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Assessment of the Effect of Biological Growth-Regulating Preparations on the Yield of Agricultural Crops under the Conditions of Steppe Zone

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ABSTRACT

Increasing the production of high-quality agricultural products with minimal negative impact on environmental components is one of the priority tasks of modern agriculture. Due to the global world trends aimed at ensuring a sustainable and safe economy and reducing the use of chemical protection agents, it is predicted that the share of alternative biological methods in the European agricultural sector will increase to 10%, the area of agricultural land for organic farming will increase by 50%. Under the conditions of intensification of agricultural production, a comprehensive approach to the use of microelements and microbial biological preparations, which enhance growth processes, anti-stress, protective effect and increase the yield of agricultural crops, becomes expedient. The article deals with the effects of biological growth-regulating preparations on winter wheat, sunflower hybrids, and vegetable peas. It was established that when processing winter wheat with the "Grainactive-C" preparation, the greatest increase in grain yield was observed under the conditions of 3-fold treatment of crops in the phase of tillering, flag leaf, and grain filling (3.2 t/ha, or 18%). At the same time, the greatest effect was recorded when treating crops in the tillering phase, where the yield increase was 2.9 c/ha, or +16% compared to the control. It has been studied that the effectiveness of the preparation "Nano-Agro" when applied to sunflower hybrids also depends on the time of its application. The same increase – 0.9 t/ha of seeds (+12% compared to the control) was observed during pre-sowing treatment of seeds and during the vegetation phase (before flowering), but the yield increase when treating sunflower after flowering phase was only 0.32 t/ha (4%). In order to restore disturbed soils and increase the efficiency of agricultural production, the introduction of leguminous crops into the crop rotation becomes important, after harvesting them up to 80 kg/ha of biological nitrogen remains and humus accumulates in the arable layer of the soil up to 10.8 t/ha. Treatment of vegetable peas seeds with Rhizohumin contributed to the accumulation of humus by 3.96 t/ha. Through field studies, the article proves the positive effect of growth-regulating preparations on agricultural crops under the conditions of the Steppe zone of Ukraine.

Keywords: agricultural lands, winter wheat, sunflower hybrids, vegetable peas, growth-regulating preparations, organic agriculture.

INTRODUCTION

Traditional methods of agricultural production, which are based on the application of mineral fertilizers and pesticides, allow increasing the gross harvest of crops by up to 20%. However, as a result of the intensive and systematic use of chemicals, the scale of their negative impact on the soil is increasing, which equates to the scale of global environmental problems. Of the total amount of chemicals, only 5 to 20% is used for its intended purpose, the remaining 80% is dispersed in the environment, accumulates in the soil, and is included in the system of global circulation of chemicals as well as trophic food chains (Breus et al., 2018).

According to the research by the Food and Agriculture Organization, among the total area of 4.85 billion hectares of the world's agricultural land, 26% is degraded and polluted; as a result of this, the world loses about ¼ of all agricultural harvest, the stability of agroecosystems is disrupted, whereas the problems of food safe and ecological safety of the environment are increasing. Depending on the high level of anthropogenic load on soils, the report of the Intergovernmental Panel on Climate Change raised the issue of using biological technologies for growing agricultural crops and finding innovative methods to increase world food supplies (Pichura et al., 2020).

The leading role among agricultural crops in the world is played by wheat, it forms the basis of the food ration of the population of many countries. Wheat grain is used for food and fodder purposes. The ratio of protein and starch in wheat grain is on average 1:6–7, which is the most favorable for human to maintain normal body weight and his working capacity. An important component of high-quality grain production is the use of adaptive wheat varieties, and the realization of the productivity potential depends significantly on abiotic and biotic factors. In addition, the yield and quality of wheat grain significantly changes due to the use of nitrogen fertilizers (Breus et al., 2022).

