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ВЛИЯНИЕ ПРИМЕНЕНИЯ БИОПРЕПАРАТОВ И ГЕРБИЦИДОВ НА ФОРМИРОВАНИЕ УРОЖАЙНОСТИ СРЕДНЕСПЕЛОГО СОРТА СОИ В УСЛОВИЯХ ПРИАМУРЬЯ

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Изучено влияние гербицидов (Бизон, Стратос Ультра) и препаратов природного происхождения (Био-Фиш, Био-Альго) на формирование урожая, посевные качества и первоначальный рост среднеспелого сорта сои Журавушка селекции Федерального научного центра «Всероссийский научно-исследовательский институт сои». Исследования проводили в 2020 и 2021 гг. на опытном поле Всероссийского научно-исследовательского института сои, расположенном в южной части Амурской области (с. Садовое Тамбовского района). Было установлено, что в среднем за два года применения препаратов природного происхождения Био-Фиш и Био-Альго для предпосевной обработки семян и вегетирующих растений увеличились сохранность растений к периоду уборки и урожайность, повысились посевные качества семян. Наибольшая сохранность к уборке наблюдалась при обработке семян перед посевом препаратом Био-Фиш, а вегетирующих растений – гербицидами (составила 93,9%, что на 6,4% больше показателей контроля и на 7,8% – варианта, где использовалась только гербицидная обработка). Анализ структуры урожая показал, что в среднем за годы исследований предпосевная обработка семян препаратом Био-Фиш и вегетирующих растений гербицидами Бизон, Стратос Ультра способствовала росту количества бобов до 5,8 шт., семян до 12,9 шт. на одно растение по сравнению с контрольным вариантом. Масса семян с одного растения увеличилась до 2,47 г относительно контроля. Применение биопрепаратов обусловило повышение биологической урожайности независимо от варианта обработки на 0,64 т/га в сравнении с контролем и на 0,66 т/га относительно гербицидной обработки.

Ключевые слова: соя, биопрепарат, гербицид, сохранность, посевные качества семян, урожайность

EFFECT OF BIOPREPARATIONS AND HERBICIDES USE ON THE YIELD FORMATION OF A MID-RIPENING SOYBEAN VARIETY UNDER CONDITIONS OF THE AMUR REGION

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The effect of herbicides (Bison, Stratos Ultra) and the preparations of natural origin (Bio-Fish, Bio-Algo) on the yield formation, sowing qualities and initial growth of the mid-ripening soybean variety Zhuravushka selected by the Federal Scientific Center "All-Russian Scientific Research Institute of Soybean" was studied. The studies were conducted in 2020 and 2021 in the experimental field of the All-Russian Scientific Research Institute of Soybean located in the southern part of the Amur Region (Sadovoye village, Tambovsky District). It was found that an average of two years of application of the preparations of natural origin Bio-Fish and Bio-Algo for pre-sowing treatment of seeds and vegetative plants increased the safety of the plants to the harvest period and crop yield, as well as improved the seed quality. The greatest preservation to harvesting was observed when the seeds were treated before sowing with Bio-Fish and the vegetative plants with herbicides (93.9%, which is 6.4% more than in the control variant and 7.8% more than in the variant where only herbicide treatment was used). Analysis of the yield structure showed that, on average over the years of research, pre-treatment of seeds with Bio-Fish and the vegetative plants with herbicides Bizon, Stratos Ultra increased the number of beans to 5.8 pieces, and the seeds to 12.9 pieces per plant compared to the control variant. Seed weight per plant increased to 2.47 g relative to the control. The use of biological preparations increased the biological yield regardless of the treatment variant by 0.64 t/ha compared to the control and by 0.66 t/ha compared to the herbicide treatment.

