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**INFLUENCE OF
PRE-SOWING SEED
TREATMENT AND
FOLIAR FERTILIZERS
ON THE
PHOTOSYNTHETIC
ACTIVITY OF SOYBEAN
CROP**

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The aim of the study was to study the effect of pre-sowing treatment of seeds with bacterial preparations and foliar top dressing on the formation of the photosynthetic apparatus, dry matter accumulation and productivity of soybean crops of the Slavna variety in the conditions of the Right-Bank Forest-Steppe of Ukraine. The research was conducted in 2024–2025 in the experimental fields of the Institute of Feed and Agriculture of the Podillia NAAS. The soil cover of the experimental plots is represented by gray medium loamy soils with a humus content of 2.03%, a slightly acidic pH reaction (5.0) and an average level of mineral nutrition. Pre-sowing treatment of soybean seeds was carried out with the bacterial preparation Rizoline (3.0 l/t), with the bioprotector Rizosave (1.0 l/t) and the organo-mineral fertilizer Helprost (2.0 l/t), and foliar top dressing was carried out with the organo-mineral fertilizer HELPROST in key phases of vegetation. The parameters of the photosynthetic activity of plants were estimated by the leaf surface area, photosynthetic potential and dry matter accumulation. The obtained data were subjected to statistical processing by generally accepted methods, which ensured the reliability of the results. The results of the studies indicate that the combination of bacterial preparations and foliar feeding contributed to a more intensive development of the leaf apparatus and an increase in the efficiency of photosynthesis. The largest leaf surface area (64.5 thousand m²/ha) and photosynthetic potential (3.90 million m² days/ha) were obtained in the variant with pre-sowing seed treatment Rizoline + Rizosave + Helprost in combination with foliar feeding HELPROST.

Analysis of the dynamics of dry matter accumulation showed its gradual increase with each phase of development and maximum values during the seed filling period. The lowest dry biomass yield (4.7 t/ha) was observed in the variant with treatment only with Helprost without foliar fertilization, while the application of foliar fertilizer provided its increase to 6.7 t/ha. The results obtained confirm the effectiveness of the integrated use of bacterial preparations and organo-mineral fertilizers in the technology of soybean cultivation, which allows to increase the photosynthetic potential of plants, the accumulation of dry matter and the formation of a high and stable crop yield in conditions of unstable temperature regime and limited moisture supply of the Right-Bank Forest-Steppe.

Keywords: soybean, variety, pre-sowing seed treatment, foliar fertilization, leaf area, photosynthetic potential, dry matter.

Table 3., Lit. 11.

Statement of the problem. In the current conditions of intensification of agricultural production and increased environmental requirements, the search for effective and at the same time environmentally safe methods of increasing the productivity of leguminous crops, in particular soybeans, is of particular importance [1–2].



One of the key components of such methods is pre-sowing seed treatment, which significantly affects the initial phases of plant growth and development, the formation of the root system and the realization of their productive potential [3]. At the same time, the traditional use of mineral fertilizers, especially nitrogen fertilizers, is not always economically justified and can cause soil degradation and negative environmental consequences [4]. In this context, a promising direction is the use of bacterial preparations in combination with organo-mineral fertilizers, both in pre-sowing seed treatment and foliar feeding. The introduction of specialized microorganisms, in particular *Bradyrhizobium japonicum*, during soybean seed inoculation promotes the formation of nitrogen-fixing nodules on plant roots, which increases their ability to assimilate atmospheric nitrogen [5]. This not only reduces the crop's need for mineral nitrogen fertilizers, but also improves the physiological and biochemical state of plants, their resistance to stress factors and potentially contributes to increasing yields [6]. However, the effectiveness of pre-sowing treatment and foliar feeding is largely determined by growing conditions, the composition of organo-mineral fertilizers and the interaction between microbiological and agrochemical factors. This necessitates the need for further scientific research in this area.

Analysis of recent research and publications. In modern scientific and experimental research, much attention is paid to improving the technology of soybean cultivation, in particular, pre-sowing treatment of seeds with bacterial preparations and organo-mineral fertilizers, as well as foliar feeding [7,10]. It has been proven that the effectiveness of realizing the potential of the crop largely depends on the formation of symbiotic relationships between plants and nitrogen-fixing microorganisms, as well as on balanced mineral nutrition in the early stages of growth. Many studies indicate that seed inoculation with preparations based on *Bradyrhizobium japonicum* stimulates the formation of nodules on the roots, activates the biological fixation of atmospheric nitrogen and improves nitrogen nutrition of plants. This promotes plant development, the formation of yield and allows partially or completely to reduce the application of mineral nitrogen fertilizers. Studies also show that combining inoculation with balanced mineral nutrition increases the chlorophyll content index and improves the chemical composition of seeds, which generally has a positive effect on yield and quality indicators of products compared to the option without seed treatment [6, 8-9].

