Productivity, quality and efficiency of spring durum wheat cultivation when treating crops with a biological product

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Abstract. The production experiments were carried out based on the farm "Yaroslav the Wise" of the Starooskol district of the Belgorod region. The article studies the effect of the biological product Biogor KM during the pre-sowing treatment of grain in combination with double spraying of growing plants of spring durum wheat Dar Chernozemya 2. One of the experiments provides for grain processing with the period of "germination-ripening" of its wheat plants reduced by 8 days. The second variant, in addition to processing the grain, had two sprayings carried out during the growing season. The second experiment lasted even less by 12 days in comparison with the control variant. The article establishes the positive influence of the biological product on the formation of the productivity structure of spring durum wheat plants. Grain processing in combination with spraying during the growing season led to the formation of the best productivity structure: plant height was 39% higher, the number of spikelets was 41.8% higher, the number of spikelets was higher by 35.3%, and the grain weight per spike was 39.2% versus the control variant. The yield in the experiment was in direct proportion to the method of application of the biological product and the conditions of the growing season. The largest increase in yield - 0.40 t / ha or 14.5% was obtained in the variant with grain processing in combination with double spraying of plants during the growing season, the average yield for the studied period was 3.14 t / ha and was maximum, indicators of economic and bioenergy efficiency was also the best.

1. Introduction

For domestic crop production, each agricultural season poses certain risks of not receiving the yield of all agricultural crops. The main impact on the harvest, as a rule, is predetermined by climatic features, reserves of technology for cultivating crops, and the economic capabilities of the economy. The unstable situation on the market of fuels and lubricants, fertilizers, components, plant protection products, and other means of production causes the impossibility of obtaining stable crop yields, for the solution of which a much larger number of resources is required annually [1, 3].

To solve this problem, the article develops the ways of conducting economic activities based on the development of modern adaptive landscape farming systems in combination with the minimization of the main elements of the technology of cultivation of agricultural crops, based on the strengthening of...
environmentally friendly methods. These methods include rational use of natural resources, introduction of intensive-type varieties, improvement of seed material, high-quality seed production, microbiological preparations with an immunizing effect without completely excluding the use of pesticides and fertilizers. The biological reserves of agricultural technologies for the cultivation of agricultural crops are a large-scale use of biological products, by a consortium of microorganisms, biological products of fungicidal action, which turned out to be harmless to the environment and economically effective on virtually all agricultural crops [2, 4].

At present, when the tendency to reduce the share of fertilizers and pesticides in the production of crop products is quite rapid, it is biological products of comprehensive action that are becoming especially relevant as a reserve for partial compensation of fertilizers and fungicides for plants. The most widespread are consortia of microorganisms that have the properties of stimulating plant immunity and regulating their growth and development. The identification, reproduction, and testing of new strains of microorganisms made it possible to establish one of their main properties - the ability to suppress phytopathogenic microflora. Due to this property, the likelihood of the manifestation of the disease decreases, the competitive ability of cultivated plants increases, and, accordingly, the level of productivity and quality of products increases [5, 7].

A more complete picture of the effect of microbiological preparations on the yield and quality of the products obtained can be obtained by conducting a network of field experiments on the most common agricultural crops.

The article carried out this study in the conditions of different growing seasons on spring wheat, on the level of productivity, which depends on the level of provision of the population with high-quality products of processing of its grain. To obtain high-quality grain, it is necessary to apply a large number of nitrogen fertilizers, which leads to an increase in costs, in connection with which the profitability of the production of spring durum wheat grain decreases. Therefore, the study of the peculiarities of the influence and assessment of the effectiveness of the use of biological preparations on the production process of spring durum wheat is of relevance today [6, 8].

In our field experiments, it was decided to study the less well-known preparation Biogor, KM (produced by STC "BIO") and its effect on the duration of the growing season, productivity, yield, and grain quality of spring durum wheat.

2. Purpose of the study
The purpose of the study is to determine the features of the application and assess the effect of the microbiological preparation Biogor, KM on the length of the growing season of spring wheat, the formation of the structure of productivity by plants, the yield depending on the method of application of the preparation, the content and collection of crude protein, the economic and bioenergetic efficiency of grain production of spring durum wheat.