Keywords: soybean, biological preparation, herbicide, livability, sowing seed qualities, crop yield

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Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Every year, soybean production volumes are increasing worldwide, including in Russia. However, soybean yield in our country still remains low. In 2020 and 2021, the area under soybean cultivation in Russia was 2.86 million and 3.07 million hectares, respectively. The majority of soybean cultivation is concentrated in the Far Eastern Federal District, particularly in the Amur region, which accounted for 67.9% (844.5 thousand hectares) in 2020 and 70.9% (882 thousand hectares) in 2021. Despite having significant cultivation areas, Russia's soybean yield is lower compared to leading countries in this field, with an average yield of 16.8 c/ha, while Canada achieves 31.2 c/ha and Brazil reaches 35.5 c/ha [1].

The profitability of soybean cultivation largely depends on the agricultural practices employed. It has been established that to ensure consistently high yields, the cultivation technology of soybeans should be improved through the use of various preparations that positively influence plant growth and development [2, 3]. In recent years, organic farming has emerged as a promising direction in agriculture, which involves, among other things, avoiding the use of chemical plant protection agents and synthetic growth stimulators. Instead, bio-preparations are used, which affect vital processes in plants [4]. The advantages of such preparations are primarily their accessibility, environmental and human safety, as well as the absence of restrictions on the time of field entry after the treatment[1] [5, 6].

For this study, biostimulants of natural origin, Bio-Fish and Bio-Algo, were chosen. Bio-Fish is a highly effective natural anti-stress adaptogen, whose main active substance is arachidonic acid (a polyunsaturated fatty acid of natural origin and a precursor to a range of physiologically active substances called eicosanoids). Plant cells cannot synthesize this acid on their own, so its additional introduction is essential. In combination with other components in the Bio-Fish preparation (chitosan, triterpene acids), arachidonic acid mobilizes the plant's defense mechanisms, making them more resistant to diseases, stimulating the full development of the root system, and ensuring the preservation of crops under extreme natural conditions. Bio-Algo is an immune stimulator made from high-quality organic concentrate of brown seaweed from northern latitudes with a high content of microelements, plant-origin hormones, amino acids, and vitamins. It acts as a biostimulant and anti-stress agent with fungicidal, bactericidal, and insecticidal properties, providing plant resistance to adverse environmental factors [7].

The purpose of the study is to investigate the influence of the natural origin preparations Bio-Fish and Bio-Algo (pre-sowing seed and vegetative plant treatment) as well as the herbicides Bizon and Stratos Ultra on the sowing qualities, initial growth, and productivity of a mid-ripening soybean variety Zhuravushka under the conditions of the Amur region.

Objectives:

1. Determine the degree of influence of the bio-preparations Bio-Fish and Bio-Algo, and the herbicides Bizon and Stratos Ultra on the initial growth and sowing qualities of the Zhuravushka soybean seeds.

[1] *Syrmolot O.V.* Soybean productivity depending on application of biological preparations under conditions of Primorye // Siberian Bulletin of Agricultural Science. 2014. N 4. pp. 62-67.

2. Investigate the effect of bio-preparations on plant preservation and yield structure of the examined variety.

3. Determine the biological seed yield of the Zhuravushka soybean variety under different treatment options.

MATERIAL AND METHODS

The experiment was conducted in 2020 and 2021 at the experimental field of the All-Russian Scientific Research Institute of Soybean located in the village of Sadovoe, Tambov District, Amur Region. The soil of the experimental plot was meadow chernozem, heavy in terms of particle size distribution, with medium permeability (density 1.02-1.10 g/cm^3, porosity 43.8%), and pH of 5.4. It contained 2.3-2.7% humus, 20-40 mg/kg ammonium nitrogen, 30-70 mg/kg nitrate nitrogen, 50-80 mg/kg available phosphorus, and 170-200 mg/kg exchangeable potassium (according to Kirsanov's method). The total area of the plot was 11.25 m^2, with a measurement area of 2.25 m^2 and a 4-fold replication. The arrangement of the plots was block-randomized.

Seed treatment with biopreparations was carried out on the day of sowing at a rate of 20 ml/ton. Treatment of vegetative plants was performed at the trifoliate leaf stage with herbicides Bizon (active substance - bentazone, concentration 1.5 l/ha) and Stratos Ultra (active substance - cycloxidim, concentration 1 l/ha) in combination with the biopreparation Bio-Algo (concentration 5 ml/l).

