

Biotechnological Processing of Organic and Domestic Waste and the Effect of Obtained Vermicompost on Soil Fertility

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ABSTRACT

Vermicomposting in comparison to conventional composting has several advantages, such as faster treatment of organic waste and production of manure compost with lower levels of salinity. Therefore, the determination of optimal mixtures of organic waste and manure for vermicomposting and deployment of local earthworms for this procedure have important implications in plant agriculture. In this work, the vermicompost was prepared from mixtures of manure (cattle, horse and sheep) and household organic waste (wood shavings, paper, leaves, fruit and vegetable waste) in various ratios. To convert the organic waste to the vermicompost we used the local earthworm *Eisenia fetida* (Savigny, 1826), while a hybrid species *Eisenia anderii* (Iogonen, 1995), served as control. Chemical analysis of the resulting vermicompost revealed significant increase in nutrient content compared to the initial substrate: the total nitrogen (N) was increased by 79%, phosphorus (P) by 89% and potassium (K) by 62%. The efficacy of the vermicompost, which was evaluated to have high NPK content, was further studied by observing its impact on the growth of local cucumber variety Miracle F1. As a control, the plants were cultured in medium without vermicompost (black sand). In this work, we examined the effect of different proportions of vermicompost on the development and yield of cucumber seedlings. The experiments were conducted in the greenhouse of the Institute of Biochemistry, Samarkand State University. Cucumber seedlings were grown in a medium containing 10%, 20%, 30% vermicompost.

Keywords: organic waste, household waste, *Eisenia fetida*, *Eisenia anderii*, vermicompost, NPK.

INTRODUCTION

In our country and neighboring countries, for commercial purposes, the *Eisenia Andrey* hybrid is used in vermicomposting technology. Because vermicultures of this species develop well only when they are adequately supplied with optimal

conditions (feed, humidity and temperature). The species selected in the experimental options: *Eisenia Fetida* is a common type of organic waste recycling in our climatic conditions, which is common in the regions of the country, adapted to local conditions (temperature, humidity). Until recently, *Eisenia Andrey* gebrid has been conducting

research on the decomposition of industrial and household waste, as well as food waste.

Earthworms are important in neutralizing wastes and some pollutants in soil that have a harmful effect on flora and fauna (Justyna and Katarzyna, 2019). Vermicomposting of sewage sludge using *Eisenia fetida* is an efficient process. Through this biotechnological process, such wastes were converted into granular biofertilizer with high NPK content (Jakub et al., 2019). It was shown that the structure and content of beneficial compounds were improved in soil treated with vermicompost mixtures (Mixtures et al., 2022). Biofertilizers are rich in nitrogen, phosphorus and potassium assimilating bacteria, which increases soil fertility (Ramy et al., 2022). The use of natural organic fertilizers (vermicompost) to prevent contamination with pesticides in agroecosystems is important for ecological safety (Lishchuk et al., 2023). The earthworm fauna of Uzbekistan includes 23 species belonging to 9 genera (Ikram et al., 2023). *Eisenia fetida*, distributed throughout Uzbekistan and noted for its high biotechnological potential, was used to prepare vermicompost from animal organic waste that accumulates in large quantities in the livestock sector of agriculture (Khafiza et al., 2024). Vermicompost is a product of organic waste that is broken down to a level absorbable by plants, as a result of the activity of *Eisenia fetida* and various microorganisms (Edwards et al., 2010). Vermicompost can serve as alternative to the mineral fertilizers currently in use. It is an organic fertilizer rich in micro and macro elements, bioactive substances, humic acid, vitamins, and growth hormones (Atiyeh et al., 2001). Organic fertilizers are indispensable tools for achieving high productivity in agriculture while also protecting the environment from contamination by various harmful chemicals. Research indicates that organic fertilization in the cultivation of agricultural vegetables has a positive effect on their productivity. The use of organic fertilizers, such as vermicompost, in cucumber plants increased their yield by 15% compared to the control (Omar et al., 2003). The impact of vermicompost obtained through different technological processes on the development of cucumber seedlings was explored. A mixture of plant waste and cow manure was prepared in a ratio of 3:1. This was then used to prepare vermicompost which was mixed into a substrate of peat and perlite at proportion of 5%, 10%, 15%. The addition of vermicompost had a positive effect on the morphological and