3. Materials, conditions and research methods
Industrial experiments on the use and assessment of the effectiveness of the preparation Biogor, KM in the cultivation of spring durum wheat were carried out according to generally accepted methods in 2017-2020 on the farm "Yaroslav the Wise" of the Starooskolsky district of the Belgorod region in conditions of different growing seasons. The object of study in our experiments was the spring durum wheat variety Dar Chernozemya 2. The sowing of the experiments was carried out on an area of 3000 m², the area of the experimental plot was 250 m², and the counting of 200 m² was repeated four times. The scheme of the experiment is as follows: pre-sowing treatment of grain with water (control), grain processing Biogor, KM and grain processing Biogor, KM + double spraying of vegetative plants.

According to the manufacturer's data, Biogor KM is a microbiological fertilizer for treating seeds to increase their germination, increase germination energy, and advanced the development of the plant root system. It is also recommended to use it in the form of spraying on vegetative plants as an antistress agent that stimulates plant immunity with a subsequent increase in the level of yield and
product quality. Contains a concentrate of lactic and propionic acid bacteria, bacteria producing cellulases, proteases, amylases, polysaccharides, amino acids, and harmonic growth-stimulating substances.

The soil of the experimental plot is typical chernozem with a humus content in the arable layer of 5.24%, the pH of the salt extract is 6.2, with an average content of basic nutrients.

The climatic conditions during the years of the production experiments were different both in terms of moisture supply and heat. The most favorable for the growing season of spring durum wheat were 2017 and 2020. A distinctive feature of 2017 in comparison with 2020 was a deficit of precipitation against the background of a higher temperature. The growing season of spring wheat in 2018 had its peculiarities since the amount of precipitation was high, but they fell after the period of filling the caryopses and did not affect the harvest. In 2019, the average daily temperature was 20°C less, and there was less precipitation during the growing season, but since their presence coincided with the period of earing-filling of kernels, the average yield according to the variants of the experiment was 3.5 higher than in 2018. c/ha. In general, the conditions of the growing seasons correspond to the average annual values, are typical for the conditions of the region, and allow an objective assessment of the effectiveness of the use of a biological product.

4. Research results

The four-year research with production experiments reveals the influence of the biological product Biogor KM on the growing season of spring durum wheat plants Dar Chernozemya 2 (table 1).

| Experience Option           | Seedlings-maturation | Sowing-maturation |
|----------------------------|----------------------|-------------------|
| Control                    | 84                   | 95                |
| Biogor, KM seeds           | 76                   | 85                |
| Biogor, KM seeds + by vegetation | 72           | 79                |

On average for 2017-2020 the germination-maturation period decreased with the use of the biological product. When processing only grain, it was less than the control (84) by 8 days and amounted to 76 days, and when processing seeds + during the growing season, it was at all by 12 days. Plants of spring durum wheat variety Dar Chernozemya 2 matured faster, as evidenced by the data for the sowing-ripening period for 10 days in relation to the control variant when treating only grain - 85 days and for 16 days when carrying out two sprays during the growing season in combination with seed treatment - 79 days. This pattern was traced in all years of research. According to the phases of development of spring durum wheat plants, a decrease in the germination-tillering period was noted in comparison with the control by 4-5 days when processing only grain, and by 9-12 days compared with the Biogor option, KM seeds + during the growing season. Such dynamics persisted in the subsequent interphase periods, which is confirmed by the duration of the growing seasons of wheat, both for individual years and on average for 4 years.

The use of the biological product Biogor, KM had a direct effect on the formation of the height of spring durum wheat plants. Linear growth depended both on the conditions of the growing season and the characteristics of the use of the biological product. During four years of research, the average height of spring wheat plants was 65.8 cm on the control, at the pre-sowing treatment of seeds only the height was higher by 3.4 cm and was 69.2 cm, and with the addition of double spraying of seeds to pre-sowing treatment the height of spring wheat plants was maximal - by 6.7 cm above the control - 72.5 cm.

In the formation of the area of the leaf apparatus of spring durum wheat plants Dar Chernozemya 2, a certain pattern was noted: the area of the leaf apparatus increased with the use of a biological product for processing only grain and was even larger with pre-sowing seed treatment in combination with double spraying of vegetative plants. The maximum leaf area was obtained both in the entire study...
years and on average for 2017-2020. on the variant of the experiment Biogor KM + for vegetation and amounted to 32.5 thousand m² / ha, while in the control only 26.7 thousand m² / ha.

