Efficiency of vermicompost in a microplot field experiment

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Abstract. The paper studies the properties of vermicompost (biohumus) obtained by processing food waste with the Californian worm Eisenia andrei Bouche. Vermicomposting allows transforming human waste into a highly effective fertilizer. It is shown to be enriched with organic carbon, humic acids, nitrogen, and phosphorus. In order to determine the effectiveness of the fertilizer, a microplot field experiment was conducted with a test crop of arugula of the Poker variety, including a control (agro-gray soil) and a variant with vermicompost at a dose of 500 g / m^2. The results of the experiment indicate a higher (by 1.5-2 times) seed germination energy, growth rate and development of the crop against the background of the use of vermicompost, which is expressed in the dynamics of biometric parameters (the width and length of leaf blades are 44-49% higher, the height of plants is 38% higher, compared to the control). The productivity of the test culture exceeded the control indicators by 80%. The value of the studied vermicompost determines the need to develop vermicomposting based on food waste, as one of the most promising areas in the field of solving problems of increasing soil fertility and recycling organic waste.

1 Introduction

Currently, one of the problems of a planetary scale is the disposal of human waste, including food waste. Vermitechnologies help to cope with this task with minimal economic costs, allowing the disposal of organic matter and converting it into vermicompost (or, as they often say, biohumus), which significantly increases the yield of crops. Fertilizers obtained by processing any organic substrates with earthworms contribute to the development of sustainable agriculture and the restoration of the fertility of agricultural soils.

In most cases, vermicomposts are produced on the basis of processing pig, horse, cattle manure, poultry droppings, organic waste from industry (woodworking, pulp and paper, etc.). The properties of these fertilizers and their effectiveness in growing certain crops have been studied quite well. Food waste is extremely rarely used to create biohumus, and there is practically no data on its properties and effect on plant yields.

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2 Materials and methods

The aim of this work is to study the properties of vermicompost obtained by processing food waste and to identify its effectiveness in a field microplot experiment.

The objects of the study were vermicompost and arugula of the Poker variety. Vermicomposting was carried out for 8 months using the "home container" technology in laboratory conditions. Shredded food waste of plant origin (banana, carrot, beet peel, fruit, squash, pumpkin remains, as well as tea and coffee) were processed by the red Californian worm Eisenia andrei Bouche in 5 containers, where the temperature was maintained at 20-22°C, humidity at 80-90%, aerobic conditions were observed (the substrate was regularly loosened to saturate it with oxygen).

Research methods. The properties of vermicompost and agro-soil, on which the field microplot experiment was conducted, as well as their qualitative composition of humus were determined using generally accepted methods and techniques in soil science [1-2].

To determine the effectiveness of vermicompost, a dose of 500 g/m^2 (based on 5 t/ha) was selected; higher doses could cause alkalization of the soil and have an inhibitory effect on plant development, which is confirmed by published data [3-4].

The microplots were 0.25 m2 in size, the experiment was repeated three times, the fertilizer was evenly incorporated into the upper 10 cm soil layer. The Poker variety of arugula, which is characterized by rapid growth and development, was used as a test crop. The seeds of the crop were sown in each plot in equal weight - 0.25 g. The scheme of the experiment, which was carried out for 20 days, is as follows:

- Control (agro-soil) - agro-gray (name given according to [5]) / Greyzemic Phaeozem (Aric) (in accordance with [6]).
- Agro-soil with vermicompost at a dose of 500 g / m^2.

Throughout the experiment, biometric observations were carried out, at the end of the experiment, the productivity of the green mass of the test crop was assessed.

3 Results

To obtain vermicompost, 150 mother cultures of Eisenia andrei Bouche worms were weighed in 30-piece batches and placed in five containers (1.75 l each) with soil (200 g each) taken from the arable horizon of agro-gray soil. The first two months were adaptation months, during which the number and weight of worms could both increase and decrease. After adaptation, the worms rapidly reproduce and grow. After four months of the experiment, when their number (7-10 times) and weight (4-5 times) increased, the worms were moved to larger containers (6 liters each), since a large accumulation of individuals causes their suppression, cessation of reproduction, and the spread of diseases [7-8]. By the end of vermicomposting, the number of worms had increased 15-16 times, and their weight had exceeded the initial weight by 10-15 times. During the last 3 weeks, feeding of the worms was stopped, during which time they passed the entire substrate through their digestive organs once again, which improved the quality of the fertilizer. After removing the vermicompost from the containers, it was dried and passed through a sieve with a diameter of 3 mm to give it a "soil-like" appearance and ease of use.

