Comparative analysis of organic fertilizers of different origins

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Abstract. Reproduction of soil fertility under conditions of intensive land use is associated with the use of ameliorants. The decrease in livestock and the resulting deficit of manure as a traditional organic fertilizer have set the task of obtaining fertilizers based on the processing of organic waste. Therefore, an important scientific task is to assess their chemical composition and the effectiveness of their impact on crops. In a model experiment with biohumus "AgroVerm", a fertilizer obtained by fermentation of organic residues, and the effluent "Samorod", the effect of the chemical composition of fertilizers on the vital, morphometric and biochemical parameters of Tríticum aestivum L. was assessed. The results of the study of the chemical composition of humic fertilizers showed their similar mineral composition with a predominance of K, Si, Cl, Cu and Ca. The proportion of free humic acids in the biohumus and bioorganic fertilizer exceeded the same indicator in the effluent by 4 and 3 times, respectively. The analysis of IR spectra of organic fertilizers indicates a significant diversity of functional groups in the vermicompost sample and bioorganic fertilizer. At the same time, the maximum values of germination were noted for the variant of application of the preparation "AgroVerm", and morphometric indicators for bioorganic fertilizer and the preparation "Samorod". The highest values of tolerance indices were observed in the variant of using the preparation "Samorod". Determination of the pigment content showed that all organic fertilizers increased the content of carotenoids, chlorophyll a and b. The results of the study indicate that these fertilizers have practical significance and can be recommended for use in industrial crop production.

1 Introduction

One of the most pressing problems in agriculture is maintaining soil fertility by restoring its agronomic properties.

The current level of soil productivity is determined by a set of factors, including crop rotation structure, soil cultivation, use of fertilizers and plant protection products [1].

Humus is the most important component of the soil, its main properties and even taxonomic affiliation depend on it [2]. In natural biocenoses, humus dynamics are stable and are determined by external factors, which include water, salt and temperature

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conditions. The use of mineral-based fertilizers also leaves its mark on the humus state of arable land. In this case, the biomass of agricultural crops increases, but at the same time, the activity of soil microbiota increases [3-4].

Increased activity of soil microflora leads to the fact that cellulose-decomposing fungi and bacteria very quickly subject plant residues in the soil to the mineralization process and the process of humus destruction begins [5]. Organic matter formed during photosynthesis in biocenoses eventually enters the soil and is processed by soil microorganisms [6].

One of the areas of intensification of crop production and increasing the productivity of cultivated lands based on environmental principles is the use of various organic fertilizers in growing crops. Humic preparations contain a high concentration of organic and mineral substances, hormone-like components and biologically active compounds that actively participate in the formation of the crop. Humic fertilizers contain these components and are not toxic, do not accumulate in the natural environment and support the existence of soil flora and fauna, contribute to the formation of a water-resistant soil structure, and contribute to the accelerated detoxification of pesticides [7].

For a long time, livestock and poultry waste were the main types of organic fertilizers. It has been noted that fresh manure and chicken droppings, as well as plant residues, are a source of phytopathogenic microorganisms, helminths, nematodes, antibiotics, heavy metals, insect larvae and weed seeds. The continued accumulation of agro-industrial waste will become a serious environmental problem in 20-30 years [8]. Currently, there are many ways to process organic livestock waste into fertilizers (use for biogas production, vermicomposting, passive composting, biofermentation, etc.) [9]. Therefore, an important scientific task is to assess their chemical composition and impact on crops.

2 Materials and methods

Three types of liquid organic fertilizers were used in the study: biohumus preparations "AgroVerm" (obtained as a result of vermicomposting of cattle manure, manufactured by OOO "Bioera", https://begagro.com, Moscow, Russia), the effluent preparation "Samorod" (obtained after microbiological transformation of livestock waste manufactured by OOO "Integrated Utilization Systems", http://komplesu.ru/, Orenburg, Russia) and the liquid fraction of bioorganic fertilizer (hereinafter BO fertilizer), obtained as a result of fermentation of food and plant waste with their subsequent enrichment with bacteria. Bacillus (the fertilizer was obtained according to patent RU 2824464 C1) [10].