The following agronomic practices were applied: deep tillage without plowing in two tracks (cultivator KPE-3.8, tillage depth 10-15 cm), early spring harrowing, application of soil herbicide, and wide-row cultivation. Manual sowing (using seed drills) was carried out at optimal timing: May 24-26 in 2020 and May 26-28 in 2021. Harvesting was done manually, and the threshing of sheaves was performed on a stationary thresher. Seed quality parameters (germination energy and laboratory germination) were determined according to the applicable methods specified in GOST 12038-84, and the weight of 1,000 seeds was determined according to GOST 12042-80. Statistical analysis of the obtained data was performed using the method of variance analysis (according to B.A. Dospeshov)[2] in the Statistika 10 software.

The vegetation period of 2020 was characterized by unstable temperature regime and occasional soil overmoistening during certain stages of soybean development. The temperature regime in May was favorable for field work, with average temperatures exceeding the long-term average by 0.1-1.6 °C (see Fig. 1). The monthly precipitation sum exceeded the climatic norm by 46.2% (see Figure 2). Throughout all three ten-day periods of June, the air temperature was lower than the long-term average and deviated from the norm by 0.7-2.9 °C, resulting in delayed growth and development of soybean plants, which only managed to form the second trifoliate leaf.

In July, the average monthly air temperature exceeded the climatic norm by 2.6 °C, accelerating the accumulation of heat. The agrometeorological conditions in August (the pod formation stage) proved to be extremely challenging. The temperature during the three ten-day periods of August was below the norm by 0.25-1.28 °C, with the average monthly temperature being 1 °C lower than the norm. In the second ten-day period of August, the weather was unstable and rainy, with the amount of precipitation exceeding the long-term average almost threefold - 96 mm and 35 As a result, soybean plants were partially suppressed due to the unfavorable conditions. The significant amount of precipitation led to soil overmoistening. The rainfall in September exceeded the long-term norm by 40%, despite the air temperature being above the norm by 14.0 and 12.4 °C, respectively.

The weather conditions in 2021 were satisfactory but had deviations from the long-term average (see Fig. 1, 2). Throughout the entire vegetation period, there was an uneven temperature pattern. The total precipitation during the soybean growing season reached 509 mm, which was 68 mm higher than the long-term av-

[2]*Dospekhov B.A.* Methodology of field experience: textbook. Moscow: Kolos, 1979. 416 p.

