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Study of the characteristics of soil mixtures obtained by vermicomposting

Vermicomposting is a sustainable and environmentally friendly element of organic waste management. Being a biological processing method involving a complex of soil organisms, vermicomposting requires the selection of conditions for the cultivation of transformer organisms, primarily dung worms (lat. *Eisenia fetida*). The duration and quality of the formation of the final product are influenced by the physicochemical conditions of worm cultivation, the composition of the starting material, methods of its placement, etc. We studied the influence of the composition of the substrate and the conditions of cultivation of *Eisenia fetida* on the characteristics of the resulting vermicompost in conditions of laboratory experiment. The biological characteristics of soil mixtures obtained by vermicomposting were studied, taking into account the physicochemical factors (humidity, pH, temperature) of their formation. It has been shown that the composition of the mixture significantly affects the characteristics of the vermicomposting process and the biological properties of the resulting product.

Keywords: vermiculture, vermicompost, *Eisenia fetida*, biological properties, physicochemical factors.

Introduction

Most of the biowaste such as: food waste [1], manure [2-3], bird droppings [4], waste from hydrolysis production, pulp and paper mills [5], biochemical plants, oilseeds [6], meat processing plants [7] and others, can be processed into organic fertilizer or obtained feed protein using vermiculture. Research [8] has proven the nutritional value of a substrate based on cattle waste products for vermiculture, in which intensive growth of earthworms was observed. In general, it can be argued that vermicultivation makes it possible to improve the quality of the soil substrate by increasing the quantitative and qualitative composition of stable humic compounds in it, optimizing physical properties (porosity, moisture retention, etc.), the formation of beneficial microflora, etc.

Biohumus exceeds manure and composts in humus content by 4–8 times, and also has other valuable properties: moisture capacity, hydrophilicity, mechanical strength of granules, absence of weed seeds, and the presence of a large amount of beneficial microflora [9]. Various enzymes, vitamins, soil antibiotics, and plant growth and development hormones were found in vermicompost [10]. The addition of vermicompost to the soil substrate significantly reduces plant stress, accelerates seed germination, and increases resistance to diseases [11]. The application of vermicompost to agricultural crops provides an increase in yield from 20 to 46 %, and also promotes greater growth of the above-ground parts of plants, an increase in the protein content in them and a decrease in nitrate content [12].

For vermicomposting, species of earthworms are used that are adapted to a high rate of consumption of organic waste, digestion and assimilation of organic substances, resistant to a wide range of environmental factors, have short life cycles and high reproductive potential. In practice five species of worms are widely used as the basis for vermiculture — *Eisenia andrei, Eisenia fetida, Dendrobaena veneta, Perionyx* *excavatus* and *Eudrilus eugeniae*. The dung worm *Eisenia fetida* is most often used in vermicomposting because it is distributed throughout the world and is hardy in a wide range of temperatures and humidity [13].

There is information that for vermiculture of *Eisenia fetida* the optimal temperature is from +20 to +25 ºC, humidity 85 %, pH 5–9. However, physicochemical conditions of detention and the composition of the substrate affect the reproductive activity, life expectancy, viability, and population density of worms [14-15]. Low population density leads to a decrease in the rate of waste processing and a deterioration in the quality of the resulting product.

It is obvious that different types of substrates can stimulate or suppress the development of vermiculture. It has been revealed that different types of worms react differently to changes in the composition of the substrate. For example, research results [16] showed that on a nutrient substrate based on cattle manure and a mixture of municipal solid waste, the biomass of *P. sansibaricus* and *P. excavatus* increased, but the total number of *P. excavatus* cocoons in the substrate was significantly greater than in the group from *P. sansibaricus*. The article [17] shows the nutritional value of substrates based on cattle waste products with the addition of pig manure and rice straw for red worms (*Perionyx excavatus*). At the same time, the detrimental effect of a nutrient substrate based on pure pig manure was discovered, resulting in the formation of an acidic environment, leading to the death of part of the worm population [18]. When vermicultivating *Eisenia fetida* on a nutrient substrate of pig manure with a high ratio of carbon to nitrogen, the number of worms increased by a factor of 36 days compared to a substrate with a low ratio. On nutrient substrates based on raw sediment from primary settling tanks with the addition of various organic wastes (leaves, paper), the death of worms was observed. When mixed with cattle manure, vermiculture adapted to the substrate for a long time, but at the end of the study, young worms were obtained [19].

