Achieving the balance of macronutrients with the No-till technology in the cultivation of agricultural crops with microbiological fertilizers

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Abstract. The current research provides data on the change in the agrochemical parameters of soils with the No-till technology. The results, obtained from the agrochemical examination of the farm's soils, show that the No-till technology reduces the degradation processes in the soils. In the soils of land plots where the No-till technology is applied, the nutrients are differentiated according to the conditions, while an increase in the content of macronutrients in the upper fifteen-centimeter soil layer is observed. In terms of the content of microelements, no clear differentiation in soil depth was found over a ten-year period. An analysis of the data obtained on the application of microbiological fertilizers on the content of nutrients in plants during the period of their maximum accumulation suggests that there is a slight increase in the nitrogen content in plants. The greatest effect on this indicator was revealed with the combined application of the following fertilizers: Azotovit, Fosfotovit (an increase of 0.51%), and BioAzFK (an increase of 0.22%). The yields of spring wheat with the application of microbiological fertilizers increased by 12.0-45.0%. Under the conditions of the pesticidal seed treatment with the fertilizers containing tebuconazole, fluxaproxade, and thiamethoxam, the yields increased by 19.0-38.0%.

1. Introduction
Currently, in the world, the No-till technology is recognized as the highest level of minimization in soil cultivation and sowing. This system is an agricultural practice and a distinct way of thinking about sustainable agro-ecosystem management. No-till farming is a resource-saving technology for the cultivation of agricultural crops without any soil cultivation, except for sowing. Under the No-till system, the influence of nature and climate is reduced to 20%, and 80% is accounted for technologies and management in agriculture [1, 2].

Over the past 50-60 years in the countries, where the intensive technologies for the cultivation of agricultural crops have been developing, the soil fertility of agricultural lands has deteriorated more than twofold. Traditional methods of intensive tillage sooner or later would lead to a decrease in the soil humus, a decrease in soil biological activity and (or) erosion up to soil degradation, as well as a decrease in yields [3].

Zero tillage or Direct drilling (No-till) has a number of environmental and economic advantages, however, it implies significant changes in the farming system. Maximum preservation of plant residues on the surface and minimization of the number of soil treatments would inevitably lead to shifts in all processes in agrobiocenosis, including biocenotic, which determine the phytosanitary
situation in crops. Several scientists consider that the transition from plowing crop residues to leaving them would exacerbate the problem of agricultural phytophages [4, 5].

The No-till technology preserves soil nutrients and promotes better absorption of nitrogen, phosphorus and potassium by plants, which leads to an increase in the economic efficiency with application of fertilizers [5].

When growing crops with the use of no-till farming, it is very important to pay attention to environmental safety. With zero technologies, all activities are carried out with the use of chemicals. This is a required seed treatment with chemicals in pre-sowing of continuous herbicides application. After that it would be necessary to treat crops with mixtures consisting of herbicides and insecticides. An increase in the doses of pesticides used leads to a number of serious negative consequences: pollution of the atmosphere and waters, accumulation of chemicals in food, feed, and soil, the emergence of pesticide-resistant forms of pests, unpredictable effects on wild animals and birds [6].

Modern intensive crop production is impossible without the use of fertilizers, regulators of plant growth and ontogenesis, control of the number of pests and beneficial micro- and macroorganisms. It is very difficult to completely abandon the use of chemistry in agriculture. However, an alternative way is the application of microbiological fertilizers and biofungicides [7].

Compared to chemical plant protection products - pesticides, biological products: are safe or low toxic for humans and the environment; do not violate natural bonds in the biocenosis; have a selective effect, and do not contribute to the emergence of resistance in insects [8].

2. Materials and methods

The aim of the research was to observe and define the influence of the No-till technology on the change in the agrochemical composition of soils, the effect of microbiological fertilizers on the availability of nutrients from the soil and the productivity of spring wheat.

To examine the effect of microbiological fertilizers on the availability of nutrients and the productivity of spring wheat, the current research was carried out at LLC “Kameshkirsiki Feed Mill” (Russia, Penza region, Kameshkirsiki district). The data from the agrochemical soil examination (in 2010 and 2020) at the LLC “Kameshkirsiki Feed Mill” was used to define the effect of long-term No-till technology application on the change in agrochemical parameters of soils. The No-till technology has been successfully applying on the farm since 2011.

