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INFLUENCE OF MICROFERTILIZERS AND BACTERIAL PREPARATIONS ON THE PRODUCTIVITY OF WINTER BARLEY IN THE SOUTHERN STEPPE OF UKRAINE

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Problem statement. Improving the technology of growing winter barley and introducing appropriate agricultural measures that ensure the profitability of the crop and its environmental friendliness is relevant and of great practical importance. One of these techniques is the use of growth-regulating substances. However, the new synthetic and natural preparations currently proposed for production require comprehensive verification. The scope of possible use of such preparations is determined by the effectiveness of their action, as well as biological, technological, environmental and economic assessments. The information obtained in such experiments will allow us to conduct an objective comparison of the proposed preparations in specific soil and climatic conditions and develop a technology for their application.

Thus, our task was to study the effect of microfertilizers and bacterial preparations together with chemical mordants in the cultivation of winter barley in the soil and climatic conditions of the southern steppe zone of Ukraine. The obtained data will make it possible to clarify and recommend to production effective and environmentally friendly preparations that ensure high and stable grain yields of this crop in the current economic conditions.

For the first time, the features of growth and development of winter barley plants and the regularities of crop formation depending on the inoculation of seeds with microfertilizers, biologics, chemical plant protection products, their mixtures and meteorological conditions of the growing area were established.

To guarantee the nutritional regime of the soil, when changing hydrometeorological parameters, the use of trace elements and bacterial preparations for balanced plant nutrition is of particular importance.

Analysis of recent research and publications. Microelements, as chemical elements that ensure the normal passage of all physiological processes of vital activity of the plant organism, are used in small quantities compared to the main nutrients. Lack of iron, boron, cobalt, zinc, copper does not lead to plant death and it is most often detected on crops late, but it causes a decrease in the speed and consistency of biochemical and physiological processes, which ultimately reduces the yield and worsens its quality [1]. The positive effect of trace elements is that they take part in redox processes, carbohydrate and nitrogen metabolism, increase the resistance of plants to diseases and adverse environmental conditions. Under the influence of trace elements in the leaves of plants, the content of chlorophyll increases, photosynthesis improves, and the assimilation activity of the entire plant increases [2].

Foliar top dressing of agricultural crops has become particularly widespread in recent years, primarily due to its high economic profitability. Among grain crops, barley is most sensitive to a lack of copper and boron, and a lack of manganese is often observed on alkaline soils [1; 2]. The need for trace elements in barley increases especially strongly with the introduction of increased doses of phosphorus and potassium. This is due to the fact that when high doses of phosphorus are applied, the availability of zinc and high doses of potassium – boron to barley plants decreases [3].

Manganese has a direct inhibitory effect on the growth of fungal pathogens, especially powdery mildew of winter barley, and also contributes to the production of lignin and suberin, which gives plant cells resistance to infection. However, a deficiency of this trace element leads to the accumulation of nitrate nitrogen in the leaves, which, in turn, reduces the immunity of crop plants to diseases such as rust and mold [4].

An important trace element for winter barley plants is copper, the lack of which coincides with a lack of zinc, and on sandy soils also with a lack of magnesium. A characteristic feature of the action of copper is that this trace element increases the resistance of plants against fungal and bacterial diseases, that is, it reduces the incidence of grain crops with various types of smut, increases the resistance of plants to brown spotting [5].

The use of cobalt in the form of fertilizers for winter barley crops also increases its yield, since due to its positive effect, favorable conditions are created for respiration and energy metabolism, as well as protein biosynthesis of nucleic acids [6, p. 13–35].

In addition to affecting the yield of winter barley grain, trace elements also affect its structure. The use of zinc, manganese, copper and boron increases the mass of 1000 barley seeds, increases the germination rate of its seeds, overall and productive bushiness, and resistance to adverse factors [7].

One of the indicators of the degree of supply of plants with trace elements is their content in the soil, and it is very important to know not the total number of individual trace elements, but the availability of available forms that determine their availability for plants. The volume of content of available forms, most often for Cu, Mo, Co, Zn, does not exceed 10–15% of their gross reserves, and for B it does not exceed 2–4%. The mobility of trace elements in the soil is determined by its type, the nature of parent rocks and vegetation, as well as the microbiological activity of the soil.

