Original Paper

Response of Young Maize Plants to Rational and Above-Limit Doses of Vermicompost

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In a two-year pot experiment carried out in a vegetation cage located on the premises of the Slovak University of Agriculture in Nitra, the effect of vermicompost (Vc) used at a dose 8.3 to 16.6 times higher than permitted by the Nitrates Directive on young maize plants on their phytomass was investigated. The results showed that excessive amounts of vermicompost did not have a depressing effect on the growth of young maize plants. On the contrary, they increased the production of phytomass. The legislatively determined nutrient doses should take into account the type of organic fertilizer and the different abilities of plants to convert nutrients into phytomass formation.

Keywords: fertilization, nitrate directive, nitrogen, phytomass, maize

1 Introduction

Young plants are significantly more sensitive to higher nutrient concentrations in the soil than older ones, and for this reason it is appropriate to sow many plants in soils with a medium supply of available nutrients and fertilize them several times during the growing season than to sow them in soils with a high level of available nutrients. Dividing the total dose of nutrients, especially nitrogen, into several smaller application doses (before sowing and during vegetation) is carried out mainly for crops with a longer vegetation period, 100 days or more, which achieves greater use of N from fertilizer for crop formation and at the same time reduces the amount of N leached into groundwater.

A condition for successful agricultural activity is its economic efficiency, therefore farmers try to rationally limit economic inputs, which include the costs of labour, machinery and equipment associated with each fertilizer application. For this reason, farmers do not fertilize crops frequently, unlike the hobby sector, where small-scale growers fertilize with nitrogen almost every two weeks in the spring months or even in the first weeks of summer. Farmers (large-scale growers) choose application dates, nutrient doses and specific fertilizers so that the costs associated with fertilizer application bring the greatest profit, and for this reason, in Slovakia, fertilization with mineral N fertilizers when growing maize is usually carried out in two, rarely three terms. The same is true in Central European countries, but in South American countries, China, the USA and other countries we often encounter four to five application rates of N fertilizers (Shrestha et al., 2018; Li et al., 2020).

One option to limit the number of applications and at the same time supply the necessary amount of nitrogen is to apply a fertilizer that releases N gradually. In addition to industrially produced N fertilizers belonging to the group of fertilizers with gradual nitrogen release, vermicompost also belongs to this group. Its application rate of 170 $kg \cdot ha^{-1}$ of total N, i.e. the rate permitted by the European Commission (1991), supplies 8 to 30 kg of inorganic N to the soil. In addition, approximately 50 kg

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of nitrogen in the form of N_{in} is released by mineralization in the first year (Kováčik & Ryant, 2024). As a result, the total amount of N available to plants in the first year after Vc application is around 60–80 kg N. The stated quantity creates the prerequisites for achieving average maize grain yields. Similarly, Bhattarai et al. (2004) found that if the N dose is divided into three doses, a total application rate of 60 kg·ha^{-1} N is sufficient to achieve average yields. Shrestha et al. (2018) report that with two applications of N fertilizer, a farmer should provide a total of 80 kg·ha^{-1} of mineral N to maize plants. However, higher amounts of N are required to achieve maximum yields. Maize grown for grain increases phytomass production up to a N dose of 200 kg·ha^{-1} (Shrestha et al., 2018). The supply of mineral N through organic or inorganic fertilizers at a dose above 450 kg·ha^{-1} has a depressing effect on maize plants (Yu-Kui et al., 2009). From the above, it is clear that maize farmers have knowledge about the impact of various (insufficient, rational and above-limit) doses of mineral N on yield of plants, however, there is less knowledge about the impact of various doses of N in the form of organic fertilizers, and so the aim of this experiments is to point out the difference in the impact of the maximum dose set by the European Commission (1991) and the applied dose of N significantly above the limit.