The sunflower has also a significant role in the structure of world's agriculture. This is the main oil crop in Ukraine and one of the most important oil crops in the world. The seeds of its zoned varieties and hybrids contain 50–52% of oil, and the seeds of selected varieties – up to 60%. Compared to other oil crops, sunflower yields the highest harvest of oil per unit area (750 kg/ha on average in Ukraine). Sunflower oil accounts for 98% of total oil production in Ukraine. Sunflower oil is widely used as a food product in its natural form (Dudiak et al., 2019, Pichura et al., 2021a). The nutritional value is determined by the high content of polyunsaturated fatty (linoleic) acid (55–60%), which has significant biological activity and accelerates the metabolism of cholesterol esters in the body, which positively affects human health. Sunflower oil also includes the components that are very valuable for the human body, such as phosphatides, sterols, and vitamins (A, D, E, K).

An equally important agricultural crop that significantly affects the completeness of human food ration is vegetable peas. It is of great importance for the complete nutrition of the population due to the balanced content of the protein-carbohydrate composition, biological activity, and mineral agents. Peas contain: 18–22% of dry matter, 4.8–7.0% of sugars, 6.8% of starch, 0.8–1.7% of fiber, 4.8–5.2% of crude protein, 0.2 % of fat, 0.9% of ash. Regarding the total sugar content, peas contain 95% of sucrose. In terms of protein content, peas occupy a leading position among vegetables. Also, 100 grams of raw mass contains 25–60 milligrams of ascorbic acid (vitamin C) – the daily norm for a person; 0.40 milligrams of carotene, 0.34 milligrams of thiamine, 0.19 milligrams of riboflavin (B2), 2.6 milligrams of nicotinic acid (PP), etc. In Ukraine, peas are grown on an area of 4.3 thousand hectares, the gross harvest is 49.45 thousand tons, the average yield is 12.46 tons/ha (Pichura et al., 2023).

One of the ways to realize the biological yield potential of all three agricultural crops, along with selection-genetic and biotechnological methods, is the use of highly effective plant growth regulators of the new generation.

For example, for peas, the microorganisms used for the production of bacterial fertilizers contribute to the supply of mineral nutrients and physiologically active agents (phytohormones, vitamins) to plants. The mutually beneficial symbiotic effect of bacterial preparations with leguminous plants influences the activation of biological processes in the rhizosphere of plants and the development of their root system. Of the total amount of biological nitrogen formed in the amount of 100–200 kg/ha, 60–75% is spent on crop formation, 25–40% remains in the soil with post-harvest plant residues, increasing its fertility and the yield level of agricultural crops by 26% (Boiko et al., 2018, Pichura et al., 2021b).

The positive spectrum of influence of such preparations on wheat cultivation is very wide: increasing yield, improving grain quality, strengthening plant resistance to adverse environmental factors, reducing the quantity of protection agents when used together with growth regulators, etc. This is evidenced by the experience of many research institutions and numerous scientific and industrial inspections. Currently, growth regulators are widely used in production as important elements of ecologically safe resource-saving technologies (Breus et al., 2021).

For example, in the works of the world's leading scientists (Hashem et al., 2019, Thomas Müller & Undine Behrendt, 2021, Kumera Nemea et al., 2021, Dominique Holtappels et al., 2021, Ying Ma, 2019), the effective effect of biological preparations and plant growth regulators on productivity and improving the quality of agricultural products has been proven. Also, some scientists in their research presented the nanotechnologies for increasing the yield of agricultural products based on growth-regulating preparations with carbon and copper content, which protect plants from pathogenic organisms and negative environmental factors (Shagufta Afreena et al., 2022, Archana Singh et al., 2021). Additionally, in their works, scientists suggest the use of biostimulants and bioprotectors based on seaweed extracts, humic substances, protein hydrolysates, amino acids and plant extracts to improve plant growth and yield as well as reduce the negative impact of abiotic and biotic environmental factors (Reda Ben Mrid, 2021, Dudiak et al., 2021).

Orientation of agricultural production at biological methods of plant protection will contribute the reduction of anthropogenic load on agrocenoses, restoration of soil fertility, obtaining a high level of crop yield, profitability of agricultural production, and ecologically safe crop production. Thus, the main goal of the article is to study the influence of biological growth-regulating preparations on the yield of winter wheat, sunflower hybrids and vegetable peas under the conditions of Steppe zone of Ukraine.