The analysis of microbiological fertilizers under the conditions of LLC “Kameshkirsiki Feed Mill” was organized on the reference plots in 2020-2021. The following Russian microbiological fertilizers and biofungicides were used:

**Azotovit** is a microbiological fertilizer based on living bacteria with nitrogen-fixing properties. The content of the bacterium *Azotobakter chroococcum* in the fertilizer of living strains B-9029 reaches 5 billion/cm³ (solution 5×10⁹ CFU/g);

**Phosphatovite** is a microbiological fertilizer containing 120 mln/cm³ (solution 0.12×10⁹ CFU/g) of living material of strain B-8966 bacteria *Bacillus mucilaginosus* Bac 10 and beneficial microorganisms of soil microflora;

**BioAzFK** is a microbiological fertilizer for improving nitrogen, phosphorus and potassium nutrition with anti-stress, growth-accelerating, immunostimulating properties. The content includes:
- Nitrogen-fixing bacteria *Azotobacter chroococcum*, titer not less than 1×10⁷ CFU/ml;
- *Bacillus megaterium* phosphorobilizing bacteria, titer not less than 1×10⁸ CFU/ml;
- Phosphorus- and potassium-mobilizing bacteria *Bacillus mucilaginosus*, titer not less than 1×10⁶ CFU/ml;
- Natural polysaccharides, phytohormones, vitamins;

**Fitosporin-M** is a biofungicide, the main active ingredient is a living spore bacterium *Bacillus subtilis* (hay bacillus);

**Biocomposite-correct** is a microbiological fertilizer, is a suspension in the culture liquid of a consortium of highly effective strains of different types of bacteria. The fertilizer contains living bacteria and products of their metabolism;
**Organit N** is a microbiological fertilizer, contains *Azospirillum zeae* VKPM B-12542 (titer not less than $1 \times 10^9$ CFU/ml);

**Organit P** is a microbiological fertilizer, contains viable spores of *Bacillus megaterium* VKPM B-12463 (at least $1 \times 10^9$ CFU/ml)

**Organica S** is a biofungicide, contains spores of *Bacillus amyloliquefaciens* VKPM B-12464 (titer not less than $5 \times 10^9$ CFU/ml)

**Biodux** is a growth regulator arachidonic acid, the composition includes a complex of biologically active polyunsaturated fatty acids of the fungus *Mortierella alpina*.

These fertilizers were used for seed treatment and spraying during the growing season in the tillering phase. The experiments were carried out in the cultivation of a zoned variety of spring wheat under conditions of the Penza region.

### 3. Results and discussion

Analysis of the agrochemical examination shows that over a ten-year period with the use of No-till technology in the farm, such indicators as the content of humus, alkaline hydrolysable nitrogen, mobile forms of phosphorus and potassium in the average fields of the farm have been improved (Table 1).

**Table 1.** Changes in soil agrochemical parameters under the influence of the No-till technology.

| Plot (field) number | Changes over 10 years (2010-2020) | Humus, % | Alkaline hydrolysable nitrogen mg/kg soil | Mobile phosphorus, mg/kg soil | Mobile potassium, mg/kg soil | pHKCl |
|---------------------|-----------------------------------|----------|------------------------------------------|-------------------------------|-------------------------------|-------|
| 1                   | 0.25                              | 44.4     | 11.5                                     | 49.0                          | -0.06                         |       |
| 2                   | 0.44                              | 1.1      | -14.4                                    | 4.1                           | -0.10                         |       |
| 3                   | -0.14                             | 34.7     | 35.4                                     | 3.7                           | 0.04                          |       |
| 4                   | 0.28                              | 37.0     | -6.8                                     | 3.7                           | -0.25                         |       |
| 5                   | 0.91                              | 34.3     | 9.3                                      | 1.5                           | -0.02                         |       |
| 6                   | -0.03                             | 19.8     | 5.2                                      | -12.1                         | -0.15                         |       |
| 7                   | 0.83                              | 28.0     | -10.2                                    | 15.8                          | 0.35                          |       |
| 8                   | 0.78                              | 17.2     | 33.2                                     | 11.4                          | 0.17                          |       |
| 9                   | 0.83                              | 21.3     | 6.1                                      | 25.6                          | 0.18                          |       |
| 10                  | 0.44                              | 46.2     | -9.2                                     | 12.8                          | -0.15                         |       |
| 11                  | 0.50                              | 32.1     | 5.9                                      | 13.0                          | -0.12                         |       |
| 12                  | 0.40                              | 30.7     | -5.6                                     | 30.0                          | -0.17                         |       |
| 13                  | 0.45                              | 32.5     | 5.0                                      | 18.0                          | -0.10                         |       |
| Average             | 0.42                              | 29.2     | 5.0                                      | 12.9                          | -0.03                         |       |

For some fields (plots) of the farm, in 2020 there was a decrease in the humus content to 0.25% compared to the data of 2010, which was due to the fact that the No-till technology was introduced in these fields in 2015-2016. For the rest of the fields, there is a positive dynamics of an increase in the humus content to 0.91%. The content of alkaline hydrolysable nitrogen, as the most potentially available form, increased in all fields. The increases ranged from 1.1 to 46.2 mg/kg soil. Changes in the content of mobile phosphorus were associated with the use of phosphorus fertilizers in the cultivation of crops on the farm. In some fields, a decrease in the content of mobile phosphorus to 14.4 mg/kg was observed. In turn, in some fields, the content of this element increased by 5.0-35.4 mg/kg soil. A decrease in the content of mobile potassium was obtained only in two fields, which was due to the fact that during the survey period in 2020, sunflowers were cultivated on these plots and characterized by a high removal of potassium from the soil by the vegetative mass. The increase in mobile potassium on average in the fields of the farm was 12.9 mg/kg of soil. According to the agrochemical survey, it could be seen that the acidity of the soil was stable. The average indicator over a ten-year period decreased by 0.03, which was below the index of the possible error.

