

IMPACT OF VERMICOMPOST EXTRACT APPLICATION INTO SOIL AND ON PLANT LEAVES ON MAIZE PHYTOMASS FORMATION

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ABSTRACT

Nowadays in scientific literature many opposing data are presented of the impacts of vermicompost extract on the quantity and quality of crop production. Therefore, the principal objective of two independent experiments was to study the effects of vermi-extracts, which were applied before maize sowing into soil and during the growing season on the maize leaves, on its phytomass formation. The first, field experiment consisted of 9 variants. Variant 1 was the control one without the extract application. We studied the effect of the rising doses (90, 130, 170, 210 dm³·ha⁻¹) of vermi-extract applied into soil before the maize sowing in the variants E₁, E₂, E₃, E₄. In the variants E₁+E, E₂+E, E₃+E, E₄+E along with the rising doses of vermi-extract was also applied the uniform dose of vermi-extract (40 dm³·ha⁻¹) at the growth stage BBCH 15. The second, pot experiment was pursued in the vegetation cage and comprised 3 variants: variant 1 was the control, in the variants 2 and 3 the foliar application of vermi-extract was used. The vermi-extract was applied once (growth stage BBCH 12) in the variant 2 and in the variant 3 it was used twice (at growth stages BBCH 12 and BBCH 16). The achieved results show that the vermi-extract applied in the presowing period increased the yield of maize grains if the application doses were 130–170 dm³·ha⁻¹. The positive or negative impact of the foliar application by vermi-extract on the yield of maize grains depended on the period of application and the grown cultivar. In order to increase the starch content in grains it was more suitable to carry out the presowing vermi-extract application than during the growing season. The presowing application and the foliar application of vermi-extract tended to decrease the nitrogen content in grain. The foliar application of vermi-extract had the positive impact on the plant height and stalk thickness of the maize plants only in short term. The information obtained from the first half of maize growing season related to the plant height and stalk thickness was not the appropriate indicator for the assessment of maize grain yields.

Keywords: vermicompost, vermi-extract, foliar application, maize.

INTRODUCTION

Compost production has decreased continually in Slovakia since 1990 on the other hand the slight increase of the waste material production suitable for composting has been recorded.

The reasons are the considerable financial costs needed for the produced composts transportation, therefore the agricultural companies buy them in the limited volumes. One solution providing the continual composts production and also their sale consists in their final preparation, i.e. the produc-

tion of liquid or dried composts. The effects of “the liquid composts“, i.e. water extracts from composts and vermi-extracts on plants have been studied by the world scientists for many years [Ložek, Fecenko 1998, Ghorbani et al. 2008].

During the given period, both positive and negative results have been achieved. The main reason of the negative results is considered to be the fact that composts and also vermi-composts are produced from different kinds of waste, which causes that the undesirable matters are getting into extracts leading to the inhibitive even toxic impacts on crops. Therefore, it is necessary to utilize only clean components for the production of all types of composts which are used for the production of extracts [Kostecka 2009, Kováčik 2014].

If the appropriate components are used for the production of vermicomposts and subsequently vermi-extracts, these matters can have a positive impact on the phytomass formation of the cultivated crop [Tejada et al. 2008, Singh et al. 2010]. The use of vermi-extracts in the diluted form eliminates their potential negative impacts on crops [Gutiérrez-Miceli et al. 2008].

In spite of the recorded positive and negative effects, the evidential and unevidential effects of vermi-extracts on the seed germination and yield of crops was observed [Frederickson 2002, Zaller 2006]. It is important to emphasize that the majority of the experiment results shows a positive impact of the foliar application of vermi-compost extracts on the chlorophyll and phytomass formation of the cultivated crops [Arancon et al. 2004, Edwards 1998, Pant et al. 2009]. It is recommended to add either a small quantity of N or NPK fertilizers, or the fertilizers containing Cu, Zn, B, etc. into the vermi-extracts [Ingham 2005, Gutiérrez-Miceli et al. 2008, García-Gómez et al. 2008]. Depending on the dose and growth stage of plants the foliar application of vermi-extracts increases yields in a rather extensive scale, i. e. from 5% to 27% and sometimes by 35% [Kováčik 2014]. The recorded positive effect of the vermi-compost extracts (often enriched by NPK fertilizers) on a plant is not the result of percolated nutrients content but predominantly it is the result of impact of the percolated humic acids and fulvo acids, the growth regulators – auxins, gibberelins and cytokinins [Grappelli et al. 1987, Tomati et al. 1988, Tomati, Galli 1995, Arancon et al. 2005, Pant et al. 2012].

