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THE EFFICIENCY OF AGROCHEMICALS BASED ON EKO-SP HUMUS SUBSTANCES ON SOYBEAN CROPS IN THE SOIL AND CLIMATIC CONDITIONS OF THE KURSK REGION

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Abstract. The results of laboratory and goal experiments on the study of the effectiveness of the use of agrochemicals based on EKO-SP humus substances in the cultivation of soybeans on chernozem soils of the Kursk region are presented. It was found that the treatment of soybean seeds with a humic preparation EKO-SP contributed to an increase in seed germination readiness by 4%, laboratory germination by 3% and had a stimulating effect on the growth of seedlings. The introduction of the preparation EKO-SP for pre-sowing cultivation at a dose of 2.5 l/ha and double treatment of crops in the phase of the 3rd and the 6th ternate leaf at a dose of 1.2 l/ha increased the activity of legume-rhizobial symbiosis, contributed to an increase in the number of nitrogen-fixing knobs by 11.5 pcs./plant, the mass of knobs — by 1.16 g/plant, the amount of fixed nitrogen in the air — by 27.0 kg /ha in comparison with the control variant. When using EKO-SP on soybean crops, the number of beans from the 1st plant increased by 1.7 pcs., the number of grains in a bean - by 0.2 pcs., the weight of grain from the 1st plant — by 1.41 g, the weight of 1000 grains - by 3.4 g, which contributed to an increase in the yield of soybean grain by 5.1 centner/ha or by 21.5%, an increase in the protein content in grain by 1.9%, fat — by 0.9%. When calculating the economic efficiency, it was found that the use of the humic preparation EKO-SP in the cultivation of soybeans was economically profitable. The introduction of EKO-SP at a dose of 2.5 l/g for pre-sowing cultivation, as well as double treatment of crops at a dose of 1.2 l/ha in the phase of the 3rd and the 6th ternate leaf provided a conditionally net income of 70,404 rubles/ha, at a cost of 1 centner of soybean grain equal to 1305.42 rubles and a profitability level of 187.3%. Taking into account the significant cost reduction due to the introduction of agrochemicals based on EKO-SP humus substances in tank mixtures with pesticides, the economic efficiency of using this preparation was even higher.

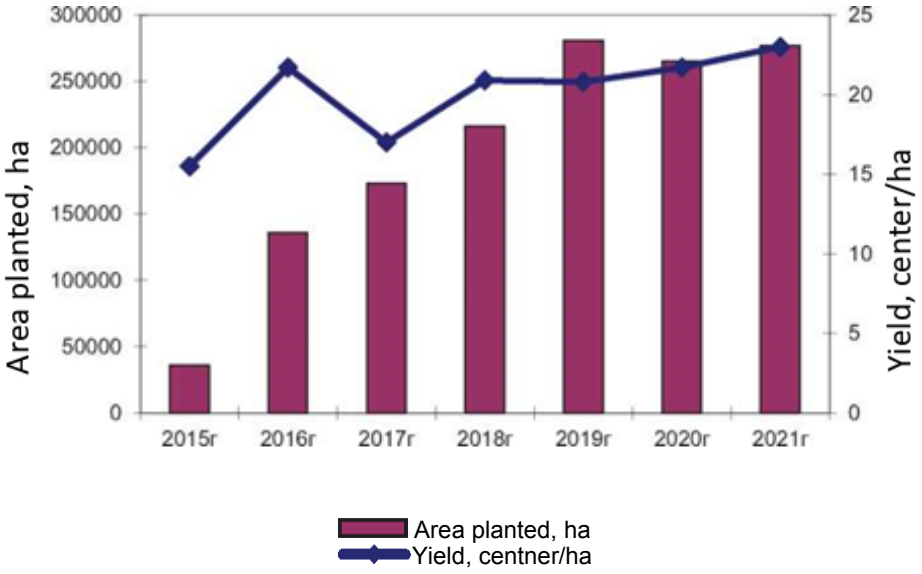
Keywords: soy, agrochemicals based on humus substances EKO-SP, symbiotic activity of nodule bacteria, yield, yield formula, protein, fat, economic efficiency

Introduction

In recent years, with a shortage of - productive resources and a steady increase in energy prices in the farms of the Kursk region, preference has been given to crops and technologies for their cultivation that require the least energy consumption. In this regard, it is of great interest to increase the crops of soybean - a food, commercial and forage crops, which are important in - conditions of protein deficiency [1, 2]. In comparison with grain cereals, soy grain contains 2-3 times more protein substances, which provides a high yield of transferable protein and essential amino acids [3].

