The effect of the tank mixtures of humic substances and herbicides on the abundance of microbial communities in chernozem during chickpea cultivation

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Abstract. The effect of treatment of chickpea crops with chemical and biological plant protection agents on several groups of soil microorganisms was studied. Pesticides were used separately and in tank mixtures with humic substances. The treatment of plants with pesticides had a multidirectional effect on the numbers of microorganisms in the soil. It was found that the addition of humic substances to chemical pesticides increases the number of microorganisms in the soil, which is associated with its adaptogenic effect on plants. The use of tank mixtures of humic substances with pesticides on chickpea crops turned out to be most effective with second assortment of pesticides, but it was also effective with standard pesticides. For biological preparations, the opposite effect was observed: biological products were more effective without adding humic substances to them.

1. Introduction
Modern agriculture makes it possible to achieve high crop productivity largely due to the rational use of fertilizers and plant protection products. The share of plant protection products in the formation of the crop yield is 40–50% in modern technologies [1]. With the threat of mass infestation by the most dangerous species of pests, the use of pesticides is a mandatory element to prevent economic losses. However, their use can negatively affect the cultivated crop, causing stress in plants and negatively affecting the biological activity of the soil [2]. To reduce the negative effects of the pesticides application, humic substances can be used, which act as stimulants and adaptogens [3]. Their use has a positive effect on the growth and development of plants, and also increases the biological activity of the soil [4].

In this regard, it is important to optimize the use of pesticides considering the economic thresholds of harmfulness and monitoring the pests populations. This approach should include increasing their biological effectiveness and the development of scientific basis for the joint application of pesticides and biological products.

Until now, the influence of herbicidal treatment on soil microbial communities remains poorly studied [5]. The biological activity of the soil largely depends on the physiological state of the plants growing on it, since root systems are an important source of nutrients for microorganisms, especially in the rhizosphere [6]. The use of pesticides can have an indirect effect on soil microbiota, and the use of
humic preparations in the composition of tank mixtures mitigates the negative effects of stress caused by pesticides [7].

In this regard, the purpose of this work was to study the effect of two different plant protection systems and their combinations with humic preparations on the microbiological activity of Haplic Chernozem during the cultivation of chickpea.

2. The object of study

A field experiment was laid at the territory of the Federal Rostov Agricultural Research Center, to assess the effect of chickpea treatment with various options for plant protection (standard assortment of pesticides, a new assortment of pesticides, biological protection products) in combination with humic preparation BIO-Don or without it (table 1). Each variant was laid in triplicate.

| №   | Variant             | Fertilizers | Preparations / Application dose |
|-----|---------------------|-------------|---------------------------------|
| 1.  | Control             | No fertilisers |                                  |
| 2.  | Humate              | No fertilisers | BIO-Don 10 / 0.3 l/ha          |
| 3.  | Mineral fertilizers | N40P40K40   |                                  |
| 4.  | Mineral fertilizers + humate | N40P40K40 | BIO-Don-10 / 0.3 l/ha          |
| 5.  | Biopreparations     | N40P40K40   | Planriz / 0.3 l/t               |
|     |                     |             | Geostim / 1 l/ha               |
|     |                     |             | Planriz / 0.3 l/t               |
| 6.  | Biopreparations + humate | N40P40K40 | BIO-Don-10 / 0.3 l/ha          |
| 7.  | Pesticides 1        | N40P40K40   | Gezagard / 3 l/ha              |
|     |                     |             | Bi-58 New / 1 l/ha             |
|     |                     |             | Gezagard / 3 l/ha              |
| 8.  | Pesticides 1 + humate | N40P40K40 | Bi-58 New / 1 l/ha             |
|     |                     |             | BIO-Don / 0.3 l/ha             |
|     |                     |             | Sinkler / 0.6 l/t              |
|     |                     |             | Lazurit / 1 kg/ha              |
| 9.  | Pesticides 2        | N40P40K40   | Optimo / 0.5 l/ha              |
|     |                     |             | Ampligo / 0.2 l/ha             |
|     |                     |             | Sinkler / 0.6 l/t              |
|     |                     |             | Lazurit / 1 kg/ha              |
| 10. | Pesticides 2 + humate | N40P40K40 | Optimo / 0.5 l/ha              |
|     |                     |             | Ampligo / 0.2 l/ha             |
|     |                     |             | BIO-Don / 0.3 l/ha             |