2 Material and Methods

The 2-year pot experiment was performed in the vegetation cage located on the premises of the Slovak University of Agriculture in Nitra (48° 180´ N, 18° 050´ E) in 2021 and 2022. The size of the cage was 20 × 20 × 5 m. On its sides and ceiling there was the metal mesh with the size of a mesh 15 × 15 mm, which protected the experiment against birds.

The total number of treatments (tr.) was 4 (Table 1). Treatment 1 was unfertilized – control treatment (soil without vermicompost). In treatment 2, the maximum legally permitted dose vermicompost (Vc) was applied, and in treatments 3 and 4, the above-limit doses of Vc were applied. Treatments 1–4 examined the impact of increasing quantity of Vc in the growing medium, which was prepared by mixing different portions of soil and vermicompost. The pots (cylinder-shaped containers 35 cm high and 35 cm in diameter) contained 20 kg of soil (Haplic Fluvisol) in treatment 1 and 20 kg of the mixture consisting of soil and applied vermicompost in treatments 2–4. In treatment 2, the mixture consisted of 0.24 kg Vc and 19.76 kg soil, which corresponds to the maximum annual dose of N in the form of organic fertilizers permitted by the European Commission (1991), i.e. permitted by the so-called Nitrates Directive (ND). Vermicompost dose in treatment 2 took into account the N content in vermicompost and also the methodology for performing pot experiments (Ivanič et al., 1984). In treatment 3, the growth medium was prepared by mixing 18 kg of soil (S) with 2 kg of vermicompost, representing a ratio of S : Vc = 9 : 1 (10% Vc by weight). In treatment 4, the mixture consisted of 16 kg of soil and 4 kg of vermicompost, representing a ratio of S : Vc = 4 : 1 (20% Vc by weight). Pots with soil and vermicompost were placed on trays that had the capacity to capture up to 1,000 ml of soil solution flowing out of the pots in case of heavy rains.

The same soil (Haplic Fluvisol) was used in all 4 treatments. This soil was taken from a field located in the cadastral area of the village of Drážovce (Nitra district), from the soil layer 0.00–0.30 m, which was homogenized and sieved through a 3 × 3 cm sieve. The vermicompost used in the experiments was produced and supplied by VermiVital s. r. o. (Záhorce, Slovakia). The basic agrochemical parameters of the used soil and vermicompost are indicated in Table 2. The following analytical methods were used for determining the agrochemical parameters of the soil and vermicompost used. Ammonium ($N\text{-}NH_4^+$) was measured by the Nessler's colorimetric method; $N\text{-}NO_3^-$ by colorimetric method with phenol – 2.4 disulphonic acid, where the extract from soil was achieved by using

Table 1 Overview of the treatments and individual amounts of used soil and vermicompost in the pot experiment

Treatment		S	Vc	Characteristics of vermicompost doses	N in Vc	
No.	designation	kg·pot^{-1}			g·pot^{-1}	%
1	S	20.00	0.00	–	–	–
2	S + $Vc_{(ND)}$	19.76	0.24	dose Vc permitted by the ND (170 kg·ha^{-1} N)	3.81	100.00
3	S + $Vc_{(10)}$	18.00	2.00	10% Vc content on the substrate	31.75	833.33
4	S + $Vc_{(20)}$	16.00	4.00	20% Vc content on the substrate	63.50	1666.66

No. – number, S – soil, Vc – vermicompost, ND – nitrate directive

Table 2 Parameters of soil and vermicompost used in the experiment (100% dry matter)