Thus, to effectively carry out the composting process, it is necessary to control the conditions for cultivating worms, primarily the composition of the nutrient substrate, as well as temperature, humidity, pH, species composition and population density of worms. This ultimately affects the biological properties of vermicompost.

The purpose of our research: to study the biological characteristics of soil mixtures of different compositions obtained by vermicomposting.

Tasks:

1. To study changes in the physicochemical parameters of substrates of various compositions during the vermicomposting process.
2. Assess the biological qualities of vermicompost of various compositions when germinating seeds of monocotyledonous and dicotyledonous plants on it.

Material and methods

The experiment was carried out in laboratory conditions. To cultivate worms and produce vermicompost, a commercial vermicomposter "WormCafe" (Tumbleweed, Australia) was used, with four trays for breeding worms.

The plant substrate for breeding worms was collected from suburban summer cottages in Karaganda and presented in 3 versions:

Substrate № 1 — dried above-ground vegetative parts (grass) of white clover (*Trifolium repens*);

Substrate № 2 — dried leaves of fruit trees — apple (*Malus domestica*) and pear (*Pyrus communis*);

Substrate № 3 — a mixture of dried white clover grass (*Trifolium repens*) and leaves of fruit trees (*Malus domestica, Pyrus communis*).

The substrate was moistened and placed over the entire surface of the tray in a layer 12–15 cm thick (Fig. 2). Each tray was divided into 3 sections, into which 10 individual worms were released.

Worms *Eisenia fetida* purchased from one of the private vermiculture farms in Karaganda were used as a biological culture.

The duration of the study was 90 days. During the entire experiment, measurements of temperature, humidity, and pH of the substrate were carried out. The growth and development of worms was monitored, the time of laying, the number of cocoons, and the number of sexually mature worms were recorded.

Soil temperature measurements were carried out with a standard thermometer. Humidity measurements were carried out using a gravimetric moisture analyzer "MB 23" (Ohaus, Japan). pH measurement using an "Itan" ion meter (Tomyanalit, Russia).

To assess the biological properties of the soil substrate, soils taken in the vicinity of the faculty were used as a comparison group. One soil sample was collected from an area with suppressed vegetation and visible signs of soil degradation. The second soil sample was collected in an area where the natural state of vegetation and soil horizons was preserved (Fig. 1).

A *B*

Figure 1. Area with suppressed (*A*) and close to natural (*B*) vegetation cover

Seeds of a monocotyledonous plant, oats (*Avena sativa*), and seeds of a dicotyledonous plant, peas (*Pisum sativum*), were used as test systems for the biological assessment of the resulting vermicompost. During the assessment, a substrate from experimental trays and control soil samples was placed in each Petri dish. Each Petri dish contains 10 oat seeds. The same manipulations were done with pea seeds.

Results and Discussion

The observation showed that favorable conditions, manifested in a relatively larger number of cocoons and individuals of sexually mature earthworms, were found in woody substrate № 2, which contained tree leaves. Average values were obtained in herbaceous substrate № 1 (Table 1). The lowest value was found in substrate № 3, which contained a mixed substrate of woody and herbaceous residues.

Table 1

Number of cocoons and mature earthworms in the vermicomposter in 3 months

Indicators	Substrate № 1	Substrate № 2	Substrate № 3
Number of cocoons, units.	15 ± 0.12	27 ± 0.19	8 ± 0.06
Number of mature worms, units	16 ± 0.15	23 ± 0.37	6 ± 0.22

During 3 months of cultivation, measurements of humidity, temperature and pH of the substrates were carried out. During the observations, it was revealed that these physicochemical indicators of different substrates differed significantly (Fig. 2).

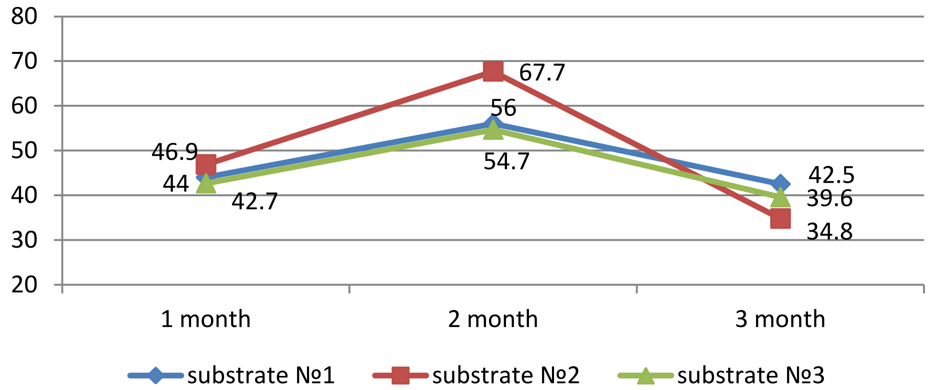
Measurements carried out in the 1st month of the experiment showed that the highest humidity of 46.9 % was in wood substrate № 2, the lowest humidity was 42.7 % in mixed substrate № 3. The temperature in all experimental substrates varied within the error of the thermometer and averaged 22 °C. It should be noted that in mixed substrate № 3 the highest temperature was recorded at the lowest humidity.

