Evaluation of *Hermetia illucens* fly maggots zoocompost influence on some agrophysical parameters of soil

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**Abstract.** Nowadays the application of intensive agriculture methods, based on using mineral fertilizers, plant-protecting agents, cultivating operations, has resulted in soil cover degradation. The usage of organic fertilizers can improve the structure and agrochemical characteristics of soil. As organic fertilizers the composts of various compositions are used, including those based on poultry-farming and stock-raising enterprises' waste with the use of other components – peat, sapropel, wood processing waste and food production waste. The application of composts represented with vermicululture products is also known – the organic matter vermicomposting products, or those formed at rearing insects, for example, *Hermetia illucens* fly. As a result of organic waste bioconversion by feeding it to *Hermetia illucens* fly maggots a zoocompost is formed, which is a mix of maggots' excrements and undigested waste residues. In this work we researched the influence of zoocompost, formed at rearing maggots of a fly of the dipteran order – *Hermetia illucens*, – its amount, conditions and methods of its application on physical characteristics of soil fertility – granulometric texture and moisture deposit at the end of growing season. The evaluation was performed by results of a micro-plot field experiment on a specially allotted plot. The research findings have demonstrated that zoocompost in its nutrient elements content corresponds to organic fertilizers, and by its physical parameters it can be used as soil loosener. The application of zoocompost to soil samples in amount of 5 t/ha increases the moisture deposit by 28.4% and improves the structural state of soil to the «good» grade in comparison with the control plot.

1. Introduction

Fertility is the main specific attribute of soil, which distinguishes it from the native rock. The concepts of «soil» and «fertility» are inseparable. Fertility is formed as a result of long development of natural soil-building process. In the contemporary view fertility is the ability of soil to satisfy the needs of plants for nutrient elements and water, provide their root systems with enough air and warmth, as well as with favorable physical-chemical environment for the normal growth and development [1].

Intensive agriculture methods, based on the extensive use of mineral fertilizers, plant-protecting agents, intensive tillage, have resulted in soil cover degradation. The increase of agricultural production efficiency should be achieved by means of soil self-regeneration mechanism on the basis of organic matter recovery and usage. So, a focus should be put not so much on intensification of
applying fertilizers and pesticides, but on intensifying the processes of accumulation and transformation of energy in the form of organic matter in the soil [2].

All the factors and parameters of soil fertility are divided into agrophysical, biological and agrochemical. The granulometric texture is among the main agrophysical factors, which determines the crop-producing ability of soils, as the physical properties of soil – its water, air, thermal and nutrient regime – depend on it [3,4].

The structuredness of soil provides the simultaneous existence of aerobic microzones in it, the ratio of which varies depending on textural aggregates’ size and porosity. This can accelerate or inhibit the processes of nutrient elements intake by microorganisms.

The fertility of soil is a property, which is able to self-regenerate both in natural conditions, and in conditions of agricultural exploitation. Providing the self-regeneration of soil fertility is the crucial task of sustainable soil use in conditions of intensive agriculture [5].

The Belgorod region is rightfully considered one of the leading agrarian territories of the Russian Federation, with the rapidly developing agriculture and stock raising. Possessing 1.1% share of ploughland, the Belgorod region produces over 4% of the national gross agricultural product. It should be mentioned that the problem of preserving and increasing soils fertility, their protection, ecology and sustainable use are considered top priority [1].

At the same time, many crop-growing regions of the country are located in risk farming areas not only by climatic conditions, but also by soil parameters, so for the successful crop farming they require constant application of various fertilizers. All types of fertilizers are classified into 3 large groups – mineral, organic and organo-mineral. But not all fertilizers are equally good.

Mineral fertilizers are a source of only three nutrient elements for soil – nitrogen, phosphorus and potassium. Application of mineral fertilizers is one of the main methods of intensive agriculture. Their usage provides a sharp rise of crop yield of any crops both from the developed lands, and from barren and meager soils. But the intensive application of acid-forming mineral fertilizers intensifies the processes of ameliorants leaching and mineralization of organic matter in soil, which affects humus content and alters acid-alkaline balance – resulting in acidification and salinization of soils.

In recent 30-40 years the humus content in top soil layer has reduced from 10 % to 5 %. In total, over 10 mln tons of humus has been lost. All these factors taken together deteriorate the general physical properties of soil – the structure is altered, the air-holding capacity and moisture permeability are reduced, the mechanical composition changes as well.