MATERIAL AND METHODS

The study of the effect of biological growth-regulating preparations on winter wheat and sunflower hybrids was carried out on the basis of field research in the southern Steppe zone of Ukraine using graphic and cartographic materials. The study was conducted on the basis of the use of two preparations "Grainactive-C" (for winter wheat) and "Nano-Agro" (for hybrid sunflower).

The scheme of the experiment of the effect of the stimulator "Grainactive-C" on the productivity of winter wheat "Dryada-1" was as follows:

- without treatment (control);
- crop treatment during the tillering phase;
- crop treatment during the flag leaf phase;
- crop treatment during the grain filling phase;
- triple crop treatment. The recurrence of the experiment – four times, the area of the scoring plot – 100 m^2.

The scheme of the experiment of the effect of the stimulator "Nano-Agro" on the productivity of the sunflower hybrid "Siujet":

- control (without treatment);
- seed treatment before sowing;
- treatment during the vegetation phase;
- treatment after flowering phase;
- triple crop treatment. The recurrence of the experiment – four times, the area of the scoring plot – 100 m^2.

The experiments on the application of boron (B) and molybdenum (Mo) fertilizer were carried out during field crop rotation on the fields of the southern Steppe zone of Ukraine according to the following scheme:

I. Factor A. Pre-sowing treatment of vegetable pea seeds:

- $N_{30}P_{40}$ – base;
- base + treatment of seeds with Rhizohumin;
- base + treatment of seeds with boron;
- base + treatment of seeds with boron and Rhizohumin;
- base + treatment of seeds with boron and molybdenum;
- base + treatment of seeds with molybdenum;
- base + treatment of seeds with molybdenum and Rhizohumin;
- base + treatment of seeds with boron, molybdenum and Rhizohumin

II. Factor B. Sowing dates:

- early period – the third decade of March;
- late period – first decade of April.

The study of the effective influence of biological preparations on growth indicators, the formation of above-ground mass of vegetable peas and indicators of soil fertility was carried out with the use of Rhizohumin and trace elements in the early and late sowing periods. The influence of boron and molybdenum trace elements and the bacterial fertilizer Rhizohumin on the timing of phenological phases of development, the length of interphase periods of vegetable peas and the humus condition of soils were studied.

RESULTS AND DISCUSSION

The treatment of winter wheat seeds with biological agents contributed the activation of nitrogen-assimilating enzymes in plants, which led to additional protein synthesis in the grain. The study of the action of the "Grainactive-C" preparation on winter wheat crops testified its positive effect on crop yield. "Grainactive-C" is the newest preparation with a systemic positive effect on agricultural crops. The active agent is a soluble, biologically active organic compound containing nitrogen atoms, which accelerates metabolic processes in plants, promotes the development of nitrification and ammonification processes in the soil, and accelerates plant growth under the conditions of moisture deficiency. At the same time, the formation of a plant-bacterial association contributes to a significant accumulation of nitrogen in the soil, which improves its fertility indicators and increases the yield of winter wheat. It was determined that the effectiveness of the "Grainactive-C" preparation depended on the phase of plant development during which growth stimulator treatment was carried out (Table 1).

It was determined that when treating winter wheat with the preparation "Grainactive-C", the greatest increase in grain yield was observed under the conditions of 3-fold treatment of crops during the phase of tillering, flag leaf, grain filling (0.32 t/ha, or 18%). At the same time, the greatest effect was recorded when treating crops during the tillering phase, where the yield increase was 0.29 t/ha, or +16% compared to the control. The tillage of crops during the phase of the flag leaf contributed to an increase in the yield by 0.07 t/ha (4%), and during the phase of grain filling – 0.08 t/ha (4.5%), which were within the error of the experiment, i.e. 0.092 t/ha.

The "Grainactive-C" preparation is ecologically safe for the environment, decomposes in the soil, does not create an addictive effect, reduces the risk of plant diseases, and has a positive effect on the productivity of agricultural crops. It was also determined the positive influence of the "Nano-Agro" preparation on the productivity of the sunflower hybrid (Table 2).

