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BIOLOGICAL MECHANISMS OF REGULATION OF WINTER WHEAT PRODUCTIVITY IN THE CONDITIONS OF THE WESTERN FOREST-STEPPE OF UKRAINE

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Abstract. The western Forest-Steppe of Ukraine belongs to the area of risky seed production because of the low natural fertility of soils (estimated by 33 points) and a large amount of rainfall (680–760 mm), which causes every 2–3 years to obtain low-yielding seeds. Scientific studies indicate an increase in the productivity of plants of various cultures through the use of growth stimulants and bacterial preparations containing a balanced complex of biologically active substances, which contribute to the activation of the basic life processes in plants and the root zone. The search and selection of highly effective and competitive biological products in various soil and climatic zones remains an urgent issue. Our studies were aimed at assessing the effectiveness of pre-sowing treatment with Vympel-K growth stimulator applied separately and in combination with the bacterial preparations Diazophyte (based on the nitrogen fixing bacterium *Agrobacterium radiobacter*) and Polymyxobacterin (based on the phosphorus-mobilizing bacterium *Paenibacillus polymyxa*) for the yield and sowing qualities of winter wheat (Zolotokolosa variety). For comparison, a variant with water seed treatment and a variant with Vitavax disinfectant dressing were also evaluated. It was established that with the joint use of the studied preparations, seed germination rates are higher by 4.8%, the percent of overwintered plants – by 5.5%, seed yield – by 0.54 t / ha, the mass of 1000 seeds – by 2.1 g, germination energy of collected seed – by 2.1%, laboratory germination – by 2.2%. The increasing of the genetic potential of the varieties that are introduced into production due to the elements of biologized growing technology allows to regulate the growth and reproduction processes and adjust the nutritional conditions of winter wheat, since biological preparations are environmentally friendly and their low cost helps to reduce the cost of produced seeds.

Key words. *Triticum;* Seed treatment; Growth stimulator; Bacterial preparation; Field germination; Plant overwintering; Seed yield.

INTRODUCTION

The use of biological preparations in environmentally friendly technologies for growing crops is aimed at regulating the most important life support processes of the plant organism and soil microflora helps to mobilize the potential of the variety in the genome of nature and breeding. An important aspect of their action is to increase resistance to adverse environmental factors – high and low temperatures, phytotoxicity of pesticides, disease and pest damage (Волощук, І.С. 2011; Герман, М.М. 2011; Господаренко, М.М. et al. 2018; Грицаєнко, З.М., Пономаренко, С.П. et al. 2008; Ростоцький, О. 2012; Чабанюк, Я.В.. et al. 2015; Bushong, J.T. et al. 2014).

Particularly noteworthy is their use in seed-growing technologies of winter wheat cultivation, since the seeds are the carriers of all the important biological/physiological properties of the variety and affect the quality and quantity of the yields obtained in subsequent reproduction. The widespread use in the production of various mechanisms and machines leads to their injury, penetration of microorganisms, that negatively affects the growth and development of plants and leads to a decrease in yield properties and sowing qualities of seeds (Биловус, Г.Я., Волощук, И.С. et al. 2015a; Дульнев, П.Г., Косих, В. 2010; Малиновська, І.М., Ткаченко, М.А. 2015; Волкогон, В.В. 2015; Засуха, Т. 2001; Ремесло, О.В. et al. 2013; Popko, M. et al. 2018).

The studies of many authors have established that pre-sowing treatment of seeds with biological preparations contributes to a better development of the root system of plants in the early stages of growth, playing an important role in providing nutrients and water, the more efficient the functioning of the root system, the higher the productivity (Andreichenko, L.V. et al. 2010; Биловус, Г.Я., Волощук, И.С. et al. 2015b; Боровая, В.П. 2009; Волощук, О.П. et al. 2014; Господаренко, Г.М. 2015; Господаренко, Г.М. et al. 2009; Жердецький, І.М. 2009; Кочмарський, В.С. 2005; Марчук, И.Ю. et al. 2012; Сірошан, А.А. et al. 2015; Сметанко, О.В. et al. 2018; Ткаленко, Г. 2015; Фатеев, А.И. et al. 2013; Bauer, P. et al. 1995).