To reveal in more detail the influence of the biological product on spring durum wheat plants, the article analyzes the structure of productivity, carries out considering the following indicators: ear length, number of spikelets in an ear, number of grains in an ear, weight of grain per ear and weight of 1000 grains (Table 2).

Table 2. The structure of the productivity of spring wheat plants of the variety Dar Chernozemya 2, depending on the treatment with a biological product Biogor, KM, 2017-2020.

| Experience Option                  | Ear length, cm | Spikelets per ear, pcs. | Grains per ear, pcs. | Grain weight per ear, g | Weight of 1000 grains, g |
|-----------------------------------|----------------|-------------------------|----------------------|-------------------------|-------------------------|
| Control                           | 6.4            | 12.2                    | 20.1                 | 1.02                    | 35.3                    |
| Biogor, KM grain processing       | 7.7            | 14.6                    | 24.2                 | 1.24                    | 37.2                    |
| Biogor, KM grain + by vegetation  | 8.9            | 17.3                    | 27.2                 | 1.42                    | 38.4                    |
| Average                           | 7.7            | 14.7                    | 23.8                 | 1.2                     | 37.0                    |

In our experiments, the structure of productivity of spring wheat plants varied both over the years of research depending on the treatment with a biological product. The mass of 1000 grains was relatively stable and low variability, which varied from 35.3 g to 38.4 g on average for the studied period (2017-2020), and according to the variants of the experiment, its value was 37.0 g.

Over four years, the length of ears of spring wheat varied from 6.4 cm to 8.9 cm, on average for the variants of the experiment 7.7 cm. When only seeds were treated with a biological product, wheat plants formed a 1.3 cm longer ear length in comparison with control, which was at the level of 7.7 cm. An even greater (by 2.5 cm or 39%) ear length was on the Biogor KM + variant during vegetation - 8.9 cm. The number of spikelets on average per 1 plant varied from 12.2 pcs. up to 17.3 pcs. In the variant with grain treatment only, the plants formed 19.7% (or 2.4 pcs.) Spikelets more than in the control, and when processing seeds and vegetative plants, wheat plants formed an even larger number of spikelets - 17.5 pcs., Or 5.1 pcs. more (by 41.8%). The same variant had the best grain content of the ear - an average of 27.2 pcs per plant, which is 7.1 pcs. or 35.3% more than in the control. The grain weight per spike varied from 1.02 g/plant. (on control) up to 1.42 g/plant (on the variant Biogor, KM + for vegetation).

The main indicator for evaluating the biological product used on spring durum wheat plants of the Dar Chernozemya 2 variety is the yield level. In our studies, it varied from 2.10 t/ha to 4.51 t/ha. It was variable both by years of research and by variants of experience.

Over the entire research period, reliably large increases in yield were obtained in all variants of the experiment in comparison with the control. The yield level was the lowest in 2018 and the average for the variants of the experiment was 2.23 t/ha, the growing season of 2019 turned out to be more favorable with an average yield level of 2.58 t/ha, in 2017 - 2.80 t/ha and the maximum average yield level according to the experience options was obtained in 2020 - 4.22 t/ha (table 3).

In 2017, on the variant with the treatment of the biological product Biogor, KM of only spring wheat grain, the yield increase was - 0.17 t/ha or 6.4%, on the variant of seed treatment in combination with spraying during the growing season, the yield was higher by 0.27 t/ha. ha or 10.2%.

In 2018, there were fewer clear differences in yield compared to 2017, so the increase obtained in the variant with grain processing was - 0.13 t/ha or 6.2%, in the variant with spraying the increase was 12.9% more control.
Table 3. Yield of spring wheat variety Dar Chernozemya 2 depending on treatment with biological product Biogor, KM, t / ha 2017-2020

| Experience Option          | 2017  | 2018  | 2019  | 2020  | Average | +/- to control t/ha | %    |
|----------------------------|-------|-------|-------|-------|---------|---------------------|------|
| Control                    | 2.65  | 2.10  | 2.33  | 3.89  | 2.74    | -                   | -    |
| Biogor, KM grain           | 2.82  | 2.23  | 2.67  | 4.27  | 3.00    | 0.26               | 9.4  |
| Biogor, KM grain + by vegetation | 2.92  | 2.37  | 2.75  | 4.51  | 3.14    | 0.40               | 14.5 |
| Average over the years     | 2.80  | 2.23  | 2.58  | 4.22  | -       | 0.33               | 12.0 |
| LSD05                      | 0.21  | 0.16  | 0.28  | 0.19  | -       | -                   | -    |