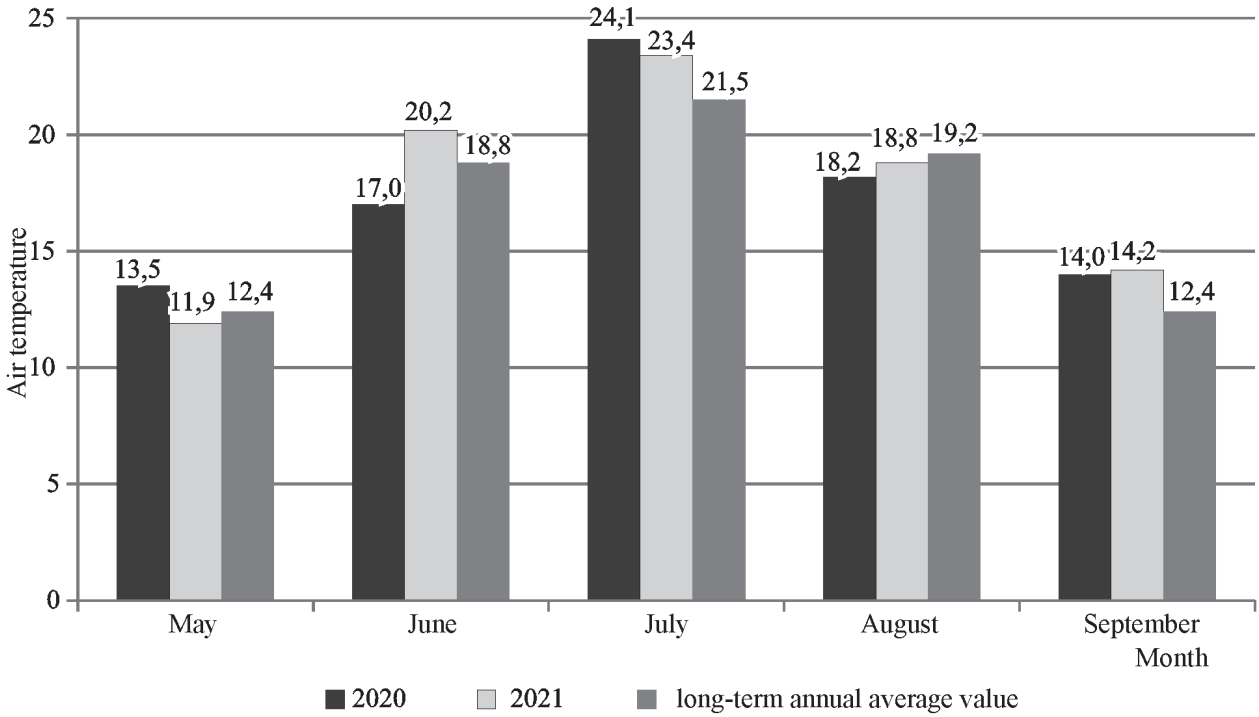

Рис. 1. Среднемесячная температура воздуха за вегетационный период (метеостанция г. Благовещенска)

Fig. 1. Average monthly air temperature for the growing season (Blagoveshchensk weather station)

