Influence of microbiological preparations on the rate of decomposition of winter wheat straw and the productivity of sugar beet in the conditions of the Kursk region

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Abstract. The influence of the preparations Mycobact, Gumistim and Trichophyte on the microbiological activity of typical black earth, decomposition of winter wheat straw and the yield of the next crop of crop rotation - sugar beet was studied. It was found that the treatment of chopped straw after harvesting winter wheat with the preparation Gumistim at a dose of 5 l / ha for 90 days of exposure increased the microbiological activity of the soil (loss of linen tissue) to 62.9%, while the loss of linen tissue in the control variant was equal to 46.9%. The use of microbiological preparations Trichophyte at a dose of 7 l / ha and Mycobact at a dose of 3 l / ha as destructors contributed to an increase in the degree of decomposition of linseed linen to 68.1 and 75.3%, respectively. Straw treatment with microbiological preparations Gumistim at a dose of 5 l / ha, Trichophyte at a dose of 7 l / ha, Mycobact at a dose of 3 l / ha, as well as two-fold processing of sugar beet crops in the phase of closing leaves in rows and the phase of closing leaves in row spacing with these preparations contributed to an increase in the yield of sugar beet by 3.5-4.3 t / ha, increased the cost of gross production by 3500-4300 rubles, and given the low cost of the fertilizers themselves and the small rates of their application, it was economically profitable. The value of the conditionally net income from the use of microbiological preparations was 2040-2950 rubles / ha. The most cost-effective was the use of the microbiological preparation Mycobact.

1. Introduction

Soil fertility is an urgent problem, since technogenic intensification had a significant impact on reducing the potential soil fertility [1-2]. Alienation of a large amount of organic matter from the fields with the yield of the main and by-products leads to a decrease in the content of humus in the soil [3].

Earlier (about 30 years ago), the problem of returning organic matter to the fertile soil layer was solved by the introduction of bedding manure, and the lack of mineral elements was compensated by the introduction of the required amount of mineral fertilizers. Today, there is a tendency to reduce the use of organic fertilizers [4]. Data from monitoring the fertility of arable lands in the Central Black Earth Region allow us to conclude that it is necessary to introduce organic substances, since the current standards do not allow achieving the required balance [5].

The use of residues of the plant part of the crop, which is not of commercial interest (straw) is a reserve for increasing the content of organic substances in the soil, provided that additional processing is necessary [6-7].
However, as a result of global chemicalization, beneficial species of microorganisms in the soil are in a suppressed state, which leads to a decrease in the rate of decomposition of plowed crop residues. In the fields you can find undecomposed straw of the last year, the year before last, and even the third year [8-9]. Therefore, increasing soil biogenicity due to the introduction of beneficial microorganisms as a result of the use of microbiological preparations is an urgent problem.

Based on this, the purpose of this study was to study the effectiveness of using microbiological preparations Mycobact, Trichophyte and Gumistim as straw destructors in winter wheat and their effect on the yield of the next crop of crop rotation - sugar beet in the black earth soils of the Kursk region.

2. Materials and methods
The experimental part of the work was carried out during 2016-2019 at the Kursk Federal Agrarian Scientific Center. The objects of research were: pure fallow, winter wheat, sugar beet, barley (according to the crop rotation scheme with alternation). Microbiological preparations Mykobakt, Trichophyte, Gumistim were used as objects of research.

Mycobact is a microbiological fertilizer, which is a culture liquid containing microorganisms, their spores and metabolites formed during cultivation, as well as the remains of the nutrient medium. The active ingredient of the drug is a bacterial-fungal complex (Micrococcusluteus strain PBT-1 and Penicillium sp. Strain PBT-2). Mycobacter activates the activity of microorganisms, nitrogen-fixing, cellulose- and lignin-decomposing bacteria, helps to accelerate composting, remove obsolete root system, suppress phytopathogens, improve soil structure. The drug is recommended to accelerate the decomposition (humification) of organic residues of natural origin.

Trichophyte (aqueous suspension of the bacterium Trichoderaviride) is an insect-fungicidal preparation based on the fungus of the genus Trichoderma. As a result of the action of the chitinase and gluconase enzymes produced, Trichophyte is a bio-destructor of straw and cellulose waste, promotes the decomposition of polysaccharides and the conversion of substances into accessible forms for plants.

