

## INFLUENCE OF BIOACTIVE PRODUCTS ON NITROGEN FIXATION AND YIELD OF SOYBEAN AT DIFFERENT LEVELS OF MINERAL NUTRITION

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**Topicality.** Today, in the context of environmental and economic crises in the world, attention to the use of the potential of agroecosystems and minimization of the pesticide and agrochemicals load has increased. For this purpose, the use of environmentally safe plant growth stimulants and the latest microfertilizers is one of the most promising methods in crop production. Scientific substantiation and adaptation to the soil and climatic conditions of a particular growing zone, as well as studying the impact of bioactive products on varietal characteristics of the crop are needed to improve the environmentally safe technology of soybean cultivation. **Purpose.** For increase of productivity by 15–20 % and biologization of crop cultivation, it is necessary to determine the best variants of combining mineral fertilization with foliar dressing, seed and crops treatment with bioactive products for soybean varieties. **Methods.** Field method, quantitative-weight, laboratory, mathematical and statistical methods were used. **Results.** We determined that the activity of nitrogen-fixing symbioses formation on soybean largely depends on the method of treatment with bioactive substances, in particular, stimulants of Vympel brand and Orakul microfertilizer. When processing soybeans with biologically active drugs, the mass of nodules increases much more intensively than their number. The increase in the mass of bubbles was up to 50.7 % in the Diadema Podillia variety and up to 60.8 % – in the Samorodok variety. The application of the investigated methods of seed treatment and foliar dressing ensured an increase in the soybean seed yield of the Diadema Podillia variety by 4.4–42.7 %, and of the Samorodok variety by 4.7–44.4 %, depending on the level of mineral nutrition. **Conclusions.** Growth stimulants of Vympel brand and Orakul microfertilizers are effective for increasing yields, enhancing nitrogen fixation soybean. The use of bioactive products can serve as an important element of economic and environmentally safe technologies for growing soybeans, which can reduce the impact of stress factors on plants, in particular, the lack of fertilizers.

**Key words:** soybean, nitrogen-fixing activity, microfertilizers, growth stimulants, soybean yield

**Introduction.** Global environmental and economic problems, as well as the shortage of protein products for the world's population, require increasing the production of the most nutritious and low-cost protein-containing products, one of which is soybeans [1, 2].

Ukraine is a leader in soybean production in Europe, where a competitive soybean industry is being formed: the area under crops, yield and production of soybeans are increasing. Soybeans are both highly profitable crop and one of the best predecessors in modern crop rotations, which improve soil fertility [3]. Soybeans are an ideal precursor for cereals due to the presence of nitrogen-fixing bacteria and have a positive effect on the entire agricultural sector. This is very economically advantageous in case of insufficient fertilizer application [4, 5].

However, in the context of production in-

tensification, it is not always possible to achieve the maximum genetic potential of soybean varieties and efficiently use material and technical resources in existing technologies. Therefore, there was a need to improve cost-effective and environmentally friendly crop cultivation technologies. One of such elements was physiologically active drugs (plant growth regulators and innovative microfertilizers). Such products increase plant resistance to diseases and activate physiological processes, affecting metabolism, thereby contributing to the realization of potential productivity [4, 6, 7]. According to numerous studies, growth regulators and micronutrient fertilizers increase the yield of field crops. It is advisable to apply them both in pre-sowing seed treatment and during the growing season [8, 9].

Scientific sources suggest that microele-

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ments (molybdenum, cobalt, boron, copper, zinc, manganese, etc.) have a significant impact on symbiotic nitrogen fixation and also enhance the activity of the symbiotic nitrogen fixation process in combination with pre-sowing bacterisation and the application of plant growth stimulants [10, 11].

The Ukrainian market is saturated with such products, but their manufacturability and effectiveness are unstable and can lead to unexpected results when combined with other measures in one technological process. Reduction of the rate of nitrogen fertilizers in crop cultivation technologies while maintaining the productivity of agrocenoses is possible through the use of stimulants and microfertilizers that improve the state of agricultural ecosystems. In addition, the use of environmentally friendly products that reduce the application of agrochemicals is an urgent task for agriculture.

