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Effects of Vermicompost Application on Plant Growth Stimulation in Technogenic Soils †

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Abstract: The aim of this study was to support the use of waste materials formed from a mixture of technogenic soils for growing plants through adding vermicompost leachates. The effect on the growth of underground and above-ground biomass was evaluated on plants of the bush variety of tomato (Solanum lycopersicum). Three different types of biodegradable waste (apple pomace, matolin, and horse manure) were used in the experiments, from which individual vermicomposts were subsequently produced. The effect of the addition of vermicompost leachates to the soil was manifested in all the statistically evaluated parameters of the bush tomato plants. It was found that the highest values were achieved for the root weight (+2.91 g; $p < 0.01$) and for the stem (+1.92 g, $p < 0.01$). The lowest values were observed in the control plants without application of the vermicompost leachates.

Keywords: vermicompost; stimulation; biomass; technogenic soil; *Solanum lycopersicum*

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1. Introduction

Nowadays, there is increasing pressure to recycle waste materials due to the efforts of maintaining the ecosystem and the use of energy and nutrients. Soils burdened with industrial activity, the so-called technosoils, are known for their reduced proportion of organic matter. A recently published meta-analysis [1] stated the average value of their organic carbon content is approximately 4.3%. In addition, these technogenic soils are also known for the content of toxic substances that cause changes in their biological activity, which are often manifested as the diversity of soil microorganisms [2–5], and also in their structure down to the level of soil microstructures [6–11]. All the above-mentioned changes reduce the functions of these technogenic soils and make their regeneration impossible. The enrichment of technosoils with vermicompost can contribute to their agricultural use.

Vermicomposting is a sustainable approach to waste management and it represents the process of the decomposition of organic waste through the cooperation of earthworms (genus *Eisenia*) and microorganisms [12]. It includes physical processes such as the fragmentation, aeration, and overturning of wastes, as well as biochemical processes such as enzymatic digestion, the transformation of waste materials, and their enrichment. Earthworms modify the physico-chemical and biological state of organic matter, reduce the C/N ratio, increase the surface area, expose more sites for microbial action and improve the decomposition process [13].

However, more generally, vermicompost can be described as, most often, a dark, weakly sticky mass of a solid state resembling humus or peat [14]. Factors affecting vermicompost quality include, for example, aeration, moisture [15], temperature [16], pH value [17,18], and the content of chemical substances, or elements, respectively [19]. A very important feature is the ability to supply crops with growth hormones such as auxin, gibberellin, or cytokinin, and the presence of fulvic acids and humic acids acting as plant growth regulators [20]. Aeration, mechanical mixing, additional nutrients (additives), extraction time, water quality, and temperature affect mainly the efficiency of the extraction of the substances mentioned above [21].

The aim of this work was to evaluate the effect of the application of vermicompost leachates extracts on the growth stimulation of tomato plants (*Solanum lycopersicum* L.) in a mixture with a technogenic soils.

2. Material and Methods

2.1. Preparation of Vermicomposts and Their Aqueous Solutions

Three different types of biodegradable waste (apple pomace, matolin, and horse manure) were used in experiments, from which individual vermicomposts were subsequently produced.

A specially designed glass laboratory extractor with a volume of 10 L was used for the preparation of aqueous extracts from vermicomposts. This extractor was equipped with a magnetic stirrer (850 rpm), an aeration device, and four probes (pH, EC, dissolved oxygen and temperature). During the production of aqueous extracts, a constant temperature of 30 °C and an air flow of 10 L/min were maintained. For leaching, one kilogram of fresh vermicompost was placed in a perforated basket (volume 1250 mL) and placed in a glass container containing 9 liters of demineralized water.

The ratio of vermicompost to water was 1:9. A dressing was then prepared from the leachates after 48 h of aeration, in a ratio of 1:10 with demineralized water. The dressing was applied in two variants, by spraying the leaf and dressing the substrate. One dose represented 100 mL of solution or demineralized water for control purposes. Pre-grown determinant varieties of *Solanum lycopersicum* plants were used as test plants.