Gumistim is a humic fertilizer produced from vermicompost, peat and infusions of medicinal plants. The fungicidal and bactericidal properties of the drug are due to the presence of natural fungicides and antibiotics, secreted by the intestinal microflora of the earthworm during vermicultivation. Gumistim helps to strengthen immunity, increases plant resistance to diseases and adverse environmental conditions.

The soil of the experimental site is a typical powerful chernozem of heavy loamy granulometric composition. The humus content in the arable layer is 6.1%, mobile phosphorus (according to Chirikov) - 15.6, exchangeable potassium (according to Maslova) - 11.3 mg / 100 g of soil. The reaction of the soil medium is neutral (pH 6.5 ... 7.0).

The experiments were repeated 3 times. The plots were in the shape of an elongated rectangle with an accounting area of 100 m². The experimental scheme included the following options: 1. Control, without processing straw and crops of sugar beet with microbiological preparations; 2. Straw processing (Gumi-stim, 5 l / ha) + processing of sugar beet crops in the phase of closing leaves in rows (Gumistim, 5 l / ha) + processing of sugar beet crops in the phase of closing leaves in the rows (Gumistim, 5 l / ha); 3. Processing of straw (Mycobact, 3 l / ha) + processing of sugar beet crops in the phase of closing leaves in rows (Mycobacter, 3 l / ha) + processing of sugar beet crops in the phase of closing leaves in the rows (Mycobact , 3 l / ha); 4. Straw processing (Trichophyte, 7 l / ha) + processing of sugar beet crops in the phase of closing leaves in rows (Trichophyte, 3 l / ha) + processing of sugar beet crops in the phase of closing leaves in the rows (Trichophyte, 3 l / ha).

Chopped straw and winter wheat stubble at a dose of 5.0-5.5 t / ha (the amount of post-harvest residues left in the field after harvesting) were treated with microbiological preparations with a knapsack sprayer 3-5 days after harvesting and were immediately embedded in the soil with a disc harrow BDT-3 to a depth of 8-10 cm. The main tillage (plowing) was carried out in the first ten days of October to a depth of 28-30 cm.
The microbiological activity of the soil was determined by the application method, by laying linen sheets into the soil to a depth of 15-20 cm. The decomposition of linen sheets was observed 90 days after their laying.

The study period for winter wheat straw treated with microbiological preparations was determined in 2017-2019. The application rate of mineral fertilizers - N90P90K90 - for the main tillage. In the experiment, the following determinations were carried out: soil moisture - by thermostatic - weighting method (AA Rode, 1963); nitrate nitrogen - colorimetrically - by the disulfophenol method of Grandval-Lyazhu, (Vazhenin, 1965). Harvesting and accounting of the yield of sugar beet was carried out by plowing it with a beets lifter, the root crops were cleaned of tops and soil by hand and weighed in the field on a mobile decimal balance. Statistical processing of the results was carried out by the method of analysis of variance using the Microsoft Excel package [10].

3. Results

Conducted studies of microbiological activity within 90 days allow us to conclude that the linen in the control sample is decomposed only by 46.9% (table 1).

**Table 1. Influence of microbiological preparations on the degree of decomposition of linen cloths, 2016-2018 (After 90 days).**

| Options                  | weight of fabric before laying, g | weight of fabric after laying, g | weight of decomposed fabric, g | degree of decomposition,% |
|--------------------------|-----------------------------------|----------------------------------|--------------------------------|----------------------------|
| 1. Control               | 2.30                              | 1.22                             | 1.08                           | 46.9                       |
| 2. Straw processing,    | 2.24                              | 0.83                             | 1.41                           | 62.9                       |
| Gumistim (5 l / ha)      |                                   |                                  |                                |                            |
| 3. Straw processing,    | 2.11                              | 0.52                             | 1.59                           | 75.3                       |
| Mycobact (3 l / ha)      |                                   |                                  |                                |                            |
| 4. Straw processing,    | 2.35                              | 0.75                             | 1.60                           | 68.1                       |
| Trichophyte (7 l / ha)   |                                   |                                  |                                |                            |
| HCP₀⁵                    |                                   |                                  |                                | 1.6                        |

The treatment of chopped straw with a microbiological preparation Gumistim at a dose of 5 l / ha increased the loss of linen tissue to 62.9% relative to the initial weight (figure 1).