In 2020-2021 the processes of nutrients migration along the soil profile of reference plots were examined. The obtained results shown a clear differentiation of the available macronutrients in soils,
The content of macronutrients in spring wheat plants was estimated depending on the use of various microbiological fertilizers and biofungicides. Studies have shown that the use of microbiological fertilizers immobilizes nitrogen compounds in the soil and increases the availability of this element from the soil. A high activity of nitrogen absorption from the soil was observed when using such microbiological fertilizers as the combined use of Azotovit and Phosphatovit (an increase of 0.51%) and BioAsPK (an increase of 0.22%). For the other fertilizers, an increase in the nitrogen content in plants is observed in comparison with the option without microbiological fertilization at the level of 0.04-0.11%. There were no clear changes in the content of phosphorus and potassium in spring wheat plants compared to the control (Table 2).

| Option | N, % | P, % | K, % |
|--------|------|------|------|
| 1. Without microbiological fertilizers (control) | 1.27 | 0.57 | 0.61 |
| 2. Azotovit + Phosphatovit | 1.78 | 0.54 | 0.62 |
| 3. BioAzPK | 1.49 | 0.55 | 0.60 |
| 4. Fitosporin-M | 1.31 | 0.59 | 0.62 |
| 5. Biocomposite-correct | 1.33 | 0.53 | 0.62 |
| 6. Organit N + Organit P + Organica S (biofungicide) + Biodux (growth stimulator) | 1.36 | 0.58 | 0.61 |

Grain yields of spring wheat in experiments cultivated using the No-till technology, under the conditions of the growing seasons of 2020-2021 ranged from 1.91 in the control to 2.78 t/ha. The highest grain yield was obtained in the option with the combined use of Azotovit and Phosphatovit. Deviations from the control group were 0.87 t/ha. High efficiency was observed when seeds were
treated with Phytosporin and BioAsPK; the increments relative to the control were 0.55 and 0.70 t/ha, relatively (Table 3).

**Table 4.** Spring wheat productivity depending on the use of microbiological fertilizers and pesticides with the use of the No-till technology (average data for 2020-2021).

| Option | Grain yields, t/ha | Control deviations, t/ha | Weight of 1000 grains, g |
|--------|---------------------|--------------------------|--------------------------|
|        | 1<sup>a</sup> | 2<sup>b</sup> | 1 | 2 | 1 | 2 |
| 1. Without microbiological fertilizers (control) | 1.91 | 2.21 | 0.30 | 35.2 | 35.8 |
| 2. Azotovit + Phosphatovit | 2.78 | 2.60 | 0.87 | 0.69 | 37.5 | 37.9 |
| 3. BioAzPK | 2.61 | 2.65 | 0.70 | 0.74 | 37.8 | 35.9 |
| 4. Fitosporin-M | 2.46 | 2.77 | 0.55 | 0.86 | 37.8 | 39.6 |
| 5. Biocomposite-correct | 2.14 | 2.33 | 0.23 | 0.42 | 35.9 | 35.4 |
| 6. Organit N + Organit P + Orgamica S (biofungicide) + Biodux (growth stimulator) | 2.39 | 2.76 | 0.48 | 0.85 | 35.3 | 38.5 |

LSD 0.15 0.22 0.9 0.11

<sup>a</sup> - without the pesticidal seed treatment before sowing
<sup>b</sup> - with the pesticidal seed treatment before sowing (Stinger, KS (tebuconazole), Sistiva (fluxapioxad), Tiara (thiamethoxam))

The use of microbiological fertilizers with the pesticide seed treatment increased the yields of wheat by 0.42-0.85 t/ha. At the same time, the highest yield was with the combined use of Organit N and Organit P microbiological fertilizers, Orgamic S biofungicide and Biodux growth stimulator, and with Fitosporin-M. A significant increase in yields with the pesticidal treatment was observed within the application of biofungicides such as Fitosporin-M and Orgamica S, which indicates the compatibility of these fertilizers with the pesticides tebuconazole, fluxapioxad and thiamethoxam. The effect of the combined use of Azotovit and Phosphatovit with the pesticidal seed treatment was lower than the application of these fertilizers in their pure form (Table 4).

4. Conclusion

The current research, aimed at examining the influence of the No-till technology on the agrochemical properties of soils, has revealed the positive effect of this technology on the content of humus, nitrogen, phosphorus and potassium reserves in the soil. At the same time, there is a bioaccumulation of macroelements in the upper soil layer, which is associated with their removal by plant roots from deep-lying layers and the absence of soil mixing by tillage tools. Microbiological fertilizers had a positive effect on the accumulation of nitrogen in plants during the period of their maximum consumption, which indicates an increase in the degree of availability of this element by microorganisms contained in the examined fertilizers. The positive effect of microbiological fertilizers on the yields of spring wheat, both in pure form and with the use of pesticide seed treatment, was observed.

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