The world research of the vermi-compost extracts utilization deals also with the study of their

impact on the state of health. There are many recorded cases of their positive effect on the inhibition of the plant diseases [Weltzien 1991, Scheuerell, Mahaffee 2002, Utkhede, Koch 2004, Lanthier 2007, Singh et al. 2008].

In the USA several firms sell the extracts from vermi-composts as a pesticide. However, the impact of extracts on the inhibition of diseases lags behind considerably in comparison with the existing chemical pesticides [Wickland et al. 2001]. The annual growth of the extracts sold in this way represented 25% in the USA in 2002 – 2008. In spite of this fact, several scientific publications have been presented in the USA, which had not proved the fungicidal effect of vermi-extracts [Lanthier 2007, Chalker-Scott 2005].

The existence of several opposing findings related to the vermi-extracts impacts on the soil microflora, on the crop health and on the quantity and quality of the crop production requires researchers intensify research in order to study the reasons of different impacts of vermi-extracts [Scheuerell 2004].

In order to optimize the plant nutrition, predominantly related to nitrogen nutrition, the growers are recommended to monitor the nutrients content in plants, the amount of formed phytomass and chlorophyll content during the growing season. Kmeťová and Kováčik [2014] registered almost the same strong relationship between the height of maize plants and grain yield, or between the thickness of plant stalks and grain yield as well as between the chlorophyll content and grain yield. Based on this fact they claim that the information about the plant height and stalk thickness detected in the growth stages BBCH 14 till BBCH 18 indicates properly the quantity of maize yield. The data about the relationship between the maize stalk thickness and the quantity of grain yield, or between the maize height and grain yield detected in the later growth stages are scarce and there is no studies in this subject in the Slovak.

The main objective of experiments was to acquire data about the impacts of vermi-extract applied into soil and to broaden the existing knowledge about the impacts of vermi-extract applied on the plant leaves on the maize phytomass formation. The secondary objective was to complete the data about the possibility of usage the information about the plant height and stalk thickness for the purpose of maize grain yield prognosis.

MATERIAL AND METHODS

The impact of the vermi-compost extract applied into soil and on plant leaves on the maize phytomass formation was studied in two independent experiments. The first field experiment was a semi-operational one carried out in the cadastral of village Opatovská Nová Ves (48°06' N, 19°16' E), district of Veľký Krtíš, on Loamy Luvisol. The second experiment was pot one pursued on the Haplic Fluvisol in the vegetation cage located in the premises of the Slovak University of Agriculture in Nitra (48°18' N, 18°05' E). The agrochemical parameters of soils on which the experiments were carried out are given in the Table 1.

The following analytical methods were used to determine soil parameters: $\text{NH}_4^+\text{-N}$ – colorimetrically by Nessler agent and $\text{NO}_3^-\text{-N}$ – colorimetrically by the phenol-2,4-disulfonic acid after extraction from soil by the 1% K_2SO_4 water solution; inorganic nitrogen content was calculated as $\text{N}_{\text{an}} = \text{NH}_4^+\text{-N} + \text{NO}_3^-\text{-N}$; P was determined colorimetrically, K and Ca – by flame photometry and Mg – by atomic absorption spectrophotometry in extract acc. to Mehlich III method [Mehlich 1984]; C_{ox} – oxidometrically [Tiurin 1966]; N_t – by Kjeldahl distillation method [Bremner 1960] in the modifications for soils and organic substrates [Kováčik 1997]. The content of organic matters was determined by the gravimetric analysis, temperature 550–600 °C [Kováčik 1997], pH/KCl – potentiometrically in the extract 1.0 mol·dm⁻³ KCl solution [Fiala et al. 1999].