In the variant with the use of the drug Trichophyte at a dose of 7 l / ha, the degree of decomposition of flaxseed increased to 68.1%, and the drug Mycobact at a dose of 3 l / ha - up to 75.3%

The results of the experiment (in laboratory conditions) on the effect of the degree of ramicrobiological preparations on the degree of decomposition of winter wheat straw after 60 days are presented in table 2.

The degree of decomposition of wheat straw influenced the moisture supply of crops and nitrogen regime under sugar beet.

So, in the variant with the treatment of straw with the drug Gumistim at a dose of 5 l / ha, the reserves of productive moisture in the topsoil were 33.2 mm, while the moisture reserves in the soil of the control variant were equal to 31.7 mm (table 3).
Figure 1. The degree of decomposition of linen under the influence of microbiological preparations in 90 days

Table 2. Influence of microbiological preparations on the degree of decomposition of winter wheat straw, 2016-2018.

| Options | Mass of undecomposed straw, g | Mass of residues washed from the soil, g | Washed residues in the soil before adding straw, g | Mass of decomposed straw, g | Degree of decomposition relative to the initial amount, % |
|---------|-------------------------------|------------------------------------------|-----------------------------------------------|----------------------------|-----------------------------------------------------|
| 1. Control | 23.61                         | 9.02                                     |                                               | 6.79                       | 20.8                                                |
| 2. Straw processing, Gumistim (5 l / ha) | 20.27                         | 14.82                                   |                                               | 12.59                      | 35.9                                                |
| 3. Straw processing, Mycobact (3 l / ha) | 20.81                         | 10.10                                   | 2.23                                          | 12.33                      | 39.9                                                |
| 4. Straw processing, Trichophyte (7 l / ha) | 22.25                         | 9.93                                    |                                               | 12.16                      | 37.8                                                |
| HCP<sub>0.05</sub> |                               |                                         |                                               |                            | 1.3                                                 |
Table 3. Influence of processing winter wheat straw with microbiological preparations on the reserves of available moisture in the soil (mm) before sowing sugar beet, 2017-2019.

| Fertilizer system | Horizon 0-25 cm | Horizon 0-40 cm | Horizon 0-100 cm |
|-------------------|----------------|----------------|-----------------|
| 1. Control        | 31.7           | 51.6           | 125.5           |
| 2. Straw processing, Gumistim (5 l / ha) | 33.2 | 52.1 | 127.1 |
| 3. Straw processing, Mycobact (3 l / ha) | 33.9 | 52.4 | 129.4 |
| 4. Straw processing, Trichophyte (7 l / ha) | 33.5 | 52.2 | 128.3 |
| HCP<sub>0.05</sub> | 1.1            | 1.4            | 1.6             |

In variants with the processing of winter wheat straw with microbiological preparations Trichophyte (7 l / ha) and Mycobact (3 l / ha), the reserves of productive moisture in the topsoil were 33.5-33.9 mm, or by 1.8 -2.2 mm higher than the control.

The content of nitrate nitrogen before sowing sugar beet in variants with straw treatment with microbiological preparations was 3.06-3.19 mg / 100 g of soil or by 0.52-0.65 mg / 100 g is higher than in the control variant (table 4).

Table 4. Effect of processing winter wheat straw with microbiological preparations on the content of nitrate nitrogen in the soil layer 0-40 cm (N-NO₃ content, mg / 100 g soil).

| Fertilization system | before sowing period of closing the rows | before harvest |
|----------------------|------------------------------------------|----------------|
| 1. Control           | 2.54                                     | 2.66           | 0.30           |
| 2. Gumistim (5 l / ha) straw treatment + Gumistim (5 l / ha) crop treatment in the leaf closing phase in rows + Gumistim (5 l / ha) crop treatment in the leaf closing phase in rows | 3.06 | 3.17 | 0.41 |
| 3. Mycobact (3 l / ha) straw treatment + Mycobact (3 l / ha) crop treatment in the leaf closing phase in rows + Mycobact (3 l / ha) crop treatment in the leaf closing phase in rows | 3.19 | 3.37 | 0.43 |
| 4. Trichophyte (7 l / ha) straw cultivation + Trichophyte (3 l / ha) cultivation in the phase of leaf closing in rows + Trichophyte (3 l / ha) cultivation of crops in the phase of leaf closure in rows | 3.16 | 3.33 | 0.42 |
| HCP<sub>0.05</sub>   | 0.45                                     | 0.51           | 0.72           |

