Biologization of growing grain crops technology

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Abstract. The use of biologics and preparations based on amino acids (Krokus universal) for protection against diseases, as well as entomopathogenic microorganisms against pests is one of the main directions in the biologization of technology for growing cereal crops. The research was carried out in 2018-2020 on the basis of the Kuban State Agrarian University. The object of the study was the wheat and barley varieties, as well as oats. As microbiological agents, cultures of microorganisms from the collection were used: Trichoderma viride and T. lignorum, Beauveria bassiana, Metarhizium anisopliae, Azotobacter chroococcum, Bacillus megatherium, Bacillus thuringiensis, Pseudomonas fluorescens. To suppress the pathogens of bacteriosis and stimulate the growth processes of plants, the preparation based on the essential amino acids Crocus universal was used. The results of research have shown that this method is not inferior in biological effectiveness to chemical protection and even have advantages. The systematic use of biologics on cereal crops turned out to be appropriate. It provided the increase in the suppressiveness and fertility of the soil, the suppression of various pathogens and pests on winter wheat crops, the reduction in the amount of pesticides introduced, as well as high economic efficiency.

1. Introduction
The most important direction of the agricultural complex development in the Russian Federation is the stabilization of grain production [1].

The government set a task to increase the gross grain harvest to 150 million tons per year in the coming years, and thus increase grain exports by half [2]. Winter wheat, in turn, is a strategically important grain crop, which occupies more than 80% of the all-Russian loaf and export grain potential [3, 4].

In this situation, innovative methods, including biological techniques based on microbiological preparations, are needed to allow grain crops not only to survive, but also to give stable productivity at the high level [5, 6].

The yield of grain crops is affected by many natural and anthropogenic factors, so to increase the productivity of winter wheat, great attention is paid to a well-developed and properly organized technology of its cultivation, new methods of pre-sowing seed treatment with modern biological products that stimulate plant growth, improve the sowing quality of seeds, and increase productivity [7].

The use of microbiological preparations to protect plants from diseases and pests ensures the production of environmentally friendly agricultural products. Currently, 60 biological products are allowed to be used in Russia to protect plants from a number of diseases and pests [8]. However, to achieve high biological and economic efficiency, a systematic approach to biosecurity technology is required [9]. An important place in it is the inclusion in the system of preparations based on essential amino acids for the...
regulation of plant growth and development, as well as the possibility of triggering plant immunity to pathogens of bacterial diseases Pseudomonas syringae and Xanthomonas arboricola [10].

2. Materials and methods
The research was conducted in 2018-2020 on the basis of the Kuban state agrarian university. The object of the study was the varieties of wheat and barley, as well as oats, approved for use in Russia. Cultures of microorganisms from the collection: Trichoderma viride and T. lignorum, Beauveria bassiana, Metarhizium anisopliae, Azotobacter chroococcum, Bacillus megatherium, Bacillus thuringiensis, Pseudomonas fluorescens, were used as microbiological agents. To suppress pathogens of bacterial diseases and stimulate plant growth processes, the preparation based on the essential amino acids Krokus universal (11 g/t of seeds or 11 g/ha) was used. The chemicals are used as the reference: fungicides (Maxim for seed inoculation, Alto super for crop treatment), and insecticide – Imidor Pro with the consumption rates recommended by the manufacturers of drugs.

Vegetation experiments and field experiments were carried out in 4 repetitions on the basis of the Small Innovative Enterprise "Kuban Agrotechnologies" at the Kuban State Agrarian University.

Variants of seeds inoculation experiments:
- Biological protection (complex of biologics Trichoderma viride, Metarhizium anisopliae, Azotobacter chroococcum, Bacillus megatherium);
- Chemical protection (fungicide);
- Control.

Options for plant protection during the growing season:
- Biological protection (complex of biologics T. viride, Beauveria bassiana, Metarhizium anisopliae, Azotobacter chroococcum, Bacillus megatherium, Bacillus thuringiensis, Pseudomonas fluorescens);
- Chemical protection (fungicide + insecticide);
- Control.

The treatment of plant residues was carried out at night (with simultaneous incorporation into the soil) with a complex of biologics developed by us earlier (Kotlyarov, 2018): T. viride and T. lignorum, Metarhizium anisopliae, Azotobacter chroococcum, Bacillus megatherium.