Medium	N_{in}	P	K	Ca	Mg	S	N_t	C_{ox}	EC	pH_{KCl}
	$mg \cdot kg^{-1}$							%	$mS \cdot cm^{-1}$	
Soil	10.1	53.2	173.9	6,763	431.0	9.9	1,166	1.45	0.15	6.77
Vermicompost	872.6	5,062	23,907	6,663	3,351	1,187	15,874	21.3	9.68	7.47

the water solution of 1% K_2SO_4. Inorganic nitrogen (N_{in}) was calculated as a sum of $N\text{-}NH_4^+$ + $N\text{-}NO_3^-$ (N_{in} = $N–NH_4^+$ + $N–NO_3^-$). Both $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ were determined in a fresh soil sample. The contents of available P, K, Ca, and Mg were determined in the dry soil sample by the Mehlich 3 extraction procedure (Mehlich, 1984). The content of P was determined by the colorimetric method, K by flame photometry, Ca and Mg by atomic absorption spectrophotometry, S spectrophotometrically (in the leachate of ammonium acetate), total nitrogen (N_t) by distillation after the mineralization with strong H_2SO_4 (Bremner, 1960), total organic carbon (C_{ox}) after the oxidation according to Tyurin (Dziadowiec & Gonet, 1999), EC by analysis of specific electrical conductivity, and pH (in a solution of 1.0 $mol \cdot L^{-1}$ KCl, soil to solution ratio 1 : 2.5) potentiometrically.

The experiment was established according to the method of random arrangement of pots in three repetitions (each treatment consisted of 3 pots, where one pot was one repetition). The model crop was maize (*Zea mays* L.) variety P9241 from Pioneer. Sowing (10 individuals per pot) was carried out on April 27 in the first experimental year and on April 28 in the second experimental year to a depth of 0.04 m and the substrate was subsequently irrigated at 75% full water capacity. During vegetation, the pots were irrigated with irrigation water containing negligible amounts of nutrients (N – 2.15, P – 0.19, K – 0.46, Ca – 2.44, Mg – 0.42, and S 2.62 $mg \cdot L^{-1}$). The experiment was checked daily and, if necessary, continuously irrigated, sometimes even twice a day. Humidity was checked with a soil moisture meter. Ten days after emergence (the phenological growth stages BBCH-scale 12), the number of germinated plants was standardized to the same number in all pots (5 individuals per pot). At BBCH 15, 16, 17, 18 and 31–32 growth stage plants height and stem circumference (stalks thickness) were measured with a measuring tape. In growth stages BBCH 31–32, the amount of total chlorophyll and the weight of aboveground phytomass were also determined. The total chlorophyll content was determined from the last fully developed leaf by spectrophotometry, using 80% acetone as the extracting method, along with $MgCO_3$ (Šesták & Čatský, 1966) and the absorbance of the extract was converted into the concentration unit ($mg \cdot m^{-2}$) after the equations of Lichtenthaler (1987). Phytomass yield was determined by weighing two plants from all replicates, i.e., from all pots. The quantity of dry matter was determined by gravimetric analysis in aluminium crucibles at a temperature of 105 °C. The content of macroelements (N, P, K) was simultaneously determined in maize plants collected at the BBCH 31–32 growth stage. Nitrogen was determined by distillation using the Kjeldahl method after mineralization in the medium of concentrated H_2SO_4 (Cohen, 1910). Phosphorus was determined spectrophotometrically (as phospho-molybdenum blue), potassium by flame photometry after mineralization in the medium of mixture HNO_3 and $HClO_4$ (2 : 1, v/v) (Koppová et al., 1955).

The acquired results were processed using a mathematical-statistical method, multifactorial analysis of variance (ANOVA). The differences between the treatments were evaluated by LSD test at the significance level a = 0.05 (P <0.05). The PC statistical program "Statgraphics, version 5.0" was used.

3 Results and Discussion

In each of the monitored growth phases, a positive relationship was recorded between the dose of Vc and the height of the plants. The higher the application dose of Vc, the taller the plants were, but the increase in plant length was not linear, but had the character of a parabola (Table 3). The shortest plants were in the control treatment, where Vc was not applied, and the tallest were in the treatment with the largest amount of Vc in the soil substrate (tr. 4). In light of the knowledge that young plants are significantly more sensitive to higher nutrient concentrations in the soil than older ones, it was assumed that symptoms of toxic effects of high doses of N would appear in maize plants already at the BBCH 15 growth stage (fifth leaf fully developed). The assumption was not confirmed. No damage was observed on the maize plants.