Some authors who have studied the mobility of trace elements in the soil indicate a change in their content depending on the time of sampling for analysis [8; 9]. These fluctuations can be quite large, as a result of which the soil at different times the availability of available forms of trace elements varies widely. Not the least role in these processes is played by the dynamics of soil moisture, due to changes in the intensity of absorption of trace elements by the soil, the rate of their release into the soil solution. The type of soil, as well as its water-physical characteristics, also determine the effectiveness of the applied trace elements. In areas with a significant deficiency of trace elements, their introduction can contribute to an increase in crop yields by an average of 10–15% [5]. Cereals also respond positively to the introduction of manganese, increasing the yield of winter wheat by 0,15–0,3 t/ha, and the yield of winter barley by 0,3–0,45 t/ha [1; 3].

Many microfertilizers are also enriched with microbial coenoses for better efficiency and regulation of plant growth. The nature of the effect of microorganisms on plants also has a stimulating effect. It occurs due to the production of physiologically active substances as plant growth regulators of various chemical nature. Plant growth regulators, both natural and synthetic compounds, are widely used for processing plants in order to improve the quality of plant material, increase yield, facilitate its collection and storage [10; 11, p. 44; 12, p. 111].

Significant differences in the yield increases and their absence are observed when using plant growth regulators and bacterial preparations. Obviously, the reason for such discrepancies is different agricultural backgrounds, varietal sensitivity of crops, the influence of climatic factors, etc. [12, p. 111]. It is noted [13] that *Azospirillum spp.*, *Bacillus spp.*, *Pseudomonas putida*, *P. fluorescens* synthesize growth regulators and enzymes. When inoculated with these strains, the yield of plants improved.

Bacteria from the genus *Pseudomonas* showed a positive effect on the growth and development of plants, their yield during pre-sowing inoculation of wheat, corn and other plant seeds [14; 15].

A method has been patented that provides for the treatment of grain seeds before sowing with *Arthrobacter bacteria* or filtrate of the culture of these bacteria [15]. The method is developed using barley seeds. The method allows you to stimulate the growth of grain roots without mechanical impact and the use of chemicals, is not associated with high costs and ensures the stability of stimulation.

Yu.A. Shamardina notes that the use of preparations based on humic acids in spring barley crops increased the energy of seed germination, field germination, general and productive bushiness, affected the lake content of the ear and the mass of 1000 grains, increased the growth rate of leaf surface area during the growing season and the photosynthetic potential of crops, contributed to an increase in the duration of the assimilation apparatus [16]. The most effective way to use preparations based on humic acids was to spray barley crops in the tillering phase – at the beginning of stooling. Carrying out this method increased the yield of barley by 4,9–6,4 c/ha, while when they were applied to the soil for pre-sowing cultivation, the gains amounted to 2,1–3,6 c/ha, and when processing seeds it amounted to 4,1–5,6 c/ha.

Yu.V. Shurekov in his research determined that the yield of winter barley from the use of growth regulators increased by 0,19–0,24 t/ha, with a yield of 1,76 t/ha under control [17]. The maximum increase was observed in the Gumi variant with pre-sowing seed treatment as 13,64% compared to the control.

Thus, the analysis of literature sources shows that in the conditions of the south of Ukraine it is possible to obtain high and stable yields of winter barley grain, but a more complete and rational use of the agroecological potential of the zone of its cultivation is possible only with the improvement of existing elements of crop cultivation technology, and therefore the study of the influence of the use of microfertilizers, plant growth regulators or their mixtures on crop productivity is relevant.

Purpose of work. The goal of the scientific study was to establish the effect of inoculation of seed material with microfertilizers, plant growth stimulants, bacterial preparations and chemical mordants on biometric indicators, photosynthetic productivity and yield of winter barley grain when grown in the southern steppe of Ukraine.

Materials and methods of research. According to agroclimatic zoning, the territory of the farm belongs to the third Southern agroclimatic region, which is characterized by hot, very arid climatic conditions. Given this, special attention should be paid to the moisture supply of plants during the growing season. Reserves of productive moisture in the meter – long soil layer at the beginning of the spring growing season are 110–160 mm, the amount of precipitation during the growing season is 220–270 mm.

The soil of the experimental field is represented by Southern chernozem, heavy loamy, low-humus, residual solonetz on the loesses. A characteristic feature of these soils is the small thickness of the humus horizon (up to 36 cm). At a depth of 60–70 cm lies a carbonate rock. Accumulation of carbon dioxide Ca and Mg is observed in the form of white spots. The soil profile is differentiated into the upper humus horizon, the upper and lower transition horizons to the parent rock, and directly to the parent rock. The humus horizon has a dark gray color, loose, dusty-lumpy, heavy loamy. The transition between horizons is gradual. The average content of humus in the arable (0–30 cm) soil layer is 3,2% (by Tyurin), content of nitrate nitrogen is 0,17–1,35 (using an ion-selective electrode), content of mobile phosphorus is 3,19–4,05 (by Machigin), content of exchange potassium is 22,0–32,0 mg per 1 kg of soil (by Huseynov and Protasov). According to the content of mobile nutrients, the soil of the experimental site is characterized by an insufficient content of mobile nitrogen, an increased content of mobile phosphorus and a high content of mobile potassium.