Mineral fertilizers are first of all means of chemical activation of crops, so they considerably affect the soil’s microbial flora and, as a result, reduce the intensity of biological processes in it, which results in agrochemical properties degradation. Only in the Belgorod region there are nowadays over 400 thousands hectares of such soils. Besides, in recent 20–30 years, as a result of prevailing chemical methods of plant protection, the phytosanitary state of agricultural lands has also changed.

So, the mineral fertilizers can be conventionally classified as the most «useless» or even «harmful» fertilizers.

In discussions concerning the ecological assessment of various agriculture systems, which have been going on in recent years, special attention is paid to alternative or biological farming methods. These methods are based on using organic fertilizers with almost complete abandoning of mineral ones. With this, the main thing is not only increasing the crop yield and soil fertility, but obtaining the biologically complete and safe products with the simultaneous prevention of environmental pollution with agrochemicals.

The application of organic fertilizers returns not only three nutrient elements to the soil, as in case of mineral fertilizers, but much more – up to sixty. Besides, they are characterized with prolonged action and improve soil structure. The applied organic fertilizers directly influence the organic matter balance in soil, partially passing into the form of humic compounds as a result of organic fertilizers’ carbon humification. Besides, the application of organic fertilizers allows getting biologically complete and safe products with the simultaneous environment protection from agrochemical pollution.
As organic fertilizers the poultry-farming and stock-raising enterprises’ waste can be used, after performing long composting processes in storage pits or by biofermentation in bioreactors [6,7]. The high temperature of microbiological process at composting allows obtaining an environmentally safe fertilizer, which has no pathogenic flora, worm eggs, enteric pathogenic protozoa cysts, weed seeds or offensive odors. In this situation special attention is paid to using composts, obtained on the basis of stock-raising and poultry-farming organic waste (cattle and poultry manure) and other organic components – peat, sapropel, wood processing and food production waste [8].

The application of composts as organic fertilizers is also known – the products of organic matter vermicomposting [9], and composts, formed at rearing insects’ maggots, for example, of synanthropic flies or black soldier fly Hermetia illucens [10-14].

Thus, the peculiarity of rearing maggots of the dipteran insect Hermetia illucens is the opportunity of recycling any organic matter, including agricultural and farming industry organic waste, food-processing industry and other industries waste, such as food waste from restaurants, fast-food joints and grocery stores, household waste and sludge from urban sewage treatment plants [10-12, 14]. Bioconversion of waste by feeding it to Hermetia illucens maggots allows simultaneously solving a number of problems, such as:

- waste disposal,
- obtaining new high-value products – protein feed, lipids, chitin and biologically active substances,
- formation of zoocompost, which is a mix of maggots’ excrements and undigested waste residues.

The purpose of this work was studying the influence of local starter application of zoocompost, formed at rearing Hermetia illucens fly maggots, on certain physical parameters of soils fertility.

2. Materials and methods

The object of research is zoocompost, formed at rearing maggots of a fly of the dipteran order – black soldier fly (Hermetia illucens), which is considered as soil fertility improver.

The zoocompost under study, of Hermetia illucens maggots, is a loose low-caking fine-grained brown mass with faint ammonia smell and average density 430 kg/m³. Its granulometric texture is predetermined by the prevailing 1-3 mm particle-size content over 80%. The general view of zoocompost is presented in Figure 1.

![Figure 1. The general view of zoocompost, formed at rearing Hermetia illucens fly maggots.](image)

The influence of zoocompost amount, and the conditions and methods of its application on some physical parameters of soil fertility was evaluated by results of a micro-plot field experiment, carried out on a specially allotted plot. The location of experimental plot is Belgorod region, Belgorod district, Erik village, Russia. The soil is typical low-humic medium chernozem. Zoocompost of Hermetia illucens fly maggots was added to the soil in amount from 1 to 5 t/ha in spring, evenly distributed on the surface of the plot, and buried 10-15 cm deep with the floating-blade hand cultivator KP1.