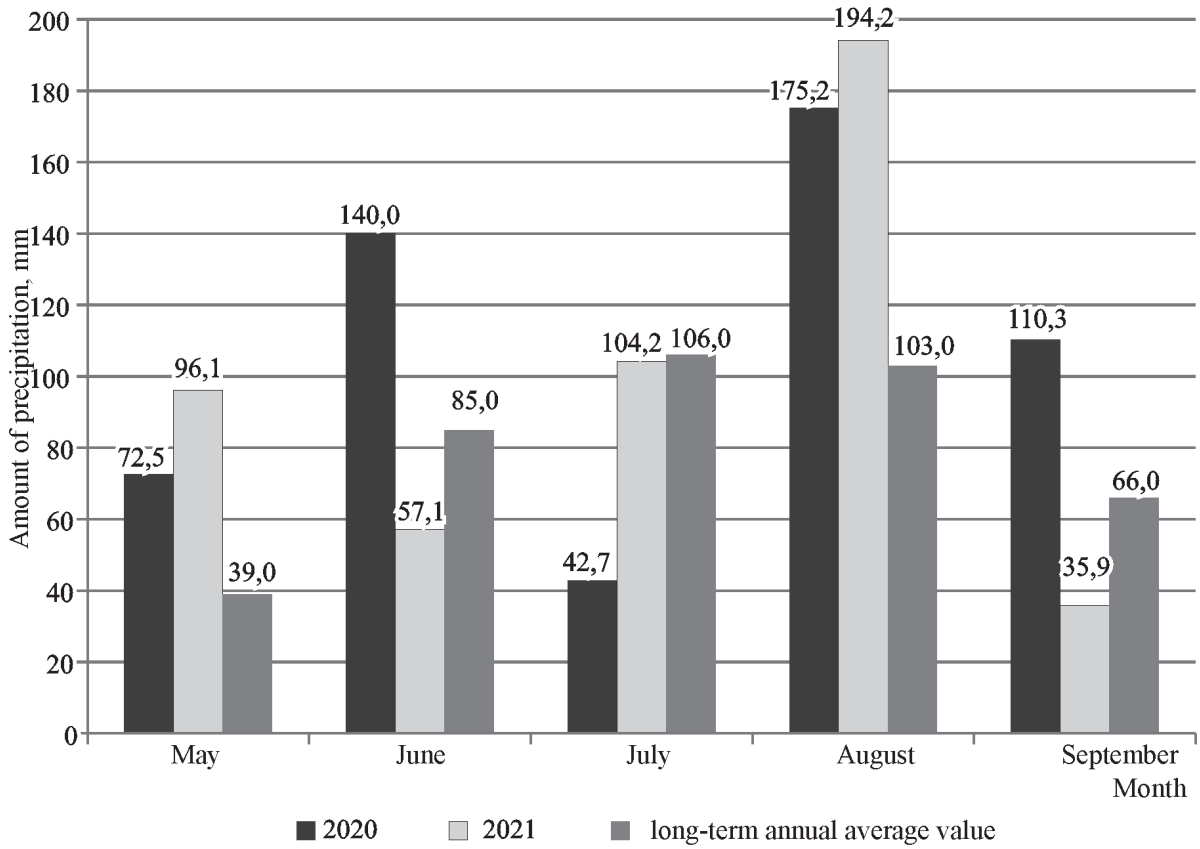

Рис. 2. Количество осадков за вегетационный период (с. Садовое)

Fig. 2. Precipitation for the growing season (Sadovoye village)

erage. The distribution of rainfall was uneven. May and August were characterized by excessive soil moisture, with precipitation exceeding the long-term norm by 57.1 mm and 91.2 mm, respectively.

The combination of temperature and precipitation during the vegetation period had both positive and negative effects on plant growth and development. Adequate heat and moisture promoted uniform germination of seedlings. In July (the flowering phase of soybeans), the temperature exceeded the long-term average, and the precipitation was at a normal level, resulting in abundant flowering and pod formation. The agrometeorological conditions in August were predominantly warm and rainy. The total precipitation for the month exceeded the climatic norm, leading to increased prevalence of phytopathogens and a decrease in crop quality. The temperature in September was 1.8 °C higher than the long-term average, while the precipitation was 45.6% below the norm.

RESULTS AND DISCUSSION

The main cause of poor soybean yield is weed infestation. To reduce yield losses in agricultural production, highly effective herbicides are actively used in combination with agronomic practices. It is well known that herbicides not only affect weeds but also the cultivated crop, making it highly relevant to combine their use with biological preparations that reduce the negative impact on plants, providing them with a boost for further growth and development [8–10].

One significant element determining seed yield is the number of productive stems that survive until harvest. To assess plant survival just before harvest, plant counting was conducted in each plot. The results showed that, on average, the highest plant survival rate was observed with the pre-sowing treatment of seeds using the Bio-Fish preparation, while the use of the herbicides promoted the survival of vegetative plants. The plant survival rate reached 93.9%, which was 6.4% higher than the control and 7.8% higher than the variant where only herbicide treatment was applied, indicating its particular importance in years with unfavorable weather conditions. When Bio-Fish was applied to the seeds before sowing without herbicide treatment the share of soybean plants survived at the moment of harvesting reached 88,4%, which is 1,4% higher than the control and 2,3% higher than in the variant with herbicides (see Fig. 3).

The study of crop structure revealed that the pre-sowing treatment of seeds with the biological preparation contributed to the reduction of herbicide toxicity on plants and had a positive impact on their growth and development. The use of only Bio-Fish seed treatment led to an increase in the number of pods by 5.8, seeds by 12.9, and seed weight by 2.47 grams per plant compared to the control. Additionally, when compared to herbicide treatment, the increase was 5.8 pods, 12.1 seeds, and 2.17 grams, respectively. The combined application of Bio-Fish and herbicide mixture resulted in a higher number of pods, seeds, and seed weight per plant compared to the control group. Treatment of vegetative plants with Bio-Algo and the herbicide mixture increased the number of pods by 2.9, seeds by 6.4, and seed weight by 1.22 grams per plant compared to the control (see Table 1).

The 2020 growing season was characterized by excessive soil moisture during certain stages of soybean plant development, which affected their growth and development. Under these conditions, the pre-sowing treatment of seeds with the studied biological preparation had the greatest positive impact on plant productivity. The yield in this variant reached 3.18 tons per hectare, which was 0.41 tons per hectare higher than the control and 0.51 tons per hectare higher than the herbicide treatment (LSD_{05} = 0.33 tons per hectare). In soybean crops where the vegetative plants were treated with herbicides Bizon and Stratos Ultra and the seeds were presown treated with Bio-Fish, the yield increased by 0.20 and 0.30 tons per hectare, respectively, compared to the control (LSD_{05} = 0.33 tons per hectare).