In the Western Forest-Steppe of Ukraine, the question of the influence of biological preparations on the productivity of winter wheat remains insufficiently studied, which led us to conduct research.

The purpose of the research was to establish the effectiveness of pre-sowing seed treatment with a growth stimulator and bacterial preparations for the yield and sowing qualities of winter wheat.

MATERIAL AND METHODS

The studies were conducted in the Seed Production Laboratory of the Institute of Agriculture of Carpathian Region of the National Academy of Agricultural Sciences (NAAS) of Ukraine in 2010–2012.

The topsoil on the experimental plots is characterized by such agrochemical parameters: humus content (by Tyurin) – 1.9 %, salt extract pH (potentiometric method) – 4.8, hydrolytic acidity (by Kappen-Hilkovits) – 2.93 mg eq. / 100 g of soil, the content of mobile phosphorus and potassium (by Kirsanov) – 98 and 86 mg per 1 kg of soil, easily hydrolyzed nitrogen (by Kornfield) – 88 mg per 1 kg of soil.

The weather conditions prevailing over the years of research distinguished by temperature and precipitation. The year of 2010 was very wet, with annual mean values of 668 mm, the total precipitation was 998.7 mm, which is 326.7 mm more. The average monthly annual indicator of air temperature in 2011 was higher by 0.9 ° C, and the total amount of precipitation was by 41.6 mm less. A higher temperature was observed in 2012, in terms of precipitation close to the average multi-year data.

The experimental plot area was 56 m^2, accounting – 50 m^2. The placement of variants was systematic, repetition – 3-fold. The seeding rate of winter wheat seeds was 5.5 million viable seeds/ha.

The sowing qualities of winter wheat seeds were determined according to DSTU 4138-2002 (State Standard of Ukraine, 2003).

The studies were performed according to generally accepted methods.

The processing and synthesis of research results were performed using Microsoft Excel. The obtained data were processed by the method of dispersion and correlation analysis (Доспехов, Б.А. 1985).

The products used for seed treatment were Vitavax, Vympel K, Diazophyte and Polymyxobacterin. Vitavax 200 FF, 34% w.s.c. is a seed disinfectant. It is used in more than 30 crops and is a patented growth regulator. Composition - carboxin 200 g / l + thiram 200 g / l, formulation: water-suspended concentrate. It not only provides disease control, but also acts in four different directions: it stimulates the germination process, helps to lengthen the period of formation of the membrane, provides improved stem formation and healthy root development, resulting in an increase in the number of homogeneous seedlings.

Vympel-K is an amber-humate complex and acts as an active antioxidant (intensively assimilates oxygen) and an adaptogen (protects the body from adverse environmental conditions, as well as toxins, both internal and external).

Diazophyte is a yellow liquid with a specific odor. It is obtained from the cultivation of active specific strains of *Agrobacterium radiobacter* in a sterile culture medium. In 1 ml of the drug there are at least 4-6 billion of viable bacteria. Producer: Institute of Agricultural Microbiology, NAAS of Ukraine.

Polymyxobacterin is a bacterial preparation, the mechanism of action of wich is associated with the property of the bacteria *Paenibacillus polymyxa* KB to produce organic acids and phosphatase, which leads to the dissolution of insoluble mineral and organic phosphates of the soil, as a result of which plants receive additional nutrition from phosphorus from soil reserves. The bacteria *Paenibacillus polymyxa* KB also have the ability to produce plant growth stimulants and B vitamins and are resistant to a number of pesticides. Producer: Institute of Agricultural Microbiology, NAAS of Ukraine.

