N_{an} – inorganic nitrogen, N_t – total nitrogen

The doses of vermicompost and nitrogen fertilizer were calculated from per hectare application doses to the application doses for the containers. In accordance with the principles of nutritionist experiments, the doses were increased fivefold [14].

Before the sowing of the seeds (24 April 2013), washed perlite was applied to the soil surface in the container up to 0.05 m, in which the maize seeds were sown. The sowing of the Pionner (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 0.05 m. By the beginning of July, the number of plants kept in the pot was 3 specimens per pot.

During the whole period of vegetation, the experiment was regularly checked and monitored for the overall health of the plants.

During vegetation the phytomass taken at the growth stage 16 (BBCH-scale) was determined by weighing. After harvesting the maize, the yield of phytomass and the yield of grain were determined by weighing. The starch content in maize grain was determined by Ewers polarimetric method [15].

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.

Results and Discussion

Table 3 shows that the statistically significantly lowest phytomass taken at the phenological growth stage 16 (BBCH-scale) was created in the control, non-fertilized treatment (tr. 1). The highest phytomass was achieved in the treatment 5, in which vermicompost (170 kg ha^{-1} N) was applied in spring along with the addition of AND fertilizer (60 kg ha^{-1} N). The obtained knowledge is in accordance with the knowledge of Tognetti et al. [16], who reports that plants positively respond to rational nitrogen fertilization.

The joint application of vermicompost and AND fertilizer (tr. 3, 5) affected the phytomass 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 taken at the phenological growth stage 16 (BBCH-scale) significantly more positively than the autumn application.

The yield of phytomass taken after harvest has developed by similar way as phytomass taken at the phenological growth stage 16 (BBCH-scale). The statistically significantly lowest phytomass yield was created in the control, non-fertilized treatment (tr. 1), i.e. in the treatment, where the lowest phytomass taken at the phenological growth stage 16 (BBCH-scale) was created. The highest yield of phytomass was achieved in the treatment 5, in which vermicompost (170 kg ha^{-1} N) was applied in spring along with the addition of AND fertilizer (60 kg ha^{-1} N). As in the case of phytomass taken at the phenological growth stage 16 (BBCH-scale), the joint application of vermicompost and AND 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 significantly more positively than the autumn application.

The impact of treatment fertilization on the grain yield was almost completely identical to its impact on the phytomass yield (Table. 3). The statistically significantly lowest grain yield was created in the control, non-fertilized treatment. The highest yield of grain was achieved in the treatment 5, in which vermicompost (170 kg ha^{-1} N) was applied in spring along with the addition of AND fertilizer (60 kg ha^{-1} N). In this treatment was created the highest phytomass taken at the phenological growth stage 16 (BBCH-scale) and also the highest yield of phytomass was achieved.

From the viewpoint of the application term, the autumn application of vermicompost exclusively (tr. 2) influenced the grain yield significantly more positively compared to the spring application (tr. 4). This confirmed the general recommendation of the practice to apply organic fertilizers in autumn, when enough organically fixed nutrients are discharged via mineralization. Even in the treatment in which vermicompost was applied in spring (tr. 4) the grain yield was on the level of the control non-fertilized treatment (tr. 1), which was surprising, because the phytomass taken in the growth stage 16 (BBCH-scale) and also phytomass yield belonged to the significantly highest. This indicates that the application of vermicompost in spring at a dose of 170 kg ha^{-1} N (tr. 4) may have been able to significantly positively affect the phytomass yield, but has also shown an obvious deficiency of nitrogen in the grain yield. This is also reflected in Kováčik's research [17], where it is stated that the application dose of 170 kg ha^{-1} N in compost or cattle manure cannot saturate the nitrogen need for maize.

Table 3 The impact of the treatments of the experiment on the phytomass taken at phenological growth stage 16 (BBCH-scale), yield of phytomass, grain yield and on the starch content

Treatment		Phytomass (BBCH 16)		Yield of phytomass (harvest)		Grain yield		Starch content	
		100 % drymass				86 % drymass		86 % drymass	
no.	labelling	g pot^{-1} (3 pieces)	rel. %	g pot^{-1} (3 pieces)	rel.%	g pot^{-1}	rel. %	[%]	rel. %
1	control	16.76 a	100.0	68.55 a	100.0	33.63 a	100.0	60.77 c	100.0
2	VC_{aut170}	24.14 b	144.1	109.64 b	159.9	50.84 b	151.2	59.59 b	98.1
3	$VC_{aut170} + N_{spr60}$	41.02 d	244.7	134.93 d	196.8	66.69 c	198.3	58.47 a	96.2
4	VC_{spr170}	24.70 c	147.4	113.79 c	166.0	33.82 a	100.6	59.35 ab	97.7
5	$VC_{spr170} + N_{spr60}$	59.42 e	354.5	170.24 e	248.4	71.51 d	212.7	60.88 c	100.2
$HD_{0.05}$		0.4919		2.2796		1.5641		1.0079	

no. - number, VC_{aut} – autumn application of vermicompost, VC_{spr} – spring application of vermicompost, N_{spr} – spring application of AND fertilizer