In treatment 2, in which a rational dose of Vc was applied, in contrast to the remaining treatments fertilized with Vc (tr. 3 and 4), no significant increase in phytomass was recorded in the first year of the experiment in growth phases BBCH 16 to 31–32. In the second year of the experiment, in treatment 2, the increases in all monitored growth phases were significant and on average for both years of the experiment and for growth phases (BBCH 15 to 32) were at the level of 19.19% (Table 3).

On average, over both years of the experiment and over the entire monitored period, in treatments 3 and 4, in which approximately 8.3 and 16.6 times more N was applied than in tr. 2 (Table 1), maize plants were 44.9% and 60.72% taller than in tr. 2 (Table 3). The recording of an increase in phytomass by 44.9% and 60.72% when increasing the N dose by approximately 733% and 1,566% points that even multiple exceeding of the permitted N dose in the form of vermicompost did not have a depressing effect on the growth of young maize plants. The same findings were reached by Kováčik et al. (2021 and 2022), who did not record a depressive effect of Vc on radish and on carrots grown in substrates with a 1 : 1 vermicompost to soil ratio, with carrots responding better to higher doses of Vc than radish. The findings confirm not only that maize is one of the crops that responds well to fertilization with organic fertilizers (Cooke, 1982; Lazcano et al., 2011), but also that it tolerates extreme doses of N. Of the total amount of N supplied by vermicompost, only 15–20% is in an accessible form. The crucial part of N in the form of N_{in} is released gradually over several weeks or even months (Kováčik & Ryant, 2024). It follows from the above that the limit of 170 kg·ha^{-1} of total N, set by the Nitrates Directive, should take into account the fact that individual crop plants respond differently to fertilization with organic fertilizers containing N, i. e. they have different abilities to utilize nitrogen for the formation of phytomass. The percentage of inorganic N utilization for phytomass formation ranges from 40 to 80% in Central European conditions (Ivanič et al., 1984).

Graded application rates of vermicompost affected the thickness (circumference) of maize stalks in a similar way to how they affected plant height. They increased it. A vermicompost dose of 170 kg·ha^{-1} N insignificantly increased stem circumference in four out of five growth phases in the first year of the experiment. In the second year, this dose (tr. 2) significantly increased stem thickness. On average over five growth phases, in the second year of the experiment, the stem thickness in the treatment with a rational dose of N enlarged by 24.05% in relation to the unfertilized treatment, but over both years of the experiment there was a 16.84% increase in thickness (Table 4). The increase in stalk thickness was a result of increased inorganic nitrogen supply to maize plants through increased doses of vermicompost. The positive response of maize to vermicompost was a consequence of its parameters. Vermicomposts contain not only a significant amount of nutrients (Table 1), but also a significant amount of phytohormones, especially auxins (Nilawonk, 2014; Morales-Corts et al., 2018), which

Table 3 Effect of vermicompost on the height of maize plants at different growth stages