RESULTS AND DISCUSSION

Investigating the effectiveness of different rates of Vympel-K growth regulator, we found that on the control (without seed treatment) the length of the roots of winter wheat variety Zolotokolosa was 2.5 mm, and the mass of 100 roots was 3.9 g. The strength of the shoot growth increased while their length grew by 0.3–0.6 mm, and the mass of 100 shoots increased by 1.6–2.0 g (Fig. 1).

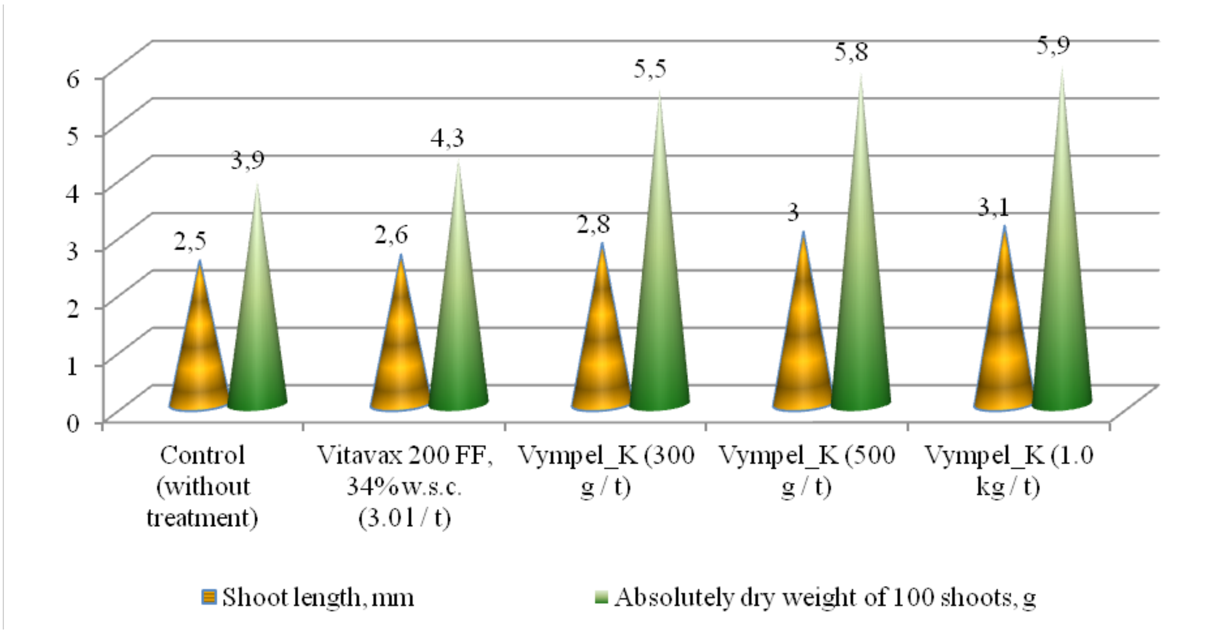

Figure 1. *The effect of Vympel-K stimulator on the strength of the growth of winter wheat seeds (2010–2012)*

According to $SSD_{0.05}$ = 0.2 g, the higher strength of the shoot growth was observed on the variant with the use of Vympel-K growth regulator in the rate 500 g / t of seeds. With this variant, seed germination energy and laboratory germination were the highest, 91 and 96%, respectively (Fig. 2).