3. Results and discussion
One of the main elements of the biologized system of plant protection from diseases and pests is the treatment of plant residues by microbiological preparations [10]. Further research in this direction showed not only the decrease in the number of phytopathogenic microorganisms, but also a shift in the composition of the soil microbiota towards its suppressive part in variants where this work was carried out for 3-7 years. Mycological analysis of soil samples for the presence of Trichoderma Viridae, as well as other saprotrophic microorganisms showed the increase in their number in the soil after prolonged treatment of plant residues with microbiological preparations. Thus, in field 6/2, where such treatments were carried out only for 2 years, pathogenic microbiota dominated, and in fields 7/1 and 7/3, where plant residues were treated for 7 years (to populate them with suppressive microbiota and suppress soil-dwelling pests), suppressive microorganisms prevailed (Figure 1). At the same time, the frequency of occurrence in all soil samples among saprotrophs was dominated by fungi of the genera Trichoderma and Aspergillus (Figure 2), and fungi of the genera Fusarium and Alternaria were isolated in equal proportions in the pathogenic complex (Figure 3).
Figure 1. Structure of the fungal soil complex in the precursor soil samples (2012-2018).

Figure 2. Structure of the saprotrophic complex of fungi in soil samples of the precursor (2012-2018).

Figure 3. Structure of pathogenic fungal complex in soil samples of the precursor (2012-2018).

Treatment of plant residues with biologic preparations provided not only a positive dynamic in the ratio of pathogenic and suppressive microbiota, but also had a positive impact on soil fertility. Thus, the results of agrochemical analyses carried out on 9 fields at the beginning of the period and at the end of the four-year application of such stubble treatments revealed the increase in the content of humus, nitrogen, mobile forms of phosphorus and potassium (Table 1). At the same time, the content of humus in the soil increased by 0.04 %, nitrogen – by 10.1 units, mobile phosphorus – by almost 1.3 times, mobile potassium – by more than 1.2 times.
Table 1. Indicators of soil fertility under the influence of plant residues biological treatment (2012-2015).

| Content of fertility elements in the soil | Years of research | 2012 | 2015 |
|------------------------------------------|-------------------|------|------|
|                                          | average | range | average | range |
| Humus, %                                 | 3.81     | 3.7-3.9 | 3.85     | 3.8-3.94 |
| Nitrogen, un.                            | 27.5     | 24.3-28.2 | 37.6     | 34.5-44.7 |
| Phosphorus, un.                          | 36       | 27-45 | 45.9     | 41-51 |
| Potassium, un.                           | 464      | 424-496 | 568     | 547-595 |

It should be noted that in other production tests, similar data were obtained on the content of humus in the soil in 2007 – 3% (before the start of stubble treatments by biologics) and in 2012 (for the 4th year of application of biologics treatments) – 3.05% (Rostov region, Aksay district, LLC “Aksayskaya Zemlya”). The increase in the nitrogen content in the soil was also detected (Krasnodar region, Kalininsky district, LLC “Zemlya”) – 2 units in 2017 (the beginning of the use of stubble treatments with biologics), 8 units in 2018 and 26 units in 2019.

Using the results obtained to calculate the doses of fertilizers (taking into account their actual presence in the soil) can help reduce costs by reducing the rate of consumption of their application.

As the rule, considerable attention is paid to seed processing. On the seeds, pathogens of bacteriosis, fusariosis, helminthosporiosis, alternariosis and smut species can occur. Thus, phytoexpertize of grain crops seeds from different regions of Russia (2017-2019), showed high infection with pathogens of alternariosis, fusariosis and bacteriosis (Table 2).

Table 2. Percentage of infected seeds with pathogens (2017-2019).

| Culture       | Variety   | Region           | Fusariosis | Alternariosis | Bacteriosis |
|---------------|-----------|------------------|------------|---------------|-------------|
| Winter wheat  | Vassa     | Crimea           | 5          | 65            | 5           |
| Winter wheat  | Gubernator Dona | Crimea     | 0          | 30            | 5           |
| Oat           | Romans    | Bashkiriya region | 5         | 90            | 5           |
| Winter barley | Bazalt    | Krasnodar region | 0          | 35            | 0           |
| Winter wheat  | Grom      | Krasnodar region | 0          | 12.5          | 0           |
| Spring wheat  | Chelyaba   | Chelyabinsk region | 20        | 70            | 0           |
| Spring wheat  | Yubileynaya | Chernozemo-Uralskaya | 15       | 65            | 15          |
| Winter wheat  | Irishka   | Stavropol region | 0          | 10            | 5           |
| Winter wheat  | Adel      | Stavropol region | 0          | 50            | 5           |
| Spring wheat  | Boyevchanka | Kurgan region    | 0          | 50            | 20          |
| Oat           | Sprint    | Bashkiriya region | 5         | 60            | 20          |

Therefore, when seed treatment fungicides are mainly used, which inhibit the emergence of seedlings, growth processes, and also negatively affect the soil microbiota and are not effective against bacterial diseases.