The agricultural technique of growing crops in the experiment was generally recognized for the steppe of Ukraine. Winter barley was placed on peas. The main tillage was carried out by peeling stubble by 6–8 cm (LDH-15). After 14 days, plowing was used to a depth of 25–27 cm. Next, cultivation was performed and harrowed with heavy tooth harrows. On the day of sowing, one pre-sowing cultivation was carried out to a depth of 6–8 cm with simultaneous harrowing with light harrows. For pre-sowing cultivation, a complete mineral fertilizer was applied at a dose of $N_{30}P_{30}K_{30}$. Before sowing, the seeds were etched with preparations according to the experiment scheme. Immediately after cultivation, winter barley was sown in the usual lowercase way. The seeding rate was 4 million tons seeds per 1 ha with seed embedding to a depth of 5–7 cm. Sowing was carried out using a SZ-3,6 seed drill to increase field germination and friendly seed germination, post-sowing rolling of crops was carried out with Ring-spur rollers (ZKKSH-6). Barley was collected in the phase of waxy ripeness, using direct combining. After harvesting, the grain was cleaned and dried on the current.

Field experiments were conducted in accordance with the generally accepted methodology of the field experiment and they were conducted during 2019–2021 years. The influence of chemical, biological preparations and micro-fertilizers on the productivity of winter barley was studied in experiments [2]. In the studies, the Deviatiy Val winter barley variety was sown. The area of the sown area was 72 m^2, the accounting area was 36 m^2, the repetition was three times.

The experiment scheme included the following variants:

1) control (water treatment 10 l/t);

2) seed Oracle + Vitavax 200FF (0,5+2,5 l/t) + water (7 l/t);

3) Reakom + Vitavax 200FF (3,0+2,5 l/t) + water (4,5 l/t);

4) Rostok + Vitavax 200FF (3,0+2,5 l/t) + water (4,5 l/t);

5) Quantum cereals + Vitavax 200FF (3,0+2,5 l/t) + water (4,5 l/t);

6) BTU-R Biocomplex + Vitavax 200FF (3,0+2,5 l/t) + water (4,5 l/t);

7) nano-mineralis + Vitavax 200FF (0,05+2,5 l/t) + water (7,45 l/t);

8) Vitavax 200FF (2,5 l/t) + water (7,5 l/t);

9) seed Oracle (0,5 l/t) + water (9,5 l/t);

10) reakom (3,0 l/t) + water (7,0 l/t);

11) Rostok (3,0 l/t) + water (7,0 l/t);

12) Quantum cereals (3,0 l/t) + water (7,0 l/t);

13) BTU-R Biocomplex (3,0 l/t) + water (7,0 l/t);

14) Nano-Mineralis (0,05 l/t) + water (7,0 l/t).

The research was accompanied by analysis of plant samples, observations of the dynamics of plant growth and development. All observations were performed in two non-contiguous repetitions. Observations, analyses, and records were performed in accordance with generally accepted methods [18–21].

Research results. Among the measures that ensure an increase in the yield of grain crops, we should note the pre-sowing preparation of seeds, which is a fairly effective, cost-effective and effective method in the successful cultivation of grain. The results obtained by US indicate a tendency to increase the length of the Rostok in variants with the use of various preparations by 0,1–2,6 cm compared to the control.

The length of the coleoptile is one of the most important features, on which the field germination of seeds largely depends. In the experiment, an increase in this indicator (by 0,7–2,1 cm) was noted in almost all variants of treatment with growth-regulating preparations, except for treatment with Quantum grain and Nano-Mineralis (12 and 14 var.), where there was a decrease in the length of the coleoptile by 0,4 and 0,1 cm compared to the control variant. Almost all the studied variants had a stimulating effect on increasing the length and number of primary roots (by 1,5–5,0 cm and 0,4–1,3 PCs, respectively) compared to the control, except for the aforementioned variants 12 and 14.

The results of the studies showed that the laboratory germination rate of winter barley seeds treated with growth-regulating substances was higher compared to the control seeds by 0,5–2,5%.

It should be noted that the best indicators that characterize winter barley seedlings were found in variant 6 – for seed treatment with the BTU-R Biocomplex together with Vitavax 200FF.