The numbers of various groups of microorganisms were studied in the soils of the experimental plots and their numbers before and after treatment were compared. The obtained data were compared with the untreated controls to take into account the natural dynamics of the soil microorganisms, which could depend from weather and not from the experimental treatments. Sampling for microbiological analysis was carried out in May 2019, before the treatment of chickpea crops, and also 2 weeks after treatment.

2.1. The studied plant protection products

2.1.1. Fungicides. To combat fusarium root rot, fusarium wilting, ascochitosis and seed mold, a Sinclair seed dressing was used (75 g/l fludioxonil [4-(2,2-difluoro-1,3-benzodioxol-4-yl)-pyrrole-3-carboxylic
Fludioxonil effectively suppresses the development of pathogens from the genus *Fusarium* and *Tilletia*, as well as *Altemaria, Ascochyta, Aspergillus, Fusarium, Helminthosporium, Rhizoctonia* and *Penicillium* spp., causing seedling diseases. This active substance is an analogue of natural antifungal substances. It has a broad spectrum of action, suppresses the growth of fungal mycelium, inhibiting the function of cell membranes by nonspecific violation of the control of osmotic pressure in the pathogen cell, and also inhibits phosphorylation of glucose during respiration. Subject to the application regulations Sinclair does not cause phytotoxicity. During the growing season, contact fungicide Optimo (200 g/l pyraclostrobin [methyl N-[(2-[(4-chlorophenyl)-1H]-pyrazol-3-yl)methyl] phenyl] (N-methoxy) carbamate) was used to combat ascocitosis. This fungicide is highly effective, since its active ingredient belongs to the strobilurin class. The mechanism of action is to inhibit mitochondrial respiration of pathogenic fungi.

### 2.1.2. Herbicides

For herbicidal treatments when growing chickpeas and peas, the preparation Gezagard (500 g/l of prometryn [N2, N4-di-isopropyl-6-methylthio-1,3,5-triazine-2,4-diamine]) was used. Prometryn belongs to the chemical class of triazines. It is a broad spectrum systemic herbicide that acts as a photosynthesis inhibitor. It is used against dicotyledonous and monocotyledonous weeds, therefore, on leguminous crops it is used only for tillage before germination. Prometryn enters the plant through the root system, moving along the xylem, penetrates the leaves [8], where binds to the quinone-binding protein D-1 (Q8), thereby blocking photosynthetic electron transport [9]. Triazines inhibit photosynthesis in all organisms with oxygen-evolving photosystems. They block photosynthetic electron transport by displacing plastoquinone from a specific-binding site on the D1 protein subunit of photosystem II (PS II). This mode of action is shared with several structurally different groups of other herbicides. That triazines are displacing plastoquinone from its functional site in the chloroplast membrane, the triazine target as a hydrophobic membrane protein. The herbicide-binding protein is one of the reaction-center proteins of PS II that not only carries plastoquinones, but also six chlorophylls and two phoephitines as well as an Fe (iron), and provides part of the anchor for the Mn (manganese) cluster for oxygen evolution [10]. The preparation Lazurit (700 g/kg metribuzin [4-amino-6-tert-butyl-3-methylthio-1,2,4-triazin-5 (4H) -one]) was studied as a herbicide for comparison with prometryn. Metribuzin has been registered since 1973. Systemic herbicide with selective spectrum of action against monocotyledonous and dicotyledonous weeds, belongs to the class of triazinones. Like Gezagard, Lazurit is recommended to be used only before germination. Its active substance actively penetrates into the ground parts, and is also capable of being absorbed by the root system. At the same time, it moves inside the plant to the point of growth. Its mechanism of action is similar to that of prometryn, based on inhibition of photosynthetic electron transport, displacing the secondary electron acceptor Qa from its binding niche to the D1 protein of photosystem II (PS II) [11].

