 https://doi.org/10.1051/bioconf/20237101059

Results of an experiment on the use of bioproducts for soybean cultivation under the conditions of Primorsky kray

Oksana Syrmolot[1], *Ol'ga* Telichko[1*], *Tat'yana* Belova[1], and *Elena* Lastushkina[1]

[1]The Far Eastern Scientific Research Institute of Plant Protection – Branch of FSBSI "FSC of Agricultural Biotechnology of the Far East named after A.K. Chaiki", 42A, Mira st., Kamen-Rybolov, 692684, Russia

Abstract. The paper presents the results of a study on the influence of bioproducts on soybean plants under the conditions of Primorsky kray. The research was carried out as a microplot experiment in 2020-2022. Bioproducts and soybean variety Primorskaya 86 served as the research object. The highest biological efficacy against Septoria blight (21.4%) was detected in the variant with a complex treatment with bioproduct Gamair. All of the studied bioproducts were equally effective against downy mildew (32 %). The bioproducts increased plant density and preservation until harvest. The highest plant density was observed in the variant with seed treatment and foliage spraying with Baktofit (60.3 plants/m^2). The highest degree of preservation was detected after seed treatment with Biocomposite-correct (93.2 plants/m^2). The plant height in the experimental variants exceeded the standard by 9.3-16.8 cm. A tendency for the growth of soybean herbage and roots was observed in the variant with a complex treament with Biocomposite-correct, which exceeded the control by 29.4 and 28.9%, respectively. The TKW increased by 10.1-26.0 % after treatment with the studied bioproducts. The seed weight per plant was by 10.5-51.1% higher in the experimental variants than in the control. Using the bioproducts allowed a significant gain in yield from 0.4 to 1.3 t/ha. The highest yield (3.8 t/ha) was observed in the variants with the treatment of seeds with Biocomposite-correct and the seed treatment with any bioproduct followed by subsequent spraying of foliage during the growing period with the same bioproduct.

1 Introduction

Soybean is the main protein and oil crop worldwide. The quantity and quality of nutrients in its seeds are unmatched by any other agricultural crop. Soybean seeds contain 35-45% protein, 17-26% oil, and approximately 30% nitrogen-free extracts as well as lecithin and vitamins [1-2].

Soybean is considered a promising field crop in Russia. The Far Eastern region plays the leading role in the national production of soybean. Primorsky kray and Amur oblast, in

* Corresponding author: olgatelichcko@yandex.ru

their turn, are the largest producers of soybean in the Russian Far East. Soybean is one of the most economically advantageous crops in the agricultural sector of Primorsky kray [3-4].

Today considerable attention is paid to the development of sustainable and safe methods for protecting plants, i.e. biocontrol. This method is an essential part of the integrated system of plant protection and unlike agrochemical application it is cheap and does not cause environmental damage and contaminate agricultural produce [5-6].

Using the bioproducts that are safe for people and environment might solve numerous problems in the production of field crops. For example, it can facilitate the growth and development of plants, stimulate the formation of flowers and seeds, accelerate maturation, increase the yield and quality of agricultural produce, and enhance non-specific resistance to many diseases of various origin [7-8].

Growth regulators are widely employed in agriculture overseas as a method for obtaining the required amount of high-quality agricultural products. In total, up to 50-80% of crops are treated with growth regulators [9-10].

The effect of each factor is specific and depends on both climatic and soil conditions as well as biological characteristics of crops. The influence of bioproducts has not been thoroughly studied in field conditions [10].

The use of bioprounducts should be accompanied by a study on their influence on plant growth and development and productivity components. This served as the background for our research.

Our research goal was to evaluate the effectiveness of bioproducts in crops under the conditions of Primorsky kray.

2 Materials and methods

The research was carried out in the experimental fields of the Department of Seed Production at FSBSI "Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K. Chaiki" in 2020-2022. Bioproducts and released soybean variety Primorskaya 86 were used as the research object.