physiological indicators of the cucumber plants, with the most significant improvement observed in a mixture containing 15% vermicompost (Nikolina et al., 2019). Cucumber productivity and fruit quality depend significantly on the quality of its seedlings. The success of healthy seedling growth is greatly influenced by the substrate used. Adding vermicompost to the peat substrate positively affected the physiological parameters of cucumber seedling leaves. Total productivity of cucumber seedlings grown on peat-vermicompost substrates was 7.4–11.1% higher than those grown on pure peat substrates (Jankauskiene et al., 2022). Choosing a suitable substrate for growing plant seedlings is crucial; it should be nutrient-rich, hygroscopic (good water absorption), well aerated and economically viable. Currently, using vermicompost in vegetable cultivation and as an additional organic fertilizer for substrates is considered effective. Its environmental friendliness boosts its appeal and use (Basheer et al., 2013). Many studies have shown that vermicompost accelerates the germination of plant seeds and the formation of vegetative organs (Zaller, 2007). It also enhances plant productivity, improves fruit quality, and increases the shelf life. The neutral pH environment, porous composition, population of beneficial microorganisms, good aeration and hygroscopic properties of vermicompost create favourable conditions for plant growth (Lazcano et al., 2011). In our experiments, we investigated whether the quality indicators of vermicompost, isolated as a product in the biotechnology of vermicompost preparation, depend on the composition of the initial substrate. It is crucial to add vermicompost to the substrate in optimal proportions to achieve positive outcomes in plant development. In our study, we aimed to determine the optimal conditions for cucumber plants by applying vermicompost in varying proportions to substrates and to studying its effect on the productivity of cucumber seedlings under greenhouse conditions.

MATERIALS AND METHODS

Preparation of vermicompost

The methods for cultivating earthworm vermiculture, both simple and fully automated, can be implemented using low-tech bioreactors to control the oxygenation, substrate temperature and humidity for vermicompost production. In this process,

a substrate with organic residues is prepared to a depth of 15 cm, and a thin layer of feed is periodically added on top, building upwards. Earthworms consistently move upwards towards new feed (Edwards et al., 2010). The best food for worms is horse, goat, cattle manure, which practically requires no prior preparation. This manure is mixed with straw in varying proportions. However, the substrate must be well-moistened. Before introducing worms to a new feed, small-scale trials are conducted where 7–10 worms are placed in 300–400 g of new feed and observed. If the worms survive and integrate into the feed, the substrate can be considered suitable. Another important feature is that the pH of the substrate should be 6.5–7.5. Usually, this indicator increases during the process. It is recommended to incorporate lime and crushed eggshells into the feed to adjust pH. Additionally, up to 60–80% moistened paper waste, along with leaves, straw, stems, can also be used as feed. Under favorable conditions, the breeding cycle for earthworms is approximately 60 days per box, whereas the cycle for organic matter can be extended up to 90 days. Furthermore, the population in boxes should be divided into three parts during summer and two parts during winter. Each division will subsequently yield a population equal to the original. Once the worms have processed all the substrate in the lower box, they begin to move through holes at the bottom of the upper container into the higher one (Preparation and use of compost. Vermicompost and method, Sherbet Suu Bishkek – 2018). In our experiences, the moisture level of the substrate was observed that the humidity of 30% began to feed. Their subsequent development processes were different at different moisture levels. The relatively humidity of the gerbrite seed had the relatively humidity of the hybrid development in the upper 70–80%. In local types, the figure was 60–70%. Accordingly, the potential of their water is provided by water every 2–3 days through water spray. The moisture content of the substrate was detected using a special electronic device. In experiments, the temperature was determined in a special electronic thermometer. The vermicomposting process is carried out in special thermal chambers at a temperature of 15–25 °C. The method used by S.A. Viuoen was used as a basis for studying the effect of substrate temperature on the biomass of earthworms. Earthworm cocoons were incubated at 25–30 °C. Laboratory thermostats were used to maintain the same level of temperature in the experiment.