### 2.1.3. Insecticides

Insecticides Bi-58 New (400 g/l dimethoate [O, O-dimethyl-S-(N-methyldiamidomethyl) dithiophosphate]) and Ampligo (50 g/l labda-cyhalothrin [a mixture of cyhalothrin isomers in a 1 : 1 ratio – (S)-a-cyano-3-phenoxybenzyl ester (Z) - (1R)-cis-3-(2-chloro-3,3,3-trifluoropropenyl)-2, 2-dimethylcyclopropeneacrylic acid and (R)-a-cyano-3-phenoxybenzyl ester (Z) - (1S)-cis-3-(2-chloro-3,3,3-trifluoropropenyl)-2,2-dimethylcyclopropeneacrylic acid] + 100 g/l chlorantraniliprol [3-bromo-4-chloro-1-(3-chloro-2-pyridyl)-2'-methyl-6'-(methylcarbamoyl) pyrazole-5-carboxanilide]) were used to control pests such as cotton moth, pea aphid, pea moth, and pea kernels.). Bi-58 New belongs to the class of organophosphorus compounds.

Its active ingredient, along with moderate toxicity for warm-blooded animals, exhibits a strong contact and systemic insecticidal effect. In addition, the drug has good acaricidal properties. Dimethoate enters plants through the root system and aboveground organs, spreads through the plant tissues by ascending and descending currents. Penetrating into plants, it makes their sap toxic to sucking pests. The preparation Ampligo belongs to the class of pyrethroids, is an intestinal and contact insecticide. This group of chemical compounds is highly selective and also lipophilic. This property allows the preparation to adhere to the surface of the leaves cuticle. In this case, the active substance penetrates
into the plant tissue gradually, and through the integument of the insect – instantly, causing rapid damage to the nervous system, then paralysis and death. Unlike organophosphate insecticides, it does not destroy hiding pests and is most often used against leaf-eating insects.

2.1.4. Biological plant protection products. Planriz is a contact biological fungicide containing \textit{Pseudomonas fluorescens} strain AP-33 with a titer of at least $2 \times 10^9$. Effective against helminthosporium rot, powdery mildew, brown rust, spotting, has a biostimulating effect. The mechanism of action is based on antibiotics produced by pseudomonads, phenazine-1-carboxylic acid and phloroglucinol derivatives, which suppress the development of the disease at the stage of mycelium growth and sporulation. Recommended for pre-sowing seed treatment, the dosage is set taking into account the predecessor and seed phytoexamination data. To accelerate the decomposition of plant residues in the surface layer of the soil and suppress the development of phytopotagens, the microbiological preparation Geostim was used. The composition includes the \textit{Trichoderma} fungus and plant growth promoting microorganisms. Geostim contributes to the implementation of one of the main agricultural techniques – the formation of a mulch layer. This contributes to the active reproduction of saprotrophic microflora. The mechanism of action is based on the ability to suppress the growth and development of other fungi, to parasitize on them, affecting hyphae and sclerotia. Pathogenic fungi lose their ability to infect vegetative plants, therefore Geostim is used for biological control and protection against a wide range of diseases caused by fungi. There is also a stimulating effect on plants due to the microorganisms that are part of it. They form symbiotic bonds with cultivated plants, colonizing the surface of the root system. When processing vegetative plants, biochemical processes, respiration and photosynthesis are enhanced, the activity of plant enzymes increases due to the release of physiologically active substances by microorganisms.

2.1.5. Humic preparation. The humic preparation BIO-Don-10 is obtained by alkaline extraction from vermicompost, which is a product of the processing of manure (cattle, pork, horse, and also poultry droppings) by means of a population of earth (compost) worms of the \textit{Eisenia foetida} species. It contains salts of humic acids, which are natural regulators (stimulators) of plant growth and development. The preparation contains at least 10 g/l of organic matter, of which 20% are humic acids, 5% are fulvic acids. Humic substances have adaptogenic properties that provide such an effect as relieving stress after the use of pesticides and exposure to adverse weather factors.