Winter barley is characterized by an average competitiveness in phytocenoses compared to winter wheat or rye. Freezing (lack of snow cover), ice crust, root rot can practically destroy its crop.

During 2019–2020 years and 2020–2021 years, overwintering of winter barley was different and ranged from 65% (2019–2020 years) up to 92% (2020–2021 years) of plants. The winter of 2020–2021 years was mild, so the crops of winter barley in these years after overwintering were not thinned out and almost intact. Plant loss in variants did not exceed 5–8% of plants.

Less favorable weather conditions were observed in the winter period of 2019–2020 years (severe and snowless winter). Reducing air temperatures to severe frosts and maintaining them for a long time led to the death of winter barley of other varieties on the farm (Metelitsa, Voskhod), which did not pass the full hardening cycle during the autumn growing season. To a lesser extent, the crops in the experimental plots were affected, but the density of plants significantly decreased. Under such conditions, the loss of plants was 30–44%, depending on the experimental variant.

On average, over two years, the highest winter hardiness of both plants and shoots was observed in variants 3, 5, 6 with seed treatment with Reakom + Vitavax 200FF, Quantum grain + Vitavax 200FF and Biocomplex BTU-R + Vitavax 200FF – 82–83 and 79–80%, respectively.

The yield of plants is primarily determined by the size and productivity of the leaves, which in the process of growth should reach the optimal size as soon as possible [22]. One of the factors regulating the size of the assimilation surface area is the creation of favorable conditions for growth and development, so that plants form the optimal area of the leaf apparatus for effective photosynthetic activity [23]. According to some authors [22; 24; 25], to achieve a yield of 3,7–4,0 t/ha of grain, crops should have a leaf area of 34–35 thousand m^2 per 1 ha during the earing phase. Our studies have shown that during the earing phase, the area of the leaf apparatus of winter barley reached the greatest value and, depending on their variant, amounted to 19,3–41,8 thousand m^2 per 1 ha.

This indicator was close to the optimal value for seed treatment Vitavax 200FF, Biocomplex BTU-R + Vitavax 200FF, Reakom + Vitavax 200FF (var. 8, 6, 3).

On average, during the growing season, the most powerful leaf apparatus was formed by plants in variants 3 and 6 (Reakom + Vitavax 200FF and BTU-R + Vitavax 200FF Biocomplex) – 29,2–30,8 thousand m²/ha (average for 2020–2021 years) (see table 1). The smallest leaf area was characterized by plants in variants 12, 13, 14 – from 13,7 to 17,2 thousand m²/ha.

The biological significance of leaf surface sizes, first of all, lies in the fact that the degree of absorption of photosynthetic active radiation (far) by crops depends on them. Therefore, to characterize the power of the assimilation apparatus, it is customary to determine the photosynthetic potential (AF) – a value that characterizes the ability of crops to use far for photosynthesis [26]. A number of authors believe that highly productive crops have an AF of at least 2,2–3,0 million tons m² per day based on 100 days of actual vegetation [22; 24; 25; 26].

Our calculations showed that in the process of growth and development of winter barley plants, the indicator of photosynthetic potential also significantly depended on the variants of the experiment (see table 2).

Biocomplex BTU-R + Vitavax 200FF – 2322–2856 thousand m²/ha per day per 1 ha (average for 2020–2021 years).

It was on these variants that this indicator was or approached the optimal value, which is due to the large size of the leaf surface. In variants 12 and 14 (seed treatment with Quantum grain and Nano-Mineralis preparations), AF was lower than the control by 5,0–14,5%, while other variants increased the value of this indicator during the growing season compared to the control by 11,1–38,9%.

An important indicator of assimilation activity in crops is also the net productivity of photosynthesis (NPF), which characterizes the intensity of accumulation of dry matter of the crop during the day per 1 m² of plant leaf surface [26].

Some authors [24; 26] argue that the maximum development of the leaf apparatus, the area of which significantly exceeds the area of sowing, leads to a decrease in the net productivity of photosynthesis. That is, this indicator is in a certain feedback loop with the size of the leaf surface, which was confirmed by our observations (see table 3).

Analysis of the dynamics of net photosynthetic productivity showed that it fluctuated during the growing season, acquiring the maximum value from the period of earing of winter barley was from 5,4 up to 6,7 g/m² per day, while in the phase of stooling, this indicator was from 2,8 up to 3,3 g/m² per day, and in the tillering phase it was from 2,3 up to 2,8 g/m² per day.