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

The addition of mineral nitrogen to the vermicompost in treatments 3 and 5 affected the height of grain yield (Table. 3) significantly more positive than the standalone application of vermicompost. The highest grain yield was achieved in the treatment 5, where the vermicompost was applied in spring with the addition of mineral nitrogen. This explains the popularity of the use of mineral fertilizers for farmers as was proposed by Kováčik [18]. The same results was also deducted by the authors Jeyabal and Kuppuswamy [19] where the joint application of vermicompost and nitrogen fertilizers increased rice yield by 15.6% compared to the standalone application of mineral nitrogen fertilizer. The rationality of organo-mineral fertilization was confirmed, when the most significant effect on plant growth parameters was achieved with the combined use of organic and mineral fertilizers [20, 21]. In this case, fertilizers are an instantaneous source of nutrients and can also accelerate mineralization of organic compounds [19], as can also be seen in our results presented in Table 3.

A negative finding is that the application of vermicompost significantly reduced the content of starch in the maize grain (Table. 3), as was confirmed by Marschner [22], where generally with the increase in the application dose of nitrogen, the content of starch in the maize grain and also in the cereal and root crops decreases. Similar results are also mentioned by the authors Sharma and Arora [23], where the application of mineral nitrogen, together with the organic fertilizers reduced starch content. On the other hand Szukaiski and Sikora [24] report an increase in the starch content of potato tubers after the application of fertilizer which was rich in nutrient content. Also Srikumar and Öckerman [25] reported an increase in starch content in potato tubers after the application of fertilizers which were rich in the content of trace elements. The surprising finding is that the highest content of starch in the grain in our experiment has been spotted in the treatment 5 where vermicompost was applied in spring (170 kg ha^{-1} N) with the addition of AND fertilizer (60 kg N ha^{-1}). The second highest starch content in the grain was achieved in the control, non-fertilized treatment (tr. 1). The standalone autumn application of only vermicompost (tr. 2) affected the starch content more positively than the spring application (tr. 4). On the contrary, the addition of nitrogen has affected starch content in an opposite way in comparison with the treatments where only vermicompost was applied. The spring application of vermicompost with the addition of the AND fertilizer affected starch content significantly more positively than the autumn application of vermicompost with the addition of mineral nitrogen and also compared with other treatments.

Table 4 The relationship between dose of nitrogen an and selected yield parameters of maize expressed as a correlation coefficient (r)

Parameter		Correlation coefficient (r)
Dependent	Independent	
Dose of nitrogen	Phytomass (BBCH 16)	0.7479**
	Yield of phytomass (harvest)	0.8466**
	Grain yield	0.7657**
	Starch content	- 0.4172

*$p<0.05$, **$p<0.01$

A very strong positive correlation was found between the doses of nitrogen, the phytomass yield and the grain yield (Table. 4). With the increasing doses of nitrogen, the phytomass and grain yield were also increased. Similar results were also reported by the authors Koul [26] and Omer [27] where plants positively responded to the addition of nitrogen, which led to the increase of their height and therefore their phytomass.

The negative impact of the nitrogen on starch content was confirmed partially in our results shown in Table 4. Between the starch content in the maize grain and the dose of nitrogen, there was a trend of negative (inconclusive) correlation.

Conclusion

The results show that the application of vermicompost, either alone or together with AND fertilizer, positively influenced observed parameters (the phytomass taken at the phenological growth stage 16 (BBCH-scale), yield of phytomass, yield of maize grain), 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 AND fertilizer affected the phytomass taken at the phenological growth stage 16 (BBCH-scale) and yield of phytomass more positively than the autumn application. From the observed parameters (the phytomass taken at the phenological growth stage 16 (BBCH-scale), yield of phytomass, yield of maize grain and the starch content) the highest valueswere found in the treatment, where vermicompost was applied in spring (170 kg ha^{-1} N) with the addition of AND fertilizer (60 kg ha^{-1} N).

With increasing of nitrogen dose, was increased the yield of phytomass and grain yield. On the contrary, was partially confirmed the depressant effects of the nitrogen on the starch content in the maize grain.

The rationality of organic-mineral fertilization was confirmed.

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