Practical experience [2] shows that inoculation of soybean seeds with *B. japonicum* strains increases the resistance of plants to water stress and adverse environmental conditions. Under water deficit, biological nitrogen fixation partially compensates for the lack of available forms of nitrogen in the soil, supporting plant growth and development [1].

Some studies note the effectiveness of combining bacterial preparations with organo-mineral fertilizers, which provide plants with the necessary macro- and microelements and at the same time create favorable conditions for the development of soil microflora.

Such a combination contributes to better initial plant growth, increasing their resistance to abiotic stresses and optimizing physiological and biochemical processes during the growing season [9].

Field experiments confirm [7] that the combination of bacterial inoculation and the application of small doses of mineral nitrogen can produce a synergistic effect in the form of a significant increase in yield and protein composition of seeds. The effectiveness of such interaction depends on the doses of fertilizers, agroclimatic conditions and soybean genotype. Thus, inoculation alone increases the yield by approximately 20%, and the joint use of inoculant with organo-mineral nutrition – up to 42% under certain conditions.

At the same time, the literature emphasizes that the effectiveness of pre-sowing inoculation and the application of organo-mineral fertilizers varies significantly depending on soil and climatic conditions, varietal characteristics of soybeans and technological parameters of the use of drugs. This necessitates further research aimed at determining the optimal combinations of bacterial drugs and fertilizers to ensure high and stable yields.

Therefore, scientific substantiation and development of effective elements of soybean growing technology in the conditions of the Right-Bank Forest-Steppe, aimed at increasing crop productivity under unstable temperature conditions and limited and uneven moisture supply in the region, is of particular importance.

It has been previously proven that maximum yield and high quality of agricultural crop products are achieved under conditions of full development and effective functioning of the assimilation apparatus of plants. The decisive factors in this process are the area of the leaf surface, its spatial location and the nature of formation during the growing season. It is these parameters that affect the intensity of absorption of photosynthetically active radiation and the level of synthesis of organic substances necessary for plant growth and development.

Optimal development of the leaf apparatus and high photosynthetic potential are largely ensured by scientifically based technological cultivation techniques that support the functional activity of leaves during the growing season. Rational leaf surface area is a key prerequisite for obtaining a high soybean yield, since leaves are the main accumulator of solar energy and the place of synthesis of organic compounds for the formation of generative organs and the accumulation of productive mass.

Studies conducted in the conditions of the Forest-Steppe of Ukraine show that the optimal leaf surface area for soybean crops is within 40–50 thousand m²/ha. Reducing this indicator limits the use of photosynthetically active radiation and reduces the level of photosynthesis and yield. Excessive development of the leaf surface also does not ensure the efficiency of crop productivity due to the thickening of crops and mutual shading of plants, which leads to premature death of leaves of the lower tiers and a decrease in the overall photosynthetic potential [7].

Therefore, the optimal combination of the size and structural organization of the leaf surface is a key factor in the effective use of solar energy and the formation of high and stable soybean yields with appropriate quality indicators.

Conditions and methodology of the study. Field studies of the influence of pre-sowing seed treatment and foliar top dressing on the photosynthetic activity of soybean crops were conducted in 2024–2025 in the experimental fields of the Institute of Feed and Agriculture of the Podillia NAAS.

The experiments were set up in accordance with generally accepted field experiment methods in compliance with the principles of repeatability and random placement of variants [11]. Photosynthetic activity was assessed by indicators of leaf surface area, dynamics of dry matter accumulation and intensity of growth processes during the growing season. The soil cover of the experimental plots was gray medium loamy soil, typical of the Right-Bank Forest-Steppe. The arable layer was characterized by an average level of fertility: humus content – 2.03%, slightly acidic reaction of the soil solution (pH saline – 5.0). The level of mineral nutrition of the soil was: mineral nitrogen –16.8 mg/kg, mobile phosphorus – 159.0 mg/kg, exchangeable potassium – 107.0 mg/kg of soil.