Year	Treatment		Growth phase (BBCH)						Δ between averages for the entire monitored period
			15	16	17	18	31 – 32		
	no.	desig.	cm					%	%
2021	1	S	19.02^{a}	26.47^{a}	34.50^{a}	44.82^{a}	53.20^{a}	100.00	0.00
	2	S + $Vc_{(ND)}$	23.07^{b}	28.48^{a}	35.20^{a}	46.25^{a}	55.88^{a}	105.04	6.11
	3	S + $Vc_{(10)}$	35.08^{c}	44.17^{b}	55.43^{b}	71.65^{b}	78.15^{b}	146.90	59.81
	4	S + $Vc_{(20)}$	40.20^{d}	51.60^{c}	61.55^{c}	76.76^{c}	85.40^{c}	160.53	77.24
	$LSD_{0.05}$		3.47	3.78	3.78	4.73	3.57		
2022	1	S	36.75^{a}	40.93^{a}	43.03^{a}	47.26^{a}	52.08^{a}	100.00	0.00
	2	S + $Vc_{(ND)}$	47.45^{b}	55.52^{b}	58.12^{b}	62.68^{b}	62.67^{b}	120.33	30.31
	3	S + $Vc_{(10)}$	47.63^{bc}	58.56^{b}	71.97^{c}	84.73^{c}	105.7^{c}	202.96	67.50
	4	S + $Vc_{(20)}$	51.21^{c}	57.70^{b}	80.77^{d}	93.30^{d}	113.1^{d}	217.17	80.00
	$LSD_{0.05}$		3.68	4.83	3.94	8.01	4.99		
$\bar{x}$	1	S	27.91^{a}	33.72^{a}	38.84^{a}	46.20^{a}	52.64^{a}	100.00	0.00
	2	S + $Vc_{(ND)}$	35.22^{b}	42.03^{b}	46.70^{b}	54.51^{b}	59.28^{b}	112.69	19.28
	3	S + $Vc_{(10)}$	41.41^{c}	51.44^{c}	63.73^{c}	78.22^{c}	91.93^{c}	174.93	63.93
	4	S + $Vc_{(20)}$	45.74^{d}	54.71^{c}	71.20^{d}	85.04^{d}	99.25^{d}	188.85	78.59
	$LSD_{0.05}$		3.28	4.33	3.43	5.01	6.22		

no. – number, $\bar{x}$ – average, desig. – designation, Δ – differences, S – soil, Vc – vermicompost, ND – nitrate directive, $LSD_{0.05}$ – 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%

cause the elongation and expansion of secondary roots, thereby improving the uptake of nutrients from the soil (Canellas et al., 2002).

Above-limit doses of vermicompost (exceeding the dose permitted by the ND) applied in treatments 3 and 4 did not have a depressing effect. On average, during the observed growth phases and both years of the experiment, they increased stem thickness by 70.39% (tr. 3 vs. tr. 1) and by 99.92% (tr. 4 vs. tr. 1 – Table 4). In the last of the monitored growth phases, in the growth phase BBCH 31–32 (average of both years), the differences in stalk thickness between treatments 2 and 1, 3 and 1, 4 and 1 were at the level of 0.42, 2.31 and 2.67 cm. The positive effect of vermicompost on maize stalk thickness was also noted by Younas et al. (2021). The presented data confirm the dependence between the amount of available nutrients in the soil and the formation of phytomass. From the above it follows that from the point of view of environmental protection it is more rational to ensure enough food for the inhabitants of planet Earth by rationalizing fertilization than by converting forest land into agricultural land, which results in the leakage of 20 to 50% of soil carbon into the atmosphere, i.e. the greenhouse gas CO_2, the amount of which in the atmosphere is constantly increasing (Lal, 2005).

The rational dose of vermicompost applied in treatment 2, on average over both years of the experiment in the last of the monitored growth phases (BBCH 31–32), significantly increased the formation of aboveground phytomass. The percentage increase reached 59.31% and exceeded the findings of Blouin et al. (2019), who, based on meta-analyses reported that vermicompost increases the yield of field crops by an average of 26% (Table 5). However, as shown by the findings of Kováčik et al. (2018), increases in phytomass formation due to the vermicompost fertilization in the pot experiments often exceed hundreds of percent.

The percentage increase in the weight of aboveground phytomass was greater in the BBCH 31–32 growth phase (Table 5) than the % increase in plant height (Table 3) and also in stem thickness (Tables 4) in the given growth phase.