The weather conditions in 2021 were generally favorable for the normal development of soybean plants. The use of bio-preparations contributed to the reduction of the negative im-

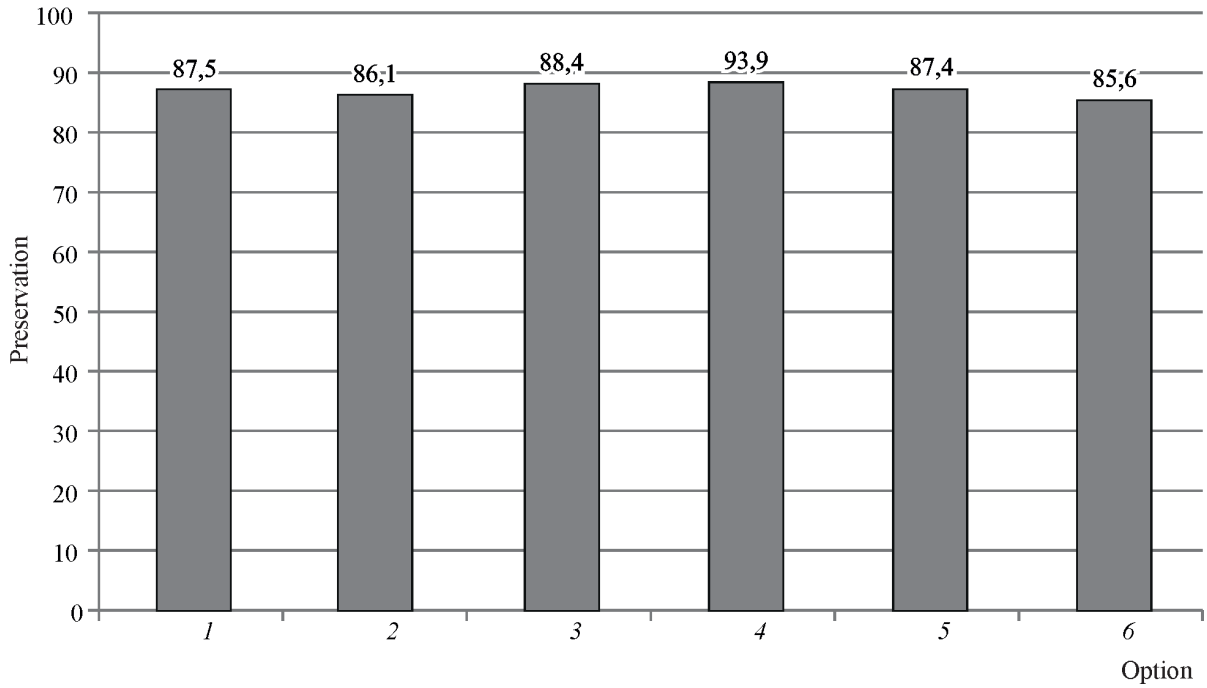

Рис. 3. Сохранность растений сои сорта Журавушка при разных вариантах обработки (средняя за 2020, 2021 гг.):

1 – контроль (без обработки); *2* – Стратос Ультра + Бизон (обработка вегетирующих растений); *3* – Био-Фиш (обработка семян); *4* – Био-Фиш (обработка семян) + Стратос Ультра и Бизон (обработка вегетирующих растений); *5* – Био-Фиш (обработка семян) + Био-Альго (обработка вегетирующих растений); *6* – Био-Фиш (обработка семян) + Био-Альго (обработка вегетирующих растений) + Стратос Ультра и Бизон (обработка вегетирующих растений)

Fig. 3. Preservation of the plants of soybean variety Zhuravushka at different treatment options (average for 2020, 2021):

1 – control (untreated); *2* – Stratos Ultra + Bizone (vegetating plant treatment); *3* – Bio-Fish (seed treatment); *4* – Bio-Fish (seed treatment) + Stratos Ultra and Bizone (vegetating plant treatment); *5* – Bio-Fish (seed treatment) + Bio-Algo (vegetating plant treatment); *6* – Bio-Fish (seed treatment) + Bio-Algo (vegetating plant treatment) + Stratos Ultra and Bizone (vegetating plant treatment)

pact of herbicides, resulting in an increase in biological yield by 0.85–1.09 tons per hectare (LSD_{05} = 0.49 tons per hectare) compared to the control and by 0.78–1.02 tons per hectare compared to the variant where herbicides were used for vegetative plant treatment (see Table 2).