Primorskaya 86 is a mid-season soybean variety (120-124 days). The height of its plants is 82 cm on average, the pod height is 16.0-18.2 cm. Leaves are ternate, moderate in size, and oval. The color of perianth is white. Seeds are ovate-oblong, yellow, and matt with brown hilum. The oil content is 19.6-20.6%, the protein content is 39.2-40.1%.

The soil in the experimental fields was meadow-brown loam soil containing 3.08-3.13 % humus, 9.5 mg of hydrolyzable nitrogen per 100 g of soil, 14.12 mg of P_2O_5 per 100 g of soil, and a pH of salt extract of 5.3.

The following bioproducts were used: seed treatment and foliar spraying with Gamair, SP (*Bacillus subtilis,* strain M-22); seed treatment and foliar spraying with Baktofit, SP (*Bacillus subtilis*, strain IPM 215); seed treatment with Biocomposite-correct, Zh (a complex of different bacterial species and strains, 1x10 CFU/ml); seed treatment and foliar spraying with Biocomposite-correct; seed treatment with Biocomposite-correct + Biosteam Start, Zh (organic and mineral liquid fertilizer based on amino acids of plant origin).

The plan of our experiment included:

- Control (without treatment).
- Seed treatment (30 g/t) and foliar spraying with Gamair (60 g/ha).
- Seed treatment (2 kg/t) and foliar spraying with Baktofit (2 kg/ha).
- Seed treatment with Biocomposite-correct (1.0 l/t). seed treatment (1.0 l/t) and foliar spraying with Biocomposite-correct (2.0 l/ha).
- Seed treatment with Biocomposite-correct (1.0 l/t) + Biosteam Start (1.0 l/t).

Soybean seeds were sprayed manually with a bioproduct and sticking agent Na-KMTs by the semi-dry method one day before sowing. The spraying of soybean plants was performed manually with compression sprayer OP-207 at the cotyledon stage and the stage of flower-bud formation and initial flowering.

The area of one experimental filed plot was 10 m^2. The experiment was conducted with four repetitions; the positioning of the field plots was systematic.

Biocomposite-correct is a complex of five economically important strains of several beneficial bacterial species (no less than 1 x 10 CFU/ml). This bioproduct can be used in all agricultural systems and during any stage of crop rotation; it is characterized by fungicidal, growth-promoting, antagonistic, nitrogen-assimilating, and phosphate mobilizing properties. This allows its wide use for various purposes – from the decay of crop residues, the inhibition of pathogens in soil, and plant protection against infections to the improvement of soil fertility and microflora [11].

Organic and mineral fertilizer Biosteam Start is an amino acidic biostimulator, which activates seed germination, stimulates the development of beneficial microflora in rhizosphere, serves as additional source of energy at the initial stage of seedling growth, provides a starting complex of nutrients, enhances plant immunity, and decreases the influence of stress factors [11].

Baktofit is a microbiological product (fungicide and bactericide) containing spores and cell culture of *Bacillus subtilis* (strain IPM – 215). This species synthesizes compounds with antibiotic and antagonistic properties and growth regulating substances, which enhance the development of plants [11].

Gamair is a biological bactericide based on *Bacillus subtilis* (strain M – 22 VIZR) with an antibacterial and antifungal effect. It inhibits the development of root rot, protects plants against leaf and stem diseases, and reduces pesticide-induced stress [11].

Seeds were sown with seed drill SKS 6-10 at a depth of 3-4 cm and 45 cm inter-row spacing. The seeding rate was 500 thousand seeds per hectare. The area of one experimental plot was 10 m^2. The experiment was conducted with four repetitions; the positioning of the field plots was systematic.

Our experiment was set up according to generally accepted methodology of field experiments [12]. Field observations were conducted and records were made in compliance with the methodology of the State variety testing of agricultural crops [13, 14].

The statistical processing of the experimental data was performed by the methods of correlation analysis and the analysis of variance using corresponding software.