The increase in the acreage under soybeans in the Kursk region is observed every year.

If in 2010-2015 the planting acreage of soybean in the region was 36-40 thousand hectares, then in 2016 — 136, in 2017 - 173, in 2018 - 216, in 2019 - 281, in 2020 - 265, in 2021 - 277 thousand hectares. The average yield of soybeans in the region - ranged from 17.0 centner/ha in 2019 to 21.7 centner/ha in 2020, and the gross yield of soybean grain in 2019 and 2020 was 600,000 and 553,000 tons, respectively (Fig.1).



In some areas of the Kursk region, such as Belovsky, Sudzhansky, Zolotukhinsky, Bolshesoldatsky, the yield of soybeans in recent years exceeds the average regional value and ranges from 21.4-29.7 centner/ha. This indicates sufficient reserves in - increasing the level of yield and growth of the gross yield of grain of this valuable leguminous crop. It is possible to ensure stable production of high yields of high-quality soybeans only by introducing a new generation of agritechnologies for cultivation, in which the principles of intensification, biology and resource conservation are organically integrated into a whole [4,5, b].

The main elements of soybean cultivation technologies aimed at increasing the yield of high-quality products are: the use of early-ripening and ultra-early ripening, high-yielding varieties adapted to the conditions of their cultivation, the introduction of effective plant protection systems against weeds, pests and diseases, resource-saving methods of tillage, a scientifically based fertilizer system [7,8]. Thus, the development of soybean cultivation technologies based on taking into account the characteristics of varietal - agrotechnics, their adaptation to soil and climatic conditions of cultivation, is a very urgent task and is widely demanded among agricultural producers.

Given the constant increase in prices for mineral - fertilizers and plant protection products, agricultural producers are forced to find other ways to increase soybean yields — to cultivate it using agrotechnologies of a new generation. The basis of such technologies is the widespread use of biological preparations, growth regulators and bacterial fertilizers, which make it possible to increase the immunity of plants to the most dangerous pathogens of diseases, the use of which from an economic point of view becomes more profitable and environmentally safe [9,10,11].

An important place among biological fertilizers and plant growth stimulants is currently occupied by humic preparations. Humates are a group of natural high-molecular substances that, due to the specifics of their structure and physiochemical properties, have high physiological activity. They do not possess toxic, carcinogenic and mutagenic properties and are not characterized by embryological activity. Humic preparations give a boost to metabolism and the growth of beneficial soil microflora, help to increase the protective attributes of plants against the effects of adverse physical (heat, cold), chemical (heavy metals, radionuclides, salinization) and biological (fungal, bacterial, viral diseases) factors, as a result contribute to the formation of high yields of agricultural crops [12, 13,14].

Such biofertilizers include the EKO-SP preparation, produced on the basis of humic substances from vegetable raw materials (lowland peat), containing in its composition: humic and fulvic acids, vegetable - hormones, amino and simple organic acids, trace elements in an easily digestible (chelated) form, useful soil microflora. EKO-SP is an inducer of plant immunity, has adaptogenic properties, promotes anti-stress resistance of plants to diseases and adverse environmental conditions, has high chemical purity and solubility, boosts crop yields and increases product quality. The preparation is used for seed treatment and foliar treatment of plants at all stages of vegetation (from seed treatment to additional fertilizing after stress suffered by plants).

Purpose, materials and research procedure

The purpose of this research was to determine the effectiveness of the use of agrochemicals based on EKO-SP humus substances in soybean cultivation in the soil and climatic conditions of the Kursk region.