It is known that most pre-sowing seed treatments increase the intensity of metabolic processes during germination with effective mobilization of reserve substances under the influence of corresponding active enzymes. As a result, seedlings emerge, and their quality influences further development, viability, and productivity of plants [11–14]. Laboratory studies of growth processes at the initial stages of plant development showed that seed treatment positively influenced their seeding qualities despite herbicide treatment (see Fig. 4).

The natural origin preparations Bio-Fish and Bio-Algo had a positive influence on the initial growth of soybean seedlings of the Zhuravushka variety. The length of seedlings was 1.2–2.7 cm greater with the combined treatment of bio-preparations and herbicide compared to the control, and it exceeded the data from the herbicide treatment variant by 4.0–5.5 cm (see Table 3).

The number of abnormally developed seedlings decreased by 6–8% compared to the variant where herbicides were used. The variation range, which characterizes the most complete and uniform seed germination, was 20.9% when Bio-Algo was used, which was 2.3% lower than the control.

Табл. 1. Биометрические показатели растений сои сорта Журавушка (в среднем за 2020, 2021 гг.)
Table 1. Biometric indicators of the plants of soybean variety Zhuravushka (on average for 2020, 2021)

Treatment		Number, pcs. per one plant		Seed weight per one plant, g
seeds before sowing	vegetative plants	beans	seeds	
Control (without treatment)		21,3	39,7	7,76
Distilled water	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha)	21,3	40,5	8,06
Bio-Fish (20 ml/t)	Distilled water	27,1	52,6	10,23
	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha)	24,3	47,4	9,31
	Distilled water + Bio-Algo (5 ml/l)	23,9	46,9	9,14
	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha) + Bio-Algo (5 ml/l)	23,9	46,1	8,98
LSD_{05}, pcs. per one plant		3,0	5,8	1,22
F_{fact}		5,6	5,1	
F_{theor}		2,9	2,9	

Note. Here and further in the tables the concentration of herbicides and biopreparations is given in brackets.

Табл. 2. Биологическая урожайность сои сорта Журавушка, т/га
Table 2. Biological yield of soybean variety Zhuravushka, t/ha

Treatment		2020	2021	Average for two years	Increment
of seeds before sowing	of vegetative plants				
Control (without treatment)		2,77	2,48	2,63	–
Distilled water	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha)	2,67	2,55	2,61	−0,02
Bio-Fish (20 ml/t)	Distilled water	3,18	3,33	3,26	0,63
	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha)	2,97	3,57	3,27	0,64
	Distilled water + Bio-Algo (5 ml/l)	2,65	3,48	3,07	0,44
	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha) + Bio-Algo (5 ml/l)	2,46	3,42	2,94	0,31
$LSD_{05,}$ t/ha		0,33	0,49		
F_{fact}		5,58	6,20		
F_{theor}		2,90	3,97		

CONCLUSION

Thus, over the course of two years of research, the use of natural-origin preparations had a positive influence on the initial growth of seedlings, germination vigor, and laboratory seedling emergence of the mid-ripening variety Zhuravushka. The length of the seedlings increased by 3.6-8.1% with combined treatment of bio-preparations and herbicides compared to the control, and it exceeded the herbicide treatment variant by 13.1-18.0%. Plant survival rate just before harvest, on average for 2020 and 2021, was highest when the Bio-Fish preparation was used for pre-sowing seed treatment in combination with herbicides, reaching 93.9%. This was 6.4% higher than the control and 7.8% higher than the variant where only herbicide treatment was applied.

