The microorganisms natural consortia effectiveness in the white cabbage crop cultivation

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Abstract. The research on effectiveness of microbial consortia with growth-regulating and anti-pathogenic functions on the yield and quality of white cabbage had been carried out in the field conditions for 2 years. It was obtained that under N₉₀P₁₂₀K₁₅₀, the use of the experimental biofungicide Tridem promoted an increase in nitrogen-fixing activity in the soil and a decrease in the infectious conditions in the rhizosphere under cabbage hybrids. The use of the experimental microbial complex BIS provided an increase in the mass of heads of cabbage, the accumulation of biologically active substances in them, and contributed to an increase in the biodiversity of soil microbiota. The combined use of the biofungicide Tridem and the microbial complex BIS stimulated an increase in yield, had a positive effect on the quality of cabbage and contributed to a decrease in the number of pathogenic fungi and bacteria in the soil under cabbage.

1. Introduction.
Increasing the productivity of agricultural crops and improving the quality of the yields are the most important problems in modern crop production, which could be solved by selecting productivity stimulants and optimizing the phytosanitary state of agroecosystems using environmentally friendly technologies of protection and plant growing stimulants. Plants in biogeocenoses represent the core of complex biological consortia and microorganisms, which includes various groups of heterotrophs, the specific microbiocenosis of phytopathogenic species and their antagonists. The biocenotic process, where the organisms of each trophic level participate, determines the stability and phytosanitary well-being of the agroecosystems. The most important part of biological protection in general is microbiological protection of plants from diseases based on biocenotic principles [1]. The induction of anti-stress activity in plants in relation to a variety of negative environmental factors is an important targeted action of biological products, and, especially, it is promising in stressful conditions for plants [2]. Of particular importance is the search for natural strains of antipathogenic microorganisms, stimulants of the vegetable crops growing, effective in low-productive agroecoses, creating conditions for normal activity in the soil microbiome.

2. Materials and methods
Field experiments were carried out in the Moscow region, Odintsovo district, at the Federal Scientific Vegetable Center (55.65°N, 37.19°E). The soil of the experimental plot is sod-podzolic heavy loamy.
The agrochemical characteristics of the arable soil layer before planting seedlings were as follows: the content of humus according to Tyurin – 1.62%, pH – 6.1, hydrolytic acidity – 1.32 meq/100 g, the amount of absorbed bases – 19.2 meq/100 g, the degree of saturation with bases – 93.6%, the content of mobile phosphorus - 472 mg/kg, exchangeable potassium - 167 mg/kg, mineral nitrogen - 9 mg/kg.

The experiment scheme: Factor A - experiment options: 1. \(N_90P_{120}K_{150}\), 2. \(N_90P_{120}K_{150} + \text{Tridem (in cassettes)} + \text{BIS (spraying)}\), 3. \(N_90P_{120}K_{150} + \text{Tridem (in cassettes)} + \text{Tridem (spraying)}\), 4. \(N_90P_{120}K_{150} + \text{Tridem (in cassettes)}\), 5. \(N_90P_{120}K_{150} + \text{BIS (seed soaking + spraying)}\), 6. \(N_90P_{120}K_{150} + \text{BIS (spraying)}\). Factor B - cabbage hybrids: 1 - F1 Zarnitsa (medium early), 2 - F1 Mechta (medium late).

The research was carried out on an intensive \((N_90P_{120}K_{150})\) fertilizer of mineral nutrition. For both hybrids variants of seed treatments with BIS, soils for growing seeds with Tridem, variants with foliar treatment of plants with fertilizers, variants with combined use of fertilizers were duplicated.

Experimental biofungicide Tridem was developed on the basis of strains of soil fungi of the genus *Trichoderma*, isolated from the soil of the experimental field of the Federal Scientific Vegetable Center, and is intended to improve fertility, natural nitrogen fixation of soils and suppress a number of phytopathogenic microorganisms when growing vegetable crops.

Microbial complex (MC) BIS consists of bacteria of the genera *Pseudomonas* and *Rhodococcus*, and soil yeast of the genus *Rhodotorula*, capable of producing physiologically active substances that increase stress resistance and productivity of vegetable crops.

White cabbage hybrids were bred at the Federal State Scientific Institution Federal Scientific Vegetable Center. For hybrid F1 Zarnitsa the average head weight is 0.8-1.8 kg, the marketable yield is 209-710 c/ha [3]. For hybrid F1 Mechta the average head weight is 2-3 kg, yield 70-80 tons per hectare [4].

Weather conditions in 2019 were defined by increased average monthly temperatures (except for July) relative to long-term, as well as low precipitation - by 37% relative to the average annual, which together had an overall negative impact on the growth and development of cabbage, but this factor was partially offset by timely use of watering. Average air temperature for the growing season in 2020 was + 15.8 °C, which is 1.0 °C higher than the average long-term data, while the maximum was observed in June - 18.7 °C, but the temperature lower than the average long-term (by 0.7 °C) in May led to a slightly later warming of the soil and a shift in the timing of transplanting seedlings. In the period from May to July, 494 mm fell, which is 2.5 higher than the average long-term values (+296 mm). At the same time, precipitation was mainly of a downpour nature, which negatively affected the development of cabbage.