A.A. Nichiporovich argues for this by intensive assimilation of young leaves and its longer duration of work during the day [22]. The area of leaves at this time is close to optimal, which improves lighting conditions and does not cause shading of plants.

The highest level of photosynthetic potential for the entire growing season was formed in variants 3 and 6 (Reakom + Vitavax 200FF) and for the entire growing season of NPF in variants where a larger leaf area was observed and a higher photosynthetic potential was lower compared to the control. Therefore, in these variants, the mutual shading of leaves due to the formation of their larger area in the crop leads to a decrease in photosynthetic productivity. The yield of agricultural crops is the final generalizing indicator of the efficiency of their cultivation, an important characteristic is not only the value of the yield, but also its constancy over the years (see table 3). In our experiments, the yield of winter barley grain depended not only on the studied preparations, but also on the weather conditions of the growing years.

Table 1

Dynamics of leaf surface area in winter barley depending on the experiment variants on vegetation phases, thousand m²/ha

Experiment variant	Vegetation phases by year											
	2020 year				2021 year				Average for 2020–2021 years			
	tillering	stooling	earing	Milk ripeness	tillering	stooling	earing	Milk ripeness	tillering	stooling	earing	Milk ripeness
1	9,0	17,2	19,9	12,4	13,7	26,0	30,1	18,8	11,4	21,6	25,0	15,6
2	11,3	22,6	25,2	14,3	17,1	34,3	38,2	21,6	14,2	28,5	31,7	17,9
3	15,2	30,4	33,3	19,1	23,1	46,1	50,4	29,0	19,2	38,3	41,8	24,1
4	10,4	16,7	20,9	10,9	15,7	25,3	31,6	16,5	13,1	21,0	26,2	13,7
5	15,1	24,3	26,8	12,1	22,9	36,8	40,6	18,4	19,0	30,5	33,7	15,3
6	15,2	29,3	32,0	16,2	23,0	44,4	48,5	24,6	19,1	36,9	40,3	20,4
7	11,7	19,9	23,8	12,6	17,7	30,2	36,1	19,1	14,7	25,1	30,0	15,9
8	12,3	22,8	27,6	15,3	18,6	34,6	41,8	23,2	15,5	28,7	34,7	19,3
9	13,7	23,8	26,1	13,4	20,7	36,0	39,5	20,3	17,2	29,9	32,8	16,8
10	14,4	24,1	25,7	12,1	21,8	36,5	39,0	18,3	18,1	30,3	32,4	15,2
11	11,4	19,3	21,4	11,6	17,3	29,2	32,4	17,6	14,4	24,2	26,9	14,6
12	7,4	13,5	15,4	7,3	11,2	20,4	23,3	11,0	9,3	16,9	19,3	9,1
13	8,8	16,0	18,2	9,2	13,4	24,3	27,5	13,9	11,1	20,2	22,8	11,5
14	10,4	17,0	18,5	8,9	15,7	25,7	28,0	13,5	13,1	21,3	23,2	11,2

Table 2

Photosynthetic potential of winter barley crops depending on experimental variants, thousand m^2 per day per 1 ha (2020–2021 years)

Variant	Vegetation periods			During vegetation
	Tillering-stooling	Stooling-earing	Earing-milk ripeness	
1	577	816	711	1418
2	745	967	747	1577
3	1028	1450	1196	2322
4	794	1122	978	1950
5	820	1138	962	1932
6	1348	1858	1462	2856
7	730	947	732	1545
8	828	1074	830	1752
9	787	1020	789	1664
10	795	1031	797	1682
11	802	1133	988	1970
12	494	698	608	1212
13	642	907	790	1576
14	549	775	676	1347

Table 3

Winter barley grain yield depending on pre-sowing treatment seeds by year, t/ha

№	Preparation	Yield, t/ha			± to control
		2020 year	2021 year	Average for 2020–2021 years	
1	Control (without treatment)	2,43	3,89	3,16	
2	Oracle seeds + Vitavax 200FF	3,95	5,27	4,61	+1,45
3	Reakom + Vitavax 200FF	4,16	5,80	4,98	+1,82
4	Rostok + Vitavax 200FF	4,09	5,41	4,75	+1,59
5	Quantum grain + Vitavax 200FF	4,25	5,67	4,96	+1,80
6	Biocomplex BTU-R + Vitavax 200FF	4,34	5,76	5,05	+1,89
7	Nano-Mineralis + Vitavax 200FF	3,92	5,14	4,53	+1,37
8	Control + Vitavax 200FF	3,88	4,92	4,40	+1,24
9	Oracle seeds	3,36	4,28	3,82	+0,66
10	Reakom	3,65	4,39	4,02	+0,86
11	Rostok	3,42	4,50	3,96	+0,80
12	Quantum grain	3,68	4,52	4,10	+0,94
13	Biocomplex BTU-R	3,76	4,78	4,27	+1,11
14	Nano-Mineralis	3,19	4,31	3,75	+0,59