Soil samples were taken from the arable layer before sowing and at the stage of beans ripening. The tank mix treatment was carried out in the bean formation phase. During this phase, chickpea plants are most vulnerable to cotton bollworm, acacia moth and pea aphid. At the experimental site, agricultural technologies were used for cultivating peas and chickpeas, recommended for the Azov zone of the Rostov region.

3. Methods of study

The microbiological activity of the soil, the number of groups of microorganisms was determined by the standard method of sowing dilutions of soil suspension on solid nutrient media [12]. The number of the following groups of soil microorganisms was determined: 1) bacteria using organic forms of nitrogen (copiotrophs) on nutrient agar; 2) bacteria using mineral forms of nitrogen on starch-ammonium agar (ISP 4); 3) actinomycetes, counted on starch-ammonium agar (ISP 4); 4) soil micromycetes on Czapek agar with the addition of streptomycin. The pairwise comparison of independent groups with corresponding controls were performed with the use of Student’s t-test at $p < 0.05$.

4. Results and discussion

The number of ammonifying bacteria varied quite significantly before sowing, and was in the range of 11.9–48.6 million CFU/g. After treatment, there was a noticeable increase in the number of this group of microorganisms, which is associated with the active development of plant root systems. As a result, after the second sampling, the number of ammonifying bacteria was in the range of 22.86–72.36 million CFU/g (table 2).
As can be seen from the data shown in Table 2, changes in abundance were expressed to varying degrees, depending on the experimental variants. At the same time, the treatment had a significant effect, superimposed on the action of abiotic environmental factors.

| Fertilizers          | Variant                  | Before treatment | After treatment | Change in numbers, % | Change compared to the control, % |
|----------------------|--------------------------|------------------|-----------------|----------------------|----------------------------------|
| No fertilizers       | Control                  | 24.36±4.57       | 55.56±0.52      | 128<sup>b</sup>      | 0                                |
|                      | Control + Humate         | 12.57±6.34       | 57.33±20.29     | 356<sup>b</sup>      | 228                              |
| Medium dose of fertilizers | Mineral fertilizers     | 20.07±3.68       | 22.86±0.74      | 14                   | 0                                |
|                      | Mineral fertilizers + Humate | 11.92±6.18   | 36.00±12.33     | 202<sup>b</sup>      | 188                              |
|                      | Biopreparations          | 16.14±4.12       | 46.43±11.65<sup>a</sup> | 188<sup>b</sup> | 174                              |
|                      | Biopreparations + Humate | 28.30±8.41       | 43.81±7.68<sup>a</sup> | 55                   | 41                               |
|                      | Pesticides               | 24.40±2.93       | 38.64±2.71<sup>a</sup> | 58<sup>b</sup>  | 44                               |
|                      | Pesticides + Humate      | 19.21±2.61       | 49.01±7.93<sup>a</sup> | 155<sup>b</sup> | 141                              |
|                      | Pesticides 2             | 48.56±7.18       | 50.20±5.76<sup>b</sup> | 3                    | -11                              |
|                      | Pesticides 2 + Humate    | 18.77±7.30       | 72.36±17.54<sup>a</sup> | 285<sup>b</sup> | 271                              |

<sup>a</sup> Significant difference compared to the corresponding control.

<sup>b</sup> Significant difference with values before treatment.

Due to the significant variability of the microorganisms numbers in the soils of the experimental plots prior to the treatment, the treatment effects can be judged only by comparing the relative change in microorganisms numbers for each variant (Tables 2–6, column 5). However, this change could be due to the action of natural factors between the two samplings. To take it into account, the observed relative changes have been normalized to the corresponding untreated controls (Tables 2–6, column 6).

In almost all cases, humate treatment led to a higher number of ammonifiers in the soil. At the same time, in the control without fertilizers, their number was 228% higher than the control, with a medium dose of fertilizers – by 188%.

The greatest difference was observed when humate was added to the tank mixture with new pesticides, when humate was added, an increase of 271% was observed, and without it, a decrease of 11%. In the case of standard pesticides, the humate variant also shows a large increase in the numbers of ammonifying bacteria. However, when used together with biological products, the opposite result is observed – a mixture with humate gives a smaller increase in the number of microorganisms.