According to the study it has been determined that the effectiveness of the preparation "Nano-Agro" also depends on the time of its application. The same increase – 0.9 t/ha of seeds (+12% compared to the control) was observed during pre-sowing treatment of seeds and during the vegetation phase (before flowering), but the yield increase when treating sunflower after flowering phase was only 0.32 t/ha (4%). The largest increase in yield was established with triple crop treatment during the indicated phases of sunflower development – 0.16 t/ha (+22% compared to the control). The positive effect of the biological preparation was observed at the initial stages of the development of crop due to an increase of the root system and resulting increase of the absorption of nutrients from the soil.

Pre-sowing treatment with the "Nano-Agro" growth stimulator helps to increase the immune effect of plants, increases their resistance to adverse weather conditions, protects against pests and helps to reduce the pesticide load on the soil.

Studies of the effect of growth-regulating preparations on the growth characteristics of

Table 1. The effect of the "Grainactive-C" stimulator on the productivity of winter wheat

№	Variant	Productivity, t/ha					+/-	Rating
		Recurrence				Average		
		I	II	III	IV			
1	Without treatment (control)	1.82	1.68	1.94	1.76	1.8	0	5
2	Tillering phase	2.01	2.12	2.16	2.09	2.09	+0.29	2
3	Flag leaf phase	1.91	1.86	1.92	1.79	1.87	+0.07	4
4	Grain filling phase	1.8	1.96	1.85	1.9	1.88	+0.08	3
5	Triple crop treatment.	2.13	2.06	2.21	2.05	2.12	0.32	1

Note: $HIP_{0.05}$ – 0.092 t/ha.

Table 2. The effect of the "Nano-Agro" stimulator on the productivity of the sunflower hybrid

№	Variant	Productivity, t/ha					+/-	Rating
		Recurrence				Average		
		I	II	III	IV			
1	Control (without treatment)	0.7	0.68	0.79	0.77	0.73	0	5
2	Seed treatment before sowing	0.83	0.78	0.89	0.75	0.82	0.09	3
3	Vegetation phase	0.81	0.86	0.78	0.8	0.82	0.09	2
4	Flowering phase	0.76	0.8	0.72	0.74	0.76	0.03	4
5	Triple crop treatment	0.87	0.92	0.85	0.64	0.89	0.16	1

Note: $HIP_{0.05}$ – 0.054 t/ha.

vegetable pea showed that the timing of sowing had a significant effect during the phase of technical ripeness of vegetable pea. The difference depended on the weather conditions of the separate year. In the most favorable soil moisture supply and air humidity, the difference was 6-7 days in the variant without seeds treatment with boron, molybdenum and Rhizohumin.

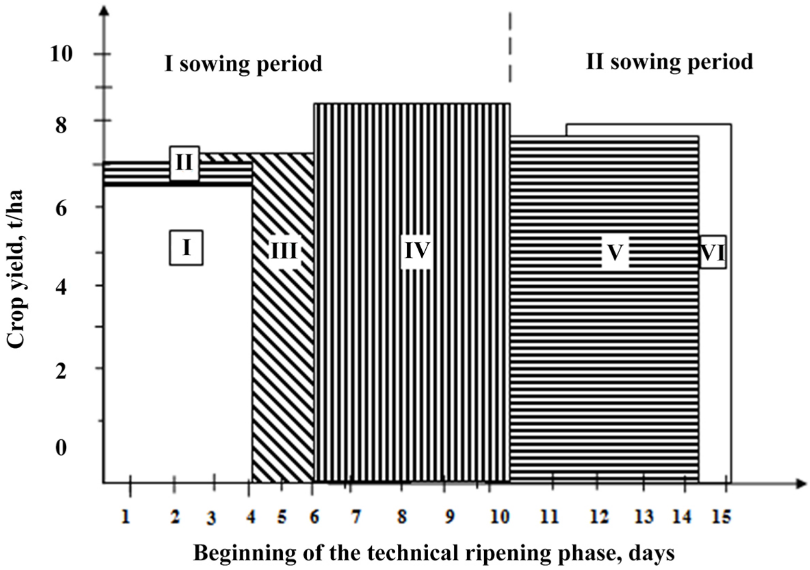

Figure 1. Modeling the impact of seed treatment with boron, molybdenum, and Rhizohumin on crop yield and the beginning of technical ripening phase of vegetable peas

Table 3. Growth dynamics of the linear height of the vegetable pea during all development phases, depending on the seeds treatment and sowing dates, cm