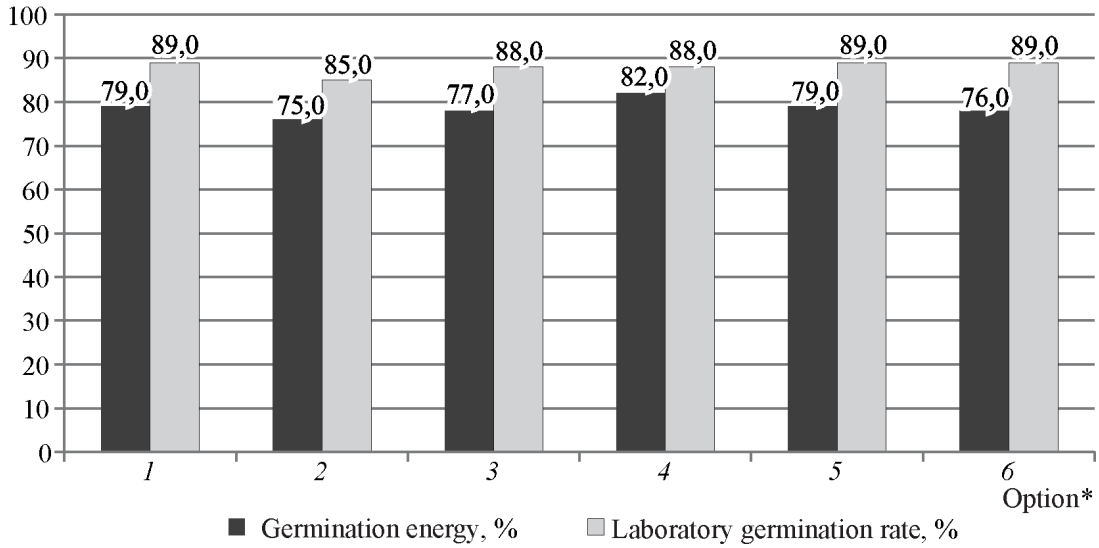

Рис. 4. Влияние разных вариантов обработки на посевные качества семян сои сорта Журавушка (2020, 2021 гг.)
*Описание вариантов обработки см. на рис. 3

Fig. 4. The impact of Bio-Fish on the sowing qualities of soybean seeds of the Zhuravushka variety (2020, 2021)
*See Figure 3 for the description of the treatment options

Табл. 3. Влияние биопрепаратов и гербицидов на первоначальный рост проростков сои сорта Журавушка (в среднем за 2020, 2021 гг.)

Table 3. The impact of Bio-Fish on the initial growth of soybean seedlings of the Zhuravushka variety (on average for 2020, 2021)

Treatment		Abnormally developed seedlings, %	Seedling length		
of seeds before sowing	of vegetative plants		Average value, cm	Variation range, %	Variation coefficient, %
Control (without treatment)		11,3	33,3	23,2	13,5
Distilled water	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha)	17,3	30,5	22,6	17,5
	Distilled water	10,0	35,2	23,2	12,5
Bio-Fsh (20 ml/t)	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha)	11,3	34,5	22,7	13,4
	Distilled water + Bio-Algo (5 ml/l)	9,3	36,0	20,9	13,1
	Stratos Ultra (1l/ha) + Bizon (1,5 l/ha) + Bio-Algo (5 ml/l)	9,3	35,2	26,3	17,4
LSD_{05}, cm			2,2		

The bio-preparations also had a significant influence on the formation of crop structure elements. Pre-sowing seed treatment with Bio-Fish, both without herbicide treatment and in combination with the herbicides, led to an increase in the number of pods by 3.0-5.8, seeds by 7.7-12.9, and seed weight by 1.55-2.47 grams per plant compared to the control. Moreover, the use of natural-origin preparations, Bio-Fish and Bio-Algo, helped reduce the negative impact on soybean plants, resulting in increased seed yield. Pre-sowing seed treatment with Bio-Fish increased grain yield by 0.31-0.64 tons per hectare compared to the control and by 0.33-0.66 tons per hectare compared to herbicide treatment (LSD_{05} = 0.45 tons per hectare).

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