The purpose of the research is to determine the optimal variants of mineral fertilization in combination with foliar feeding of soybean varieties and seed and crop treatment with bioactive products that meet their biological requirements and increase productivity by 15–20 %, as well as biologization of crop cultivation in the Western Forest-Steppe.

**Materials and Methods.** In our research, the effectiveness of 8 variants of seed and plant treatment using stimulants and microfertilizers during growing season on soybean of Samorodok and Diadema Podillia varieties at different levels of mineral nutrition (1<sup>st</sup> – no fertilizers; 2<sup>nd</sup> – N<sub>10</sub>P<sub>26</sub>K<sub>26</sub>; 3<sup>rd</sup> – N<sub>20</sub>P<sub>52</sub>K<sub>52</sub>) was studied as follows: 1. No treatment (control); 2. Treatment in 2–3 leaf stage (Vympel); 3. Seed treatment (Vympel-K) + treatment in 2–3 leaf stage (Vympel); 4. Seed treatment (Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum); 5. Seed treatment (Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum) + treatment in 2–3 leaves stage (Vympel); 6. Treatment of crops in the budding stage (Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron); 7. Treatment of crops in 2–3 leaves stage (Vympel) and budding (Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron); 8. Seed treatment (Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum) + treatment of crops in 2–3 leaves stage (Vympel) and bud-

ding (Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron).

The soil on the experimental plots is podzolised, low-humus, medium loamy, slightly washed out on loess-like loam of brownish-paler colour. The humus content in the topsoil is from 3.3 to 3.7 %, nutrients: nitrogen – 112 mg/kg, phosphorus – 260 mg/kg, potassium – 152 mg/kg. Hydrolytic acidity is 2.35 mg kg/eq per 100 g of soil, pH (salt) is 5.7.

In this study, the main methods of research were field (phenological observations and records), quantitative-weight (determination of the yield structure), laboratory (determination of the mass and number of soybean nodules), mathematical and statistical (determination of the reliability of the results).

All records and observations were carried out in accordance with the work programme and calendar plan according to generally accepted methods of research in crop production [12–16].

**Results and Discussion.** According to the results of the studies, it was found that the number and weight of root nodules depended largely on the soybean variety, seed and crop treatment with biologically active products (Table 1).

Unequal number and weight of nodules were formed on the soybean roots of Samorodok and Diadema Podillia varieties during the stage of nodule formation. Thus, on average, over the years of research, the Samorodok variety had 21–30 nodules weighing 0.35–0.89 g, and the Diadema Podillia variety had 30–38 g and 0.58–0.93 g, respectively. Therefore, with a lower number of root nodules of Samorodok variety, their weight was significantly higher compared to Diadema Podillia variety. Accounting for nodules during seed formation showed that their number and weight increased compared to the first sampling. This suggests that the growth of nodules in soybean continues during the period of seed formation. In this sampling, Diadema Podillia had a lower nodule weight and a higher nodule number than Samorodok. This indicates that Samorodok has a slightly higher symbiotic potential than Diadema Podillia.

Seed treatment with Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum increased the number and weight of root nodules of both soybean varieties compared to the control

**Table 1. Number and weight of nodules per soybean plant depending on the treatment with biologically active substances (average for 2019–2020)**

Variety	Variant of treatment	Nodules per 1 plant, pcs.		Nodule weight per 1 plant, g		Symbiotic potential, kg/ha
		pod formation	seed formation	pod formation	seed formation	
Diadema Podillia	1	30	37	0.58	0.73	434
	2	34	42	0.61	0.87	515
	3	36	44	0.74	0.99	610
	4	38	45	0.84	1.01	623
	5	36	43	0.88	1.03	634
	6	38	39	0.58	0.81	482
	7	36	40	0.62	0.89	529
	8	34	42	0.93	1.10	675
Samorodok	1	21	34	0.35	0.79	604
	2	22	34	0.39	0.85	650
	3	26	38	0.53	0.98	763
	4	25	39	0.67	1.16	933
	5	25	40	0.80	1.20	934
	6	23	34	0.49	0.92	708
	7	22	35	0.54	0.97	758
	8	30	39	0.89	1.27	1006