In 2019-2021, the laboratory of technologies for cultivating field crops and agroecological assessment of lands of the Federal State Budget Scientific Institution "Kursk Federal Agrarian Research Center" laid the experience of studying the effectiveness of the use of the agrochemicals EKO-SP on soybean crops. The studies were carried out in a three-course grain rotation with the following crop sequence: spring barley — soy - spring wheat. The scheme of the experiment contained the following options: 1. Control (without preparation treatments); 2. Introduction of the preparation EKO-SP at a dose of 2.5 l/ ha for pre-sowing cultivation; 3. Introduction of the preparation EKO-SP at a dose of 2.5 l / ha for pre-sowing cultivation + treatment of crops in the phase of the 3rd ternate leaf at a dose of 1.2 l/ha + treatment of crops in the phase of the 6th ternate leaf at a dose of 1.2 l/ha.

The soil of the experimental site is a typical powerful chernozem of heavy loamy granulometric composition on a carbonate loess-like loam. When laying the field experiment, the content of humus (according to Tyurin) in the arable layer was 5.3%, alkaline hydrolyzable nitrogen — 69.0 mg/kg, active forms of phosphorus and potassium (according to Chirikov) — 8.8 and 14.5 mg/kg respectively, the reaction of the soil medium is weakly acidic — pH 5.4.

The variants in the experiment were arranged - systematically in one tier, in threefold repetition. The area of the registration plot is 200 m^2.

The technology of soybean cultivation corresponds to the generally accepted one for farms in the Central Chernozem region. Soybean variety — Kazachka, seeding rate — 0.6 million germinating seeds / ha, seeding method — row (row spacing width 15 cm), mineral nutrition background — $N_{30} P_{30} K_{30}$. Harvesting and crop accounting were carried out by a self-propelled combine "Sampo-500" by direct and 12% moisture content of grain. To determine the yield formula 1-2 days before the start of soybean harvesting, 4 sheaf samples were taken from each plot. After drying the sheaves, the following was determined: the number of beans from the 1st plant; the number of grains in the 1st bean; the mass of grain from the 1st plant; the mass of 1000 grains.

The amount of total nitrogen in the roots and above the ground mass of soybeans was determined by Kjeldahl. In the soybean grain samples, the protein and fat content was determined on the grain analyzer "Infratec™1241". The nature of the grain was determined according to GOST-10840-76, the mass of 1000 grains — according to GOST- 10842-76. The economic efficiency of the use of agrochemicals based on humus substances EKO-SP was calculated according to the generally accepted methodology. To process experimental data, the dispersion method of mathematical analysis according to B.A. Dospekhov was used (1985).

In addition to field studies in laboratory conditions, the effects of the EKO-SP preparation on the germination energy and laboratory germination of soybean seeds according to GOST 12038-84 were determined.

Meteorological conditions during the experiment were typical for the conditions of the Kursk region and were characterized by warm and arid weather. Average daily temperature of soybean growing season (May-September) in 2019, 2020 and 2021 was, respectively, 1.3, 1.4 and 1.1 °C above the norm with the precipitation totaling to 72.3, 74.7 and 86.7% of their average long-term amount (288 mm).

Results and Discussion

The results of laboratory studies showed that the treatment of soybean seeds with agrochemicals based on EKO-SP humus substances at a dose of 0.3 l/t contributed to an increase in germination energy (on the 3rd day of germination) - by 4%, laboratory germination of seeds (on the 7th day of germination) — by 3% compared to the control variant, and further on, it had a stimulating effect on the growth of soybean grain seedlings (Fig. 2, Table 1).

The introduction of agrochemicals based on EKO-SP humus substances into the soil for pre-sowing cultivation at a dose of 2.5 l/ha provided an increase in field germination of soybean seeds by 3.5%, contributed to better growth and development of plants, the formation of a more powerful vegetative mass and root system in comparison with the control variant (Table 2).

An important biological feature of soy is the assimilation of nitrogen in the air in symbiosis with nodule bacteria (Rhizobiales). Soy, being a new crop in the Central Black Earth region, needs mandatory inoculation with active strains of virulent tuberous bacteria. The effectiveness of bean-rhizobial symbiosis depends on the size and activity of the symbiotic apparatus. Most often, the number and mass of nodules per plant are used as these indicators [15].