Better water and nitrogen regimes in variants with a higher degree of straw decomposition had a positive effect on the yield of sugar beet. So, in the variant with the treatment of straw with the Gumistim preparation at a dose of 5 l / ha and the double treatment of sugar beet crops in the phase of closing leaves in rows (Gumistim 5 l / ha) and the phase of closing leaves between rows (Gumistim 5 l / ha) the yield of sugar beet increased by 3.5 t / ha or 6.8% in comparison with the control (table 5).

Treatment of winter wheat straw with Trichophyte at a dose of 7 l / ha and sugar beet crops in the phase of closing leaves in rows (Trichophyte 3 l / ha) and the phase of closing leaves in the aisles (Trichophyte 3 l / ha) increased the yield of root crops by 3.6 t / ha or 6.9%.

The use of the microbiological preparation Mycobact as a straw destructor at a dose of 3 l / ha and the treatment of sugar beet crops in the phase of leaf closing in rows (Mycobact 3 l / ha) and the phase of closing leaves in the aisles (Mycobact 3 l / ha) provided the maximum harvest - 4.3 t / ha or 8.3%.

The use of microbiological preparations as destructors of wheat straw and the treatment of sugar beet crops was economically beneficial (table 6).
Table 5. Influence of microbiological preparations on the yield of sugar beet, the content and yield of sugar from 1 hectare of sowing, 2017-2019.

| Options                                                                 | Productivity, t / ha | Root ratio: tops | Content sugar, % | Sugar yield, c / ha | % to control |
|------------------------------------------------------------------------|----------------------|------------------|------------------|---------------------|--------------|
| 1. Control                                                             | 51.6                 | 1:0.66           | 18.3             | 94.4                | 100          |
| 2. Gumistim (5 l / ha) + Gumistim (5 l / ha) processing of sugar beet crops in the phase of closing leaves in rows + Gumistim (5 l / ha) processing of sugar beet crops in the phase of closing leaves in rows | 55.1                 | 1:0.87           | 20.9             | 115.1              | 121.9        |
| 3. Mycobact (3 l / ha) + Mycobact (3 l / ha) treatment of sugar beet crops in the phase of closing leaves in rows + Mycobact (3 l / ha) processing of sugar beet crops in the phase of closing leaves in rows | 55.9                 | 1:0.94           | 21.2             | 118.5              | 125.5        |
| 4. Trichophyte (7 l / ha) + Trichophyte (3 l / ha) processing of sugar beet crops in the phase of closing leaves in rows + Trichophyte (3 l / ha) processing of sugar beet crops in the phase of closing leaves in rows | 55.2                 | 1:0.85           | 21.1             | 116.5              | 123.4        |
| NPS                                                                   | 0.92                 | 0.5              |                  |                     |              |

Table 6. Economic efficiency of using micro-biological preparations in the cultivation of sugar beet, 2017-2019.

| Options                                                                 | Cost of the drug, rubles, kg / l | Application rate, l / ha | Costs per hectare, rub | Productivity, t / ha | Increase in yield from the use of the drug, t / ha | Cost-most of the increase, rub. | Conditionally net income per hectare, rubles |
|------------------------------------------------------------------------|----------------------------------|--------------------------|------------------------|----------------------|--------------------------------------------------|----------------------------------|---------------------------------------------|
| 1. Control                                                             | -                                | -                        | -                      | 51.6                 | -                                               | -                                | -                                           |
| 2. Gumistim (5 l / ha) + Gumistim (5 l / ha) + Gumistim (5 l / ha)     | 120                              | 1320                     | 1320                   | 55.1                 | 3.5                                             | 3500                             | 2180                                        |
| 3. Mycobact (3 l / ha) + Mycobact (3 l / ha) + Mycobact (3 l / ha)     | 150                              | 1350                     | 1350                   | 55.9                 | 4.3                                             | 4300                             | 2950                                        |
| 4. Trichophyte (7 l / ha) + Trichophyte (3 l / ha) + Trichophyte (3 l / ha) | 120                              | 1560                     | 1560                   | 55.2                 | 3.6                                             | 3600                             | 2040                                        |