The vermi-compost extract was obtained after two-day taking interfusion of the vermi-compost mixture and potable water, with the ratio between compost and water as 1 : 10 (m/v). Subsequently, the mixture was settling for 24 hours. After the sedimentation of the solid particles the upper, liquid part was decanted. The parameters of the used

vermi-extract are given in Table 2. The vermi-compost was produced from the compost consisting of cow dung (cca 50%), sheep dung (cca 10%), green grass (cca 10%) and wood chips (30%) fermented for 3–4 months. After that period, 1/5 of the older vermi-compost containing earthworms and cocoons of earthworms was added to the whole volume of compost. One dm³ of old vermicompost contained 70 earthworms with an average weight of 0.42 grams per creature. The newly-formed compost was transported to the halls with appropriate ventilation and it was piled up the height of 30 cm. There the compost fermented for 120 days with concurrence of earthworms and the earthworms were engrossed by the crushed fruit (300 kg) and vegetables (100 kg) of the total amount 400 kg of fodder per month and 1 Mg.

The field experiment consisted of 9 variants described in Table 3 with three repetitions and it was based on the method of long parcels of land, and each field had the width of 18 metres and length of 110 metres.

The test crop was maize, cultivar Stira, FAO 420 sown 65,000 grains per hectare. The variant 1 was control, without the extract application. The increased doses of vermi-extract were applied into soil in the variants 2 to 9 during the spring soil preparation. The doses of vermi-extract were identical in the pairs of variants 2 and 3, 4 and 5, 6 and 7, 8 and 9 (90, 130, 170, 210 dm³·ha⁻¹, respectively), five days before the maize sowing. The uniform dose (40 dm³·ha⁻¹) of vermi-extract in a form of the foliar application was used in the unpaired variants (3, 5, 7, 9) during the growth stage BBCH 15 using the sprinkler of 18 metres span.

The maize harvest was carried out in the growth stage BBCH 97 by the six-row combine. The maize grain from each variant was transported by a truck to the drier where it was weighed

Table 1. Soil agrochemical parameters before the foundation of experiments in a soil layer 0.0–0.3 m

Experiment	Soil	pH _{KCl}	N _{an}	P	K	Ca	Mg	N _t	C _{ox}	Org. M.
			mg·kg ⁻¹ d.m.					g·kg ⁻¹ d.m.		
Field	Loamy Luvisol	6.47	13.35	74	222	1,860	341	1,604	20.80	50.2
Pot	Haplic Fluvisol	6.52	17.6	26	300	4,670	1,096	3,234	22.95	95.9

Table 2. Parameters of vermi-extract

N _t	P _t	K _t	Ca _t	Mg _t	HA _t	FA _t	pH
mg·dm ⁻³							
1,100	980	6,540	508	421	8,200	194	7.02

Explanation: t – total, HA_t – total humic acids, FA_t – total free amino acids.

Table 3. Variants of field experiment – the way of vermi-extracts application

Variant	Vermi-extract dose (dm ³ ·ha ⁻¹)		
	before sowing	at growth stage BBCH 15	total
1. Control	0	0	0
2. E ₁	90	0	90
3. E ₁ +E	90	40	130
4. E ₂	130	0	130
5. E ₂ +E	130	40	170
6. E ₃	170	0	170
7. E ₃ +E	170	40	210
8. E ₄	210	0	210
9. E ₄ +E	210	40	250

Explanation: E – vermi-extract; BBCH – Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie scale according to Zadoks et al. [1974].

and its water content was determined at the same time. At the end of the experiment the contents of N, P, K, Ca, Mg and starch in the maize grain, as well as thousand kernel weight (TKW) were determined. Nitrogen was determined by distillation by Kjeldahl method after mineralization in the medium of concentrated H₂SO₄ [Cohen 1910]. Phosphorus was determined spectrophotometrically, potassium and calcium by flame photometry, magnesium by atomic absorption spectrophotometry after mineralization in the medium of mixture HNO₃ and HClO₄ (2:1, v/v) [Koppová et al. 1955]. Starch was determined polarimetrically by Ewers method [ISO 10520].

The pot experiment – 22 kg of Haplic Fluvisol was taken from 0.3 m of humic horizon into the plastic pots of the diameter 0.35 m and height of 0.35 m. The agrochemical soil parameters are given in Table 1. The same methods were used to determine agrochemical soil parameters as in the field experiment. The experiment consisted of 3 variants with 5-times repetitions (Table 4).

The vermi-compost was applied in autumn in a dose of 170 kg N·ha⁻¹ into soil of all the variants. The variant 1 was control without treatment of vermi-extract. In variants 2 and 3 the

foliar application of vermi-extract was used. This extract was applied once in the dose of 40 dm³·ha⁻¹ in the variant 2 and twice in doses 40 dm³·ha⁻¹ of vermi-extract in the variant 3, totally 80 dm³·ha⁻¹. The first application of extracts was carried out in the growth stage BBCH 12 (var. 2 and 3) and the second application in the growth stage BBCH 16 (var. 3). Before the application the extract was diluted by water in the ratio 1 : 25 (v/v) and the created vermi-dilution was applied on the maize leaves.