As can be seen from the data in Table 3, for the group of bacteria utilizing mineral nitrogen, the dynamics are opposite to those of ammonifiers. For most plots, by the time of the second sampling, there is a decrease in their numbers by 15–53 percent. Growth was observed only in the variant with a combination of humate and pesticides 2. At the beginning of the experiment, the numbers of these bacteria varied from 57.33 to 103.45 million CFU/g, and after the second sampling, the number of the range was 27.88–70.45 million CFU/g.

It can be concluded that by the time of sampling, a significant amount of readily available organic matter had entered the soil, which is associated with the development phase of chickpea plants. It is known that chickpea plants are characterized A1 by an extremely active release of organic acids both by leaves and by the root system.

Compared to soybeans, chickpeas release 35 times more citric acid and 16 times more malic acid [13]. This massive input of readily available organic matter into the soil apparently leads to an increase in the number of ammonifiers (which are copiotrophs and active hydrolytics) and a simultaneous...
decrease in the number of bacteria utilizing mineral nitrogen in the studied soils. At the same time, if we normalize the data on untreated controls, that is, not taking into account the influence of weather or the phase of plant development, then the results of treatment are quite similar for both groups of bacteria.

**Table 3.** The numbers of bacteria utilizing mineral nitrogen, $10^6$ CFU/g.

| Fertilizers        | Variant                  | Before treatment | After treatment | Change in numbers, % | Change compared to the control, % |
|--------------------|--------------------------|------------------|-----------------|----------------------|-----------------------------------|
| No fertilizers     | Control                  | 73.32±13.81      | 48.96±5.59      | -33\(^b\)            | 0                                 |
|                    | Control + Humate         | 61.94±9.86       | 40.06±3.99      | -35\(^b\)            | -2                                |
| Medium dose of fertilizers | Mineral fertilizers | 59.26±10.15      | 27.88±3.30      | -53\(^b\)            | 0                                 |
|                    | Mineral fertilizers + Humate | 61.63±7.68  | 42.97±9.43\(^a\) | -30                  | 23                                |
|                    | Biopreparations          | 75.09±11.50      | 58.85±6.31\(^a\) | -22                  | 31                                |
|                    | Biopreparations + Humate | 94.65±22.53      | 61.58±6.77\(^a\) | -35                  | 18                                |
|                    | Pesticides 1             | 57.33±13.89      | 37.60±5.01\(^a\) | -34                  | 19                                |
|                    | Pesticides 1 + Humate    | 60.38±8.26       | 51.19±13.36\(^a\) | -15                  | 38                                |
|                    | Pesticides 2             | 103.45±15.68     | 59.21±3.62\(^a\) | -43\(^b\)            | 10                                |
|                    | Pesticides 2 + Humate    | 58.47±1.35       | 70.45±7.21\(^a\) | 20                   | 73                                |

\(^{a}\) Significant difference compared to the corresponding control.
\(^{b}\) Significant difference with values before treatment.

At the same time, the effect of treatment options on bacteria using mineral forms of nitrogen is similar in nature, but significantly smaller in scale compared to the effect on bacteria using organic nitrogen. Here, the maximum difference between the variant and the corresponding control is 73\%, for the variant with pesticides 2 and humates, while the similar difference for ammonifiers was 271\%. In the nature of the observed changes, the only significant difference is that in the control without fertilizers, the treatment with humates did not differ from the control.

According to the data in table 4, it can be seen that actinomycetes, like other bacteria grown on mineral nitrogen medium, decreased their numbers from the beginning to the end of the experiment both in controls and in variants with treatment. Similarly to the previous group of microorganisms, the only exception was the variant with a combination of pesticides 2 with humate, where an increase of 86\% was observed. In other variants of the experiment, the decrease varied from 11 to 73\%.

A slightly different picture is observed if we analyze the changes normalized relative to controls. It can be noted that humate treatment in the control variants led to a decrease in the number of actinomycetes, both at an average dose of mineral fertilizers and without fertilizers. A similar situation was observed for variants with treatment with biological preparations. However, when using chemical both mixtures of pesticides, humate showed a positive effect on the number of actinomycetes in the soil.