№	Variant	Phases of development			
		3-leaves	Budding	Bean formation	Technical ripening
I sowing period					
1	$N_{30}P_{40}$ – base	17.6	53	60	63
2	Base + Rhizohumin	24	62	70	72
3	Base + B	22	65.3	71	74
4	Base + B + Rhizohumin	27	67.6	76	80
5	Base + Mo	29	72.6	79	82
6	Base + Mo + Rhizohumin	28	71	80	81
7	Base + B+ Mo	28	77	86	89
8	Base + B + Mo + Rhizohumin	29	73	86	92
II sowing period					
1	$N_{30}P_{40}$ – base	19	51	59	61
2	Base + Rhizohumin	25	58	65	73
3	Base + B	24	61	68	73
4	Base + B + Rhizohumin	26	65	75	78
5	Base + Mo	29	67	77	83
6	Base + Mo + Rhizohumin	28	68	76	80
7	Base + B+ Mo	28	73	81	86
8	Base + B + Mo + Rhizohumin	28	76	82	89
A. Evaluation of the significance of the main effects					
HIP_{05}	A=	1.3	2.1	3.6	4.5
	B=	1.0	1.7	4.1	6.0
B. Assessment of the significance of partial differences					
HIP_{05}	A=	2.4	0.4	2.1	1.9
	B=	1.9	2.6	3.4	4.3

Delaying the sowing dates (until the middle and end of April) does not provide a practical result in studied zone due to the increase in average daily temperatures, which leads to the leveling of results and even to a decrease in yield due to the fact that peas are biologically a crop of early sowing dates.

It was determined that the treatment of pea seeds with boron in the first period of sowing did not affect the duration of its vegetation period, and in the second period of sowing, with increasing the temperatures, an acceleration of its development on two days was observed. The effect of the molybdenum was reversed: in all cases, it delayed the technical ripening phase by an average of 4 days both when applied in its pure form and in combination with boron. When seeds were treated with molybdenum and Rhizohumin, the technical ripening phase started on 5 days later than in the control variant (Fig. 1).

Under the conditions of increased air temperature on the second period of sowing, the duration of the vegetation period of vegetable peas was reduced on 2 days. The treatment with Rhizohumin and trace elements contributed to increased growth of peas, which improved the process of photosynthesis (Table 3).

It was determined that the greatest height of the vegetable pea was in the period of seeds technical ripening in the first and second terms of sowing in variants with complex seed treatment with boron, molybdenum and Rhizohumin and reached 92 cm for the first term and 89 cm for the second term (increased by 45% compared to with control). Increased growth, an increase in the number of leaves and internodes of stems contributed to the improvement of aeration, illumination of crops and the formation of a powerful assimilation apparatus.

At the early stages of ontogenesis, seed treatment with Rhizohumin, boron, and molybdenum contributed to the growth of above-ground green mass and the accumulation of dry matter on the early and late sowing periods (Table 4).

Table 4. Dynamics of the accumulation of above-ground mass of vegetable peas in the main phases of development under the influence of seed treatment g/m^2

№	Variant	Raw mass				Mass of dry matter			
		3-leaves	Budding	Flowering	Technical ripening	3-leaves	Budding	Flowering	Technical ripening
I sowing period									
1	$N_{30}P_{40}$ – base	196	570	603	1241	30	146	175	397
2	Base + Rhizohumin	216	670	740	1420	37	169	204	456
3	Base + B	206	760	806	1483	35	190	229	445
4	Base + B + Rhizohumin	233	840	870	1556	39	189	232	466
5	Base + Mo	276	860	870	1634	42	188	220	441
6	Base + Mo + Rhizohumin	293	910	993	1769	46	199	239	478
7	Base + B+ Mo	276	900	980	1760	41	192	236	458
8	Base + B + Mo + Rhizohumin	253	916	1010	1783	42	192	240	463
II sowing period									
1	$N_{30}P_{40}$ – base	166	556	603	1160	32	148	179	371
2	Base + Rhizohumin	196	646	720	1372	38	168	205	439
3	Base + B	190	730	916	1510	36	194	233	463
4	Base + B + Rhizohumin	213	773	893	1612	39	193	243	468
5	Base + Mo	266	846	900	1648	46	201	234	461
6	Base + Mo + Rhizohumin	286	876	996	1705	48	205	254	487
7	Base + B+ Mo	276	880	986	1745	46	199	250	488
8	Base + B + Mo + Rhizohumin	273	900	1003	1751	44	201	251	484

The increase in green mass of vegetable peas, as a result of seed treatment with molybdenum and Rhizohumin in the 3-leaves phase during the first sowing period, was 49%. During the second sowing period, this indicator in the variant with complex treatment of trace elements and Rhizohumin increased by 64% compared to the control (Fig. 2).