Biochemical analyzes were held at the Federal State Scientific Institution Federal Scientific Vegetable Center [5]. The number of individual groups of soil microorganisms was assessed by seeding decimal dilutions on the corresponding agar nutrient media [6]. The primary identification of micromycetes and bacteria was carried out according to the indicators [7, 8].

3. Results and discussion
For plant protection, the most promising strains of microorganisms that have not only a direct targeted effect on harmful objects, but also increase the disease resistance of plants, indirectly protecting them due to the phytoregulatory activity of producer strains [9]. The holistic concept of microbiological protection involves the development and use of biological products based on live cultures of antagonist microbes with prophylactic and prolonged action, as well as preparative forms based on metabolic complexes for a rapid decrease in the population density of phytopathogens [10].

Antagonistic fungi play an important role in suppressing the development of plant diseases. Fungi have a wide range of antagonistic properties - hyperparasitism, competition for a nutrient substrate, produce antibiotics and other substances that inhibit the vital activity of phytopathogens [11]. Micromycetes *Trichoderma spp.* occupy a special position as producers of polyfunctional biofungicides synthesizing rich hydrolase complexes. They have high hyperparasitic and antagonistic activity, activity against phytopathogenic micromycetes, have a phytoregulatory effect, participate in
the decomposition of complex organic polymers, enriching the soil with nutrients available to the plant [12, 13, 14].

The bacterial-yeast complex BIS has a stimulating and anti-stress effect on plants, which is largely due to the accumulation of various physiologically active substances, in particular, amino acids during cultivation under conditions of liquid-phase fermentation. In this way, bacteria are released into the medium valine and proline. Yeast accumulates in significant amounts aspartic and glutamic acids, alanine, valine and lysine. During the experiments, it was noted, that those seeds of cabbage to had been soaked for 10 minutes in a 0.1% solution of MC BIS before sowing, had much stronger stemmed seedlings and roots on 45-55% longer and thicker, in comparison with the cabbage seedlings from other options, for both tested hybrids. The assessment of the infectious conditions of the soil in the experiment with two hybrids of white cabbage was carried out during the head harvesting. Under conditions with mineral nutrition, the diversity of pathogenic microorganisms in the soil by the end of the growing season was significant. Bacteria Xanthomonas spp. and Pseudomonas spp. causing vascular and mucous bacteriosis, have been found in the rhizosphere zone of hybrid F1 Zarnitsa. From micromycetes, Cladosporium, Botrytis, Alternaria, Fusarium, Sclerotinia were found. In the rhizosphere of the hybrid F1 Mechta the pathogenic microbiota was smaller in number and less diverse, but causative agents of bacteriosis also dominated in number. From micromycetes, Cladosporium, Alternaria, Fusarium were found. Soil treatment for sowing with biofungicide Tridem contributed to the absence of representatives of Xanthomonas spp. In the rhizosphere of both hybrids; Cladosporium and Alternaria were found from pathogenic micromycetes, but in insignificant quantities. The growth of dilutions on nutrient media showed that, despite the presence of pathogens in the soil of this variant, fungi of the genus Trichoderma completely suppressed the pathogenic microbiota 5-8 days after the onset of development. In variants with soaking seeds in a solution of MC BIS, the conditions of pathogenic microbiota in the rhizosphere of cabbage remained high and was comparable to the control variant. However, the biodiversity of soil microflora was significant, that in turn weakened the effect of pathogenic microbiota and, ultimately, reflected at the state of cabbage - losses from diseases decreased by 20-25% from control.

The most favorable biological state of the soil was characterized by the variant with soil cultivation with Tridem and foliar treatment of plants with BIS under conditions with the high biodiversity of soil microorganisms a decrease in the diversity and occurrence of pathogenic bacteria and micromycetes was noted. On the total yield (Table 1), cabbage processing methods were reflected in the following way. The greatest productivity was observed in variants with combined treatments by both consortia. Joint seed treatment with foliar treatment of plants in the field with 0.1% BIS solution gave an increase in yield for both hybrids, in comparison with variants without the drug. Soil treatment in cassettes with biofungicide Tridem had a stimulating effect on the increase in yield to a lesser extent than the combined treatment with spraying plants in the field with the biological preparation Tridem, but still more than without biofungicide for both hybrids.

| Table 1. White cabbage yield, t/ha. |
|-------------------------------------|
| Hybrid (factor A) | Variant (factor B) | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|-------------------|-------------------|---|---|---|---|---|---|---------|
| 1                 | 28.1              | 32.4 | 28.9 | 26.7 | 31.6 | 29.10 | 29.5 |
| 2                 | 35.8              | 45.5 | 45.6 | 43.0 | 45.5 | 43.4 | 43.1 |
| Average           | 32.0              | 39.0 | 37.3 | 43.0 | 34.9 | 38.6 | 36.3 |