The observed picture can to some extent be associated with the biotic interactions of different groups of microorganisms, in particular, with the competition between non-mycelial bacteria and actinomycetes. In the absence of the stressful effect of chemical pesticides, the leading factor suppressing the growth of actinomycetes in the soil is the increased number of ammonifying bacteria.

The number of fungi in the soil under chickpeas showed very significant changes from the beginning of the experiment to its end (table 5). The increase in the number of fungi was 302\% in the control variant without fertilizers, and 88\% in the variant with an average fertilization dose. The number of soil fungi at the beginning of the experiment varied from 32.05 to 96.15 thousand CFU/g of absolutely dry
soil. At the end of the experiment, it increased several times and amounted to 59.43–190.67 thousand CFU/g of absolutely dry soil.

Table 4. The numbers of actinomycetes, 10⁶ CFU/g.

| Fertilizers            | Variant                | Before treatment | After treatment | Change in numbers, % | Change compared to the control, % |
|------------------------|------------------------|------------------|-----------------|----------------------|-----------------------------------|
| No fertilizers         | Control                | 3.69±0.84        | 3.26±0.43       | -11                  | 0                                 |
|                        | Control + Humate       | 3.96±1.19        | 3.01±0.24       | -24                  | -13                               |
| Medium dose of fertilizers | Mineral fertilizers | 4.66±1.86        | 3.02±1.17       | -35                  | 0                                 |
|                        | Mineral fertilizers + Humate | 5.27±1.30   | 1.44±0.21       | -73<sup>a</sup>      | -38                               |
| Biopreparations        |                        | 3.88±1.07        | 3.32±0.29       | -14                  | 21                                |
| Biopreparations + Humate |                      | 6.54±1.85        | 2.26±0.54       | -66<sup>a</sup>      | -30                               |
| Pesticides 1           |                        | 3.78±1.14        | 2.08±0.21       | -45                  | -10                               |
| Pesticides 1 + Humate  |                        | 2.50±0.89        | 2.08±0.21       | -17                  | 18                                |
| Pesticides 2           |                        | 4.69±0.17        | 3.61±0.48       | -23                  | 12                                |
| Pesticides 2 + Humate  |                        | 2.63±0.00        | 4.89±1.03       | 86<sup>a</sup>       | 121                               |

<sup>a</sup> Significant difference with values before treatment.

Table 5. The numbers of soil fungi, 10³ CFU/g. See comments to the table 2.

| Fertilizers            | Variant                | Before treatment | After treatment | Change in numbers, % | Change compared to the control, % |
|------------------------|------------------------|------------------|-----------------|----------------------|-----------------------------------|
| No fertilizers         | Control                | 32.05±5.00       | 96.88±16.20     | 302<sup>b</sup>      | 0                                 |
|                        | Control + Humate       | 42.42±1.39       | 59.43±12.64     | 140                  | -162                              |
| Medium dose of fertilizers | Mineral fertilizers | 64.52±4.78       | 56.99±4.29      | 88                   | 0                                 |
|                        | Mineral fertilizers + Humate | 91.30±5.94   | 114.19±18.61<sup>a</sup> | 125          | 37                                |
| Biopreparations        |                        | 49.85±16.62      | 69.88±8.39      | 140                  | 52                                |
| Biopreparations + Humate |                      | 42.81±20.73      | 131.90±23.76<sup>a</sup> | 308<sup>b</sup> | 220                               |
| Pesticides 1           |                        | 58.78±3.69       | 95.04±7.88<sup>a</sup> | 162<sup>b</sup> | 73                                |
| Pesticides 1 + Humate  |                        | 40.62±1.35       | 123.92±21.32<sup>a</sup> | 305<sup>b</sup> | 217                               |
| Pesticides 2           |                        | 96.15±12.02      | 190.67±14.76<sup>a</sup> | 198<sup>b</sup> | 110                               |
| Pesticides 2 + Humate  |                        | 73.99±22.77      | 110.30±11.01<sup>a</sup> | 149<sup>b</sup> | 61                                |

<sup>a</sup> Significant difference compared to the corresponding control.