HIP_{05}, t/ha (2020 year) – 0,46;

HIP_{05}, t/ha (2021 year) – 0,63

Thus, in the less favorable weather conditions of the vegetation of 2019–2020 years, this indicator averaged 3,72 t/ha with a variation from 2,43 up to 4,34 t/ha. The growing season of 2020–2021 years was more favorable both in terms of moisture availability and the nature of winter, so the crop yield was higher by 1,18 t/ha and it varied from 3,89 up to 5,76 t/ha, depending on the experimental variants.

On average, winter barley formed three excellent levels of productivity in two years. The first level was obtained in variants with a yield of 4,75 up to 5,05 t/ha, which was significantly higher than the yield in the control variant by 1,59–1,89 t/ha. In particular, the highest yield was obtained in such variants of the experiment (variants 2, 3, 4, 5, 6): when treating seeds with Oracle seeds + Vitavax 200FF, Rostok + Vitavax 200FF, Reakom + Vitavax 200FF, Quantum grain + Vitavax 200FF and BTU-R + Vitavax 200FF Biocomplex.

Among these variants, the highest yield was observed in variant 6. The second level of performance is obtained in the following variants (7, 8, 10, 12, 13) as 4,02–4,53 t/ha, a significant increase in yield was 0,86–1,37 t/ha compared to the control, but when compared with each other, the yield indicators were within the error range of the experiment.

The third level of productivity was formed in variants 9, 11, 14 with unilateral use of Oracle seed, Rostok, Nano-Mineralis preparations – the yield here was less than the control or without a significant excess over the control variant.

Growth regulators, bacterial and microfertilizers also affected changes in the structural parameters of the crop (see table 4).

Under their influence, the height of plants increased by 1,3–10,2 cm (except for variants 12 and 14). The tallest plants were in variant 6 as their height was 86,2 cm on average over two years. Plants in this variant also had a high number of grains in the main ear (21,5 PCs.). In variants 2, 3, 5, 6, 8, 9, 10 the plants had the highest coefficient of productive tillering as 2,0.

Treatment of seeds with such preparations as Rostok, seed Oracle, Reakom and Vitavax 200FF, as well as mixtures of such preparations as Nano-Mineralis, BTU-R Biocomplex, Quantum grain, Reakom, seed Oracle with Vitavax 200FF also increased the mass index of 1000 grains by 1,7–2,8 g compared to the control variant.

Thus, the use of some growth-regulating, bacterial preparations and microfertilizers improved both the yield and elements of the crop structure of winter barley plants.

On average, according to the experiment, the highest individual plant productivity was observed in variants 6 and 3 – when treating seeds with such preparations as the BTU-R + Vitavax 200FF Biocomplex (3,0+2,5 l/t) and Reakom + Vitavax 200FF (3,0+2,5 l/t).

In modern conditions, in improving the technology of grain production of grain crops, including winter barley, the development of energy-saving technologies is becoming very relevant, where considerable attention is paid to agricultural techniques that do not require high energy consumption. In particular, to ensure efficient grain cultivation, it is particularly important to introduce progressive organizational, economic and agrotechnological measures into production. At the same time, the priority should include the rational use of fertilizers, including bacterial and microfertilizers, plant growth regulators and other agro-economic measures.

Therefore, one of our tasks was to determine the economic efficiency of the studied preparations when processing winter barley seeds with them. To calculate the economic efficiency of growing winter barley, the basic technological map of its cultivation in the southern steppe zone of Ukraine was analyzed.

According to the technological maps for growing winter barley, the cost per 1 ha is 9042–9159 UAH/ha, depending on the variant. Thus, the lowest costs are observed without the introduction of growth-regulating substances as 9042 UAH/ha, while when using microfertilizers, monetary costs increase by 10–131 UAH/ha compared to the control.