Clearer differences in yield on the experimental options were obtained in 2019, where in the variant with grain processing the increase was - 0.34 t/ha or 14.6%, it was even greater in the variant where grain and vegetative plants were processed - 0.42 t/ha or 18.0%.

Vegetation of spring durum wheat variety Dar Chernozemya 2 and treatment of plants with biological products in 2020 showed the greatest differences in yield increases. A smaller increase in yield in relation to the control this year was obtained in the variant with processing only grain before sowing - 0.38 t/ha or 9.7%, the largest with double spraying during the growing season - 0.62 t/ha or 15.9%.

On average, over 4 years, the yield varied from 2.74 t/ha to 3.14 t/ha. The variant of the experiment with the use of only pre-sowing seed treatment provided an increase in yield of 0.26 t/ha or 9.4%, wheat plants in this variant formed on average for 2017-2020. 3.00 t/ha of grain. The largest increase in yield - 0.40 t/ha or 14.5% was obtained on the variant of grain processing in combination with double spraying of plants during the growing season, the average yield for the studied period was 3.14 t/ha and it was the maximum one.

The research provides for a qualitative assessment of the grain of spring durum wheat, depending on the use of a biological product. The crude protein content over the years of research ranged from 13.1% to 16.9%. In 2017, the differences in the content of crude protein were as follows: in the control 13.1%, Biogor, KM grain by 0.6% more (13.7%) and the maximum by 1.7% more (15.4%) in the variant Biogor, KM grain in combination with double spraying during vegetation. The most variable in the content of crude protein in wheat grain was in 2018, where the differences were according to the options: Biogor, KM grain is 0.7% more (14.9%), 2.2 more (16.4%) on the Biogor option, KM grain in combination with double spraying during vegetation.

It should be noted that in relation to the protein content in grain, the following annual pattern was observed - on average for 4 years in the control it was the smallest, and in the variants, with the treatment of only seeds it was 0.5% more and amounted to 14.9%, seeds + by growing season by 1.9% and amounted to 16.3%, which is higher than the control, where the average crude protein content over the years was 14.4% (Table 4).

On average for 2017-2020 the protein content was maximum in the variant with the application of Biogor KM, grain processing in combination with double spraying during the growing season - 16.3%. Indicator FDM 95, protein harvest was the maximum in the same variant - 511.8 kg/ha, which is 117.2 kg or 29.7% more than the control; in this variant, the protein harvest was the lowest and amounted to 394.6 kg/ha.

When studying the influence of various agrotechnical methods of cultivating agricultural crops, it is necessary to assess the economic efficiency of their implementation. In our experiments, this was provided for in all studied years of production experiments. Average for 2017-2020 the selling price of the grain of spring durum wheat of the corresponding quality amounted to 14,500 rubles per ton (Table 5).
Table 4. The content and collection of crude protein in the grain of spring wheat varieties Dar Chernozemya 2, depending on the treatment with the biological product Biogor, KM, % t / ha 2017-2020

| Experience Option                  | 2017  | 2018  | 2019  | 2020  | Average | FDM | Protein harvest, kg / ha |
|-----------------------------------|-------|-------|-------|-------|---------|-----|-------------------------|
| Control                           | 13,1  | 14,2  | 14,7  | 15,4  | 14,4    | 105 | 394,6                   |
| Biogor, KM grain                  | 13,7  | 14,9  | 15,2  | 15,9  | 14,9    | 97  | 447,0                   |
| Biogor, KM grain + by vegetation  | 15,4  | 16,4  | 16,5  | 16,9  | 16,3    | 95  | 511,8                   |

Table 5. Economic efficiency of cultivation of spring durum wheat varieties Dar Chernozemya 2, depending on the application Biogor, KM 2017-2020.