Chemical analysis of the biofertilizer showed a high content of organic carbon (23%, in terms of humus 46%), nitrogen (total 2.13%, mobile 345 mg/100 g) and phosphorus (total 0.9%, mobile 500 mg/100 g) (Table 1). The sum of absorbed cations Ca^{2+} and Mg^{2+} was 34 mmol(+)/100 g of soil, the reaction of the environment is strongly alkaline (pHwater 9.18). Vermicompost is characterized by a high proportion of humic acids (34% of the total carbon), twice the proportion of fulvic acids (humus type: humate).

Table 1. Properties of vermicompost.

Parameter	Value
Organic carbon	23%
Gross nitrogen Mobile nitrogen	2.13% 345 mg/100 g
Gross phosphorus Mobile phosphorus	0.90% 500 mg/100 g
Sum of absorbed cations Ca(++) and Mg(++)	34 mmol(+)/100 g
pHwater	9.18
Fulvic acids (FA)	15%
Humic acids (HA)	33%
HA:FA	2

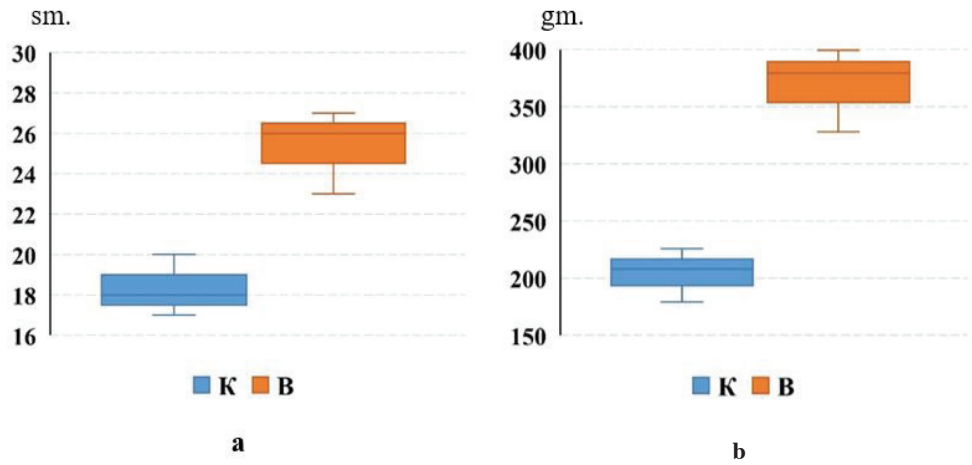
The properties of the arable horizon of the agro-soil on which the experiment was conducted are as follows: medium loamy granulometric composition, high content of absorbed cations (in total 40 mmol(+)/100 g of soil), pHwater 6.54, humus content 5.53%, total nitrogen 0.25%, phosphorus 0.28% (Table 2). The humus type is defined as fulvate-humate [9].

Table 2. Properties of agricultural soil.

Parameter	Value
Organic carbon	3.2%
Gross nitrogen	0.25%
Gross phosphorus	0.28%
Sum of absorbed cations Ca(++) and Mg(++)	40 mmol(+)/100 g
pHwater	6.54
Granulometric composition	medium loam
Fulvic acids (FA)	23.4%
Humic acids (HA)	26.0%
HA:FA	1

The results of the experiment showed that vermicompost obtained from food waste stimulates seed germination. Despite the simultaneous emergence of shoots in the control plots and against the background of biofertilizer (on the 2nd day after sowing), the number of shoots in the latter was 1.5-2 times greater. The development of plants in the variant with vermicompost also outpaced that in the control. Thus, the first true leaves of arugula against the background of fertilizer appeared a day earlier. Biometric observations revealed the growth-stimulating effect of vermicompost: the average rate of plant height increase in the period from the 11th to the 15th day after the start of the experiment was 1.4 cm/day in the plots with fertilizer, which is 2 times higher than in the control plots (0.75 cm/day). The parameters of the arugula leaf blades against the background of biofertilizer were also larger in size compared to the control plants: the length was on average 11.8 cm, the width was 5.2 cm, while in the control it was 7.9 cm and 3.6 cm, respectively.

On the 20th day of the experiment, the following parameters of the test crop were determined: the maximum height of plants from each plot (Figure 1a), the mass of their above-ground part, as well as the total green biomass in each experimental plot (Figure 1b).



K – control (agro-soil), B – agro-soil + vermicompost

Fig. 1. Average maximum plant height at the end of the experiment (a) and average total aboveground biomass of the test crop (b) under microplot experiment conditions. *Source:* Compiled by the authors.