A dynamic factor determining the level of efficiency of grain production is yield. This indicator characterizes not only the level of agricultural culture, but also reflects the result of production intensification and its economic feasibility. The highest yield gains from the use of growth-regulating substances ranged from 1,59 up to 1,89 t/ha compared to the control. However, all the preparations, but in different ways, contributed to an increase in the yield of winter barley. Thus, variants 9, 11 and 14 (seed treatment alone with Oracle seeds, Rostok, Nano-Mineralis preparations) had no significant effect compared to the control. In general, according to the experiment, positive indicators of profitability of winter barley grain production were obtained (from 2 up to 67%). The lowest monetary costs per unit of production were found when growing of barley using Quantum cereals, Nano-Mineralis and without applying microfertilizers – this technology ensured profitability of production at the level of 2–21%. The use of some microfertilizers makes it possible to increase the level of profitability of barley grain production by 12–46% compared to the control with minimal costs for their use.

In the context of variants, we identified the advantage of using Biocomplex BTU-R + Vitavax 200FF preparations (variant 6). Seed treatment with this mixture was the most economically feasible, because the net income here was 1997 UAH/ha and 6091 UAH/t, and the profitability level was 67%. At the same time, this variant provided lower labor and money costs for the production of one ton of grain.

Conclusions. Thus, to ensure a high increase in the yield of winter barley grain of the Deviatiy Val variety on the chernozems of the southern steppe of Ukraine, in order to

Table 4

Structural indicators of winter barley plants depending on pre-sowing treatment of seeds with microfertilizers

№ of variant	Plant heights, cm	Grain number in the main ear of corn, PCs.	Productive tillering	Mass of 1000 grains, g	Density of productive stem stand, PCs./m^2
1	76,0	19,3	1,5	33,0	295
2	79,9	20,3	2,0	35,3	286
3	81,4	21,2	2,0	35,7	294
4	77,3	19,5	1,5	33,0	326
5	80,6	20,8	2,0	35,7	288
6	86,2	21,5	2,0	35,8	291
7	78,6	20,0	1,7	34,9	302
8	81,1	20,6	2,0	35,5	290
9	80,1	20,5	2,0	35,4	272
10	81,3	20,6	2,0	35,5	269
11	77,4	19,8	1,7	34,7	309
12	74,6	19,3	1,2	31,4	330
13	76,9	19,5	1,5	33,0	325
14	72,0	19,0	1,5	32,0	308

increase the germination, winter hardiness, grain yield, it is quite effective to use modern microfertilizers and bacterial preparations together with chemical preparations (Vitavax 200FF) for inlay of seed material, which at the lowest cost of their purchase and application provide a yield of 3,0–4,0 t/ha, reduce labor costs and funds for the production of a unit of production, and, this also means high economic efficiency of growing the crop.

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Kovalenko O.A. Influence of microfertilizers and bacterial preparations on the productivity of winter barley in the Southern Steppe of Ukraine

Purpose. The article is devoted to the results of scientific research that was conducted during 2019–2021, which aimed to determine the influence of inoculation of seed material with microfertilizers (Oracle seeds, Reakom, Rostock, Quantum grain), plant growth stimulant (Nano-

Mineralis), bacterial drug (Biocomplex BTU-R), chemical pesticide (Vitavax 200FF) and their mixtures for biometric indicators (plant height, coleoptile length, leaf assimilation surface area), photosynthetic activity, net photosynthesis productivity, productivity and yield of winter barley grain grown in southern Steppe of Ukraine. The goal was achieved by establishing a one-factor field experiment using 0,5 to 3,0 liters of formulations, depending on their class and a working fluid of 10 liters for inoculation of one ton of seed culture.

Methods: general scientific (dialectical – observation of the dynamics of culturegrowth and development; method of hypotheses – experimental scheme; method of analysis – study of research object; method of synthesis – formation of conclusions, recommendations for production; method of abstraction – theoretical generalization of research; calculation method – establishing economic and energy efficiency measures) and special (field method – study of the relationship of the object with biotic and abiotic factors in specific conditions of the research area; laboratory methods: morphophysiological – biometric parameters of plants; chemical – chemical composition of grain and soil; physical – physical indicators of soil and seeds, statistical methods: comparative-calculation – economic efficiency of cultivation technologies For generalization and processing of experimental data used statistical, calculation and comparative-computational methods: variance, correlation and regression analysis.

Research results. In our research, the maximum indicators of plant height, leaf area of crops and their photosynthetic productivity were formed in research areas where mixtures of preparative forms of microfertilizers and bacterial with chemical pesticides were used, namely: Reakom + Vitavax 200FF (3,0+2,5 l/ton) + Water (4,5 l/ton) and Biocomplex BTU-R + Vitavax 200FF (3,0+2,5 l/ton) + Water (4,5 l/ton). The highest productivity of culture and economic efficiency was achieved by using a mixture of bacterial preparation Biocomplex BTU-R with chemical pesticide Vitavax 200FF – seed treatment with this mixture was the most economically feasible, as net profit was 1997 UAH/ha and 6091 UAH/ton, and the level of profitability was 67%. This option provided lower labor costs and money for the production of one ton of winter barley grain.