The maize sowing of the hybrid PR38V91 from the company Pioneer (FAO 310) was carried out in the second decade of April. 10 seeds were sown into a pot. The sowing depth was 0.03 m. During the whole growing season the experiment was checked regularly, the state of vegetation health was monitored and before the first application of extracts the number of plants was consolidated to three plants per pot, which left until the end of the maize vegetation.

In the growth stage BBCH 17 the content of nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, copper, manganese and iron was detected in the aboveground phytomass of maize plants. The same methods were used for the determination of N, P, K, Ca and Mg as in the field trial. Sulphur was determined nephelometrically after mineralization in the medium of mixture HNO₃ and HClO₄ (3:2, v/v) [Koppová et al. 1955]. Zn, Cu, Mn and Fe were determined by the method of optical emission spectrometry with the inductively coupled plasma after mineralization in mixture of H₂O₂ and HNO₃ (1 : 5, v/v) in the closed microwave system [Zbiral et al. 2005].

The experiment was terminated in the growth stage BBCH 97. The grain yield, the weight of aboveground phytomass and thousand kernel weight were detected.

The obtained results were statistically elaborated, analysis of variance (ANOVA) was performed and the differences between the variants were evaluated subsequently by LSD test in the PC program Stathgraphic, version 5.

Table 4. Variants of pot experiment - the term and dose of vermi-extracts and vermi-solution application

Variant	Term of application (growth phase)	Dose of vermi-extract			Dose of vermi-solution
		dm ³ ·ha ⁻¹	cm ³ ·plant ⁻¹	cm ³ ·pot ⁻¹	cm ³ ·pot ⁻¹
1. Control	–	–	–	–	
2. E	BBCH 12	40	0.5	1.5	39
3. 2E	BBCH 12 and BBCH 16	40+40	0.5	1.5+1.5	39+39

Explanation: see Table 3.

RESULTS AND DISCUSSION

Field experiment

The presowing application of the vermi-compost extract had the evidential impact on the grain yield, the starch content in grain, thousand kernel weight, and phosphorus content in grain of maize (Table 5).

The lowest application dose of extract into soil (var. E₁) did not increase the grain yield (Table 6). All the other application doses of vermi-extract (var. E₂, E₃, E₄) increased the grain yield of maize in comparison with the control variant. The growths were significant after application the doses of 130 and 170 dm³·ha⁻¹ and insignificant with the dose of 210 dm³·ha⁻¹. The highest yield, and the highest yield increase in relation to the control treatment, was detected in variant E₂, wherein 130 dm³·ha⁻¹ of extract was applied before the maize sowing.

The increased dose of extract in relation to variant E₂ had a depressive impact, in spite of that, the yields in the variants E₃ and E₄ were higher than in the control, unfertilized variant. The obtained data point out the fact that if the presowing application of vermi-extract should result in a considerable increase of yield, it is necessary to apply the doses higher than 90 dm³·ha⁻¹, or it is appropriate to use the doses in the range 130–170

dm³·ha⁻¹. The obtained results mean the original information in the Slovak environment as so far only the foliar effectiveness of vermi-extract has been tested.

The presowing application of the vermi-compost extract increased considerably also the starch and phosphorus contents in the maize grain. The differences of the starch and phosphorus contents between the variants treated by vermi-extract were minimal, however, we can claim that along with the increase of the application dose of vermi-extract the starch and P content in the maize grain was decreased slightly (Table 5). The vermi-extract usage decreased the TKW, and when 90–170 dm³·ha⁻¹ was applied the decrease was significant statistically. The presowing utilization of vermi-extract did not significantly affect the nitrogen, magnesium, potassium and calcium contents in the maize grain, and grain from the variants 3-5 treated by vermi-extract had lower nitrogen and calcium contents than from the control variant (Table 5 and 6).