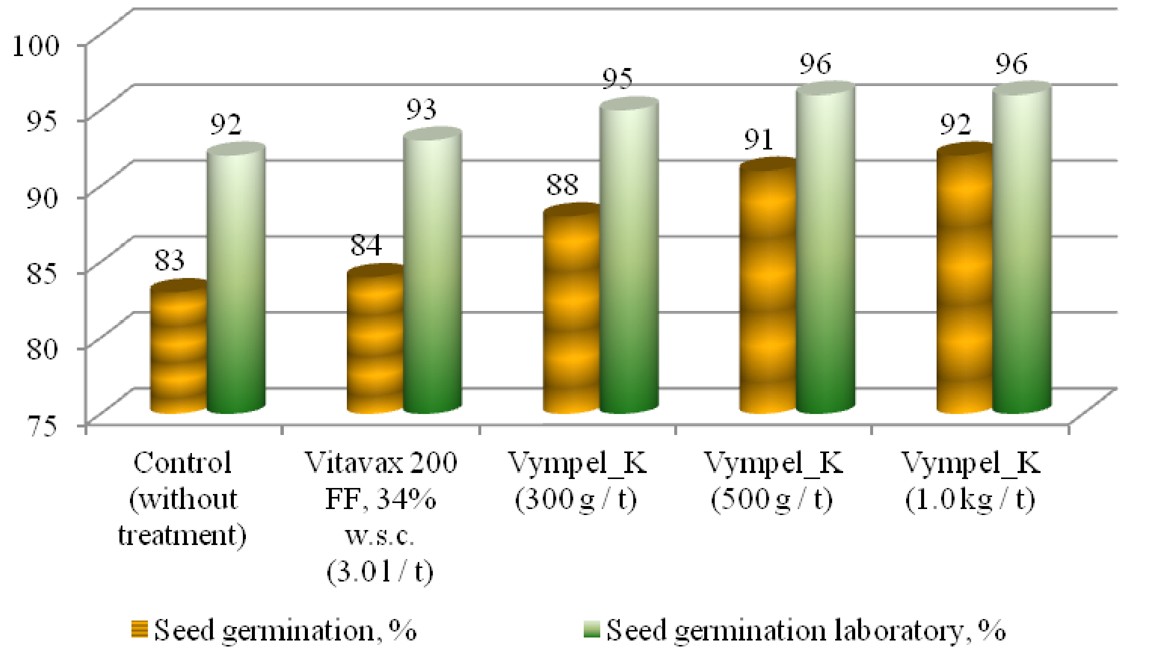

Figure 2. *The effect of Vympel-K growth stimulant on germination energy and laboratory germination of winter wheat seeds (2010–2012)*

Increasing the application rate to 1.0 kg / t did not have a significant effect on these indicators. The efficiency of the lower rate (300 g / t of seeds) of Vympel-K was also lower.

High seed sowing qualities may not always provide good field germination. The sowing seeds are affected by the temperature, soil moisture and pre-sowing preparation, seed depth, etc., therefore field germination over the years of research compared to the laboratory one was by 12.7–13.4% lower (Table 1).

Table 1. *The effect of presowing treatment of seeds with biological preparations on their field germination and the wintering of plants of winter wheat variety Zolotokolosa (2010–2012), %*

Seed treatment	Seed germination			Overwintered plants		
	average	± to control		average	± to control	
Control (without treatment)	78.6 ± 6.2	–	–	85.7 ± 2.9	–	–
Vitavax 200 FF, 34 % w.s.c.	80.9 ± 7.8	2.3	–	91.1 ± 2.5	5.4	–
Vympel-K	83.3 ± 5.8	4.7	2.4	93.4 ± 1.9	7.7	2.3
Vympel-K + Diazophyte	83.5 ± 6.7	4.9	2.6	94.0 ± 1.5	8.3	2.9
Vympel-K + Polymyxobacterin	83.9 ± 6.6	5.3	3.0	94.2 ± 2.2	8.5	3.1
Vympel-K + Diazophyte + Polymyxobacterin	85.7 ± 7.5	7.1	4.8	96.6 ± 0.5	10.9	5.5
$SSD_{0.05}$	1.4			0.3		

Note: Application rate of Vympel-K – 500 g / t, Diazophyte – 100 ml for one-hectare rate of seeds, Polymyxobacterin – 150 ml for one-hectare rate of seeds

However, the positive effect of the growth regulator was observed. Compared with the control, seed treatment with Vitavax 200 FF, 34% w.s.c. (3.0 l / t) contributed to an increase in field germination by 2.3%, and presowing treatment with Vympel-K growth regulator contributed to a higher field germination by 4.7% than the control (seed treatment with 10 l/t of water) and by 2.4% than Vitavax seed treatment.