*Variants of treatment:*

1. Control;
2. Treatment of crops with Vympel in the stage of 2–3 leaves;
3. Treatment of seeds with Vympel-K + treatment of crops in the stage of 2–3 leaves with Vympel;
4. Seed treatment with Vympel-K + Orakul nasinnia + Oracle colofermin molybdenum;
5. Seed treatment with Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum + treatment of crops in the stage of 2–3 leaves with Vympel;
6. Treatment of crops in the budding stage Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron;
7. Treatment of crops in the stage of 2–3 leaves Vympel + treatment of crops in the budding stage with Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron;
8. Seed treatment with Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum + treatment of crops in the 2–3 leaf stage with Vympel + treatment of crops in budding stage with Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron.

(no treatment). Thus, for Diadema Podillia variety, in the variants without seed treatment during the second sampling, there were 37–40 nodules per plant, and 42–45 nodules per plant – after seed treatment. In Samorodok variety, these indicators were 34–35 and 38–40 nodules per plant, respectively.

Under seed treatment, the weight of nodules also increased: in Diadema Podillia variety – from 0.73–0.89 g without seed treatment to 0.99–1.10 g with treatment. In Samorodok variety, these indicators were 0.79–0.97 and 0.98–1.27 g, respectively. The increase in the weight of the nodules was up to 50.7 and up to 60.8 %, according to the variety.

The largest number and weight of root

nodules of soybean, respectively, and the highest indicators of symbiotic potential of plants (1006 kg/ha) were observed in variant 8 on crops of Samorodok variety.

Thus, the combination of complex seed treatment and two foliar feeding in the stages of 2–3<sup>rd</sup> trifoliolate leaf and budding has a positive effect on the nitrogen fixation productivity of soybean of both varieties. Studies have shown that the level of soybean seed yield significantly depended on the factors studied (Table 2).

The studied methods of seed and crop treatment provided an increase in the soybean seed yield of Diadema Podillia variety from 0.09 to 0.65 t/ha (4.4–42.7%) and of Samorodok variety – from 0.10 to 0.67 t/ha (4.7–44.4%), de-

**Table 2. Yield of soybean varieties depending on fertilization and treatment of seeds and crops with biologically active products (average for 2019–2020), t/ha**

Variants of treatment	Samorodok			Diadema Podillia		
	No fertilizers	N <sub>10</sub> P <sub>26</sub> K <sub>26</sub>	N <sub>20</sub> P <sub>52</sub> K <sub>52</sub>	без добрив	N <sub>10</sub> P <sub>26</sub> K <sub>26</sub>	N <sub>20</sub> P <sub>52</sub> K <sub>52</sub>
1. Without seed and crop treatment (control)	1.35	1.93	2.23	1.57	2.03	2.28
2. Treatment of crops with Vympel in the stage of 2–3 leaves	1.44	2.04	2.35	1.70	2.12	2.40
3. Treatment of seeds with Vympel-K + treatment of crops in the stage of 2–3 leaves with Vympel	1.64	2.15	2.56	1.95	2.31	2.63
4. Seed treatment with Vympel-K + Orakul nasinnia + Oracle colofermin molybdenum	1.78	2.38	2.68	2.06	2.46	2.75
5. Seed treatment with Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum + treatment of crops in the stage of 2–3 leaves with Vympel	1.86	2.46	2.77	2.16	2.56	2.85
6. Treatment of crops in the budding stage Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron	1.67	2.20	2.59	1.99	2.38	2.63
7. Treatment of crops in the stage of 2–3 leaves Vympel + treatment of crops in the budding stage with Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron	1.76	2.30	2.64	2.09	2.47	2.73
8. Seed treatment with Vympel-K + Orakul nasinnia + Orakul colofermin molybdenum + treatment of crops in the 2–3 leaf stage with Vympel + treatment of crops in budding stage with Vympel + Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron	1.95	2.57	2.91	2.24	2.65	2.93
LSD <sub>05</sub>	A (fertilization)			0.041		
	B (variant of treatment)			0.033		

pending on the chemical and the level of mineral nutrition. It should be noted that on the background without fertilizers, the percentage efficiency of these treatments in terms of yield increase was slightly higher than on fertilised backgrounds.