Observations of the symbiotic activity of plants during the years of the experiment showed that the use of the preparation EKO-SP in soybean cultivation created optimal conditions for the normal vital activity of nodule bacteria on plant roots. This, in turn, increased the activity of legume-rhizobial symbiosis, contributed to an increase in the number and mass of nitrogen-fixing

nodules on soybean plants (Table 3).

The introduction of agrochemicals based on humus substances EKO-SP for cultivation at a dose of 2.5 l/ha and double treatment of crops in the phase of the 3rd and the 6th ternate leaf at a dose of 1.2 l/ha increased the number of nodules by 11.5 pcs./plant, the mass of nitrogen-fixing nodules - by 1.16 g/plant in comparison with the control variant (Fig. 3).

Calculations of the amount of fixed nitrogen by the Hopkins-Peters coefficient [15] showed that as a result of the symbiotic activity of nodule bacteria during the vegetation period, soy binds from 65.1 to 92.1 kg/ha of nitrogen, which satisfies the need of plants for it by 50-60%. The use of agrochemicals based on EKO-SP humus substances on soybean crops activated the - symbiotic activity of nodule bacteria and contributed to an increase in the amount of fixed nitrogen by soybean plants (Table 4).

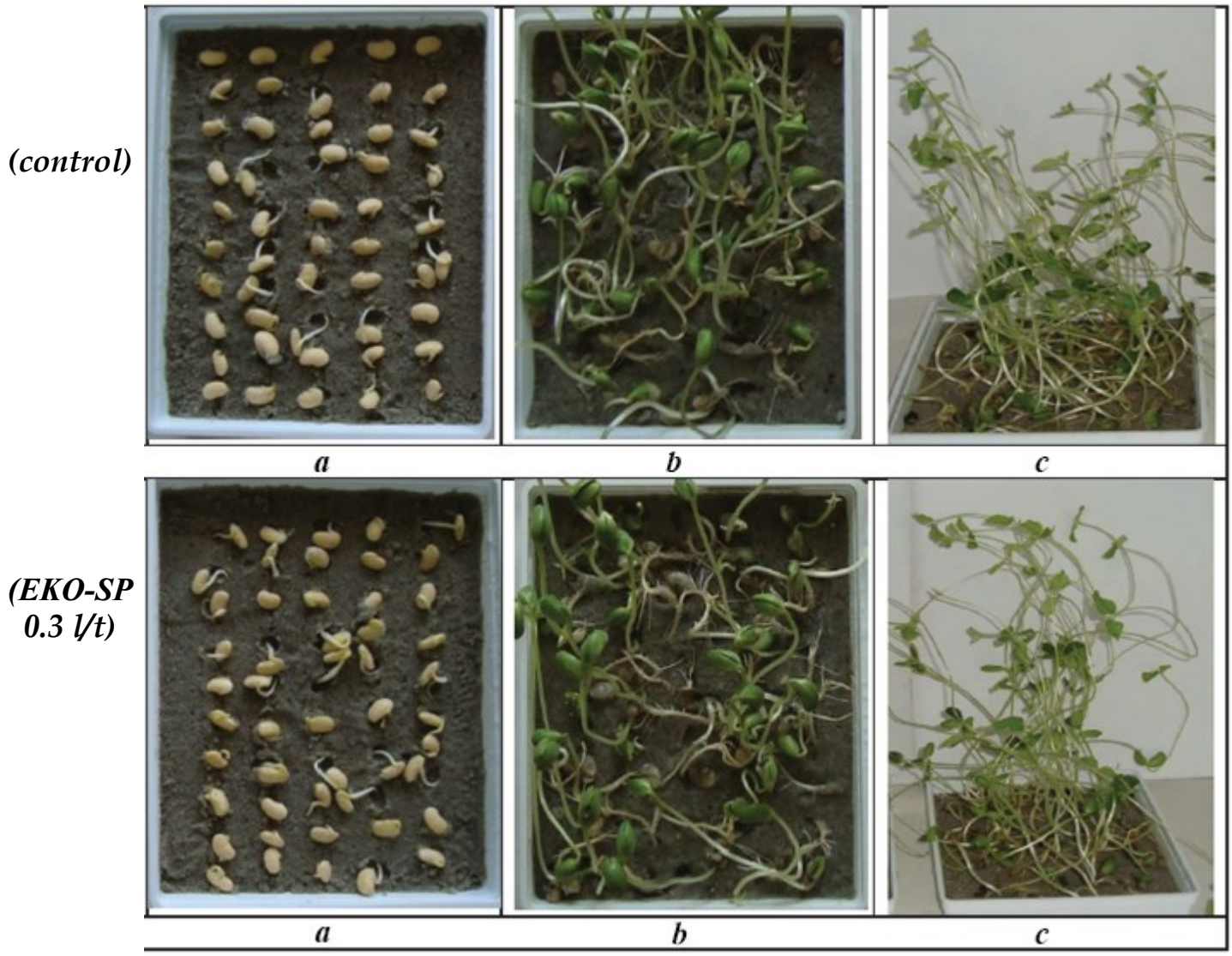


Figure 2**. Effect of agrochemicals based on EKO-SP humus substances on the germination energy and laboratory germination of soybean seeds (a — on day 3, b - on day 7, c — on day 14 of germination)**

Table 1. **Effect of agrochemicals based on EKO-SP humus substances on the germination energy and laboratory germination of soybean seeds**

Experiment variant	Germination energy (on the 3rd day of germination), %	Laboratory germination (on the 7th day of germination), %
1. Control (without preparation treatment)	86	91
2. EKO-SP, seed treatment, 3 l/t	90	94

Table 2. **Effect of agrochemicals based on EKO-SP humus substances on the field germination of soybean seeds (2019-2021)**