Pre-sowing seed treatment was carried out according to the experimental scheme using bacterial preparations and nutrition regulators, which created favorable conditions for the initial growth and development of plants (Table 1).

The research was conducted on the soybean variety Slavna. Foliar fertilization was carried out in certain phases of vegetation in order to optimize the photosynthetic activity of crops and increase the efficiency of nutrient use. The obtained experimental data were subjected to statistical processing using generally accepted methods, which ensured the reliability and scientific validity of the obtained results.

Table 1

Field experiment scheme

Factor A – pre-sowing seed treatment	Factor B – foliar feeding
<ol style="list-style-type: none"> 1. Without pre-sowing treatment 2. Pre-sowing treatment with Rizoline+Rizosave 3. Pre-sowing treatment with HELPROST organo-mineral fertilizer 4. Pre-sowing treatment with HELPROST organo-mineral fertilizer+ Rizoline+Rizosave 	<ol style="list-style-type: none"> 1. Without foliar feeding 2. Foliar feeding in the budding phase with the organo-mineral fertilizer HELPROST 3. Foliar feeding in the bean formation phase with the organo-mineral fertilizer HELPROST 4. Foliar feeding in the seed filling phase with the organo-mineral fertilizer HELPROST 5. Foliar feeding in the phases of budding + bean formation with the organo-mineral fertilizer HELPROST 6. Foliar feeding in the phases of budding + seed filling with the organo-mineral fertilizer HELPROST 7. Foliar feeding in the phases of bean formation + seed filling with the organo-mineral fertilizer HELPROST 8. Foliar feeding in the phases of budding + bean formation + seed dressing with HELPROST organo-mineral fertilizer

The source is based on my own research.

Research results. The research showed that the size of the soybean leaf surface at different stages of growth and development was largely determined by pre-sowing seed treatment with bacterial preparations and foliar feeding (Table 2).

The highest values of the leaf surface area were recorded in the variant with pre-sowing seed treatment with Rizoline (3.0 l/t) + Rizosave (1.0 l/t) + Helprost (2.0 l/t) in combination with foliar feeding in the bean filling phase with the organo-mineral fertilizer HELPROST, where the leaf surface area reached 64.5 thousand m²/ha.

Table 2

Formation of leaf area of soybean plants depending on bacterial and mineral nutrition, thousand m²/ha

Pre-sowing seed treatment	Foliar feeding	Periods of growth and development			
		budding	beginning of flowering	end of flowering	poured seeds
Without pre-sowing treatment	Without foliar feeding	19,3	29,7	50,0	51,0
	Budding	19,7	40,3	54,1	56,2
	Bean formation	20,0	35,3	54,3	59,3
	Pouring seeds	19,9	32,4	52,6	58,0
	Budding+Bean Formation	20,3	38,5	55,7	59,2
	Budding+Seed filling	19,1	39,7	53,9	56,9
	Bean formation + Seed filling	21,5	35,9	53,7	60,6
	Budding+Bean formation+Seed filling	19,3	40,0	56,4	60,7
Rizoline+Rizosave	Without foliar feeding	24,5	29,5	51,8	53,0
	Budding	21,2	30,2	57,1	58,5
	Bean formation	23,4	29,0	58,1	61,0
	Pouring seeds	20,0	30,0	53,7	55,0
	Budding+Bean Formation	24,3	33,1	58,4	61,1
	Budding+Seed filling	21,2	33,2	56,3	57,3
	Bean formation + Seed filling	22,0	29,5	55,7	56,2
	Budding+Bean formation+Seed filling	24,0	32,5	57,9	61,3
Helprost	Without foliar feeding	22,2	29,3	53,8	54,5
	Budding	22,4	41,1	55,8	54,1
	Bean formation	21,8	34,8	55,3	57,2
	Pouring seeds	20,9	35,1	54,0	55,4
	Budding+Bean Formation	21,3	40,6	54,2	58,2
	Budding+Seed filling	20,0	36,7	55,0	57,1
	Bean formation + Seed filling	22,1	34,9	54,9	60,0
	Budding+Bean formation+Seed filling	23,5	38,4	57,0	61,6
Rizoline+Rizosave+ Helprost	Without foliar feeding	24,8	28,8	53,0	55,9
	Budding	24,0	37,6	54,1	59,0
	Bean formation	23,8	32,4	59,0	63,1
	Pouring seeds	22,9	31,7	53,6	64,5
	Budding+Bean Formation	25,0	35,7	58,9	60,2
	Budding+Seed filling	23,1	34,3	55,6	56,7
	Bean formation + Seed filling	22,4	30,9	57,8	58,8
	Budding+Bean formation+Seed filling	24,0	36,0	58,5	59,8

The source is based on my own research.