The pot experiment treatments significantly determined the chlorophyll content of maize leaves (Table 8). With the increasing amount of vermicompost in the soil, i.e. with the increase in the amount of available nutrients in the soil, the content of total chlorophyll (chlorophyll $a + b$) in maize leaves increased because the content of available N, but also Mg, S and other nutrients in the soil increases the content of total chlorophyll in plants (Kmeťová & Kováčik, 2014). There is a strong positive correlation between nitrogen

Table 4 Effect of vermicompost on the circumference of maize stalks at different growth stages

Year	Treatment		Growth phase (BBCH)						Average for the entire monitored period (BBCH 15–32)
			15	16	17	18	31 – 32		
	no.	desig.	cm					%	%
2021	1	S	1.88^{a}	2.17^{a}	2.43^{a}	2.70^{a}	2.97^{a}	100.00	100.00
	2	$S + Vc_{(ND)}$	2.05^{a}	2.31^{a}	2.85^{b}	2.97^{a}	3.10^{a}	104.38	109.30
	3	$S + Vc_{(10)}$	3.31^{b}	3.51^{b}	4.20^{c}	4.53^{b}	4.95^{b}	166.67	168.72
	4	$S + Vc_{(20)}$	3.75^{c}	4.23^{c}	4.85^{d}	5.05^{c}	5.17^{c}	174.07	189.71
	$LSD_{0.05}$		0.32	0.27	0.41	0.36	0.17		
2022	1	S	2.05^{a}	2.33^{a}	2.55^{a}	2.88^{a}	3.08^{a}	100.00	100.00
	2	$S + Vc_{(ND)}$	2.35^{b}	3.02^{b}	3.30^{b}	3.52^{b}	3.80^{b}	123.38	124.05
	3	$S + Vc_{(10)}$	2.75^{c}	3.38^{b}	4.68^{c}	5.65^{c}	5.73^{c}	186.04	172.15
	4	$S + Vc_{(20)}$	3.38^{d}	4.96^{c}	6.25^{d}	6.22^{d}	6.23^{d}	202.27	209.78
	$LSD_{0.05}$		0.26	0.39	0.21	0.26	0.22		
$\bar{x}$	1	S	1.97^{a}	2.25^{a}	2.49^{a}	2.79^{a}	3.03^{a}	100.00	100.00
	2	$S + Vc_{(ND)}$	2.20^{a}	2.67^{b}	3.08^{b}	3.24^{b}	3.45^{b}	113.86	116.84
	3	$S + Vc_{(10)}$	3.03^{b}	3.45^{c}	4.44^{c}	5.09^{c}	5.34^{c}	176.24	170.39
	4	$S + Vc_{(20)}$	3.57^{c}	4.60^{d}	5.55^{d}	5.63^{d}	5.70^{d}	188.12	199.92
	$LSD_{0.05}$		0.25	0.27	0.30	0.27	0.20		

no. – number, $\bar{x}$– average, desig. – designation, S – soil, Vc – vermicompost, ND – nitrate directive, $LSD_{0.05}$ – 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%

Table 5 Effect of vermicompost on the weight of aboveground phytomass of maize plants in the BBCH 31–32 phase (100% dry matter)

Treatment		2021		2022		$\bar{x}$	
No.	desig.	g·plant^{-1}	%	g·plant^{-1}	%	g·plant^{-1}	%
1	S	2.36^{a}	100.00	2.25^{a}	100.00	2.31^{a}	100.00
2	S + $Vc_{(ND)}$	2.57^{a}	108.90	4.79^{b}	212.89	3.68^{b}	159.31
3	S + $Vc_{(10)}$	9.68^{b}	410.17	12.27^{c}	545.33	10.98^{c}	475.32
4	S + $Vc_{(20)}$	11.48^{c}	486.44	16.15^{d}	717.77	13.82^{d}	598.27
$LSD_{0.05}$		0.36		1.52		1.24	

No. – number, $\bar{x}$ – average, desig. – designation, S – soil, Vc – vermicompost, ND – nitrate directive, $LSD_{0.05}$ – 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%

Table 6 The effect of vermicompost on the content of three macroelements in the aboveground phytomass of maize and on the content of total chlorophyll in last developed leaf in the growth phase BBCH 31 – 32 (on average in two years)