When calculating the economic efficiency of using microbiological preparations, the following indicators were taken as a basis: the cost of the drug Mycobact - 150 rubles / l, Gumistim - 120 rubles / l, Trichophyte - 120 rubles / l; the yield of sugar beet in the control variant and according to the variants of the experiment - actually obtained in the experiment; the cost of root-fruits of sugar beet - prevailing in 2019 (1 thousand rubles / t).
4. Discussion
Our calculations showed that the treatment of straw with microbiological preparations Mycobact (3 l / ha), Gumistim (5 l / ha), Trichophyte (7 l / ha) and two-fold treatment of crops with these preparations in the phase of closing leaves in rows and closing of leaves in the aisles, increased the yield of sugar beet by 3.5-4.3 t / ha and contributed to the receipt of 2180-2950 rubles of conditionally net income per hectare minus the costs associated with the actual introduction of drugs. The most cost-effective was the use of the microbiological preparation Mycobact.

5. Conclusion
As a result of the research, the high efficiency of the microbiological preparations Mycobact , Gumistim and Trichophyte in increasing the microbiological activity of the soil and decomposition of wheat straw has been established. The use of the drug Gumistim at a dose of 5 l / ha increased the loss of linen tissue to 62.9% relative to the initial weight. Straw treatment with a microbiological preparation Trichophyte at a dose of 7 l / ha increased the degree of decomposition of flaxseed to 68.1%, and with Mycobact preparation at a dose of 3 l / ha - up to 75.3%. Straw treatment with microbiological preparations Gumistim at a dose of 5 l / ha, Trichophyte at a dose of 7 l / ha, Mycobact at a dose of 3 l / ha, as well as two-fold processing of sugar beet crops in the phase of leaf closing in rows and in the closing phase leaves in row spacings Gumistim (5 l / ha), Trichophyte (3 l / ha), Mycobact (3 l / ha) increased the yield of sugar beet by 3.5-4.3 t / ha with a yield in the control variant equal to 51.6 t / ha, increased the cost of gross production by 3500-4300 rubles and given the low cost of the fertilizers themselves and the small rates of their application, it was economically profitable. The value of the conditionally net income from the use of microbiological preparations was 2040-2950 rubles / ha. The most cost-effective was the use of the microbiological preparation Mycobact.

In this regard, to increase soil biogenicity and accelerate the degree of decomposition of straw, before embedding it in the soil, microbiological preparations Mycobact (3 l / ha), Trichophyte (7 l / ha) and Gumistim (5 l / ha) should be widely used).

References
[1] Lopyrev M I, Postolov V D, Dedov A V and etc. 2010 Catalog of agricultural landscapes projects in agriculture (fertility preservation, territorial organization of farming systems, resistance to climate change) (Voronezh: Publishing house Polyart) 164
[2] Semykin V A, Kartamyshev N I, Maltsev V F, Dedov A V and etc. 2012 Biologization of agriculture in the main agricultural regions of Russia. (Moscow: Kolos) 471
[3] Kiryushin V 2012 Agronomic soil science (Moscow: Kolos) 131
[4] Dedov A V, Nesmeyanova M A and Khryukin N N 2012 Methods of biologization and reproduction of fertility of chernozems. Agriculture 6 4-6
[5] Chekmarev P A, Lukin S V 2013 Monitoring of fertility of arable soils of the Central Chernozem regions of Russia Agrochemistry 4 pp 11-22
[6] Lazarev V I, Kaznacheev M N, Aydiev A Yu, Stifeev A I and Sounin V A 2003 The effectiveness of biological products on crops (Kursk: Kursk Research Institute of Agroindustrial Production) 127
[7] Bezler N V and Cherepukhina I V 2013 Plowing of barley straw and crop productivity in grain- and-row crop rotation. Agriculture 4 11-13
[8] Kharchenko A G 2012 A new key to the restoration of soil fertility. Grain magazine 9 Retrieved from: http://www.zernoua.com/p=14127
[9] Petrov V B and Chebotar V K 2011 Microbiological preparations in practical plant growing in Russia: functions, efficiency, prospects. Chief agronomist 5 16-19
[10] Dospekhov B A 1985 Experimental methodology (Moscow: Kolos) 351