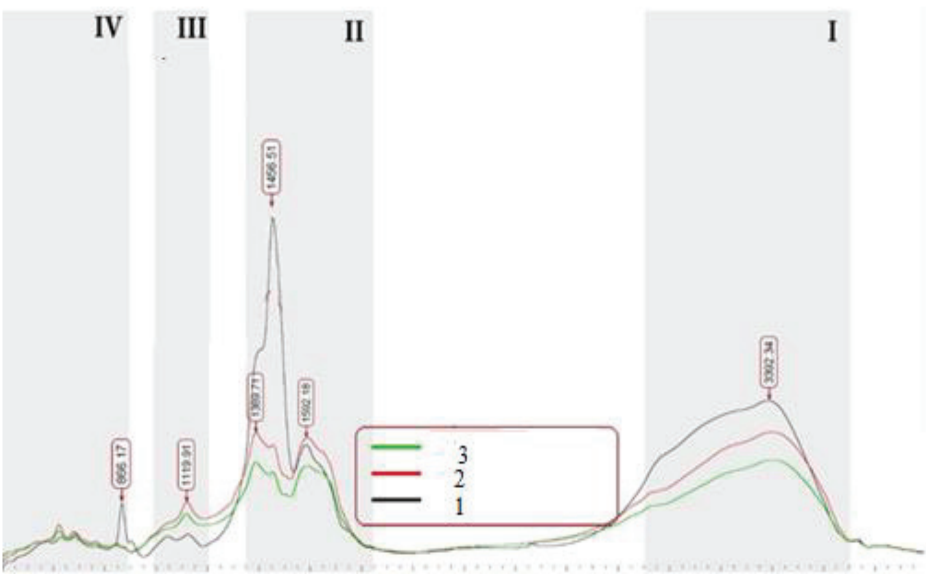
The composition of the provided fertilizer samples was studied using IR spectroscopy on an IR-Tracer-100 infrared Fourier spectrometer (Shimadzu, Japan) and X-ray fluorescence spectroscopy on an X-ray apparatus "Spectroscan MAX-GVM" (OOO NPO "Spectron", St. Petersburg, Russia). The content of free humic acids was determined according to GOST 54221-2010 [11].

The object of the study was spring wheat plants of the "Uchitel" variety. The experimental design included an assessment of seed growth in the following options: 1 - control; 2 - "Samorod" preparation; 3 - "AgroVerm" preparation; 4 - bioorganic fertilizer. Seeds were grown in vegetative vessels filled with quartz sand, to which humic fertilizer preparations were added. Next, the seeds were planted and germinated in accordance with GOST 12038-84, then the length and weight of the above-ground and underground organs (on the 28th day) were determined, as well as the content of photosynthetic pigments according to the method of N.D. Smashevsky [12-13].

3 Results and Discussion

The study of the chemical composition of humic fertilizers showed that samples of all preparations contained such chemical elements as K, Cl, Si and Cu, while the vermicompost sample was distinguished by the presence of sulfur, chloride ion effluent and calcium, and the bioorganic fertilizer sulfur and iron. The study of the quantitative composition of fertilizer samples by X-ray fluorescence analysis made it possible to determine that in both samples the proportion of potassium did not exceed 7%, silicon 10%, and copper 2%. In addition, such elements as aluminum, titanium, sulfur, iron and calcium were found.
The yield of humic acids for the AgroVerm preparation was 4.5%, bioorganic fertilizer 3.3%, and for the effluent no more than 1%.

According to the results of IR spectroscopy, humic acids are present in the dry residue of evaporated samples of vermicompost, bioorganic fertilizer and effluent, the presence of which is confirmed by the presence of absorption peaks at wavelengths of 2924 cm-1 (ν(-CH_2^-) = 2940-2945; 2870-2840 cm-1), 1633 cm-1 (ν(-C=O)ArCOOH = 1710-1660), 1417 cm-1 (ν(-CH_2^-) = 1480-1410), 3300 cm-1 and 1516 cm-1 (ν(-N-H) = 3370-3270, 1570-1515) (Figure 1).



1 - AgroVerm, 2 - BO fertilizer, 3 - Samorod

Fig. 1. IR spectra of humic acids of fertilizers.

For the IR spectrum of the "AgroVerm" preparation, a peak at a wavelength of 868 cm^{-1} is noted in the region of complex deformation vibrations of amines, amides, aliphatic cyclic and hetero compounds, which in this case is more characteristic of substituted aromatic rings. And the absorption peaks in the range of 900-675 cm^{-1} indicate out-of-plane deformation vibrations of C-H, and depending on the degree of substitution and their location, the peak can float and take a broadened form.