Chemical analysis

Nitrogen, phosphorus, and potassium in manure are determined based on separate experiments: Total nitrogen content of manure was determined according to Iodlbauer; Determination of general phosphorus in the manure; The predecessor manure is burned in a dry or wet way to check the general phosphorus of manure. As a result, these solutions are checked in colorful mechanics or volume. Dry or wet burning methods of manure is written on the detection of phosphorus in the plant. Determination of total potassium in manure; The essence of the experiment is similar to burning in the determination of total phosphorus in manure.

Seedling cultivation

The experimental study was conducted on the Miracle F1 cucumber variety. The experiment took place within the greenhouse facilities of the Institute of Biochemistry, Samarkand State University. Cucumbers of the Miracle F1 variety were cultivated in a greenhouse environment utilizing a dual-layered polymer film during the years 2022–2023. Planting of cucumber seeds was performed in early January, where seeds were sown in pots with a diameter of 12 cm and filled with substrate. Adequate watering was provided as required throughout the growth period. The seedlings were cultivated for a duration of 30 days under controlled conditions, maintaining daytime/nighttime temperatures at 22–25 °C/16–20 °C, with relative air humidity levels of 50–60%. Miracle F1 cucumber variety was used as an object of investigation, with 6 replicates. The substrate composition was formulated in varying proportions: black sand, sand + 10% vermicompost, sand + 20% vermicompost, and sand + 30% vermicompost. Biometric measurements were conducted every 10 days, totaling 3 assessments over the course of 30 days. In early February, seedlings were transplanted into rows, coinciding with daytime/nighttime temperatures of 20–28 °C/16–20 °C, and relative humidity levels of 60–80%.

Statistical analysis

Statistical processing and visualization of the results were performed using Microsoft Excel 2013 (USA) software. The results of the experiment were statistically summarized by evaluating the arithmetic means of 5 repeated experiments at

a statistical significance level of $p \leq 0.05$. Mathematical-statistical analysis included determination of mean values, standard deviations, and probability calculations according to the method described by Lakin, 1990.

RESULTS AND DISCUSSION

Vermicompost obtained from substrates of different composition

In the biotechnological process, cattle, horse and sheep manure originated from agricultural livestock farms was processed by *Eisenia fetida* and *Eisenia anderium*. The resultant products exhibited differences in color (Fig. 1) and chemical composition. Specifically, vermicompost derived from cow manure displayed a dark grey color, while that from horse manure exhibited a light brown coloration, and sheep manure-derived vermicompost appeared dark brown. Notably all three samples possessed an odorless and granular

texture. Some chemical parameters of resultant vermicompost were analyzed (Table 1). Throughout the experiment, the abiotic environmental factors such as temperature, humidity, and pH were maintained at optimal levels for the growth and activity of *Eisenia fetida*.

According to the analysis, NPK and pH indicators were determined in the chemical parameters of the substrate both before and after the experiment. Accordingly, the levels of NPK in the substrate prepared from cattle manure increased to 2.24%, 1.94%, 1.53% from initial values of 0.43%, 0.21%, 0.58%, respectively. Similarly, the NPK content in the substrate prepared of horse manure increased to 1.99%, 1.66%, 1.61% from initial levels of 0.58%, 0.27%, 0.62%, respectively. Likewise, in the substrate made from sheep manure, the NPK concentration increased from initial value of 0.82%, 0.22% and 0.68% up to 2.84%, 1.52% and 2.16%, respectively (Table 1).