The research results for the second month of cultivation revealed a significant increase in the humidity of all three types of substrate, with a slight decrease in temperature. The humidity in wood substrate № 2 increased especially significantly.

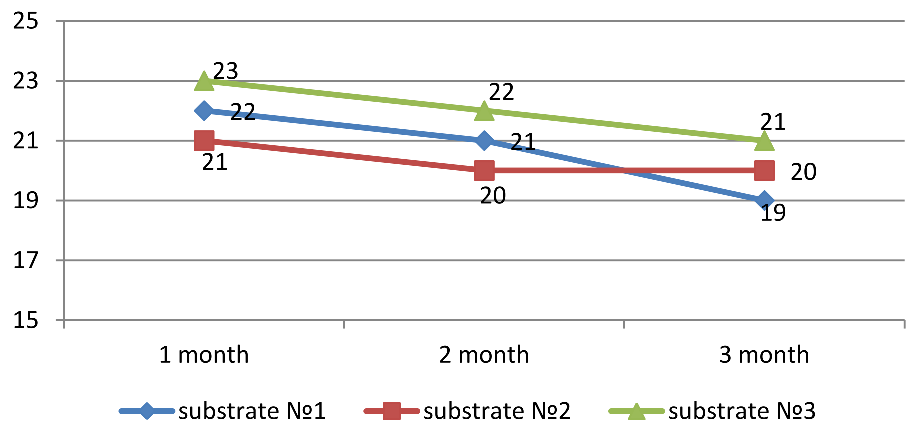
In the third month of the experiment, the humidity of all three substrate options decreased. Higher humidity was noted in grass substrate № 1, and in woody substrate № 2 the humidity reached minimum values. The temperature decreased in substrates № 1 and 3 and remained at the same values in woody substrate № 2.

Throughout the experiment, the pH in substrates № 1 and 3 was equal to 7. In the woody substrate № 2, in the first month of the experiment, the pH was also equal to 7, but in the second and third months of the experiment, the pH increased from 7 to 8.

In general, we can conclude that substrates № 1 and 3, which included herbaceous residues, had more similar indicators of humidity, temperature and pH. Wood substrate № 2 significantly differed in the dynamics of changes in humidity, temperature and pH. Particularly interesting are the sharp fluctuations in humidity and pH of wood substrate № 2 throughout the experiment. These fluctuations in physicochemical characteristics are obviously associated with a significant increase in the number of worms in the woody substrate, their activity, and, as a consequence, the degree of decomposition of plant residues, the accumulation of products of their processing by worms, which ultimately leads to changes in the temperature and pH of the substrates.



A



B

Figure 2. Dynamics of humidity indicators (*A*) and temperature (*B*) for three months

When conducting a biological assessment of substrates, observations were carried out one week and three weeks after planting pea and oat seeds. By the end of the first week after planting the seeds, a high rate of shoot formation was observed in plants planted in woody substrate significantly № 2, as well as in soil taken from an area with natural vegetation. Oats had higher growth rates compared to peas. But when grown on soil from a depressed area, the growth rates of oat shoots were lower than those of peas (Table 2).

Table 2

Length of shoots of seeds of monocotyledonous and dicotyledonous plants after a week and three weeks (in cm)

Test plant	Substrate No. 1	Substrate No. 2	Substrate No. 3	Soil from a depressed area	Soil from a natural site
1 week					
Peas	1 ±0.2	3 ±0.8	2 ±0.1	0.8 ±0.1	3 ±0.12
Oats	5 ±0.8	6.5 ±0.4	5 ±0.75	0.2 ±0.01	5 ±1.3
3 weeks					
Peas	6 ±0.6	5 ±0.3	4.5 ±0.2	8 ±0.5	7.5 ±0.3
Oats	12 ±0.5	14.5 ±0.4	23 ±0.5	13.5 ±1.25	19 ±0.4

In the third week, the growth rate of pea shoots was higher on oppressed and natural soils, i.e. the growth rate of plants on vermicompost decreased. Oat seedlings began to grow more actively on mixed substrate № 3 and soil samples from an area with natural vegetation cover (Table 2).