2.2. Experimental Plants

The plants of Solanum lycopersicum were grown in special boxes (Figure 1) equipped with aluminum foil preventing temperature changes and the influence of results by external sources of heat or cold in the laboratory (radiators and windows). The temperature in boxes was 24 °C (day) and 18 °C (night) throughout the growing season. Sodium lamps of a power of approx. 10,500 Lx were used as a source of light and partly heat. Each plant was planted in 5L containers. Fertilizer was applied 5 times in total during the vegetation period, at intervals, in the 2nd, 6th, 8th, and 10th week. In the cases where irrigation with fertilizer was not applied, control demineralized water was used instead. The time interval since planting the plants to their harvest was, in total, 13 weeks for above-ground biomass and 14 weeks for underground biomass root. Fruits were harvested in a total of 4 phases, namely, in the 9th, 10th, and 13th week.

Figure 1. The growth of *Solanum lycopersicum* plants in boxes (author's photo).

2.3. Method of Plants Growth Assessment

At harvest, the plants were divided into fruits, other above-ground biomass (stem and leaf), and underground biomass. In the case of underground biomass, rough manual separation of the root system was performed after the substrate had dried (harvesting 1 week longer). The biomass collected in this way was then washed out 3 times in demineralized water and thereby freed of from the maximum of possible soil contamination. Each variant was performed in six repetitions. Fresh biomass weights and fruit weight and number were recorded during harvest.

2.4. Statistical Evaluation

The SAS 9.3 program was used for the plant yield evaluation. The MEANS and UNIVARIATE procedure was used to determine basic statistics. Correlations and regressions between the assessed variables were calculated using the CORR and REGG procedures. Subsequently, a detailed evaluation was performed using the GLM procedure, two-factor analysis of variance. The evaluated parameters were root weight (g), stem weight (g), fruit weight (g) and number of fruits (pcs). Several variants of the model were tested. Based on the Akaike information criterion [22], a model containing the effects of application form and dose was selected. The interaction effect was not statistically significant, so it was excluded from further evaluation. The Tukey–Kramer test [23] and statistical significance levels $p < 0.05$ were used to determine the significance between individual effect levels; $p < 0.01$; $p < 0.001$.

3. Results

3.1. Basic Statistics of the Evaluated Data Set

Table 1 shows the basic statistics of the evaluated data set. The average weight of the root system was 42.47 g, with a standard deviation of 6.04 g. The weight of the stem was in the range of 46.88–81.66 g. At harvest, an average of 22.27 pieces of fruit with an average weight of 6.49 g were obtained. The weight of the fruits of the bush varieties of tomatoes ranged from 4.41 g to 8.21 g with a standard deviation of 0.77 g.

Table 1. Basic statistics of the evaluated data set.

Variable	n	$\bar{x}$	s	min.	max.	s.e.	V (%)
root (g)	191	42.47	6.04	29.87	58.04	0.44	14.23
stem (g)	192	66.60	6.31	46.88	81.66	0.46	9.47
fruits (g)	192	6.49	0.77	4.41	8.21	0.06	11.82
fruits (pcs)	192	22.27	3.61	10	29	0.26	16.22

Notes: (**n**) number of measurements; ($\bar{x}$) arithmetic mean; (**s**) standard deviation; (**min**) minimum value; (**max**) maximum value; (**s.e.**) the mean error of the arithmetic mean; (**V**) coefficient of variance (%).

As part of the statistical analysis of the obtained data, a correlation analysis was also performed. Very strong and statistically significant correlations were observed mainly between the root weight and stem weight (g) (r = 0.705; $p < 0.01$) and the fruit weight (g) (r = 0.621; $p < 0.01$), respectively. A similarly strong relationship was found between the stem weight (g) and fruit weight (g) (r = 0.624; $p < 0.01$). Moderately strong correlations were also found between the root weight (g) and fruit number (pc) (r = 0.384; $p < 0.001$), stem weight (g) and fruit number (pc) (r = 0.341; $p < 0.01$), and between the fruit number and weight (g) (r = 0.369; $p < 0.01$), respectively.