The impact of additional fertilizing by the vermi-compost extract in the growth stage BBCH 15 (Table 7) is evident in comparison to the unpaired variants (3, 5, 7, 9) with the odd ones (2, 4, 6, 8). These comparisons prove a positive impact of additional application of vermi-compost extract on the maize grain yield, which increase by 0.63 even 9.14%. This detection corresponds with

Table 5. The impact of resources of variability on maize yield parameters in field experiment

Resources of variability	n	Yield	Starch	TKW	N	P	K	Ca	Mg
		F – calculated							
Variant	4	2.643*	4.741*	5.104**	1.994	8.579**	3.407	10.683	1.334
Repetition	3	0.587	0.787	1.213	0.805	0.225	0.797	0.392	0.881
Rest	12								
All	19								

Explanation: n – degrees of freedom, TKW – thousand kernel weight.

Table 6. The impact of presowing application of vermicompost extract on the maize yield parameters – field experiment

Variant	Yield	Starch	TKW	N	P	K	Ca	Mg
	Mg·ha ⁻¹	%	g	mg·kg ⁻¹ d.m.				
1. Control	6.02 a	62.80 a	292.51 b	16,678 a	3,051 a	3,280 a	873 b	1,950 a
2. E ₁	6.02 a	64.65 b	286.09 a	16,030 a	3,541 b	3,243 a	859 ab	2,133 a
3. E ₂	6.30 b	64.59 b	286.33 a	15,654 a	3,529 b	3,358 ab	846 a	1,932 a
4. E ₃	6.28 b	64.11 b	286.90 a	15,958 a	3,427 b	3,237 a	859 ab	1,973 a
5. E ₄	6.24 ab	64.02 b	292.04 b	16,041 a	3,411 b	3,400 b	859 ab	1,964 a
LSD _{0.05}	0.242	0.973	4.664	1,047.51	199.46	154.07	5.48	204.73

Explanation: E – vermi-extract, LSD_{0.05} – least significant difference at the level $\alpha = 0.05$ (LSD test), different letters at values indicate statistically significant differences between treatments.

Table 7. The impact of sidedress by vermicompost extract on the maize yield parameters – field experiment

Variant	Yield			Starch			TKW		
	Mg·ha ⁻¹	%*	%**	g·kg ⁻¹	%*	%**	g	%*	%**
1. Control	6.02	100.00	–	628.0	100.00	–	292.51	100.00	–
2. E ₁	6.02	100.00	100.00	646.5	102.95	100.00	286.09	97.81	100.00
3. E ₁ +E	6.57	109.14	109.14	643.4	102.45	99.52	283.55	96.94	99.11
4. E ₂	6.30	104.65	100.00	645.9	102.85	100.00	286.33	97.89	100.00
5. E ₂ +E	6.34	105.31	100.63	638.4	101.66	98.84	290.00	99.14	101.28
6. E ₃	6.28	104.32	100.00	641.1	102.09	100.00	286.90	98.08	100.00
7. E ₃ +E	6.37	105.81	101.43	645.6	102.80	100.70	283.87	97.05	98.94
8. E ₄	6.24	103.65	100.00	640.2	101.94	100.00	292.04	99.84	100.00
9. E ₄ +E	6.79	112.79	108.81	646.4	102.93	100.97	286.54	97.96	98.12

Explanation: E – vermi-extract, * Control = 100%, ** presowing application = 100%.

the finding of Klimeková et al. [2007] recorded the yield increase only by 1.83% after application of 50 dm³·ha⁻¹ vermi-extract on the winter wheat leaves in the growth stage BBCH 32. The above mentioned information corresponds also with the finding of Singh et al. [2010] who stated 9.8 to 13.9% increase of strawberry yield after the vermi-extract application. In neither case the decrease of grain yield was recorded after the foliar extract application (Table 7).

The highest increase of grain yield as the result of the foliar application of vermi-extract (9.14%) was recorded in the variant 3 versus variant 2, where the lowest quantity of extract was applied in the presowing period.

The increase of the maize grain yield after the foliar application of extract varied in the broader range than after the application of vermi-extract into soil (0.63 to 9.14% versus 0.0 to 4.65%). The average increase of the grain yield after the foliar application achieved the level of 5.00% and after the application into soil only 3.16%. It is evident that a lower dose of extract (40 dm³·ha⁻¹) applied

on a leaf can have a higher impact on the yield formation of maize grain in comparison with higher doses of extract (90 to 210 dm³·ha⁻¹) applied into soil.

The common effect of the presowing and foliar application of vermi-extract compared with the control, untreated by vermi-extract variant, increased the grain yield by 5.31 to 12.79% (variants 3, 5, 7, 9 versus control).