LSD_{0.05} t/ha: factor A – 0.163; factor B – 0.184; AB interaction factor – 0.306
LSD_{0.05}: factor A - 2.6, factor B - 3.4, partial differences - 4.5

Seed treatment with rhizosphere diazotrophs could increase the biomass of roots, increase the supply of nutrients to the root system, and stimulate seed germination due to the production of biologically active substances such as vitamins, auxins, gibberellins and inhibition of the development of pathogenic microflora [15–18].
The concentration of vitamin C for F1 Zarnitsa is higher than for F1 Mechta, in all variants. Spraying of plants in the field with MC BIS promoted the greatest accumulation of vitamin C, relative to other treatment options, for both hybrids. The variant with the treatment of the soil for seedlings with biofungicide Tridem and the subsequent spraying of the plants in the field gave a lower accumulation of vitamin C relative to the other treatment options, but more relative to the background control (Table 2).

Table 2. Vitamin C content in white cabbage, mg/100 g.

| Hybrid (factor A) | 1   | 2   | 3   | 4   | 5   | 6   | Average |
|------------------|-----|-----|-----|-----|-----|-----|---------|
| 1                | 22.3| 24.7| 23.4| 25.4| 25.8| 26.5| 24.7    |
| 2                | 21.2| 23.6| 23.4| 23.7| 23.7| 24.2| 23.3    |
| Average          | 21.8| 24.2| 23.4| 24.6| 24.8| 25.4|         |

LSD: factor A - 1.5, factor B - 1.9, partial differences - 2.5

The accumulation of nitrates in the heads of cabbage of the hybrid F1 Zarnitsa is higher than in the heads of the hybrid F1 Mechta, but at the same time for both hybrids the value did not exceed the threshold limit value (TLV) 900 mg/kg for early varieties of white cabbage and 500 mg/kg for late-ripening varieties of white cabbage (Table 3). The smallest accumulation of nitrates was recorded in the variant with combined treatment of seeds and plants with a solution of BIS in the field. The greatest accumulation of nitrates was noted in the variant with the combined treatment with the Tridem preparation of the soil in cassettes with spraying of plants in the field. In other options using the drug Tridem, the indicator is also higher, in contrast to options that do not include the drug Tridem. This may be a consequence of the intensification of the supply of nitrate nitrogen to cabbage plants during treatment with this preparation, but the nitrogen-fixing properties of the preparation itself could lead to an increase in the total nitrogen in the soil during the growing season.

Table 3. Content of nitrates in cabbage heads, mg/kg.

| Hybrid (factor A) | 1    | 2    | 3    | 4    | 5    | 6    | Average |
|------------------|------|------|------|------|------|------|---------|
| 1                | 140  | 148  | 196  | 152  | 140  | 144  | 153     |
| 2                | 134  | 142  | 151  | 149  | 117  | 143  | 139     |
| Average          | 137  | 145  | 174  | 151  | 129  | 144  |         |

TLV of nitrates for early cabbage - 900 mg/kg, for late 500 mg/kg

The mass fraction of fiber in the hybrid F1 Mechta is almost 2 times higher than in the F1 Zarnitsa hybrid, in the variants with treatments it is higher than in the controls in both cultures (Table 4). The highest rates are typical for variants with foliar treatments with both fertilizers.

Table 4. Mass fraction of fiber in white cabbage, % in wet weight.

| Hybrid (factor A) | 1     | 2     | 3     | 4     | 5     | 6     | Average |
|------------------|-------|-------|-------|-------|-------|-------|---------|
| 1                | 0.40  | 0.39  | 0.47  | 0.33  | 0.44  | 0.46  | 0.41    |
| 2                | 0.72  | 0.74  | 0.91  | 0.74  | 0.79  | 0.71  | 0.77    |
| Average          | 0.56  | 0.56  | 0.69  | 0.53  | 0.61  | 0.58  |         |

4. Conclusion
Field researches of the effectiveness on white cabbage hybrids of the separate and combined action of the experimental biofungicide Tridem and the microbial complex of the stimulating effect of BIS have been carried out in the Non-Chernozem zone of Russia. Experiments have shown that the use of
biofungicide Tridem is effective for suppressing causative agents of bacteriosis in cabbage and reducing the number of pathogenic micromycetes, which is especially important for varieties of early ripening. The use of MC BIS significantly increases the yield of white cabbage, both early and late ripening, has a beneficial effect on the biochemical composition of cabbage, and also reduces the activity of pathogens by stimulating the biodiversity of soil microbiocenosis, and accordingly increases competition within the soil microbiome. The combined use of new consortia enhances the positive effects of biofungicide and biostimulant.

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