A more objective indicator, compared to the amount of green mass, is the quantity of dry matter of the above-ground part of plants. It was the maximum during the first sowing period in the variant of seed treatment with molybdenum and Rhizohumin in all phases of development and at the technical ripening phase of the seeds (478 g/m^2).

The highest yield of above-ground dry matter was during the phase of technical ripeness of vegetable pea seeds, but with the same pre-sowing treatment of the seeds, a significant difference was obtained in terms of sowing (Figure 3).

Without pre-sowing seed treatment, the early sowing period had a noticeable advantage, during which dry matter accumulated on average during the years of research by 26 g/m^2 (7%) more than during the late one. The Rhizohumin treatment of vegetable peas contributed to inhibition

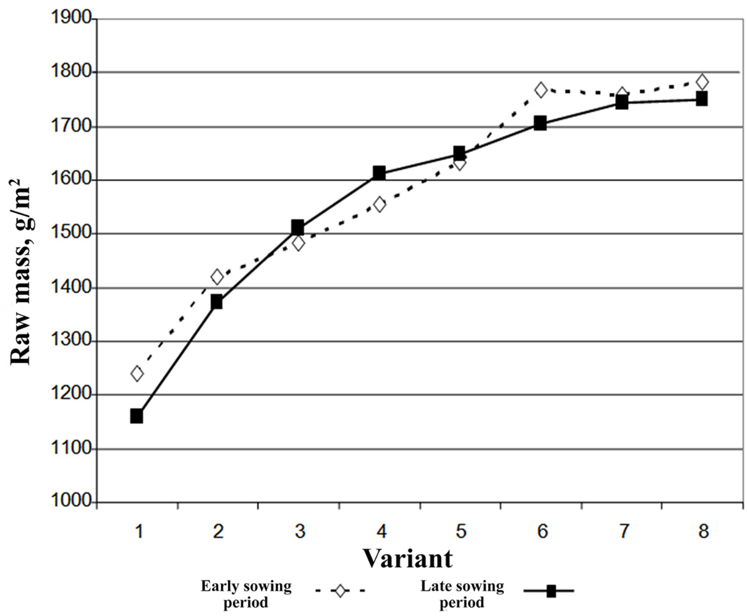

Figure 2. The influence of vegetable pea seed treatment on the accumulation of above-ground raw mass in the phase of technical ripeness in the early and late sowing periods, g/m^2

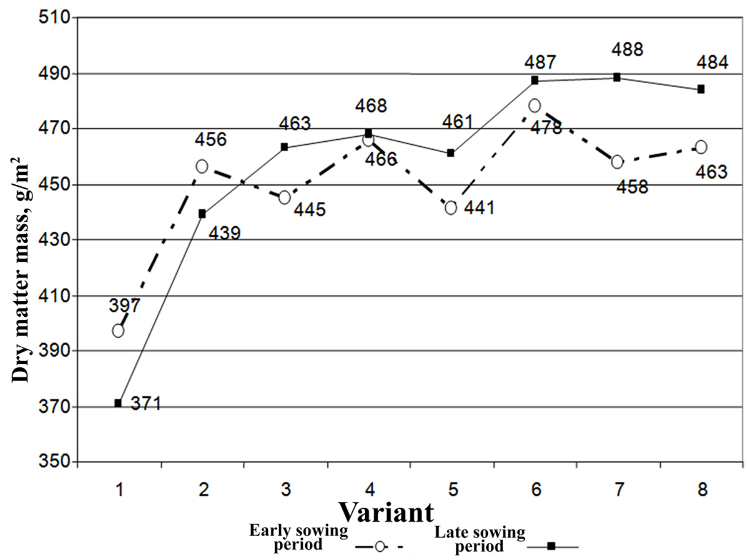

Figure 3. The influence of vegetable pea seed treatment on the accumulation of above-ground dry matter in the phase of technical ripeness depending on the time of sowing, g/m^2