Experiment variant	The number of sprouted plants per 1 m2	Field emergence, %
1. Control	54.2	90.3
2. EKO-SP (2.5 l/ha), application for pre-sowing cultivation	56.3	93.8

Table 3. **Effect of the preparation on EKO-SP humus substances on the number and weight of nodules on soybean roots (fruit formation stage) (2019-2021)**

Experiment variant	Number of nodules, pcs.	Weight of nodules, g
1. Control	24.5	0.73
2. EKO-SP (2.5 l/ha) for cultivation	34.7	1.68
3. EKO-SP (2.5 l/ha) for cultivation + treatment of crops in the phase of the 3rd and the 6th ternate leaf (1.2 l/ha)	36.0	1.89

Figure 3. **Effect of the preparation EKO-SP on the development of soybean plants and the formation of nitrogen-fixing nodules (2021)**

Table 4. **Effect of agrochemicals based on EKO-SP humus substances on the amount of nitrogen fixed by the symbiotic apparatus on soybean roots (2019-2021)**

Experiment variant	The amount of total nitrogen in the roots and aboveground mass of soybeans, %	The amount of fixed nitrogen in the air, kg/ha
1. Control	1.03	65.1
2. EKO-SP (2.5 l/ha) for cultivation	1.18	85.3
3. EKO-SP (2.5 l/ha) for cultivation + treatment of crops in the phase of the 3rd ternate leaf (1.2 l/ha) + treatment of crops in the phase of the 6th ternate leaf (1.2 l/ha)	1.20	92.1

The lowest rates of nitrogen fixation were obtained in the control variant — 65.1 kg/ha. The introduction of agrochemicals based on EKO-SP humus substances for pre-sowing cultivation at a dose of 2.5 l/ha increased the amount of fixed nitrogen in the air to 85.3 kg/ha. The highest amount of fixed nitrogen by soybean plants (92.1 kg/ha) was noted in the variant with the introduction of the preparation EKO-SP at a dose of 2.5 l/ha for cultivation and double treatment of crops with this preparation in the phase of the 3rd ternate leaf at a dose of 1.2 l/ha and the phase of the 6th ternate leaf at a dose of 1.2 l/ha.