In our further experiments, in order to increase the nutritional value of vermicompost, we

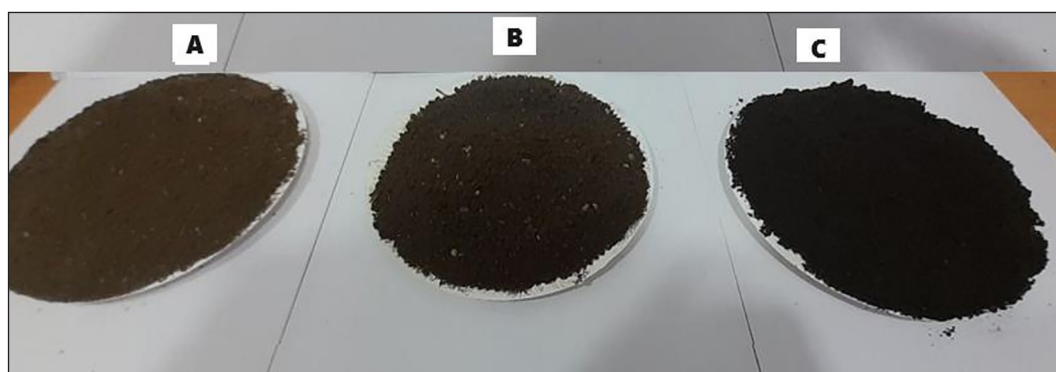


Figure 1. Vermicompost made from cattle (a), horse (b), sheep (c) manure

Table 1. Some indicators of the chemical composition of vermicompost made from cattle, horse, and sheep manure (%), ($p < 0.05$)

Chemical indicators	Cattle manure		Horse manure		Sheep manure	
Before the experiment						
General N	0.43 ± 0.2		0.58 ± 0.1		0.82 ± 0.2	
General P ₂ O	0.21 ± 0.4		0.27 ± 0.2		0.22 ± 0.4	
General K ₂ O	0.58 ± 0.8		0.62 ± 0.2		0.68 ± 0.8	
pH	7.71 ± 0.3		7.83 ± 0.4		7.88 ± 0.3	
After the experiment						
	<i>E. anderiy</i>	<i>E. fetida</i>	<i>E. anderiy</i>	<i>E. fetida</i>	<i>E. anderiy</i>	<i>E. fetida</i>
General N	2.03 ± 0.5	2.24 ± 0.3	1.99 ± 0.6	1.76 ± 0.2	2.84 ± 0.3	2.67 ± 0.5
General P ₂ O ₅	1.59 ± 0.2	1.94 ± 0.4	1.44 ± 0.2	1.66 ± 0.3	1.52 ± 0.4	1.34 ± 0.4
General K ₂ O	1.34 ± 0.2	1.53 ± 0.2	1.44 ± 0.2	1.61 ± 0.3	2.16 ± 0.2	1.57 ± 0.2
pH	7.48 ± 0.4	6.91 ± 0.1	7.41 ± 0.1	7.21 ± 0.4	7.34 ± 0.2	7.1 ± 0.2

utilized the sample exhibiting the highest NPK content, which was vermicompost derived from cattle manure. Considering the abundance of cattle manure accumulation in agricultural livestock farms compared to other organic wastes, various mixtures of vermicompost were prepared by adding different proportions of household waste such as wood shavings, paper waste, leaves and fruit and vegetable waste (Fig. 2). *Eisenia fetida*, a local earthworm species well-suited to the climatic conditions (temperature, humidity, and pH) of our region, was employed as the experimental model organism. Within the experiment, cattle manure served as a control. Upon analyzing some chemical parameters of vermicomposts derived from different substrates obtained during experiment, variations in the chemical composition of the product were observed corresponding to alterations in the composition of the initial substrate. In this experiment, the indicator closest to the most neutral medium was $\text{pH} = 7.18$ at $\text{M} + \text{S} \cdot 70/30$. The highest total nitrogen value was 2.98% in $\text{M} + \text{S} \cdot 70/30$. The highest total P_2O_5 was 2.31% at $\text{M} + \text{B} \cdot 70/30$, and the highest total K_2O was 2.56% at $\text{M} + \text{B} \cdot 80/20$ (Fig. 3).