Field observations during the growing season showed that pre-sowing treatment of soybean seeds with a bacterial preparation in combination with foliar top dressing has a positive effect on the formation and functioning of the photosynthetic apparatus of plants (Table 3).

Table 3

Formation of photosynthetic potential of soybean depending on bacterial-mineral nutrition, million m² days/ha

Pre-sowing seed treatment	Foliar feeding	Periods of growth and development			
		full steps-budding	budding - beginning of flowering	beginning of flowering-end of flowering	end of flowering - seed set
Without pre-sowing treatment	Without foliar feeding	0,73	0,91	2,06	3,22
	Budding	0,75	0,96	2,33	3,60
	Bean formation	0,76	0,95	2,25	3,56
	Pouring seeds	0,76	0,94	2,17	3,44
	Budding+Bean Formation	0,77	0,98	2,34	3,66
	Budding+Seed filling	0,73	0,93	2,29	3,56
	Bean formation + Seed filling	0,82	1,02	2,32	3,63
	Budding+Bean formation+Seed filling	0,73	0,94	2,34	3,69
Rizoline+Rizosave	Without foliar feeding	0,93	1,12	2,30	3,50
	Budding	0,81	0,99	2,25	3,58
	Bean formation	0,89	1,07	2,34	3,71
	Pouring seeds	0,76	0,94	2,15	3,40
	Budding+Bean Formation	0,92	1,12	2,45	3,83
	Budding+Seed filling	0,81	1,00	2,29	3,60
	Bean formation + Seed filling	0,84	1,02	2,25	3,54
	Budding+Bean formation+Seed filling	0,91	1,11	2,42	3,79
Helprost	Without foliar feeding	0,84	1,02	2,23	3,47
	Budding	0,85	1,07	2,48	3,74
	Bean formation	0,83	1,03	2,33	3,63
	Pouring seeds	0,79	0,99	2,28	3,54
	Budding+Bean Formation	0,81	1,03	2,40	3,69
	Budding+Seed filling	0,76	0,96	2,29	3,58
	Bean formation + Seed filling	0,84	1,04	2,34	3,66
	Budding+Bean formation+Seed filling	0,89	1,11	2,49	3,86
Rizoline+Rizosave+ Helprost	Without foliar feeding	0,94	1,13	2,32	3,57
	Budding	0,91	1,13	2,46	3,76
	Bean formation	0,90	1,10	2,43	3,83
	Pouring seeds	0,87	1,06	2,30	3,66
	Budding+Bean Formation	0,95	1,16	2,53	3,90
	Budding+Seed filling	0,88	1,08	2,38	3,67
	Bean formation + Seed filling	0,85	1,04	2,32	3,66
	Budding+Bean formation+Seed filling	0,91	1,12	2,49	3,85

The source is based on my own research

The use of these agrotechnical techniques contributed to a more intensive development of the leaf apparatus and increased efficiency of using photosynthetically active radiation. The highest rates of photosynthetic potential were observed in the variant where pre-sowing treatment of seeds was carried out with the preparations Rizoline (3.0 l/t), Rizosave (1.0 l/t) and Helprost (2.0 l/t) in combination with foliar top dressing with the organo-mineral fertilizer HELPROST in the budding and bean formation phases. Under these conditions, the leaf surface area reached 64.5 thousand m²/ha, and the photosynthetic potential was 3.90 million m²·days/ha. These data indicate the high efficiency of the combined use of bacterial preparations and foliar feeding for optimizing the photosynthetic activity of soybean crops and forming a high productive potential of the crop. Analysis of the dynamics of dry matter accumulation showed a gradual increase in this indicator at each subsequent phase of soybean growth and development, with maximum values achieved during the seed filling period. This pattern indicates an increase in assimilation processes during the growing season and active accumulation of organic matter in the generative organs of plants.

The lowest dry biomass indicators were observed in the variant where pre-sowing seed treatment was carried out exclusively with the drug Helprost at a rate of 2.0 l/t without foliar feeding – 4.7 t/ha. In variants with foliar feeding with the organo-mineral fertilizer HELPROST in the phase of budding and bean formation, regardless of the method of pre-sowing treatment, the accumulation of dry matter was significantly higher and reached 6.7 t/ha.