Additional fertilization by the extract in the growth stage BBCH 15 (odd variants versus even variants) had smaller effect on starch content and thousand kernel weight, than on the grain yield, or the given parameters were not influenced by the foliar application of vermi-extract at all. There were differences only at the level of 0.48 to 1.78%.

The impact of the foliar application of vermi-extract on the nitrogen, and also phosphorus and magnesium content was negative (Table 8).

The nitrogen content fell by 1.09 to 5.52%, phosphorus content by 0.28 to 5.10% and magnesium content by 6.1 to 9.69%. The recorded de-

Table 8. The impact of sidedress by vermicompost extract on the contents of some macroelements in maize grain – field experiment

Variant	N		P		K		Ca		Mg	
	g·kg ⁻¹	%*	g·kg ⁻¹	%*	g·kg ⁻¹	%*	g·kg ⁻¹	%*	g·kg ⁻¹	%*
2. E ₁	16.00	100.00	3.54	100.00	3.24	100.00	0.86	100.00	2.13	100.00
3. E ₁ +E	15.20	95.00	3.53	99.72	3.33	102.78	0.87	101.16	2.00	93.90
4. E ₂	15.65	100.00	3.53	100.00	3.36	100.00	0.85	100.00	1.93	100.00
5. E ₂ +E	15.48	98.91	3.35	94.90	3.48	103.57	0.85	100.00	1.81	93.78
6. E ₃	15.96	100.00	3.43	100.00	3.24	100.00	0.86	100.00	1.97	100.00
7. E ₃ +E	15.08	94.48	3.39	98.83	3.44	106.17	0.86	100.00	1.81	91.88
8. E ₄	16.04	100.00	3.41	100.00	3.40	100.00	0.86	100.00	1.96	100.00
9. E ₄ +E	15.44	96.26	3.36	98.53	3.49	102.65	0.87	101.16	1.77	90.31

Explanation: E – vermi-extract, * presowing application = 100%.

crease of the nitrogen content in the maize grain along with the parallel increase of maize grain yield corresponds with the data of Kováčik [2014] who claims that the decrease of the nitrogen content in the grains of cereals often occurs after the application of the growth stimulators without the simultaneous application of the nitrogen fertilizers. The rate of the N content drop in grains is determined by several factors, among which the unfavourable weather and the insufficient N_{an} content in soil rank among the most important factors.

Pot experiment

The obtained results (Table 9) show that it is evident the maize plants in the control variant 1 were higher before the extract application than the plants in the variants treated by vermi-extract. However, after 13–20 days from the first application by vermi-extract (6th and 13th of June) the plants treated by extract (var. 2 and 3) were higher than those in the control variant. In the following week (21st of June) these differences in height were eliminated. The increase in plant height treated by extract was recorded nine days after the second spraying (28th June) similarly like after the first spraying (var. 3 versus var. 2). The

plants of the variant 3 were the highest ones, and of the control variant were the lowest ones. In the middle of July, in the growth stage BBCH 18 and also in the following stages (BBCH 51, 59–61) the highest plants were recorded in the control variant. This means that the positive impact of the foliar application of extract on the maize plant height is evident during the first 20 days after spraying and with the older plants during the first 10 days. However, the plant height recorded at the end of the growing season refers that the stimulative effect is only the short-term one and the extract had the inhibitive impact on the plant height afterward. The detected information about the short-term stimulative effect of vermi-extracts on the plant phytomass is significant. It explains the reason of positive effects of vermi-extracts on the plant phytomass publishing in many scientific articles because they present the results of experiments lasted for only 5 or 6 weeks.

The impact of the extract application on the maize stalk thickness was the same till the growth stage BBCH 14 as the impact on the height of maize plants (Table 10). 13 days after the first application of vermi-extract (6th June) the plants treated by extract (var. 2 and 3) were considerably thicker than the plants in the control variant.