3 Results and Discussion

The meteorological conditions in the years of our experiment differed from the long-term average precipitation and temperature. Abundant precipitation was characteristic of the summer months in 2020 and their pattern was uneven throughout ten-day periods (193.5 mm in June and 140.1 mm in August, which exceeded the long-term average by 109.5 and 19.1 mm, respectively). Temperature exceeded the long-term average by 1.1-2.9 ^{o}C. The hydrothermal coefficient was 2.1 while the long-term average is 1.8 (prehumid conditions).

The growing season of 2021 was characterized by high daily temperatures and drought in the midsummer (HTC = 0.8), which adversely effected the growth and development of soybean plants. July was dry with the precipitation lower than the norm by 74.1 mm. The precipitation was 78.7 mm in June and 79.7 mm in August being by 2.3 and 54.4 mm lower than the norm, respectively. Temperature in the summer months exceeded the long-term average by 1.8-3.7 ^{o}C.

The precipitation was excessive in 2022 – 117.7 mm in June, 214.0 mm in July, and 149.7 mm in August – and hindered the formation and filling of pods at the stages of flowering and pod development. Temperature during the summer months exceeded the long-term average by 1.0-1.4 ^{o}C. The year of 2022 was prehumid with a HTC of 2.2.

In our experiment, the seedling density was strongly effected by weather conditions and available water in soil. On average over the three years, the seedling density ranged from 54.5 pcs/m^2 (complex seed treatment with Biocomposite-correct) to 60.3 pcs/m^2 (complex treatment with Baktofit) in the experimental variants; the seedling density in the control variant was 45.3 pcs/m^2. This demonstrated that the studied bioproducts had a positive effect on plant development at the initial stages (Table 1).

On average over the three years, the plant density at harvest maturity ranged within 50.6-53.7 pcs/m^2 in the experimental variants. The lowest plant density was observed in the control variant. The degree of plant preservation was by 9.2-13.3% than in the variant without treatment.

Table 1. Density and preservation of plants at harvest maturity (the average for 2020 -2022).

Variant	**Plant density at the stage of seedling emergence, plants/m^2**	**Plant density at harvest maturity, plants/m^2**	**Preservation, %**
Control (treatment with water)	45.3	36.2	79.9
Seed treatment + foliar spraying with Gamair	58.6	52.2	89.1
Seed treatment + foliar spraying with Baktofit	60.3	54.2	89.9
Seed treatment with Biocomposite-correct	54.8	51.1	93.2
Seed treatment + foliar spraying with Biocomposite-correct	54.5	50.6	92.8
Seed treatment with Biocomposite-correct + Biosteam Start	59.9	53.7	89.6
HCP_{05}	8.6	10.1	8.5

During the growing period, the severity of leaf infections was monitored and recorded. All of the studied bioproducts improved plant resistance against Septoria blight compared to the control (Table 2). Using the bioproducts decreased the severity of Septoria blight by 3.3-5.4% in comparison to the control (25.2%). The highest biological efficacy (21.4%) was detected in the variant with a complex treatment with Gamair. The bioproducts effected the development of downy mildew as well (11.9-13.1% in the experimental variants against 17.5% in the control). The biological efficacy of the studied bioproducts was 32%.

Table 2. Influence of the studied bioproducts on the severity of soybean fungal diseases (the average for 2020-2022).

Variant	**Septoria blight**		**Downy mildew**	
	DD, %	**BA, %**	**DD, %**	**BA, %**
Control (treatment with water)	25.2	-	17.5	-
Seed treatment + foliar spraying with Gamair	19.8	21.4	11.9	32.0
Seed treatment + foliar spraying with Baktofit	20.8	17.4	11.9	32.0
Seed treatment with Biocomposite-correct	20.5	18.6	12.2	30.3
Seed treatment + foliar spraying with Biocomposite-correct	21.1	16.2	11.9	32.0
Seed treatment with Biocomposite-correct + Biosteam Start	21.9	13.1	13.1	25.1
HCP_{05}	2.9	2.1	0.3	0.8

Note: DD – disease development; BA – biological activity.