of the growth and number of weeds. The lowest weediness was in the variants of the experiment involving treatment of seeds with boron, molybdenum and Rhizohumin in the first and second terms of sowing and was 1.7 pc. per 1 m^2 and 1.6 pcs. per 1 m^2, respectively, which was 31–40% of the base variant.

The use of Rhizohumin under leguminous crops contributes to the accumulation of nitrogen in the soil due to the virulence of nodule bacteria, which is determined by their number and rate of formation. Treatment of seeds with Rhizohumin increased the number of nodules by 15–43% during both sowing periods and reached a maximum in the first sowing period during the bean formation phase (140 pcs. per 10 plants), and in the second – during the budding phase and amounted 138 pcs. per 10 plants (Table 5, Fig. 4).

The use of boron, molybdenum and Rhizohumin for the treatment of vegetable pea seeds

Table 5. Dynamics of the number of nodules of nitrogen-fixing bacteria on the roots of 10 vegetable peas plants, pcs

№	Variant	Number of nodules			
		Phases of development			
		3-leaves	Budding	Bean formation	Technical ripening
I sowing period					
1	$N_{30}P_{40}$ – base	64	105	95	81
2	Base + Rhizohumin	89	121	140	136
3	Base + B	82	135	128	110
4	Base + B + Rhizohumin	93	122	143	128
5	Base + Mo	109	100	153	138
6	Base + Mo + Rhizohumin	116	183	174	150
7	Base + B+ Mo	111	200	186	161
8	Base + B + Mo + Rhizohumin	115	193	173	153
II sowing period					
1	$N_{30}P_{40}$ – base	55	90	79	74
2	Base + Rhizohumin	78	138	130	132
3	Base + B	73	135	125	119
4	Base + B + Rhizohumin	83	146	133	128
5	Base + Mo	99	126	148	147
6	Base + Mo + Rhizohumin	107	166	165	156
7	Base + B+ Mo	105	185	176	166
8	Base + B + Mo + Rhizohumin	113	180	171	161

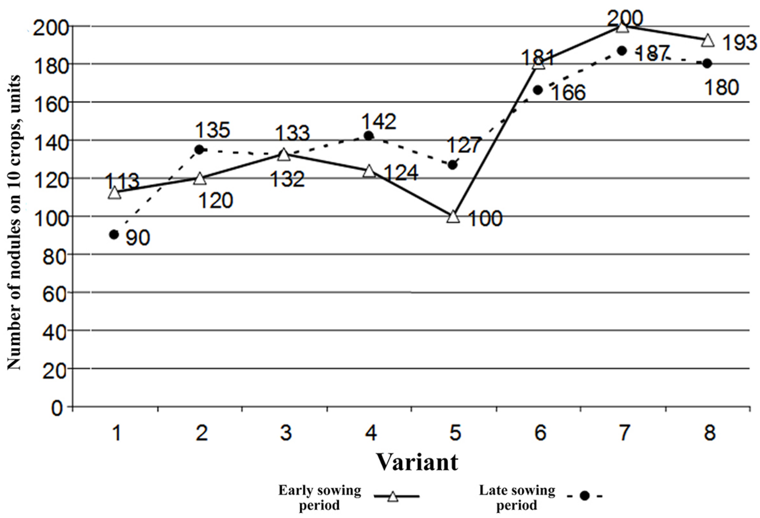

Figure 4. An influence of pea seeds' treatment with B, Mo and Rhizohumin on the number of nodules of nitrogen-fixing bacteria during different sowing periods in the budding phase, units/10 plants

contributed to a significant accumulation of nitrogen after harvesting the crop (Fig. 5, Table 6).

Taking into account global climate changes, agricultural producers have wide prospects for the use of leguminous crops, which have the ability to adapt to high temperatures and moisture deficits due to their extensive root system.