When the growth regulator Vympel-K was used together with the nitrogen-fixing bacterial preparation Diazophyte a slight increase (by 0.2%) in field germination was observed, while for the combination of Vympel-K with the phosphorus-mobilizing preparation Polymyxobacterin this increase was of 0.6%.

The combined use of Vympel-K + Diazophyte + Polymyxobacterin contributed to an increase in field germination to control by 7.1%, to Vitavax 200 FF treatment, 34% w.s.c. – by 4.8%, to presowing treatment with Vympel-K – by 2.4%. The low activity of nitrogen-fixing and phosphorus-mobilizing bacteria was due to the critical soil moisture of the sowing period of 2011 (only 4 mm).

The average percentage of overwintering of winter wheat plants, depending on the experiment variants, ranged from 85.7% in the control to 96.6 % for pre-sowing seed treatment with Vympel-K + bacterial preparations Diazophyte and Polymyxobacterin. Compared with the control, the seed dressing with Vitavax promoted to an increase in winter hardiness of plants by 5.4 %, dressing with growth regulator – by 7.7%, Vympel-K + nitrogen-fixing preparation Diazophyte – by 8.3%, Vympel-K + phosphomobilizing Polymyxobacterin – by 8.5%, and the combined use of Vympel-K + Diazophyte + Polymyxobacterin – by 10.9%. Compared these variants only with seed dressing, Vitavax 200 FF disinfectant, 34% w.s.c. these figures were 2.3%, 2.9, 3.1 and 5.5%, respectively.

The effectiveness of the biological preparations ensured a seed yield at the level of 3.85–4.22 t / ha (Table 2). The yield increase to control, depending on the experience variants, was of 8.8–19.2%, while to Vitavax seed treatment variant, 200 FF, 34% w.s.c. – 4.6–14.7%. The seed dressing with Vitavax 200 FF 34% w.s.c. (3.0 l / t) increased the yield by 0.14 t / ha compared to the control.

Table 2. *The yield of wheat seeds of winter varieties Zolotokolosa depending on the presowing treatment with biological preparations (2011–2013), t / ha*

Seed treatment	Year			Average	± to control	
	2011	2012	2013		t / ha	%
Control (without treatment)	4.15	3.08	3.39	3,54 ± 0,41	–	–
Vitavax 200 FF, 34 % w.s.c.	4.31	3.22	3.51	3,68 ± 0,42	0.14	–
Vympel-K	4.49	3.32	3.76	3,85 ± 0,40	0.31	8.8
Vympel-K + Diazophyte	4.55	3.43	3.84	3,94 ± 0,41	0.40	11.3
Vympel-K + Polymyxobacterin	4.67	3.55	4.06	4,09 ± 0,38	0.55	15.5
Vympel-K + Diazophyte + Polymyxobacterin	4.75	3.68	4.23	4,22 ± 0,36	0.68	19.2
Average	0.5	0.8	0.6			
$SSD_{0.05}$	0.05	0.08	0.06			

The presowing treatment with the growth stimulator contributed to a reliable yield increase of 0.31 t / ha, and a small increase of 0.09 t/ha was in the combined variant with Diazophyte, within the limits of error (SSD0.05 = 0.5–0.8 t / ha). More compelling was the combination of the growth regulator with Polymyxobacterin, which assisted an increase in seeds compared with Diazophyte variant by 0.24 t / ha. For the variant – Vympel-K + Diazophyte + Polymyxobacterin – the yield increase was the largest 0.68 t / ha compared to the control and 0.54 t / ha compared to the variant with seed dressing.

Depending on the experience variants, the plants formed seeds with a different mass of 1000 seeds from 42.2 g in the control to 45.0 g in the combined use of the growth regulator and bacterial preparations of nitrogen-fixing and phosphorus-mobilizing action (Table 3).