The employed bioproducts differed in their effect on the growth and development of soybean plants. At the flowering stage, the height of plants in the experimental variants exceeded the control by 9.3-16.8 cm, the plant weight and root weight were by 35.1-75.0 g and 6.7-9.0 g higher, respectively. The strongest stimulating effect on plant growth and development was recorded after the complex treatment with Biocomposite-correct.

Table 3. Influence of the studied bioproducts on the growth and development of soybean plants at the flowering stage (the average for 2020-2022).

Variant	Plant height, cm	Plant weight, g	Root weight, g
Control (treatment with water)	27.4	255.0	32.1
Seed treatment + foliar spraying with Gamair	36.7	290.1	38.8
Seed treatment + foliar spraying with Baktofit	37.7	317.5	39.5
Seed treatment with Biocomposite-correct	41.5	321.4	40.0
Seed treatment + foliar spraying with Biocomposite-correct	44.2	330.0	41.1
Seed treatment with Biocomposite-correct + Biosteam Start	42.2	322.7	40.7
HCP_{05}	7.4	54.4	6.1

The research revealed that the studied bioproducts facilitated an increase in the structural components of soybean yield compared to the control (Table 4). The number of pods per plant and the number of seeds per pod influenced the number of seeds per plant. This trait is one of the main components of yield. Plant productivity depends on the number of pods and seeds and the TKW.

All the experimental treatments resulted in a significant gain in the number and weight of seeds. The highest number of pods and seeds formed in the variant with seed treatment and foliar spraying with Biocomposite-correct. Compared to the control, this experimental treatment increased the number of pods per 11.0 pcs. and of seeds by 28.8 pcs.; the seed weight per plant increased by 51.1 %.

The highest productivity per plant was achieved after the complex treatment with Biocomposite-correct – 13.0 g, which exceeded the control by 4.4 g. The TKW in all the experimental variants confidently exceeded the control by 10.1-26.0 %. The highest TKW was observed in the variant with the complex treatment with Biocomposite-correct (213.7 g).

Biological yield in the experimental variants was 2.9-3.8 t/ha while the yield of the control was 2.5 t/ha. The yield gain amounted to 0.4-1.3 t/ha. We can conclude that the studied bioproducts had a beneficial effect on soybean yield.

Table 4. Influence of the studied bioproducts on the structural parameters and yield of soybean (the average for 2020-2022).

Variant	Quantity, pcs/plant		Weight, g/plant		Biological yield, t/ha
	pods	seeds	seeds	TKW	
Control (treatment with water)	20.1	48.5	8.6	169.7	2.5
Seed treatment + foliar spraying with Gamair	26.2	60.1	9.5	186.8	2.9
Seed treatment + foliar spraying with Baktofit	28.3	65.7	10.6	193.1	3.0
Seed treatment with Biocomposite-correct	31.0	74.4	11.8	208.7	3.8
Seed treatment + foliar spraying with Biocomposite-correct	31.1	77.3	13.0	213.7	3.8
Seed treatment with Biocomposite-correct + Biosteam Start	28.0	67.5	12.5	200.3	3.3
HCP_{05}	2.4	10.8	2.5	15.1	0.1

The conducted results established correlation between economically important traits of soybean (Table 5). The results showed a direct strong correlation between soybean yield and the number of pods and seeds, the seed weight per plant and the TKW with the correlation being 0.83, 0.97, 0.90, and 0.98, respectively. The seed weight per plant strongly correlated with the number of seeds (r=0.87). A confident correlation was established between the number of seeds per plant and the TKW (r= 0.98).

Table 5. Correlation between the economically important traits of soybean plants (the average for 2020-2022).