3. Results and discussions

At the first stage of research the chemical composition of Hermetia illucens fly maggots’ zoocompost and the content of some biogenic elements was determined. The experimental research data are presented in Table 1.
Table 1. Content of some biogenic components.

| Component          | NO₃⁻, mg/kg | NO₂⁻, mg/kg | NH₄⁺, mg/kg | N(total), mg/kg | C(org), % | Humus, % | P₂O₅, mg/100g | K₂O, mg/100g | Moisture, W, % | pH_H₂O | pH_KCl |
|--------------------|-------------|-------------|-------------|----------------|-------|-------|--------------|-------------|-------------|-------|-------|
|         | 656.2 ±28.06 | 2.66 ±0.20 | 8178.7 ±1795.4 | 6871.15 ±1473.9 | 17.20 ±0.27 | 29.65 ±0.27 | 220.33 ±28.0 | 907.00 ±25.00 | 29.65 ±0.27 | 220.33 ±28.00 | 51.00 ±0.63 | 8.02 ±0.06 |

The data of Table 1 demonstrate that the content of nutrient elements, necessary for growth and development of agricultural crops, meets the requirements of GOST 33830-2016 “Organic fertilizers on basis of waste of stock-raising. Specifications”. This allows using zoocompost as an organic fertilizer. And such physical characteristics as fine fraction and low average density allow its application as soil loosener. So, zoocompost, added to a soil layer, can perform two roles at once – of an organic fertilizer and soil loosener.

After applying zoocompost in the experimental plot such parameters of soil physical properties as granulometric texture and moisture deposit at the end of growing season were assessed. The assessment of parameters was performed in 5 months after adding zoocompost to the soil. The research findings are presented in Table 2-3.

Table 2. Moisture deposit in the experimental plot lots.

| Parameter                  | Applied zoocompost quantity, t/ha |
|----------------------------|----------------------------------|
| Moisture deposit, m³/ha    | 1 | 2 | 3 | 4 | 5 | 0, control |
| Deviation from the control, % | +13.5 | +13.2 | +14.3 | +25.4 | +28.4 | - |

Table 3. Fraction composition of soil samples (dry screening), wt. %.

| Aggregates size, mm | Applied zoocompost quantity, t/ha |
|---------------------|----------------------------------|
|                     | 1 | 2 | 3 | 4 | 5 | 0, control |
| over 10             | 58.76 | 53.58 | 46.09 | 38.14 | 37.12 | 69.03 |
| 10-7                | 4.68 | 5.27 | 5.91 | 5.62 | 7.08 | 3.90 |
| 7-5                 | 4.25 | 3.62 | 5.21 | 5.00 | 5.27 | 2.77 |
| 5-3                 | 5.96 | 5.11 | 6.31 | 7.47 | 13.34 | 4.16 |
| 3-2                 | 5.96 | 5.68 | 4.70 | 4.12 | 6.53 | 2.51 |
| 2-1                 | 6.24 | 6.18 | 14.32 | 11.08 | 21.41 | 5.72 |
| 1-0.5               | 6.03 | 7.83 | 6.61 | 15.31 | 4.28 | 6.59 |
| 0.5-0.25            | 3.76 | 5.44 | 4.84 | 7.89 | 2.19 | 3.55 |
| below 0.25          | 4.32 | 7.25 | 6.31 | 4.17 | 2.74 | 1.73 |

From Table 2 we can see that applying zoocompost in amount from 1 to 5 t/ha increases the moisture deposit in soil samples from 127.8 m³/ha in the control to 145.1 and 164.1 m³/ha, respectively. So, the maximum amount of the added zoocompost – 5 t/ha – provides also the highest increase of moisture deposit – by 28.4 % in comparison with the control plot.

It should be pointed out that increase of the applied zoocompost amount has also positive effect on the fraction composition of soil samples. The structural state of soil from the «unsatisfactory» characteristic (in the control sample) at the increased amount of the applied zoocompost (4 and 5 t/ha) is improved to the «satisfactory» and «good» grades, respectively (Table 3-4).