Conclusions. Field studies in 2024–2025 on soybean crops of the Slavna variety showed that pre-sowing treatment of seeds with bacterial preparations in combination with foliar top dressing is an effective measure for optimizing the photosynthetic activity of crops. The use of these agrotechnical techniques contributed to a more intensive development of the leaf apparatus, an increase in photosynthetic potential and the accumulation of dry matter by plants during the growing season. The largest leaf surface area (64.5 thousand m²/ha) was observed in the variant with pre-sowing treatment with Rizoline (3.0 l/t), Rizosave (1.0 l/t) and Helprost (2.0 l/t) in combination with foliar top dressing with the organo-mineral fertilizer HELPROST in the phases of budding and bean formation. Under these conditions, the photosynthetic potential reached 3.90 million m²·days/ha, which indicates a high level of use of photosynthetically active radiation. Analysis of the dynamics of dry matter accumulation showed its consistent growth during the growing season with a maximum during the seed filling period. The lowest dry biomass yield (4.7 t/ha) was observed in the variant with seed treatment only with the drug Helprost (2.0 l/t) without foliar feeding. Carrying out foliar feeding in the phases of budding and bean formation provided a significantly higher level of dry matter accumulation - up to 6.7 t/ha, regardless of the pre-sowing treatment variant. Therefore, the integrated use of bacterial preparations and foliar feeding is an effective means of increasing the productivity of soybean crops.

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АНОТАЦІЯ

ВПЛИВ ПЕРЕДПОСІВНОЇ ОБРОБКИ НАСІННЯ ТА ПОЗАКОРЕНЕВИХ ПІДЖИВЛЕНЬ НА ФОТОСИНТЕТИЧНУ ДІЯЛЬНІСТЬ ПОСІВІВ СОЇ

Метою проведеного дослідження було вивчення впливу передпосівної обробки насіння бактеріальними препаратами та позакореневих підживлень на формування фотосинтетичного апарату, накопичення сухої речовини та фотосинтетичну продуктивність посівів сої сорту Славна в умовах Лісостепу правобережного.

Дослідження виконували у 2024–2025 роках на дослідних полях Інституту кормів та сільського господарства Поділля НААН. Грунтовий покрив дослідних ділянок представлений сірими середньосуглинковими ґрунтами з вмістом гумусу 2,03%, слабокислою реакцією (рН 5,0) та середнім рівнем забезпеченості основними елементами мінерального живлення. Для передпосівної обробки насіння використовували бактеріальний препарат Різолайн (3,0 л/т) у поєднанні з біопротектором Різосейв (1,0 л/т) та органо-мінеральним добривом Helprost (2,0 л/т). Позакореневі підживлення виконували органо-мінеральним добривом HELPROST у ключові фази вегетації рослин. Параметри фотосинтетичної діяльності оцінювали за площею листкової поверхні, фотосинтетичним потенціалом та накопиченням сухої речовини. Отримані дані піддавали статистичній обробці загальноприйнятими методами, що забезпечувало достовірність результатів.

Результати дослідження показали, що поєднання бактеріальних препаратів і позакореневих підживлень сприяло інтенсивнішому розвитку листкового апарату та підвищенню ефективності фотосинтезу. Найбільшу площу листкової поверхні (64,5 тис. м²/га) і фотосинтетичний потенціал (3,90 млн м²-днів/га) зафіксовано у варіанті з передпосівною обробкою насіння Різолайн + Різосейв + Helprost у поєднанні з позакореневим підживленням HELPROST. Аналіз динаміки накопичення сухої речовини показав її поступове зростання впродовж усіх фаз розвитку та досягнення максимальних значень у період наливу насіння. Найменший приріст сухої біомаси (4,7 т/га) спостерігався у варіанті з обробкою лише Helprost без позакореневих підживлень, тоді як внесення позакореневого добрива забезпечувало її збільшення до 6,7 т/га. Отримані результати підтверджують ефективність інтегрованого використання бактеріальних препаратів та органо-мінеральних добрив у технології вирощування сої. Такий підхід дозволяє підвищити фотосинтетичний потенціал рослин, накопичення сухої речовини та формування високого і стабільного врожаю культури навіть за умов нестійкого температурного режиму та обмеженого вологозабезпечення Лісостепу правобережного.

Ключові слова: соя, сорт, передпосівна обробка насіння, позакореневі підживлення, площа листя, фотосинтетичний потенціал, суха речовина.

Табл. 3., Літ. 11.

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