Parameter	Biological yield, t/ha	Number of pods, pcs/plant	Seed weight, g/plant	TKW, g
Number of pods, pcs/plant	0.83		0.99	0.91
Number of seeds, pcs/plant	0.97	0.85	0.87	0.98
Seed weight, g/plant	0.90			0.98
TKW, g	0.98			

Thus, there was a strong direct correlation between the components of soybean yield. The high weight of seeds per plant effected many components of productivity.

4 Conclusions

Employing the studied bioproducts had a positive effect on the growth and development of soybean plants under the conditions of Primorsky kray. The bioproducts facilitated the preservation of soybean plants until harvest in comparison to the control (by 9.2-13.3% higher).

The studied bioproducts decreased the severity of Septoria blight by 3.3-5.4% (the degree of damage was 25.2% in the control variant) and downy mildew by 11.9-13.1% (17.5% in the control variant).

Using the bioproducts confidently increased the TKW by 13.8-26.0% compared to the control (169.7 g). The highest yield was detected in the experimental variants with seed treatment and the complex treatment with Biocomposite-correct (3.8 t/ha compared to 2.5 t/ha in the control variant). Strong positive correlation was established between some economically important traits of soybean plants.

References

1. A.N. Burunov, V.G. Vasin, A.V. Vasin, R.N. Saniev, Indicators of photosynthetic activity of plants and soybean yield when using growth stimulants. Izvestia of Samara Scientific Center of the Russian Academy of Sciences. Agricultural Sciences, **1**, 1, 3-12 (2022)
2. S.V. Kalashnikova, D.A. Strigun, Decrease in the activity of inhibitors of proteolytic enzymes in soybean seeds, The role of agrarian science in development: collection of research paper dedicated to the 105th anniversary of Voronezh State Agrarian University, 275-279 (2017)
3. A.S. Akulov, A.G. Vasil'chikov, Studying of some agro methods of cultivation of new soybean varieties, Legumes and Groat Crops, **1**, **25**, 36-40 (2018)
4. V.A. Fedotov, S.V. Goncharov, O.V. Stolyarov, Soybean in Russia (Agroliga Rossii, Moscow, 2013)
5. A.S. Stepanov, S.V. Makogonov, V.A. Tolpin, *Assessment of soybean yield in the Far East using regression models based on remote sensing data*. Current problems in remote sensing of the Earth from space, **16**, **6**, 194-198 (2019)

6. T.A. Aseeva, M.V. Terekhova, Effective methods for agricultural land management for soybean cultivation in Khaborovsky kray, The Russian Far East: problems of the development of the architecture and construction compex, **1**, 168-171 (2016)
7. A.O. Adesemoye, H.A Torbert, J.W. Kloepper, Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers, Microb, **58**, **4**, 921-929 (2009)
8. J. Wang, F. Islam, C. Yang, Use of phytohormones is improving abiotic stress tolerance in rice 2018, Advances in Rice Research for Abiotic Stres Tolerance, London, Elsevier 651-675 (2018)
9. O.V. Syrmolot, E.N. Lastushkina, N.S. Kocheva, The use of biological products in soybean crops, Siberian Herald of Agricultural Science, **52, 6**, 51-58 (2022)
10. Kh.P. Kokoev, A.T. Farniev, A.Kh. Kozyrev, A.A. Sabanova, Role of microbial biopreparations in increasing disease resistance and productivity of soybean plants, Journal of Proceesings of the Gorsky SAU, **4,** 56-62 (2019)
11. The listed of pesticides and agricultural chemicals admitted for use in the Russian Federation, Moscow, 1046 (2022)
12. B.A. Dospekhov, Methods of field experiment (with the basics of the statistical processing of research results), Moscow, Al'yans, **5**, 351 (2014)
13. Methods of the State variety testing of agricultural crops, Moscow, Sel'khozizdatel'stvo, **2**, 194 (1989)
14. J. Sinclair Compendium of Soybean Diseases, St. Paul, Min., **1**,104 (1982)