Table 4. Parameters of soil samples’ structural state according to S.I. Dolgov’s grading scale.

| Parameter                          | Applied zoocompost quantity, t/ha |
|------------------------------------|----------------------------------|
| Content of aggregates of fraction 0.25 - 10 mm, wt.% | 1 | 2 | 3 | 4 | 5 | 0, control |
| unsatisfactory                     | 36.92 | 39.17 | 47.60 | 57.69 | 60.14 | 29.24 |

Characteristics of soil structural state

unsatisfactory | satisfactory | satisfactory | good | unsatisfactory
4. Summary
Having analyzed the obtained research findings we can make the following conclusions:
- in biogenic components’ content the Hermetia illucens fly maggots zoocompost meets the requirements of GOST 33830-2016 “Organic fertilizers on basis of waste of stock-raising. Specifications”;
- adding zoocompost to soil samples provides the increase of moisture deposit from 127.8 m³/ha in the control sample to 164.1 m³/ha at the maximum amount of zoocompost (5 t/ha);
- increasing the amount of the applied zoocompost has positive effect on the fraction composition of soil samples. The structural and physical state of soil is improved from the «unsatisfactory» characteristic in the control sample to «satisfactory» and «good» grades at adding zoocompost in amount 4 and 5 t/ha, respectively.

5. References
[1] Solovichenko V D, Navolneva E V, Stupakov A G and Kulikova M A 2015 Soil fertility recovery is the basis of increasing the agricultural crops’cropping capacity Agro-ecological issues of soil science and arable farming: Collected papers of research and practice conf. (Kursk: Kursk department of IPO «Society of soil science named after V.V. Dokuchaev») 190–4
[2] Sabitov M M, Karpovich K I and Kuzina E V 2012 Soil cultivation as an available and efficient agrotechnological method of conservation and restoration of soils fertility Agrarian world of the Volga region 2 14–18
[3] Deinega D O, Kesan A G, Golushko K M, Limansky M A and Teplenko D A 2019 Characteristics of soils types: increasing soils fertility Ecology of river landscapes: Collected papers by the materials of the III Int. Sc. Ecological Conf. 132-4
[4] Aytemirov A A, Babayev T T, Khalilov M B and Omarov F B 2019 Physical state of soil as an important factor of soil fertility recovery Issues of AIC region development 2 (38) 15-21
[5] Chebykina E V 2020 The influence of tilling, fertilizing and crop-protecting systems on biological indices of sod-podzolic gleyic soils’ fertility Bulletin of Upper Volga AIC 2 (50) 9-14
[6] Neverova O V, Zueva G V and Sarakulov T V 2014 The ecosystem-based approach to poultry manure recycling Ural Agrarian Bulletin 126 (8) 38-41
[7] Antonova O I, Komyakova Ye M and Kalpokas V V 2019 The action of organo-mineral fertilizers from manure on the yield and grain quality of winter and spring wheat, soil nutrient content and soil biogenesity Bulletin of Altai State Agrarian University 9 (179) 5-11
[8] Kovalev N G, Rabinovich G Yu, Pozdnjakov A I and Baranovsky I N 2013 The actual and advertised value of biocomposts from various manufacturers (pursuant to the published materials) Bulletin of Russian Academy of Agricultural Sciences 3 28-31
[9] Sychev V G, Merzlaya G E, Petrova G V, Filippova A V, Popov V I and Mischenko V N 2007 Ecological and agrochemical properties and efficiency of vermicomposts and biocomposts (Moscow: VNIIA) p 276
[10] Pendyurin E A, Rybina S Yu and Smolenskaya L M 2020 The usage of black soldier fly zoocompost as an organic fertilizer Agricultural science 7-8 106-10
[11] Alvarez L 2012 The Role of Black Soldier Fly, Hermetia illucens (L.) (Diptera: Stratiomyidae) in Sustainable Waste Management in Northern Climates Electronic Theses and Dissertations p 402
[12] Sheppard D C, Tomberlin J K, Joyce J A, Kiser B C and Sumner S M 2002 Rearing methods for the black soldier fly (Diptera: Stratiomyidae) in a colony Journal of Medical Entomology 39(4) 695–8
[13] Bastrakov A I, Zagarinsky A A, Kozlova A A and Ushakova N A 2014 High-efficient bioconversion of organic substrates with black soldier fly (Hermetia illucens) maggots Biotechnology and life quality: Int. research and practice Conf. (Moscow, March 18–20,
[14] Ushakova N A, Bastrakov A I, Karagodin V P and Pavlov D S 2018 Peculiarities of organic waste bioconversion with maggots of black soldier fly Hermetia illucens (Diptera: Stratiomyidae, Linnaeus, 1758) Achievements of modern biology 138 (2) 172-182

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