3.2. Impact of Vermicompost Leachates on Plant Growth

The model equation for evaluating the effect of the application of vermicompost leachates on the amount of biomass of the bush tomato was statistically significant ($p < 0.01$) for all the monitored parameters and explained the variability of the evaluated biomass parameters from 19.4% to 82% (Table 2). The effect of the form of vermicompost application was statistically significant ($p < 0.01$) only for the root and stem weight. The interaction between the monitored effects was not statistically significant ($p > 0.05$) for any of the monitored parameters and was therefore not included in the evaluation.

Table 2. Basic statistics from the ANOVA procedure.

Rated Properties	Model		Form		Dose	
	r^2	p	F-Value	p	F-Value	p
root (g)	0.820	<0.001	59.66	<0.001	156.42	<0.001
stem (g)	0.51	<0.001	8.76	0.004	36.73	<0.001
fruits (g)	0.692	<0.001	1.04	0.308	82.79	<0.001
fruits (pcs)	0.194	<0.001	0.02	0.878	8.91	<0.001

The root weights reached statistically significantly higher values when vermicompost leachates were applied to the soil (+2.91 g; $p < 0.01$). Similar tendencies were also found for higher stem weights (g), which were also achieved when vermicompost leachates were applied to the soil (+1.92 g, $p < 0.01$). However, statistically significant application differences were not observed for fruit weights and fruit numbers.

4. Discussion

As is the evidence of previous research, the quality of vermicomposts varies depending on the input raw materials and production procedures [24,25]. A whole range of studies around the world looked at and confirmed the positive effect not only of vermicomposts, but also of their leachates, for example, on the growth of fruit [26] and vegetables [27]. Atiyeh et al. [28] confirm in their work, similar to my work, the increase in the biomass of bush tomatoes when using vermicompost based on food waste. Zeller [29] observed a greater increase in the root mass of bush tomatoes of about 10 g when vermicomposts were applied, which is also confirmed by the results presented by me. Moreover, the obtained results are consistent with the work of Edwards et al. [20]. Bachman and Metzger [30] observed a positive effect of vermicompost based on pig manure on the growth of the root systems, stems, and leaves of tomatoes. My results also align with the study by Joshi et al. [31], which describes the positive effect of vermicompost as an organic fertilizer and bioagent on plant growth. Furthermore, Pillai and Aswathy [32] observed, for example, an 18% higher yield of edible tomato berries when vermicomposts were applied to the leaf. Similarly, the positive effect of vermicompost application or vermicompost leachate was also observed in other field crops, such as (sown flax) in study [33]. Similarly to my study, Fritz [34] also evaluated the effect of leachates from vermicomposts on the yield of selected vegetable species (*Raphanus sativus*, *Rucola selvatica*, and *Pisum sativum*). In his work, this author, in contrast to my results, did not confirm the positive effect of the application of these extracts on the yield of the observed vegetable species. Contrary to the study by Fritz (2012), an even higher yield can be achieved by adding additives such as brewer's yeast.

In the case of this study, the specific kind of leachate was used as a result of the assumption that leachates prepared this way will improve the microflora in the rhizosphere and phyllosphere of technogenic soils, thereby increasing the biomass growth and plant yield.

5. Conclusions

This study shows the use of vermicompost for enriching the properties of technosoil suitable for the growth of cultural (agricultural) plants. Based upon the results achieved, in the case of *Solanum lycopersicum* plants, it can be inferred that the application of vermicompost in the form of leachates improves the overall health of soils and their productivity due to the improved intake of nutrients, the presence of humic substances and phytohormones, and that it also supports microbial activity. The effect of the addition of vermicompost leachates to the soil was manifested in all the statistically evaluated parameters of the bush tomato plants. The highest values were achieved for the root weight (+2.91 g; $p < 0.01$) and for the stem (+1.92 g, $p < 0.01$). The lowest values were observed in the control plants without the application of vermicompost leachate.

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