Mineral nutrition with the application of N<sub>10</sub>P<sub>26</sub>K<sub>26</sub> increased the yield of Diadema Podillia variety by 0.36–0.46 t/ha compared to the control, with the application of N<sub>20</sub>P<sub>52</sub>K<sub>52</sub> – by 0.64–0.71 t/ha, and for Samorodok variety – by 0.45–0.55 t/ha and 0.78–0.85 t/ha, respectively.

Among the studied methods of treatment, the highest increase in the seed yield of soybean in Diadema Podillia variety (0.60–0.67 t/ha) and Samorodok variety (0.62–0.67 t/ha) was obtained with complex seed treatment and two foliar feeding in the stages of 2–3 leaves and budding (var. 8).

### Conclusions.

The analysis of experimental data shows that seed and crop treatment with Vympel stimulants and Orakul microfertilizers increases the symbiotic potential and soybean yield. The best solution is to combine pre-sowing seed treatment with Vympel-K, Orakul nasinnia, Orakul colofermin molybdenum with crop treatment in the stage of 2–3 true leaves with Vympel and in the stage of budding with a complex of Vympel, Orakul multicomplex, Orakul colofermin molybdenum, Orakul colofermin boron at the level of mineral nutrition N<sub>20</sub>P<sub>52</sub>K<sub>52</sub>. The use of these chemicals can serve as a measure to improve cost-effective and environmentally friendly soybean cultivation technologies, which helps to reduce the impact of stress factors on plants, in particular, lack of fertilizers.

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**Власюк О. С., Квасницька Л. С. Вплив біологічно активних препаратів на азотфіксацію та урожайність сої за різних рівнів мінерального живлення. Зернові культури. 2022. 6 (2). 78–83.**

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**Актуальність.** Сьогодні у світі, в умовах екологічної та економічної криз, підвищилась увага до використання потенційних можливостей агроєкосистем й мінімалізації застосування пестицидів та агрохімікатів. Для цього використання екологічно безпечних стимуляторів розвитку рослин і новітніх форм мікродобрив є одним з найбільш перспективних прийомів у рослинництві. **Визначення проблеми.** Удосконалення технології вирощування сої екологічно-безпечними елементами потребує наукового обґрунтування та адаптації до ґрунтово-кліматичних умов конкретної зони вирощування, а також вивчення їх впливу стосовно сортових особливостей культури. **Мета.** Визначити оптимальні варіанти мінерального удобрення сортів сої у поєднанні з позакореневим підживленням та обробкою

насіння і посівів біологічно-активними препаратами, що сприяють підвищенню продуктивності на 15–20 % та біологізації вирощування культури. **Методи.** Польовий, кількісно-ваговий, лабораторний, математичний, статистичний аналіз. **Результати.** Визначено, що активність формування азотофіксуювальних симбіозів на сої значною мірою залежить від способу обробки біологічно активними речовинами, зокрема стимуляторами марки Вимпел та мікродобривами Оракул. За обробки сої біологічно активними препаратами маса бульбочок зростає набагато інтенсивніше, ніж їх кількість. Приріст маси бульбочок становив до 50,7 % у сорту Діадема Поділля і до 60,8 % – у сорту Самородок. Застосування досліджуваних способів обробки насіння та позакореневого підживлення забезпечило зростання урожайності насіння сої сорту Діадема Поділля на 4,4–42,7 %, а сорту Самородок – на 4,7–44,4 %, залежно від рівня мінерального живлення. **Висновки.** Стимулятори росту і розвитку Вимпел та мікродобрива Оракул є ефективними для підвищення урожайності та посилення азотфіксації сої. Застосування біологічно активних препаратів може слугувати важливим елементом ощадних та екологічно безпечних технологій вирощування сої, який здатен знижувати вплив на рослини стресових факторів, зокрема, нестачі добрив.

**Ключові слова:** соя, азотофіксувальна активність, мікродобрива, стимулятори росту, урожайність сої