Conclusions. According to the results of research, it is recommended for the production to conductpre-sowing treatment with the preparative mixture Biocomplex BTU-R + Vitavax 200FF (3,0+2,5 l/ton) of winter barley of the Deviatyivalvarietyon chernozems of the southern steppes of Ukraine in order to increase germination, winter hardiness, grain yield. Seed treatment should be carried out directly before sowing at the rate of 10 liters of working solution per 1 ton of seeds.

Key words: winter barley, inoculation, microfertilizer, photosynthetic activity, winter hardiness, grain yield, economic efficiency.

Коваленко О.А. Вплив мікродобрив та бактеріальних препаратів на продуктивність ячменю озимого в умовах Південного Степу України

Мета. Статтю присвячено висвітленню результатів наукових досліджень, проведених упродовж 2019–2021 рр., метою яких було встановлення впливу інокуляції насіннєвого матеріалу мікродобривами (Оракул насіння, Реаком, Росток, Квантум зернові), стимулятором росту рослин (Нано-Мінераліс), бактеріальним препаратом (Біокомплекс БТУ-р), хімічним протруювачем (Вітавакс 200ФФ) та їх сумішками на біометричні показники (висоту рослин, довжину колеоптиля, площу асиміляційної поверхні листків), фотосинтетичну активність, чисту продуктивність фотосинтезу, продуктивність і врожайність зерна ячменю озимого під час вирощування в умовах Південного Степу України. Реалізація поставленої мети здійснювалася шляхом закладання польового однофакторного досліду з використанням від 0,5 до 3,0 літрів препаративних форм залежно від їх класу та робочої рідини в 10 літрів для інокуляції однієї тони насіння культури.

Методи: загальнонаукові (діалектичний – спостереження за динамікою росту й розвитку культури; метод гіпотез – схема досліду; метод аналізу – вивчення об'єкта досліджень; метод синтезу – формування висновків, рекомендацій для виробництва; метод абстрагування – теоретичне узагальнення досліджень; розрахунковий метод – встановлення економічної та енергетичної ефективності заходів) та спеціальні (польовий метод – вивчення взаємозв'язку об'єкта з біотичними й абіотичними факторами в конкретних умовах зони проведення досліджень; лабораторні методи: морфофізіологічний – біометричні параметри рослин; хімічний – хімічний склад зерна та ґрунту; фізичний – фізичні показники ґрунту й насіння; статистичні методи: порівняльно-розрахунковий – економічна ефективність технологій вирощування). Для узагальнення та обробки експериментальних даних застосовували статистичний, розрахунковий і порівняльно-обчислювальний методи, а саме: дисперсійний, кореляційний та регресійний аналізи.

Результати досліджень. У результаті проведених досліджень максимальні показники висоти рослин, площі листкового апарату посівів та фотосинтетична їх продуктивність формувалися на дослідних ділянках, де застосовувалися сумішки препаративних форм мікродобрив і бактеріальних із хімічним протруювачем, а саме: Реаком + Вітавакс 200ФФ (3,0+2,5 л/т) + вода (4,5 л/т) та Біокомплекс БТУ-р + Вітавакс 200ФФ (3,0+2,5 л/т) + вода (4,5 л/т). Найвища продуктивність культури та економічна ефективність досягається за використання суміші бактеріального препарату Біокомплекс БТУ-р із хімічним протруювачем Вітавакс 200ФФ – протруєння насіння цією сумішшю було найбільш економічно доцільним, адже чистий прибуток при цьому становив 1997 грн/га та 6091 грн/т, а рівень рентабельності – 67%. При цьому зазначений варіант забезпечував менші витрати праці та грошових коштів на виробництво однієї тонни зерна ячменю озимого.

Висновки. За результатами досліджень рекомендовано виробництву за вирощування ячменю озимого сорту Дев'ятий вал на чорноземах Південного Степу України з метою підвищення схожості, зимостійкості, урожайності зерна проводити передпосівну обробку препаративною сумішшю Біокомплекс БТУ-р + Вітавакс 200ФФ (3,0+2,5 л/т). Обробку насіння проводити безпосередньо перед посівом у розрахунку 10 л робочого розчину на 1 т насіння.

Ключові слова: ячмінь озимий, інокуляція, мікродобрива, бактеріальні препарати, фотосинтетична діяльність, зимостійкість, урожайність зерна, економічна ефективність.