<sup>b</sup> Significant difference with values before treatment.

Taking into account the very large changes in the abundance of fungi in the control, it is rather difficult to interpret the changes associated with the treatment variants. Nevertheless, it can be noted that in some cases, the treatment of crops with the addition of humate to the mixture potentiated the
increase in the number, while in other cases the opposite effect was observed. In particular, in the control variant with average dose of fertilizers, the increase in the number was 88\%, and with the addition of humate – 125\%. When using only chemical pesticides the increase was 162\%, and with the addition of humate – 305\%. When using only biological plant protection products the increase amounted to 140\%, and in a mixture with humate it was as high as 308\%. It should be especially noted that only for the numbers of soil fungi, a synergistic effect of a biological preparations with humate was observed, while for all other groups of microorganisms the effect was opposite.

Humate showed itself somewhat worse when mixed with new assortment of pesticides, leading to 198\% growth with pure pesticides and 149\% in a tank mixture with humate. In the variant without fertilizers, humate had a negative effect on the number of fungi in the soil: in the control, the number of fungi increased by 302\%, and when treated with humate, by 140\%. This result can be explained by biotic interactions within the microbial community: apparently, a sharp increase in ammonifiers in this variant (by 356\% versus 128\% in the control) led to the suppression of other groups of microorganisms due to competition for resources and ecological niches. This was reflected in the dynamics of bacteria utilizing mineral nitrogen, actinomycetes in the variant without fertilizers with humates, but this effect was most clearly manifested for soil fungi. It is interesting to note that in the variant with the application of humate to the soil with an average dose of fertilizers, a similar effect was observed for actinomycetes, but it was not observed for bacteria utilizing mineral nitrogen and soil fungi. This may reflect the characteristics of competition for nitrogen and carbon sources among the microorganisms.

The question of the effect of pesticides application on soil microbial communities remains largely controversial. In some works it was shown that with prolonged use of pesticides, the number of microorganisms can increase due to a decrease in the harmful effects of insects on plants and an increase in their productivity [14]. A review by C.C. Lo [15] summarized the data of a number of studies on the effect of different types of pesticides on soil microbial communities. It was shown, that some pesticides had a suppressive effect on bacteria, while others, on the contrary, contributed to the increase in their biomass. Thus, pesticides from the sulfonylurea group turned out to be toxic to soil pseudomonads. In particular, metsulfuron showed significant toxicity towards the studied strains [16]. On the other hand, some phosphorus-containing herbicides, in particular, glyphosate, had a stimulating effect on microbial communities [17]. Zhang et al. [18] showed that the use of cypermethrin, an insecticide from the pyrethroid class, led to a decrease in the abundance of firmicutes in bacterial communities and the growth of gram-negative bacteria. There are also works that showed the absence of significant effects of pesticides on microbial communities. The effect of such pesticides as phorate, carbofuran, carbosulfan, thiomethoxam, imidaclorpid, chlorpyrifos, and monocrotophos on soybean cultivation was investigated and no significant changes in bacterial communities were observed [19]. At the same time, there is a consensus regarding the positive effect of humate treatment on soil microbial communities. Humic substances stimulate plants, affect the development of root systems and the intensity of root secretion, which has a pronounced stimulating effect on soil microbial communities [20].

5. Conclusions
According to the results of microbiological studies, it can be noted that the use of humate in tank mixtures with pesticides on chickpea crops turned out to be the most effective for “Pesticides 2” treatment, but it was also effective for “Pesticides 1”.

The number of all studied groups of microorganisms was initially lower in the “Pesticides 2 + humate” variant as compared to “Pesticides 2” variant, but after treatment the situation was changed to opposite which can be attributed to the protective action of the humate. When using such mixtures, the number of microbial communities in the soil under crops turned out to be higher compared to the variants with only chemical treatments. In the case of using biological protection agents, the opposite effect was observed – biological plant protection agents were more effective when used independently without adding humate to the tank mixture.
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