Table 3. *Sowing qualities of seeds of winter wheat variety Zolotokolosa depending on the presowing treatment with biological preparations (2011–2013)*

Seed treatment	Application rate of preparation, l / t, g / t	Mass 1000 seeds		Germination energy		Laboratory germination	
		g	±to control	%	±to control	%	±to control
Control (without treatment)	–	42,2 ± 0,3	–	83,9 ± 0,9	–	92,5 ± 1,2	–
Vitavax 200 FF, 34 % w.s.c.	3.0	42,9 ± 0,6	0,7	85,0 ± 1,1	1,1	94,1 ± 1,5	1,6
Vympel-K	500	43,5 ± 1,1	1,2	85,5 ± 1,5	1,6	95,0 ± 1,8	2,5
Vympel-K + Diazophyte	500 + 100	43,8 ± 1,4	1,6	86,0 ± 1,7	2,1	95,4 ± 2,1	2,9
Vympel-K + Polymyxobacterin	500 + 150	44,3 ± 1,6	2,1	86,9 ± 1,9	3,0	95,7 ± 2,5	3,2
Vympel-K + Diazophyte + Polymyxobacterin	500 + 100 + 150	45,0 ± 1,9	2,8	87,1±2,2	3,2	96,3 ± 2,4	3,8
$SSD_{0.05}$		0.4		1.0		1.5	

Compared to the control the mass of 1000 seeds significantly increased by 1.2–2.8 g (SSD0.05 = 0.4 g) in the variants treated with biopreparations. Such seeds provided a higher germination energy by 0.5–2.1% and a higher laboratory germination by 0.9–2.2% in comparison with Vitavax seed treatment.

The correlation between field germination and seed yield, depending on the use of biological origin preparations, was strong and direct (Table 4).

Table 4. *Correlation between the elements of winter wheat productivity depending on the treatment with biological preparations (2011–2013)*

Seed treatment	Application rate of preparation, l / t, g / t	Field germination, %	Seed yield, t / ha	Correlation coefficient (r)
Control (without treatment)	–	78.6	3.54	0.969
Vitavax 200 FF, 34% w.s.c.	3.0	82.9	3.68	0.978
Vympel-K	500	85.7	3.85	0.980
Vympel-K + Diazophyte	500 + 100	83.3	3.94	0.984
Vympel-K + Polymyxobacterin	500 + 150	83.5	4.09	0.986
Vympel-K + Diazophyte + Polymyxobacterin	500 + 100 + 150	83.9	4.22	0.991

Note: From 0 to 0.33 – weak, 0.33 to 0.66 – medium, 0.66 to 1.00 – strong, 1.00 – complete, both for direct and inverse correlation (r).

If on the control (without seed treatment) the correlation coefficient was 0.969, then for presowing seed treatment it grew by 0.009, and for seed treatment with the growth stimulator Vympel-K – by 0.011. Bacterial preparations contributed to a stronger correlation by 0.015 and 0.017; this indicator was the highest for their combined use with the growth stimulator – 0.991.

Our studies are confirmed by scientists (Bauer, P. et al. 1995) that growth regulators, participating in the modulation process directly or indirectly at the biochemical level, act as analogues of phytohormones, the role of which in the organogenesis of vesicles indicates their increase and activity, affects the development of the root system and activation photosynthesis and P. G Dulnev (scientific and engineering center "axo" of the Institute of Bioorganic Chemistry and Petrochemistry of the National Academy of Sciences of Ukraine) and P.A. Donchenko (Crimean Branch of Soil Microbiology of the Institute of Agriculture of the UAAS) claim an increase SRI soybean yield (at 10.6-19.0%) and spring barley (at 14.3-19.0%) under the influence of use in preplant seed treatment DG-477 formulation with rizotorfina (Дульнєв, П., Косих, В. 1998).