| Experience Option                  | Productivity, t/ha | Production cost, rubles/ha | Production costs, rubles/ha | Self-cost, rubles/ton | Profit rubles/ha | Profitability level, % |
|-----------------------------------|--------------------|---------------------------|-----------------------------|----------------------|------------------|------------------------|
| Control                           | 2,74               | 39730                     | 22121                       | 8073                 | 17609            | 79,6                   |
| Biogor, KM grain                  | 3,00               | 43500                     | 22685                       | 7562                 | 20815            | 91,8                   |
| Biogor, KM grain + by vegetation  | 3,14               | 45530                     | 22967                       | 7314                 | 22563            | 98,2                   |

Production costs for the variants of the experiment on average during the study period varied from 22121 rubles/ha (under control) to 22967 rubles/ha (Biogor KM grain + for the growing season). As the yield increased, according to experience, the cost of a ton of wheat grain decreased, which was the highest in the control - 8073 rubles/ton, and the lowest - 7314 rubles/ton in the Biogor option, KM grain + for the growing season. Profit per hectare on the Biogor, KM variant, pre-sowing treatment of only seeds was 3206 rubles more than in the control and amounted to 20815 rubles/ha. The maximum profit (22,563 rubles/ha) and the level of profitability (98.2%) were obtained on the Biogor option, KM grain + spraying during the growing season.

A clearer idea of the effectiveness of the use of agrotechnical methods can be obtained when carrying out their bioenergetic assessment. In our experiments, it depended on the number of energy costs formed, depending on the agrotechnical methods, for the cultivation, care, and harvesting of spring durum wheat. The level of bioenergy efficiency was determined mainly by the level of yield, the higher it was, the higher was the bioenergy coefficient. On average, over four years of research, the total energy consumption varied according to the experimental options from 19.34 GJ/ha to 21.42 GJ/ha (Table 6).

Table 6. Bioenergetic efficiency of cultivation of spring durum wheat variety Dar Chernozemya 2, depending on the use of the biological product Biogor, KM 2017-2020.

| Experience Option                  | Productivity, t/ha | Exchangeable energy output, GJ/ha | Total energy consumption, GJ/ha | Net energy income, GJ/ha | Energy efficiency ratio | Bioenergy coefficient |
|-----------------------------------|--------------------|----------------------------------|--------------------------------|-------------------------|------------------------|-----------------------|
| Control                           | 2,74               | 44,39                            | 19,34                          | 25,05                   | 2,30                   | 1,30                  |
| Biogor, KM grain                  | 3,00               | 48,60                            | 20,72                          | 27,88                   | 2,35                   | 1,35                  |
| Biogor, KM grain + by vegetation  | 3,14               | 50,87                            | 21,42                          | 29,45                   | 2,37                   | 1,37                  |
The yield of exchangeable energy with the crop was by 4.21 GJ/ha, or 9.5% more than the control on the Biogor KM option, pre-sowing grain treatment - 48.60 GJ/ha, an even higher yield of exchange energy was when processing vegetative wheat plants in combination with seed treatment and amounted to 50.87 GJ/ha, 6.48 GJ/ha or 14.6% more than the control, and was the largest in experience. The net energy income formed by the agroecology of spring durum wheat in the control variant was at the level of 25.05 GJ/ha, higher than in the control variant with grain processing - by 2.83 GJ/ha or by 11.3%. The maximum net energy income was obtained in the variant with a combination of seed treatment and vegetative plants - 29.45 GJ/ha, which is more than in the control variant by 4.4 GJ/ha or 17.6%. The coefficient of bioenergy efficiency in all variants of the experiment was more than 1; therefore, the cultivation of wheat was energetically advantageous. The lower bioenergetic coefficient was obtained in the control variant of the experiment, and the maximum it was in the variant of the Biogor experiment, KM processing of grain before sowing and double processing of vegetative plants was 1.37.

5. Conclusion
Thus, based on our studies on the use of the biological product Biogor, KM in the processing of grain and growing plants of spring durum wheat, we can conclude about its positive all-round influence on the following indicators: the duration of the growing season, the dynamics of the formation of the productivity structure, the level of productivity, the content and collection of protein, economic and energy efficiency of cultivation of spring durum wheat varieties Dar Chernozemya 2 in the conditions of the Central Chernozem region.

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