Table 9. The impact of one and two applications of vermi-extract on dynamics of maize growth – pot experiment

Variant	Date								
	21.V.	29.V.	6.VI.	13.VI.	21.VI.	28.VI.	15.VII.	25.VII.	5.VIII.
	BBCH								
	12	13	14	14 – 15	16 – 17	17 – 18	18	51	59 – 61
cm									
1. Control	8.33 b	12.88 b	14.44 a	19.88 a	36.00 a	45.16 a	60.22 b	105.44 b	128.11 b
2. E	7.55 a	11.33 a	15.05 b	22.94 b	36.01 a	48.88 b	55.77 a	99.11 a	118.11 a
3. 2E	7.55 a	11.33 a	15.05 b	24.00 b	36.01 a	52.05 c	58.44 b	104.00 b	118.00 a
LSD _{0.05}	0.648	1.203	0.576	2.308	0.287	2.942	1.836	2.849	3.718

Explanation: The first extract application was carried out on 24th of May (BBCH 12) and the second application on 19th of June (BBCH 16). E - vermi-extract, LSD_{0.05} – least significant difference at the level $\alpha = 0.05$ (LSD test), different letters at values indicate statistically significant differences between treatments.

Table 10. The impact of one and two applications of vermi-extract on dynamics of maize stalk coarsening – pot experiment

Variant	Date								
	21.V.	29.V.	6.VI.	13.VI.	21.VI.	28.VI.	15.VII.	25.VII.	5.VIII.
	BBCH								
	12	13	14	14–15	16–17	17–18	18	51	59–61
cm									
1. Control	2.03 a	2.24 a	2.47 a	3.15 a	4.16 a	5.02 b	4.58 ab	4.52 a	4.46 b
2. E	2.04 a	2.26 a	2.66 b	3.17 a	4.34 b	5.17 b	4.74 b	4.65 a	4.28 ab
3. 2E	2.04 a	2.26 a	2.70 b	3.17 a	4.02 a	4.21 a	4.36 a	4.48 a	4.21 a
LSD _{0.05}	0.114	0.129	0.142	0.108	0.159	0.563	0.372	0.307	0.208

Explanation: see Table 9.

The second application of the extract carried out in stage BBCH 16 (var. 3), i.e. 9 days after spraying (28th June) had evidently an inhibitive impact.

The stalks were getting thicker, however, they grew considerably slower and for longer time than the stalks of the other two variants. These data correspond partially with the information by Gutiérrez-Miceli et al. [2008], who recorded thinner stalks of the sorghum plants (*Sorghum bicolor*) in some cases after the vermi-extract application in comparison with the control variant.

In the variants 1 and 2 the stalk girth was decreased from the end of the growth stage BBCH 18. In the variant 3, wherein the second dose of extract was also applied, the stalks were getting thinner after the growth stage BBCH 51. These data point out indirectly that the extract application carried out in stage BBCH 16 delayed the maturation of stalk tissues and the transfer of the assimilates from the vegetative parts of plant to grain (Table 10).

In the growth stage BBCH 59–61 the thickest stalks were recorded in the control variant - untreated by extract, and the narrowest stalks occurred in the variant where the extract was applied twice (var. 3). Similarly, the highest yield of maize grain and straw was detected in the control variant, and the lowest yield was obtained in variant 3.

These facts result in the information that plant height and thickness of maize stalks recorded in the growth stages BBCH 12 to BBCH 51 did not

correspond with the achieved quantity of maize grain yield. On the contrary, it is possible to detect a certain relationship between the plant height, stalk thickness and grain yield only in the growth stage BBCH 59–61. These data prove the information of Kováčik [2014] that it is not unusual if the vegetation of field crops looks better optically (higher, more dark green) until the first half of the growing season but it gives lower yields than the vegetation which appears to be weaker.

The lower grain yields in the variants treated by extract, recorded in the pot experiment (Table 11), are in contrast with the data of field experiment presented in the Table 7.

The data show that in neither case the decrease of grain yield was recorded after the foliar application of extract. The reason for different effects of the identical vermi-extract on the yield of maize grain consists probably in the different dates of extract application and in the different maize cultivars. In the field experiment the extract was applied in the growth stage BBCH 15 and the cultivar Stira was grown. Whereas, in the pot experiment the extract was applied in growth stages BBCH 12 or in BBCH 12 and 16, and the cultivar hybrid PR38V91 was grown.