Treatment		Chl. *a* + *b*			*a*/*b*	N	P	K
No.	designation	mg·m^{-2}	D	mg·m^{-2}		mg·kg^{-1}		
1	S	173.65^{a}	1 vs 1	0.00	2.85	29,489^{a}	3,727^{a}	42.73^{a}
2	S + $Vc_{(ND)}$	209.21^{b}	2 vs 1	35.56	2.78	29,535^{a}	3,814^{a}	43.23^{a}
3	S + $Vc_{(10)}$	289.30^{c}	3 vs 2	80.09	2.64	30,309^{a}	4,019^{ab}	49.46^{b}
4	S + $Vc_{(20)}$	320.54^{d}	4 vs 3	31.24	2.54	32,718^{b}	4,280^{b}	56.28^{c}
$LSD_{0.05}$		28.32				2,530	424.0	3,381

No. – number, Δ – the difference between treatment, Chl. *a* – chlorophyl *a*, Chl. *b* – chlorophyl *b*, Chl. *a* + *b* – total chlorophyl, S – soil, Vc – vermicompost, $LSD_{0.05}$ – 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%

content in plants and chlorophyll content (Vos & Bom, 1993; Yoder & Pettigrew-Crosby, 1995). Maize leaves contained more chlorophyll *a* than chlorophyll *b*, which is consistent with findings of Wang (2009), Noman et al. (2018). As the proportion of vermicompost in the soil increased, the ratios of chlorophyll *a* to chlorophyll *b* decreased (Table 6). In treatment 2, the total chlorophyll content increased by 35.56 mg·m^{-2} compared to treatment 1, and in treatment 3, the content increased by up to 80.09 mg·m^{-2} compared to treatment 2. In treatment 4, the increase in total chlorophyll content was the smallest compared to the previous treatment. The content increased by only 31.24 mg·m^{-2}. The increase in total chlorophyll content in leaves has a parabolic character and is limited by the genetic makeup of individual plants (Švihra et al., 1989). The importance of determining the content of total chlorophyll in plant leaves is demonstrated by the fact that its content can predict yield and its amount in plants can indicate the nitrogen nutrition of plants. However, it is important for reliable forecast of the quantity of main product yield, in which phase the analysis of total chlorophyll is carried out. The relationship between chlorophyll content and phytomass formation decreases with plant age (Kováčik et al. 2016).

The contents of the three monitored macroelements (N, P, K) detected in the aboveground phytomass of maize in the BBCH 31–32 growth phase correspond to global knowledge (Fageria et al., 1991; Cambell & Plank, 2000; Ning et al., 2013). With increasing supply of available nutrients supplied by vermicompost, N, P and K contents in maize plants increased (Table 6). The increases in the treatment with a rational dose of N (tr. 2 vs. tr. 1) were insignificant, and conversely, all increases in the treatment with the highest amount of vermicompost (tr. 4 vs. tr. 1) were significant. In contrast to the findings of Ning et al. (2013), significantly higher potassium than nitrogen content was found in maize plants of all experimental treatments. Higher K content than N was also noted by Ahmed et al. (2010).

4 Conclusions

Above-limit doses of vermicompost did not have a depressing effect on the growth of young maize plants. Several times exceeding the dose of N (permitted by the European Commission) in the form of vermicompost resulted in the growth of taller maize plants with thicker stems, higher potassium content, and higher total chlorophyll content in the leaves. The legally prescribed nutrient doses should take into account the type of organic fertilizer and the different abilities of plants to convert nutrients into phytomass.

Statements

The authors declare that there is no conflict of interest.

Author Contributions

Peter Kováčik (PK) – conceptualization, funding acquisition, methodology, data curation, writing, validation, supervision; Jakub Neupauer (JN) – investigation, formal analyzis, visualization; Jabbarov (ZJ) – writing, visualization.

AI and AI-assisted Technologies Use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

Referencia

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