The efficacy of vermicompost obtained from the study, characterized by its high NPK content,

on the growth of a local cucumber variety, Miracle F1, was studied. As a control, medium without vermicompost (consisting of black sand only) was used. Through this study, the impact of vermicompost in different proportions on the growth and yield of cucumber seedlings was observed. The experiments were conducted in the greenhouse facilities of the Institute of Biochemistry, Samarkand State University. Cucumber seedlings were cultivated in mediums containing 10%, 20%, 30% vermicompost concentrations (Fig 4). Notably, the mixture of vermicompost with a ratio 1:9 showed higher plant performance than the rest of the vermicompost mixtures (Fig 5). This particular vermicompost mixture stimulated seedlings growth, as evidenced by a 10.1–36.4% increase in seedling length and a 19.2–26.1% increase in root length compared to control group. In addition, the stem wet mass of these seedlings was 47.7–55.9% higher than that of the control, while the fresh root mass exhibited 38.3–43.8% increase.

The effect of vermicompost application on the yield of cucumber Miracle F₁ was investigated under controlled greenhouse conditions. Two distinct methods of vermicompost application was employed. Method I involved the incorporation of vermicompost into the soil prior to transplanting



Figure 2. Cattle manure and various household waste; (a) paper waste, (b) wood shavings, (c) leaf waste, (d) fruit vegetable waste, (e) cattle manure and various household waste 9/1; 8/2; mixtures in the ratio of 7/3) for vermicompost preparation

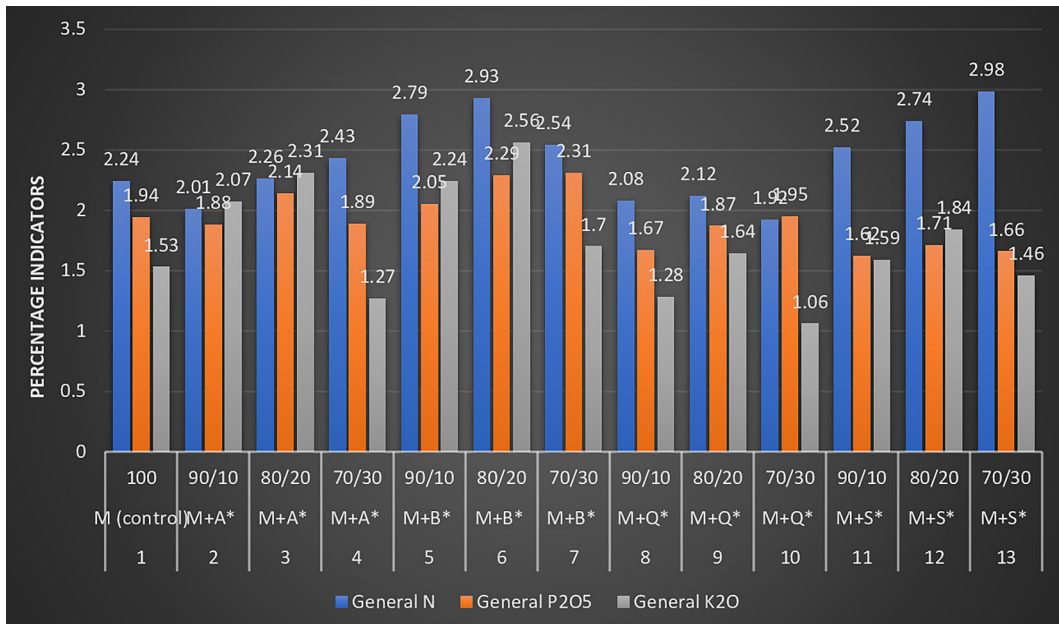


Figure 3. Some chemical parameters of vermicompost obtained from various proportions of black cattle manure and different household wastes (%)