The negative effect of the foliar application of extract on the vegetative phytomass was more considerable (9.14 to 18.5%) in comparison with the impact on the generative phytomass (0.24 to 11.3%). This caused a change of ratio between

Table 11. The impact of single and double application of vermi-extract on maize yield parameters – pot experiment

Variant	Yield				Grain/straw ratio	TKW	
	grain		straw			g	%*
	g·pot ⁻¹	%*	g·pot ⁻¹	%*			
1. Control	54.24 b	100.00	101.95 bc	100.00	0.510	251.44 a	100.00
2. E	54.11 b	99.76	92.63 ab	90.86	0.584	253.53 a	100.83
3. 2E	48.11 a	88.70	83.09 a	81.50	0.579	255.04 b	101.43
LSD _{0.05}	3.543		10.274			3.243	

Explanation: see Table 9, * Control = 100%.

Table 12. The impact of single and double application of vermi-extract on some macroelements (N, P, K) contents in plants of maize in the growth stage BBCH17 – pot experiment

Variant	N		P		K	
	mg·kg ⁻¹	%*	mg·kg ⁻¹	%*	mg·kg ⁻¹	%*
1. Control	12,894 a	100.00	4,048 b	100.00	33,466 a	10.00
2. E	13,263 b	104.41	4,386 c	108.35	33,197 a	99.20
3. 2E	13,084 b	101.47	3,779 a	93.35	31,577 a	94.36
LSD _{0.05}	220.124		185.458		1,935.324	

Explanation: E – vermi-extract, LSD_{0.05} – least significant difference at the level $\alpha = 0.05$ (LSD test), different letters at values indicate statistically significant differences between treatments, * Control = 100%.

Table 13. The impact of single and double application of vermi-extract on some macroelements (Ca, Mg, S) contents in plants of maize in the growth stage BBCH17 (pot experiment)

Variant	Ca		Mg		S	
	mg·kg ⁻¹	%*	mg·kg ⁻¹	%*	mg·kg ⁻¹	%*
1. Control	1 876 b	100,00	5 174 c	100,00	337 a	100,00
2. E	1 714 a	91,36	3 727 b	72,03	270 a	80,12
3. 2E	1 660 a	88,49	3 001 a	58,00	304 a	90,21
LSD _{0.05}	136,214		313,628		88,957	

Explanation: see Table 12.

Table 14. The impact of single and double application of vermi-extract on some microelements (Zn, Cu, Mn, Fe) contents in plants of maize in the growth stage BBCH17 (pot experiment)

Variant	Zn		Cu		Mn		Fe	
	mg·kg ⁻¹	%*	mg·kg ⁻¹	%*	mg·kg ⁻¹	%*	mg·kg ⁻¹	%*
1. Control	55.85 b	100,00	3.92 ab	100.00	49.62 b	100.00	339.34 c	100.00
2. E	53.16 b	95,18	4.26 b	111.52	51.05 c	102.88	294.38 b	86.75
3. 2E	52.02 b	93,14	3.80 ab	99.48	47.38 a	95.49	272.87 ab	80.41
LSD _{0.05}	4.074		0.586		1.408		29.047	

Explanation: see Table 12.

grain and straw in favour of grain. The extract utilization had the positive impact on the TKW.

The remarkable fact is that the contents of phosphorus, potassium, calcium, magnesium, zinc, copper, manganese and iron were lower in the growth stage BBCH 17, one week after the second application of extract, in comparison with the other variants (Tables 12, 13 and 14).

These data indicate a wide-spectral inhibition of nutrients intake as a result of foliar application of vermi-extract. Similarly, Gutiérrez-Miceli et al. [2008] recorded the decrease of N, P and K contents in the sorghum plants in the majority of cases after the application of extracts. On the contrary, Pant et al. [2012] detected a increase of N, P, K, Ca and Mg content in the plants of pak choi after using several types of vermi-extracts.

CONCLUSION

1. The vermi-extract applied in the presowing period increased the maize grain yield if the application doses were at the level of 130 to 170 dm³·ha⁻¹. In order to increase the starch content in grain it is more suitable to carry out the presowing application of vermi-extract than the application during the growing season.
2. The positive or negative impact of the foliar vermi-extract application on the maize grain yield depended on the date of the extract ap-

plication and the grown cultivar. The presowing application and foliar application of vermi-extract tended to decrease the nitrogen content in grain.

3. The foliar application of vermi-extract positively affected plant height and stalk thickness of maize only in the short term. The plant height and stalk thickness of maize recorded in the growth stages BBCH 12 to BBCH 51 did not correspond with the achieved quantity of maize grain yield. In the first half of the maize growing season the information about the plant height and stalk thickness was not an appropriate indicator for the prognostication of quantity of maize grain yield.

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