The high efficiency of the growth stimulator in combination with the bacterial preparations of nitrogen-fixing and phosphorus-mobilizing effects, in our experiments, contributed to good seed protection from external factors and to an optimal level of plant nutrition. By the combination of Vympel-K growth stimulator (500 g / t) + bacterial preparations of nitrogen-fixing action Diazophyte (100 ml for one-hectare rate of seeds) and phosphorus-mobilizing action Polymyxobacterin (150 ml for one-hectare rate of seeds) field germination of seeds increased by 4.8%, the percent of overwintered plants - by 5,5%, seed yield - by 0.54 t / ha.

The low cost of the biological preparations ensured high profitability of the production of basic seeds (Table 5). For the pre-sowing treatment of seeds with Vympel-K stimulator(500 g / t), the profitability level was by 9.1% higher than for the option of dressing with Vitavax 200 FF, 34% w.s.c., 3.0 l / t, while for the combined use of the stimulator with the nitrogen-fixing bacterial fertilizer Diazophyte, this indicator was by 11.4% higher. The highest profitability was obtained for the joint treatment of seeds with the growth stimulator and bacterial preparations (Diazophyte and Polymyxobacterin) - 40.1%.

Table 5. *Economic efficiency of using Vympel-K growth stimulator with bacterial preparations in pre-sowing treatment of winter wheat seeds of the Zolotokolosa variety (2011-2013)*

Seed treatment	Seed productivity, t/ha	The cost of seeds sold, thous. uah	Costs per 1 ha, thous. uah	Conditionally net profit, thous. uah/t	Cost price products, thous. uah/t	Profitability, %
Control (without treatment)	3,54	19,5	15,9	3,6	4,5	22,6
Vitavax 200 FF, 34% w.s.c.	3,68	20,2	16,5	3,7	4,5	22,4
Vympel-K	3,85	21,2	16,1	5,1	4,2	31,7
Vympel-K + Diazophyte	3,94	21,7	16,2	5,5	4,1	34,0
Vympel-K + Polymyxobacterin	4,09	22,5	16,2	6,3	4,0	38,9
Vympel-K + Diazophyte + Polymyxobacterin	4,22	23,2	16,5	6,7	3,9	40,1

Note. The cost of elite seeds is 5.5 thous. uah / t.

CONCLUSIONS

The use of presowing seed treatment with biological preparations in the technology of growing winter wheat is a promising direction for increasing the production of seed products, as they are environmentally friendly, and their low cost helps to reduce the cost of production of basic seeds.

Fungicides that are in production reduce the germination energy and germination of seeds, and this has a negative effect on field germination, plant density per unit area, and further productivity of sowing.

We have confirmed that the high stimulating effect of the biological preparation Vympel-K at the application rate of 500 g / t compared with the control and with Vitavax 200 FF seed treatment variant (3.0 l / t) provided a higher root growth power by 2.5 mm, mass of 100 shoots – by 1.6-2.0 g, and a high percentage of seed germination energy and laboratory germination (92 and 96%).

With the increase in the number of beneficial microorganisms in the gray forest surface-gleyed soil, the enzymatic activity intensified, which positively influenced the process of mobilization of nutrients in an accessible form, increasing the productivity of winter wheat.

Good seed protection from external factors and optimal plant nutrition provided by the combination of Vympel-K growth stimulator (500 g / t) + bacterial preparations of nitrogen-fixing and phosphorus-mobilizing action Diazophyte (100 ml for one-hectare rate of seeds) + Polymyxobacterin (150 ml for one-hectare rate of seeds) compared to the seed treatment variant with Vitavaks 200 FF, 34% w.s.c. (2.5 l / t) contributed to a 4.8% increase in field germination, 5.5% increase in the percent of overwintered plants, 0.54 t / ha (or 19.2%) increase in seed yield, 2.1 g increase in thousand-seed-weight, 2.1% increase in germination energy of the collected seeds, and 2.2% increase in laboratory germination.

Pre-sowing seed treatment with growth stimulants and bacterial preparations in the technology of growing winter wheat reduces pesticidal load at the initial stage of plant growth and its development, protects seedlings well from negative environmental factors and is environmentally friendly, and lower production costs provide high profitability for the production of basic seeds (40,1%).

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