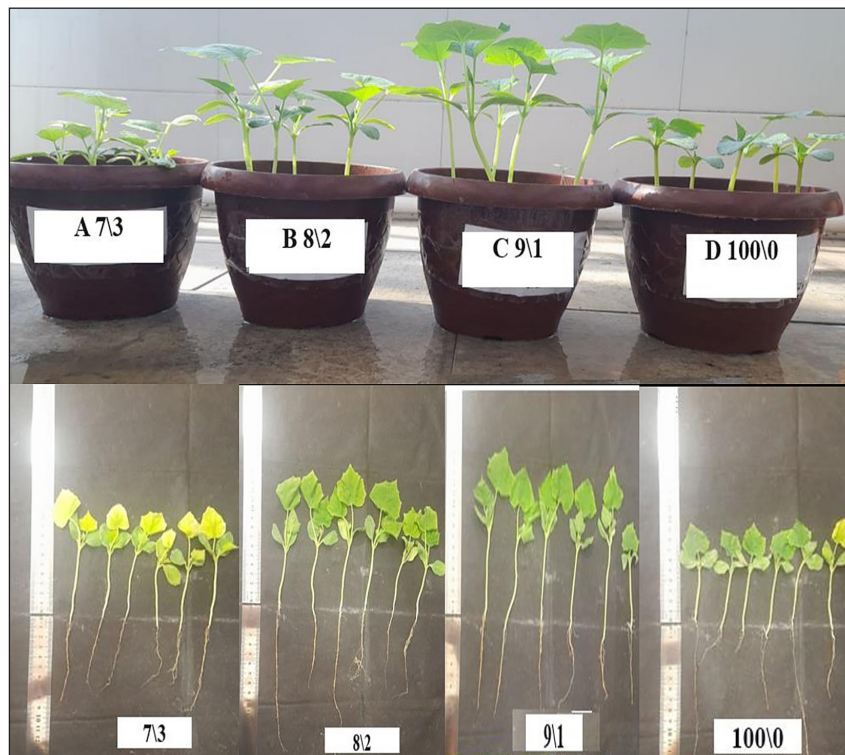


Figure 4. Cucumber seedlings grown on sand-vermicompost substrates; (a) sand + 30% vermicompost; (b) sand + 20% vermicompost; (c) sand + 10% vermicompost; (a) control – 100% sand

seedlings, while Method 2 entailed the application of vermicompost-infused water during plant irrigation. Various concentrations of vermicompost ranging from 0.5, 0.7 and 1.0 kg/m² were added to the soil, with control group receiving no

vermicompost. Among these variants, the highest yield was obtained at highest application rate of 1.0 kg/m², yielding up to 800 kg/10 m² (Table 2). In the method where vermicompost-infused water was, medium without vermicompost was used