CONCLUSIONS

In order to restore disturbed soils and increase the efficiency of agricultural production, the introduction of leguminous crops into the crop rotation becomes extremely important, after their harvesting up to 80 kg/ha of biological nitrogen remains and humus accumulates in the arable layer of the soil up to 10.8 t/ha. The treatment of vegetable pea seeds with Rhizohumin contributed to the accumulation of humus by 3.96 t/ha

Biological preparations penetrate the cells of the seedling at the early stages of plant ontogenesis, forming their increased resistance to phytopathogenic organisms and the negative impact of abiotic factors. The yield of grain crops increases by 15–20%, whereas that of sunflower – by 10–15%. Due to the system of biological protection, phosphorus and nitrogen nutrition of plants are improved, the rates of application of phosphorus and nitrogen fertilizers are reduced, and the use of nutrients by plants increased by 35%.

A vegetable pea is able to provide itself with the nitrogen needs by 65–75% and leave up to 60–80 kg/ha of biological nitrogen in the soil; as a result of this, it is a favorable precursor crop for most agricultural crops. The maximum growth of

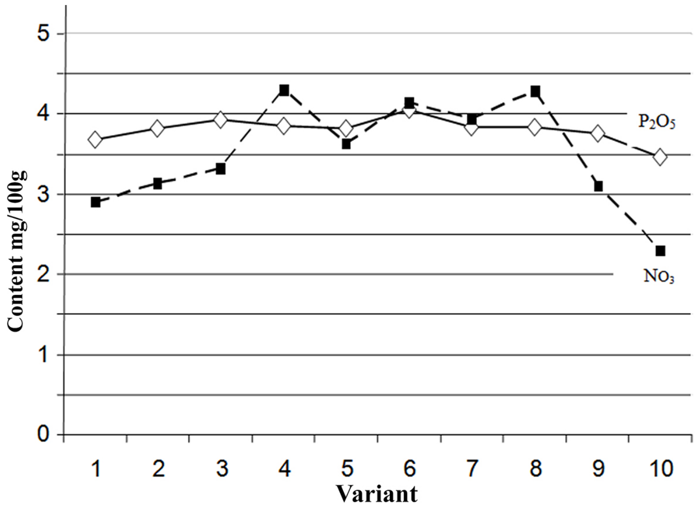

Figure 5. Nitrogen and phosphorus content in the soil layer 0–30 cm after harvesting vegetable peas, mg/100 g

Table 6. The influence of studied factors on the humus content in the soil and its growth after harvesting peas during the early sowing period

Variant	Humus content, %	Growth of humus, % relatively to		Growth of humus, t/ha relatively to	
		Spring barley	$N_{30}P_{40}$	Spring barley	$N_{30}P_{40}$
$N_{30}P_{40}$ – base	2.13	+0.17	0.00	+6.12	0.00
Base + Rhizohumin	2.19	+0.23	+0.06	+8.28	2.16
Base + B	2.17	+0.21	+0.04	+7.56	1.44
Base + B + Rhizohumin	2.20	+0.24	+0.07	+8.64	2.52
Base + Mo	2.21	+0.25	+0.08	+9.00	2.88
Base + Mo + Rhizohumin	2.24	+0.28	+0.11	+10.08	3.96
Base + B+ Mo	2.24	+0.28	+0.11	+10.08	3.96
Base + B + Mo + Rhizohumin	2.26	+0.30	+0.13	+10.80	4.68
Fallow field	2.16	+0.20	+0.03	+7.20	1.08
Spring barley	1.96	0.00	-0.17	0.00	-6.12
HIP_{05}	0.04±0.08	-	-	-	-

humus was observed during the complex treatment of vegetable peas with Rhizohumin, boron and molybdenum in the amount of 4.68 t/ha. Studies have determined that the cultivation of agricultural crops with the use of biological preparations and the introduction of leguminous crops into crop rotation contributes to the increase in the productivity of agricultural production and the improvement of soil fertility.

Taking into account the intense anthropogenic pressure and the negative consequences of global climate changes on land resources, the use of biological preparations as one of the main directions of the development of biological agriculture will lead to an increase in the profitability of agricultural production, restoration of degraded soils to an active biological state and obtaining high-quality ecologically safe plant products.

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