The use of agrochemicals based on organic substances EKO-SP on soybean crops had a positive effect on the elements of the yield formula. The introduction of the preparation EKO-SP for pre-sowing cultivation at a dose of 2.5 l/ha increased the number of beans from one soybean plant by 1.3 pcs., (in the control variant — 18.9 pcs.), the number of grains in a bean - by 0.1 pcs. (in the control variant -1.9 pcs.), the weight of grain from one plant — by 0.63 g (in the control variant — 4.22 g), the weight of 1000 grains — by 2.5 g (in the control variant — 117.7 g). In the variant with the introduction of the preparation EKO-SP for pre-sowing cultivation and double treatment of crops in the phase of the 3rd and the 6th ternate leaf, the number of beans from one soybean plant increased by 1.7 pcs., the number of grains in a bean — by 0.2 pcs., the weight of grain from one plant — by 1.41 g, the weight of 1000 grains — by 3.4 g (Table 5).

The most important morphological feature of soybeans, which determines the possibility and - effectiveness of mechanized harvesting, is the height of plants and especially the height of attachment of the - lower beans. The use of agrochemicals EKO-SP on soybean crops had a positive effect on these indicators. The average height of the stem of soybean plants cultivated in the control variant was 97.4 cm, and the height of the attachment of the lower bean was 21.9 cm. The introduction of agrochemicals based on EKO-SP humus substances for pre-sowing cultivation increased the height of soybean plants by 2.9 cm, and the height of attachment of the lower bean by 0.9 cm. In the variant with the introduction of the EKO-SP preparation for pre-sowing cultivation and double treatment of soybean crops in the phase of the 3rd and the 6th ternate leaf, the height of attachment of the lower bean to the soybean plant was 23.4 cm, or 1.5 cm higher than in the control variant.

An increase in the indicators of the yield formula, in variants using agrochemicals based on EKO-SP humus substances, provided a higher yield of soybeans. The introduction of the preparation EKO-SP for pre-sowing cultivation at a dose of 2.5 l/ha contributed to an - increase in soybean yield by 3.4 centner/ha, or by 14.3% compared with the control variant (23.7 centner/ha) (Table 6).

The highest yield of soybeans (28.8 centner/ha) was provided by the introduction of the preparation EKO-SP for pre-sowing cultivation at a dose of 2.5 l/ha and double treatment of crops with this preparation in the phase of the 3rd ternate leaf at a dose of 1.2 l/ha and the phase of the 6th ternate leaf at a dose of 1.2l/ha. The increase in yield compared to the control variant was 5.1 centner/ha or 21.5%.

The use of agrochemicals based on EKO-SP humus substances in soybean cultivation had a significant impact

Table 5. **Effect of agrochemicals based on EKO-SP humus substances on the elements of the soybean yield formula (2019-2021)**

Experiment variant	Stem length, cm	The height of the attachment of the lower - bean, cm	Number of beans from 1 plant, pcs.	Number of grains from 1 plant, pcs.	Grain weight from 1 plant,g	Weight of 1000 grains, g
1. Control	97.4	21.9	18.9	1.9	4.22	117.7
2. EKO-SP (2.5 l/ha), application for pre-sowing cultivation	100.3	22.8	20.2	2.0	4.85	120.2
3. EKO-SP (2.5 l/ha) for pre-sowing cultivation + treatment of crops in the phase of the 3rd ternate leaf (1.2 l/ha) + treatment of crops in the phase of the 6th ternate leaf (1.2 l/ha)	100.8	23.4	20.6	2.1	5.23	121.1

Table 6. **Effect of agrochemicals based on EKO-SP humus substances on soybean yield (2019-2021)**

Experiment variant	Yield, centner/ha	Increase	
		centner/ha	%
1. Control	23.7		
2. EKO-SP (2.5 l/ha), application for pre-sowing cultivation	27.1	3.4	14.3
3. EKO-SP (2.5 l/ha), application for pre-sowing cultivation + treatment of crops in the phase of the 3rd ternate leaf (1.2 l/ha) + treatment of crops in the phase of the 6th ternate leaf (1.2 l/ha)	28.8	5.1	21.5
Least significant difference$_{05}$	0.71		