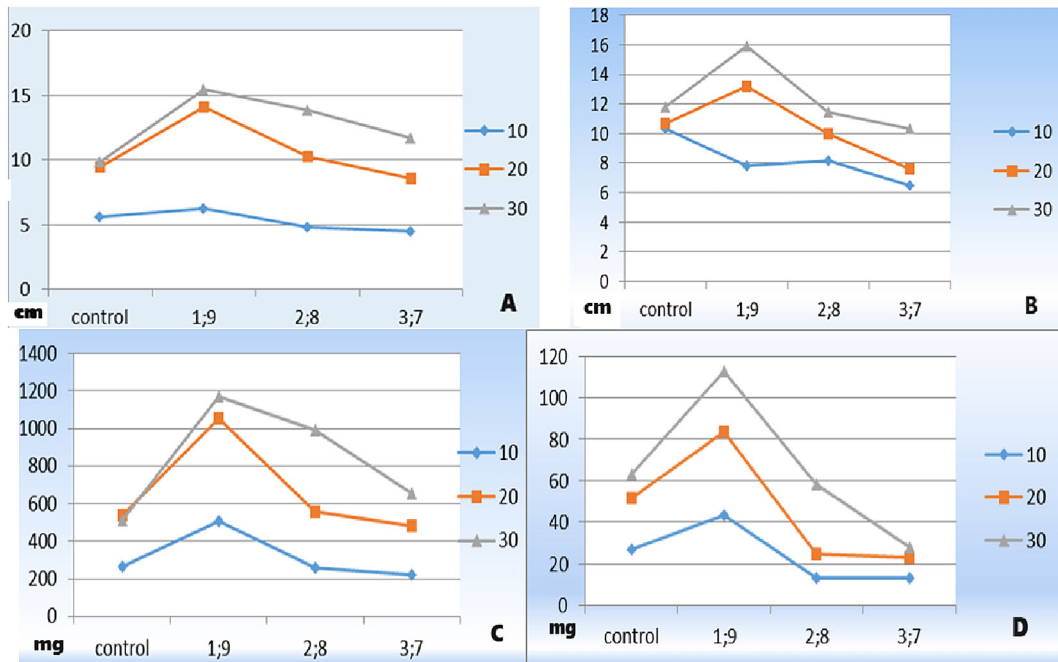


Figure 5. Changes of some biometric parameters of cucumber Miracle F₁ in various proportions of vermicompost; (a) stem length; (b) root length; (c) stem weight; (d) root weight

as a control. In the remaining options it was used at 50, 100, and 150 g/l. The highest yield was obtained at 50 gr/l 850 kg/10m² (Table 3).

In the remaining variants with higher proportions, it is possible that the vermicompost granules became more compacted in the mesh holes, thereby impeding nutrient delivery to the plants. This could have contributed to the observed lower cucumber yields.

In horticultural studies involving the application of vermicompost for vegetable production, it is established that it can be utilized either in its pure form or blended with peat as a substrate component (Kaciu et al., 2011). Numerous investigations have assessed the efficacy of incorporating vermicompost into growth media in varying proportions. According to (Atiyeh et al., 2000), vermicompost exhibits improved performance when integrated into the substrate of container environments. Further, research by Bachman and

Metzger (2008) indicates that substrates containing 10–20% vermicompost yield superior results. Conversely, several studies show that the addition of large amounts of vermicompost to the substrate, i.e. increasing the concentration of vermicompost in the substrate, resulted in slower seed germination and seedling growth (Pour et al., 2013 and Ievinsh, 2011). Our findings corroborate these earlier studies, demonstrating optimal plant performance at a 10/90 vermicompost ratio, with diminished growth observed at 20/80 and 30/70 ratios. This suggests that while vermicompost addition stimulates plant development, its effects are concentration dependent. Indeed, biologically active compounds within vermicompost contribute to robust plant growth (Arancon et al., 2004). Interestingly, (Atiyeh et al., 2004) noted reduced efficacy when vermicompost was applied to certain agricultural crops, including garlic, corn, tomatoes, and peppers. In contrast,

Table 2. The impact of applying various amounts of vermicompost to the soil on the yield of the cucumber Miracle F₁

Options	Productivity	td
Control	72.0 ± 4.14	-
0.5 kg/m ²	74.5 ± 3.81	0.44
1.0 kg/m ²	80.0 ± 3.05	1.56
1.5 kg/m ²	77.6 ± 4.04	0.96

Table 3. The impact of applying various amounts of vermicompost with water during irrigation processes on the yield of cucumber Miracle F1(kg/m²)

Options	Productivity	td
Control	72.0 ± 4.14	-
50 gr/l	85.0 ± 2.83	2.59
100 gr/l	80.4 ± 3.48	1.55
150 gr/l	80.4 ± 3.48	0.76