Conclusions

Our work assessed the influence of the substrate composition on changes in the physicochemical and biological characteristics of vermicompost during a 3-month experiment. It was revealed that, depending on the composition of the substrate, the physicochemical characteristics of the vermiculture environment change significantly. The culture of earthworms is better cultivated on a substrate composed of wood litter, which leads to sharp changes in its physicochemical properties. Different groups of indicator plants show different growth rates at different times. In the first week of development, pea shoots develop better on vermicompost obtained from leaf litter, but in the third week of the experiment, higher biological indicators comparable to fertile soil are demonstrated by pea shoots cultivated in grass-based vermicompost. Oat shoots show a low growth rate when grown on vermicompost of all types, compared to fertile soil. Relatively high biological indicators are demonstrated by oat seedlings when grown on vermicomposts obtained from leaf litter and a mixture of leaf litter and grass. Thus, the woody substrate is a good breeding ground for the earthworms *Eisenia fetida,* but it is advisable to use the vermicompost obtained from it only in the first week of plant germination. Next, it may be necessary to add soil or a substrate obtained from herbaceous residues to the substrate. Thus, further experiments are required with the selection of optimal proportions for adding vermicompost to soils of various chemical and mechanical compositions, selection of plant crops to be grown, etc.

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А.М. Айтқұлов, В.А. Наливкина, И.Н. Кружнов, А.А. Байдосова

Вермикомпостпен алынған топырақ қоспаларының сипаттамаларын зерттеу

Вермикомпосттау органикалық қалдықтарды басқарудың тұрақты және экологиялық таза элементі болып саналады. Топырақ организмдерінің кешенін қамтитын биологиялық өңдеу әдісі бола отырып, вермикомпосттау трансформаторлық организмдерді, ең алдымен тезек құртын (лат. *Eisenia fetida*) өсіру үшін культивацияны таңдауды талап етеді. Соңғы өнімнің қалыптасу ұзақтығы мен сапасына құрттарды өсірудің физикалық-химиялық жағдайлары, бастапқы шикізаттың құрамы, оны төсеу әдістері және т.б. әсер етеді. Зертханалық тәжірибеде *Eisenia fetida* тезек құртының субстрат құрамы мен культивациялау жағдайларынан алынған вермикомпосттың сипаттамаларына әсері зерттелген. Вермикомпосттау әдісімен алынған топырақ қоспаларының биологиялық сипаттамалары олардың түзілуінің физика-химиялық факторларын (ылғалдылық, pH, температура) ескере отырып зерделенген. Қоспаның құрамы вермикомпосттау процесінің ерекшеліктеріне және алынған өнімнің биологиялық қасиеттеріне айтарлықтай әсер ететіні көрсетілген.

Кілт сөздер: вермиөсіру, вермикомпост, *Eisenia fetida,* биологиялық қасиеттері, физика-химиялық факторлар.

А.М. Айткулов, В.А. Наливкина, И.Н. Кружнов, А.А. Байдосова

Изучение характеристик почвенных смесей, полученных методом вермикомпостирования

Вермикомпостирование — устойчивый и экологически безопасный элемент управления органическими отходами. Являясь биологическим методом переработки с участием комлекса почвенных организмов, вермикомпостирование требует подбора условий культивирования организмов-трансформаторов, прежде всего, навозного червя (лат. *Eisenia fetida*). На длительность и качество формирования конечного продукта влияют физико-химические условия культивации червей, состав исходного сырья, способы его укладки и др. Нами в условиях лабораторного эксперимента было проведено изучение влияния состава субстрата и условий культивации навозного червя *Eisenia fetida* на характеристики получаемого вермикомпоста. Изучены биологические характеристики почвенных смесей, полученных методом вермикомпостирования, с учетом физико-химических факторов (влажности, pH, температуры) их формирования. Показано, что состав смеси значительно влияет на особенности протекания процесса вермикомпостирования и биологические свойства полученного продукта.

Ключевые слова: вермикультура, вермикомпост, *Eisenia fetida,* биологические свойства, физико-химические факторы.

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