Table 7. **Effect of agrochemicals based on EKO-SP humus substances on the quality of soybean seeds (2019-2021)**

Experiment variant	Content, %		Grain unit, g/l
	protein	fat	
1. Control	35.5	22.1	727.2
2. EKO-SP (2.5 l/ha), application for pre-sowing cultivation	37.2	22.8	733.0
3. EKO-SP (2.5 l/ha), application for pre-sowing cultivation + treatment of crops in the phase of the 3rd ternate leaf (1.2 l/ha) + treatment of crops in the phase of the 6th ternate leaf (1.2 l/ha)	37.4	23.0	734.0

Table 8. **Economic efficiency of applying agrochemicals based on EKO-SP humus substances in soybeans (2019-2021)**

Experiment variant	Yield, centner/ha	Cost of gross yield, rub.	Production costs, rub.	Cost price, rub/centner	Net income, rub/ha	Level of - profitability, %
1. Control	23.7	88,875	35,208	1,485.56	53,667	152.4
2. EKO-SP (2.5 l/ha), for cultivation	27.1	101,625	36,212	13,362.24	65,413	180.6
3. EKO-SP (2.5 l/ha), for cultivation + (1.2 l/ha) in the phase of the 3rd ternate leaf + (1.2 l/ha) in the phase of the 6th ternate leaf	28.8	108,000	37,596	1,305.42	70,404	187.3

on the quality of grain. Thus, the introduction of the EKO-SP preparation for pre-sowing cultivation increased the protein content in the grain by 1.7%, the fat content by 0.7% in comparison with the control variant. A higher protein and fat content in the grain was obtained in the variant with the introduction of the EKO-SP preparation for pre-sowing cultivation and double treatment of crops in the phase of the 3rd and the 6th ternate leaf. The protein content in this variant increased by 1.9%, fat — by 0.9% in comparison with the control variant (Table 7).

When calculating the economic efficiency of using the EKO-SP preparation on soybean crops, the following indicators were taken as a basis: the cost of the EKO-SP preparation is 240 rubles/l; the yield of soybeans in the control variant and according to the variants of the experiment is the actual one obtained by weighing; the price of 1 ton of soybean grain is 37,500 rubles (average purchase price of soybean grain for 2020-2021)

Calculations of economic efficiency showed that the use of agrochemicals based on EKO-SP humus substances on soybean crops was economically profitable (Table 8).

The introduction of the EKO-SP preparation for pre-sowing cultivation at a dose of 2.5 l/ha increased the yield of soybeans by 3.4 centner/ha, thereby increasing the cost of gross output by 12,750 rubles/ha. The value of the net income was 65,413 rubles/ha, the cost of 1 centner of grain was 13,362.24 rubles, the level of profitability was 180.6%.

The effectiveness of the preparation EKO-SP when applied for pre-sowing cultivation at a dose of 2.5 l/ha and double treatment of crops in the phase of the 3rd ternate leaf at a dose of 1.2 l/ ha + treatment of crops in the phase of the 6th ternate leaf at a dose of 1.2 l/ ha increased: the value of the nominal income amounted to 70,404 rubles/ha, the cost of 1 centner of grain — 1,305.42 rubles, the profitability level — 187.3%. Given the significant reduction in costs due to the introduction of the EKO-SP preparation in tank mixtures with pesticides, the economic efficiency of using the preparation was even higher.

Conclusions

The results of tests of the agrochemicals based on EKO-SP humus substances indicate its high efficiency in the cultivation of soybeans. The introduction of the EKO-SP preparation for pre-sowing cultivation at a dose of 2.5 l/ha and double treatment of crops in the phase of the 3rd and the 6th ternate leaf at a dose of 1.2 l/ ha contributed to an increase in soybean yield by 5.1 centner/ha, and an increase in the protein content in grain by 1.9%, fat by 0.9%. The use of agrochemicals based on EKO-SP humus substances on soybean crops was economically beneficial due to the high effectiveness of the preparation, its low cost and low doses of application.

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