The results showed the following:

- The maximum height of plants against the background of vermicompost is higher, compared to the control, by an average of 7 cm (by 38%) (Figure 2 a, b).
- The mass of 5 plants in the variant with fertilizer is higher by 10.4 grams (more than 2 times, compared to the control).
- The total above-ground biomass of arugula in the variant with vermicompost exceeds that in the control by 1.8 times (the increase was 80%).

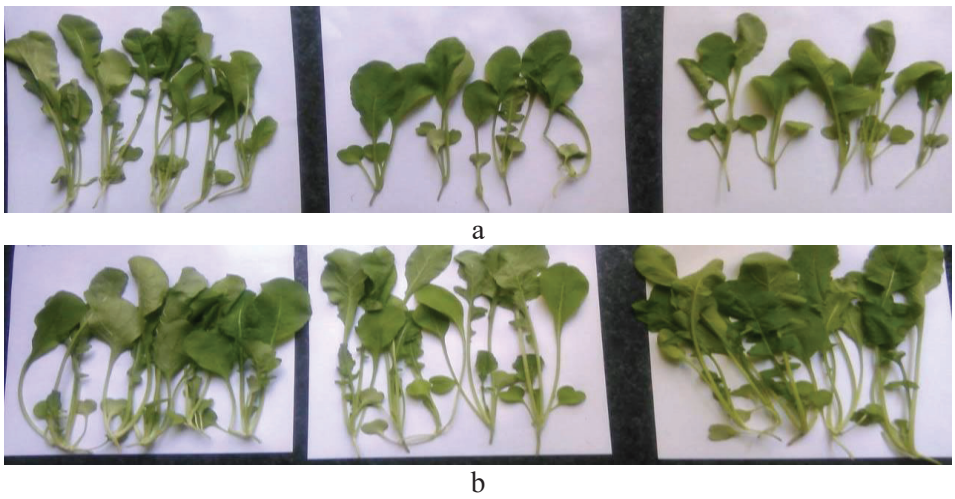


Fig. 2. Processing of experimental results. (a) control (agro-soil), three replicates; (b) control + vermicompost, three replicates.

In general, the plants in the plots with vermicompost were more developed, had 4-5 true leaves, while in the control - 2-3, singly - 4.

No special study of the change in soil properties under the influence of the added vermicompost was carried out within the framework of this study, however, it was noted

that the soil in the plots with biofertilizer was more structured and retained moisture significantly better than the soil in the control.

4 Discussion

Vermicomposts have a complex effect on soil and plants, which is due, first of all, to the enrichment of this organic fertilizer with humic substances, which play a key role in creating favorable conditions for the growth and development of crops, namely the chemical, physicochemical and physical properties of the soil, increasing their biological (including enzymatic) activity, which is discussed in many scientific publications [9-11]. The role of humic acids is especially important in increasing plant productivity, which is explained by such mechanisms of their influence on living organisms as the activation of protein synthesis in cells [12], the effect on the rate of electron-donor-acceptor reactions, interaction with cell membranes and the effect on biochemical processes [13], the penetration of humic acids into cells and interaction with intracellular components [14-15]. The latter mechanism is explained from the position of the "nuclear theory" of the structure of humic acids with different accessibility of aromatic, aliphatic structures and peripheral parts of humic and fulvic acid molecules for microorganisms, as well as from the position of the "supramolecular theory", according to which humic acids are a set of molecules with a relatively small molecular weight, combined into a kind of micellar-like structure [10].

Thus, the presence in vermicomposts, along with plant nutrition elements, of a large amount of humic substances and the dominance of humic acids in their composition determines the high value of these fertilizers, which determines the need to develop vermicomposting based on food waste, as one of the most promising, low-cost areas in the field of solving problems of increasing soil fertility and recycling organic waste from human life.

5 Conclusion

Vermicompost obtained from the activity of the Californian worm Eisenia andrei Bouche on food waste is characterized by valuable qualities: high content of gross and mobile forms of nitrogen and phosphorus, humic substances and humic acids, including.

The significant alkalinity of the fertilizer requires careful selection of the dose of its application, especially in neutral soils, but can serve as a means of reducing the acidity of soils such as podzolic, sod-podzolic, gray forest, actively used in our country as arable land.

The vermicompost used in the microplot field experiment, which is a source of nutrition, a stimulator of plant growth, biological (including enzymatic) activity of soils, a regulator of the food regime, chemical, physicochemical, physical and water-physical properties of the soil, showed high efficiency and ensured an 80% increase in the productivity of the test crop of arugula of the Poker variety.

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