The results of laboratory experiments showed (Table 3) that the use of the tank mixture Agrobiovit + Krokus universal for wheat seeds treatment is more effective (if there is no smut infection on the seeds) compared to the standard one (Maxim preparation).
Table 3. Effect of wheat seed treatment by Agrobiovit + Krokus universal on wheat seedlings biometric indicators (laboratory experiments, 2014-2018).

| Experiment option | Agrobiovit + Krokus universal | Fungicide Maxim | Control | LSD₀.₀₅ |
|-------------------|-------------------------------|----------------|---------|---------|
| Root length, cm   | 14.1                          | 10.3           | 10.6    | 0.5     |
| Sprout length, cm | 9.3                           | 8.7            | 7.8     |         |

The biological protection of grain crops against diseases in early spring was effective while treating them by a tank mixture on Krokus universal + Agrobiovit (Table 4).

Table 4. Immunological characteristics of plants in 10 days after treatment of the Tanya variety winter wheat crops by a tank mixture of Krokus universal and Agrobiovit (field experiments, 2015-2019).

| Crop processing option | Leaf damage by Septoria, % | Damage by root rot, % |
|------------------------|-----------------------------|----------------------|
|                        | disease development | disease prevalence | disease development | disease prevalence |
| Control                | 23-37                     | 70-100               | 40–50               | 85–95               |
| Krokus universal + Agrobiovit | 5-15                     | 27-33               | 7–8                | 9–11               |
| Fungicide Alto super  | 3-12                      | 25-34               | 11–19              | 43–52              |

This treatment suppresses pathogens of root rot, as well as leaf spots. In addition, it improves the biometric parameters of plants and increases the content of chlorophyll in leaves during the tillering phase (Table 5).

Table 5. Effect of the Tanya variety winter wheat crops processing by tank mix Krokus universal and Agrobiovit on biometric parameters and chlorophyll content in the plants leaves (field experiments, the phase of tillering, secondary 2015-2019).

| Crop processing option | Plant height, cm | Root length, cm | Number of shoots tillering, pcs/plant | Chlorophyll content, mg/dm² |
|------------------------|------------------|----------------|--------------------------------------|-----------------------------|
| Control                | 7.4              | 6.2            | 1.3                                  | 4.3                         |
| Krokus universal + Agrobiovit | 10.1          | 10.5           | 3.5                                  | 5.9                         |
| Fungicide Alto super  | 9.3              | 8.6            | 2.5                                  | 5.1                         |
| LSD₀.₀₅                | 0.8              | 0.2            | 0.2                                  | 0.4                         |

The increase in plant productivity led to a significant increase in yield in the variant with the use of biological plant protection relative to other options (Table 6).
Table 6. Grain yield (t/ha) of the Tanya variety winter wheat under the influence of biologized plant protection (field experiments).

| Crop processing option            | 2015 | 2016 | 2017 | 2018 | 2019 | Average |
|-----------------------------------|------|------|------|------|------|---------|
| Control                           | 5.1  | 4.7  | 6.6  | 6.7  | 6.5  | 5.9     |
| Krokus universal + Agrobiovit     | 6.9  | 6.7  | 8.8  | 7.9  | 7.8  | 7.6     |
| Fungicide Alto super              | 6.7  | 6.6  | 7.9  | 7.2  | 7.1  | 7.1     |
| LSD<sub>05</sub>                  | 0.3  | 0.2  | 0.3  | 0.3  | 0.2  | 0.3     |

The use of biological plant protection in agrotechnology showed a significant advantage over other options (Table 7), due to a significant increase in profit by more than 2 times (compared to the control one) and low cost and high return on additional costs.

Table 7. The use of biological plant protection in the Tanya variety winter wheat cultivation impact on economic indicators (average for 4 years).

| Economic performance              | Control       | Biologic protection | Chemical protection |
|-----------------------------------|---------------|---------------------|---------------------|
| Yield, t/ha                       | 5.9           | 7.6                 | 7.1                 |
| Selling price, ₽/t                | 8500          |                     |                     |
| Total cost of products, ₽/ha      | 50150         | 64600               | 60350               |
| Cost of preparation, ₽/ha         | -             | 180                 | 720                 |
| Cost price of products, ₽/ha      | 37900         | 38080               | 38320               |
| Payback for additional costs, ₽/ha| -             | 79.3                | 13.6                |
| Profit, ₽/ha                      | 12250         | 26520               | 22030               |

4. Conclusions
The results of laboratory and field experiments on the study of plants biological protection from diseases and pests showed that these methods are not inferior in biological effectiveness to chemical protection and even have advantages. The systematic use of biologics on cereal crops (while treating seeds and crops by Krokus universal and Agrobiovit preparations, as well as plant residues with biologics) proved to be appropriate. It provided a significant increase in the suppressiveness and fertility of the soil, the suppression of various pathogens and pests on winter wheat crops, reducing the number of pesticides introduced, as well as high economic efficiency.

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