When binding HA with metals, complexation occurs, to a greater extent, on carboxyl residues. The metal complicates deformation vibrations, leading to a decrease in intensity and a shift of bands to the blue zone. The peak of ≈1030 cm^{-1} in samples 1 and 2 indicates the presence of polyols in the structure of humic molecules.

Peaks at frequencies of 1650-1350 cm^{-1} are due to the –[COOH] group. Humic acids of the fertilizer and the preparation “Samorod” also have peaks in this region, however, their intensity is lower. The differences are hidden in the form in which the carboxyl group is located. The charged form –[COO]– is characterized by two peaks at ≈1590 cm^{-1} and ≈1400 cm^{-1}, and for the aprotonated –[COOH] at ≈1700 cm^{-1}. Such differences can be due to the pH of the environment or the existence of HA in the form of salts.

The bioorganic fertilizer sample contained a large number of aromatic systems in combination with heteroatoms in the overall structure of HA, as well as carboxyl groups. This can be confirmed by two weak peaks at ≈700 cm^{-1} and 620 cm^{-1}, characteristic of deformation vibrations of C-H aromatic rings.

The effluent sample also contained humic substances, but differed in the presence of peptides with peaks in the bands of 2924 cm^{-1} and 2856 cm^{-1} ($\nu(-CH_2^-)$ = 2940-2945; 2870-2840 cm^{-1}), 3250 cm^{-1} and 1575 cm^{-1} (ν(-N-H) = 3370-3270, 1570-1515). The main difference of this fertilizer is the absence of peaks in the region of ≈1030 cm^{-1}, characteristic of polysaccharides, and in the region of 600-400 cm^{-1}, in which skeletal vibrations and stretching vibrations of bonds with metals are located.

Analysis of IR spectra of humic acids of organic fertilizers of various origins indicates a significant diversity of functional groups in the vermicompost sample and bioorganic fertilizer.

Vital and morphometric indicators are used to measure and evaluate various plant characteristics. A study of the effect of fertilizers on seed germination showed that the maximum values of the indicator were noted in the variant using the AgroVerm preparation (87%) and bioorganic fertilizer (85%) (Figure 2).

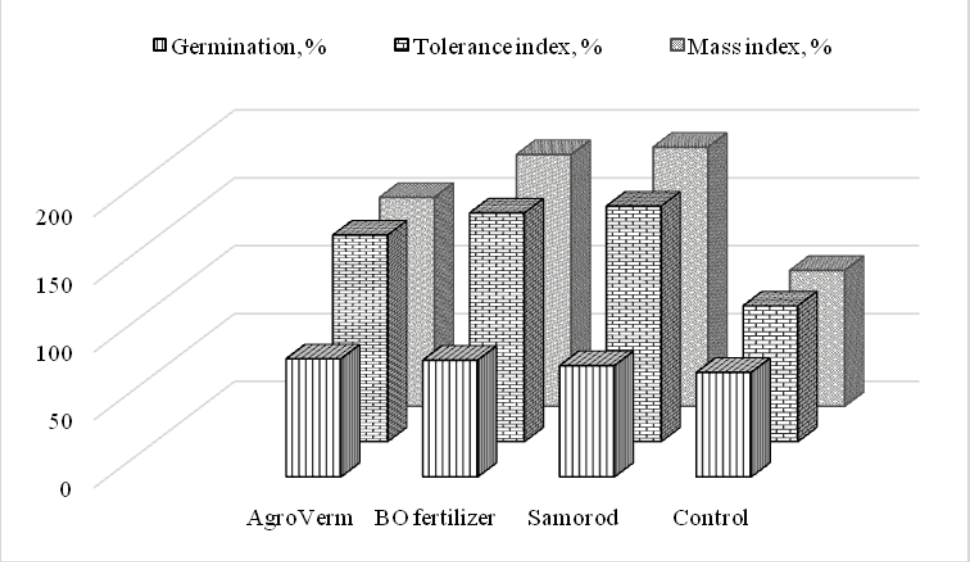


Fig. 2. Vital and morphometric indicators of *Triticum aestivum*.

Vital and morphometric indicators help researchers to assess the condition and development of plants, as well as to conduct a comparative analysis between different growing conditions. Thus, the highest values of the tolerance index and mass were noted for the drug "Samorod" and amounted to 173.4% and 190.8%, respectively. A decrease in morphometric indicators was noted in the series: liquid fraction of bioorganic fertilizer - drug "AgroVerm".