vermicompost application has been shown to enhance various growth parameters such as seed germination, stem height, leaf count and area, dry weight of leaves, root length, total yield, chlorophyll content, and nutritional quality of fruits and seeds. Specifically, the use of sheep manure vermicompost as a soil additive increased tomato stem growth (Joshi et al., 2015). Also, the results of studies on the stimulation of the development of agricultural crops, including cucumber, by endophytic bacteria isolated from plants (Akramov et al., 2023; Alikulov et al., 2023), our results confirm that vermicompost can stimulate plant growth like microbiological preparations. The addition of 10% vermicompost to the substrate has increased leaf area in plants such as radishes and calendula (Atiyeh et al., 2000), which is consistent with our findings that vermicompost application enhances plant height, leaf surface area, and yield. Application of vermicompost increases the dry weight of plants (Azarmi et al., 2009). The use of vermicompost also increases the dry weight of plants (Azarmi et al., 2009). In environments with vermicompost, the dry mass of cucumber leaves is greater than that grown without vermicompost (Sallaku et al., 2009; Mavura et al., 2017). Several studies have shown that the use of vermicomposts in vegetable cultivation positively affects plant growth. The use of vermicompost in substrates has increased strawberry yields (Singh et al., 2009) and overall yields in eggplants, tomatoes, and cucumbers (Papathanasiou et al., 2012). Plant growth and productivity in experiments depend on the amount of vermicompost added to the substrate (Abafita et al., 2014). The addition of 15–25% vermicompost to the substrate has increased the yield of cauliflower and tomatoes (Bhat et al., 2013). Using 40% vermicompost derived from food waste has resulted in a 45% higher yield in pepper production compared to environments without vermicompost (Edwards et al., 2004). The use of vermicompost in vegetable cultivation also affects the shelf life of vegetables (Azarmi et al., 2009). Adding a small amount of vermicompost to the environment positively affects the germination, growth, flowering, and productivity of ornamental plants (Eriksen-Hamel et al., 2007; Hameeda et al., 2007). Vermicompost has been shown to increase the length of corn stalks, leaf surface area, and plant biomass (Atiyeh et al., 2000). Plants grown in an environment with 30% vermicompost showed lower productivity, dry weight, root and stem length, and leaf

area compared to those grown in 20% vermicompost (Arancon et al., 2006). Plants grown in 10% vermicompost showed lower performance compared to those in 20% vermicompost (Arancon et al., 2006). The application of vermicompost to plant growth environments has been reported to enhance the development of tomato and cucumber plants (Weber et al., 2004). Earthworms play an important role in improving soil fertility, especially in eroded soils as the conditions there are not particularly good (Gafurova et al., 2020). The use of organic fertilizers in combination with mineral fertilizers is highly effective in improving the agrochemical properties of the soil and obtaining abundant yields from plants (Ortikov et al., 2023). The NPK content in cattle manure used in the experiment was 0.42%, 0.21%, and 0.58%, respectively, which contrasts with the NPK content in classically composted organic fertilizer after two months, which was 0.60%, 0.38%, and 0.64%. Meanwhile, the NPK content in vermicompost processed with vermiculture during the same period was significantly higher at 2.24%, 1.94%, and 1.53%. Our research indicates that the development of annelids, specifically *Eisenia fetida*, is more rapid in cattle manure than in other substrates. Although the exact reasons for these experimental findings are not fully understood, the noticeable changes in the chemical composition of the substrates used in our experiments suggest that there are optimal levels for using vermicompost as a nutritional resource.

CONCLUSIONS

As part of the biotechnological process, the cattle, horse, and sheep manure from agricultural livestock farms can be recycled using *Eisenia fetida* and *Eisenia anderii* species. Based on *Eisenia fetida*, the NPK content in substrates made from cattle manure locally increased from 0.43, 0.21, 0.58% to 2.24, 1.94, 1.53%. For substrates made from horse manure, the NPK values increased from 0.58, 0.27, 0.62% to 1.99, 1.66, 1.61%. For substrates made from sheep manure, the NPK values rose from 0.82, 0.22, 0.68% to 2.84, 1.52, 2.16%.

Vermicompost was prepared by mixing cattle manure with various ratios of household waste materials (wood shavings, paper waste, leaf litter, and fruit and vegetable scraps). The obtained vermicomposts showed the most neutral pH

level closest at a 70/30 M + S · mix, with a pH of 7.18. The highest total nitrogen level was also in a 70/30 M + S · mix, at 2.98%. The highest total phosphorus (P₂O₅) content was found in a 70/30 M + B · mix, at 2.31%, and the highest total potassium (K₂O) content was in an 80/20 M+B · mix, at 2.56%.

The effectiveness of the vermicompost, which was rated high in NPK content, was studied by observing its impact on the growth of the local cucumber variety, Miracle F₁. In this study, a sand to vermicompost ratio of 1:9 demonstrated higher performance indicators in plants compared to other vermicompost mixtures.

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