Photosynthetic pigments play a key role in the process of photosynthesis, and their content is an informative indicator of the provision of plants with mineral nutrition elements and organic matter. For this purpose, the content of chlorophylls *a* and *b*, as well as carotenoids, is assessed during the studies.

The results of the experiment showed that the prevalence of Chl *a* and Chl *b* in the pigment complex is typical for the spring soft wheat crop (Table 1).

The results obtained indicate that vermicompost contributed to the maximum increase in the concentration of Chl *a*, which plays a leading role in the production process. For the bioorganic fertilizer, this indicator decreased to 2.43 mg/g, but for these two fertilizers, this indicator reliably exceeded the control value.

Table 1. The content of photosynthetic pigments in the biomass of *Tríticum aestivum.*

Fertilizers	**Content, mg/g**			
	Chl *a*	**Chl *b***	**Chl *a*+Chl *b***	**Car**
AgroVerm	2.25±0.21*	1.90±0.03	4.14±0.24*	1.35±0.06*
BO fertilizer	2.43±0.06*	2.32±0.08*	4.75±0.11*	1.02±0.02*
Samorod	1.24±0.01	4.68±0.14*	5.92±0.41*	1.48±0.07*
Control	1.03±0.04	1.91±0.01	2.95±0.31	0.62±0.04

*Significantly at $p < 0.05$

While the effluent stimulated the content of chlorophyll b and carotenoids more than 2.4 times, the former acting as a duplicate of the main pigment, and the latter providing the plant with an antioxidant system that protects cells from active forms of oxygen and free radicals. And the effect of bioorganic fertilizer is manifested in a reliable increase in the proportion of Chl *a* and *b* in the pigment complex.

Further statistical analysis of the experimental data revealed a correlation between the germination rates of *Triticum aestivum*, the content of Chl a and Car with the concentration of potassium ($r = 0.91$, 0.62, and 0.87, at $p < 0.05$), which is associated with the important role of the element in plant nutrition (Table 2).

The germination index also showed a reliable correlation with the content of S, Si and Cu ($r = 0.91$, 0.70 and 0.61, at $p < 0.05$). And the tolerance index, Chl *b*, is characterized by a dependence on the content of Ca and Fe ($r = 0.89$ and 0.72 and 0.77, at $p < 0.05$).

The relationship between the concentration of carotenoids and the content of Al and Ti ($r = 0.72$ and 0.74, at $p < 0.05$) is associated with their pronounced toxicity to higher plants and an increase in the content of pigment, which reduces oxidative stress.

Table 2. Correlation coefficient between the indicators of the chemical composition of humic preparations and the parameters of *Tríticum aestivum*.

Elements	**Germination, %**	**Tolerance index, %**	**Chl *a***	**Chl *b***	**Car**
K,%	0.87*	0.22	0.62*	-0.47	0.87*
S, %	0.91$^{\times}$	0.19	0.58$^{\times}$	-0.06	0.26
Cl, %	0.89**	0.10	0.58$^{\times}$	-0.10	0.08
Si, %	0.70**	0.22	0.37	0.10	0.15
Cu, %	0.61**	0.33	0.26	0.36	0.36
Ca, %	-0.08	0.89*	-0.23	0.47$^{\times}$	0.33*
Al, %	-0.20	0.45*	-0.03	-0.21	0.72*
Ti, %	-0.23	0.54*	-0.05	0.76* *	0.74*
Fe, %	-0.18	0.72*	0.04	0.77**	0.77*

*Significantly at $p < 0.05$

4 Conclusion

The study showed that humic fertilizers differ in their chemical composition, so the products of vermicomposting ("AgroVerm") and fermentation (bioorganic fertilizer) had a higher yield of humic acids (4.5% and 3.3%, respectively) compared to the fertilizer of microbial origin (1%). All fertilizers contained elements necessary for plant growth and development (K, S, Cl, Si, Cu, Ca, etc.). The obtained results on the germination of grains indicate an increase in plant germination and the content of Chl a in the green mass under the influence of the preparation "AgroVerm" and bioorganic fertilizer. And the use of effluent contributed to the growth of the concentration of Chl b and carotenoids. The results of statistical data processing showed the presence of a reliable correlation between the concentration of chemical elements in the studied humic preparations with vital, morphometric and biochemical parameters of the spring soft wheat plant.

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