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Productivity of winter wheat depending on varietal characteristics and pre-sowing treatment of seeds with biological products

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Abstract. Winter wheat is the main food crop in the Steppe zone and the main agricultural crop in many countries of the world. The issues of intensifying grain production are inseparable from the production and use of new effective biological products for pre-sowing seed treatment, which positively affect the growth and development of winter wheat plants. The purpose of the study was to establish the effect of seed treatment before sowing with biological products on the productivity of winter wheat varieties. The study presents data on the results of an examination of 10 varieties of winter wheat for seed treatment with biological products in the conditions of the Educational and Scientific Practical Centre of the Mykolaiv National Agrarian University from 2020 to 2022. In the course of the study, generally accepted methods were used: system approach and system analysis, analysis and synthesis, field, and statistical. The influence of seed treatment with biological products and varietal characteristics of winter wheat on productivity was analysed. It was determined that the yield level depended and varied depending on the biological product used for pre-sowing seed treatment and the examined variety. Over the years of the study, biological products have affected the

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density of plants, the coefficient of productive tillering, the number of productive stems, the mass of grain per ear, 1000 grain weight, and the yield of winter wheat varieties. The best results were obtained with the combined use of the examined biological products Azotophyt-R and Phytocide-R. The conducted studies confirmed the feasibility of pre-sowing seed treatment with biological products to optimise the nutrition of plants of winter wheat varieties to form a high grain yield. The scientific achievements obtained will contribute to the widespread use of biological products for seed treatment, ensure rapid and full-fledged growth and development of winter wheat varieties, and further increase grain production and gross harvest

Keywords: soft winter wheat; grain yield; productive tillering coefficient; 1000 grain weight; grain weight per 1 ear

INTRODUCTION

One of the strategic industries for any country in the world is food production. In modern economic conditions, the importance of the agricultural sector in the economy is growing, since Ukraine's competitiveness, or gross domestic product, benefits from the sale of agricultural products. An important part of agricultural production is the cultivation of food crops. For a long time, Ukraine has been among the top ten grain producers in the world per capita.

In many countries of the world, wheat is the main agricultural crop, and in the Steppe zone it is the main food crop, so the system of agrotechnical measures should be aimed at creating favourable conditions for obtaining a high yield of this crop (Gamayunova *et al*., 2022). Worldwide, there is a growing interest in using organic farming and increasing grain production using low levels of mineral fertilisers (Petrenko *et al*., 2018). Reducing the dose of mineral fertilisers, especially nitrogen, is possible when using biological products.

The main goal of organic technology for growing winter wheat is to realise the yield potential of varieties through the rational use of natural productivity factors. In each region, it would be necessary to select such varieties, the bioecological features of which fully correspond to the natural conditions of the area (Babenko *et al*., 2018; Korkhova *et al*., 2022). Modern winter wheat varieties are characterised by high ecological plasticity, disease resistance, and grain quality (Montesinos-López *et al*., 2018; Korkhova *et al*., 2022).

In recent years, there has been an increase in interest in biological preparations, which is associated with an increase in the price of mineral fertilisers, contamination of agricultural land with chemicals and the expansion of acreage for organic farming (Kulkarni & Goswami, 2019). Biological products stimulate the growth and development of agricultural plants, increase resistance to stress, diseases, and balance nutrition. This effect is achieved due to the fact that live bacteria convert insoluble compounds into available forms, provide nitrogen nutrition, and protect plants from bacterial and fungal diseases (Panfilova & Mohylnytska, 2019).

Numerous studies by researchers around the world (Singh *et al*., 2018; Klein & Guimarães, 2018) showed that the use of complex organic fertilisers, composite growth bioregulators, inoculants, nanopreparations, biogenic elements will contribute to the regulation of plant growth and development, their resistance to stress by increasing plant immunity, activating biological processes, synthesising organic substances, increasing leaf surface area, net photosynthesis productivity, and crop yields. There is a wide range of biological products on the market, so this makes it difficult to choose them.

Grain yield is a complex trait that depends on many genetic factors and environmental changes. Successful breeding depends on information about genetic variability and the association of morphological agronomic traits with grain yield. The State Register of Varieties (2023) lists more than 600 varieties of winter wheat. For effective breeding work, raw materials must be examined in detail for compliance with specific parameters and requirements (Wu & Zhatova, 2022).

Increasing the yield of winter wheat grain in combination with reducing resource consumption and reducing the chemical load on the soil is a priority area for the development of agriculture, success in which can be achieved by greening crop production (Acharige, *et al.,* 2019; Soto-Gómez & Pérez-Rodríguez, 2022). Due to the application of excessive amounts of fertilisers, environmental pollution increases, the quality decreases, and the energy intensity of manufactured products increases (Kulkarni & Goswami, 2019).

There is insufficient information on the productivity of winter wheat in arid conditions, especially studies on modern varieties, so the creation of important traits for breeding and the organisation of breeding work is based mainly on world genetic resources or collections of cultivated plants (Lollato *et al*., 2019).

The purpose of the study consisted in establishing varietal characteristics and the influence of weather conditions during the years of the study on the productivity indicators of winter wheat, depending on the treatment of seeds before sowing with biological products.

MATERIALS AND METHODS

Experimental studies were conducted during 2020-2022 at the experimental field of the Educational and Scientific Practical Centre of the Mykolaiv National Agrarian University. The experiment scheme included the following variants: factor A – winter wheat varieties (10 variants); Factor B – biological products: control

(water treatment), Azotophyt-R, Phytocide-R, Azotophyt-R + Phytocide-R. The area of the sown plot was 50 m^2, and accounting – 26 m^2. Variants were placed using the incomplete randomisation method in four-fold repetition.

The research material was 10 varieties of soft winter wheat, owned by leading institutions of Ukraine: Antonivka, Liha odes'ka, Duma odes'ka, Versiia odes'ka, Spadshchyna odes'ka, Vidpovid odes'ka, Rodzynka odes'ka (breeding and genetic Institute-National centre for seed and variety studies); Ovidii, Khersons'ka 99 (Institute of irrigated agriculture of the National Academy of Agrarian Sciences of Ukraine), Rosynka (Institute of rice of the Ukrainian Academy of Agrarian Sciences), which are registered in the State Register of plant varieties suitable for distribution in Ukraine in 2005-2020 (State Register of Plant Varieties…, 2022). Agricultural techniques for conducting experiments were generally accepted for existing zonal recommendations for the conditions of the Southern Steppe zone of Ukraine, with the exception of factors under study. Sowing of winter wheat varieties was conducted in the first decade of October, using the seeding rate of 5 million pcs./ha.

The soil of the experimental plots is represented by southern chernozem, residual residual-lightly-alkaline heavy loamy on forest soils with a neutral reaction of the soil solution. The average humus content in the arable soil layer is 3.3%, mobile forms of nutrients: nitrates – 18, mobile phosphorus – 49, exchange potassium – 395 mg/kg of soil.

The effect of Azotophyt-R and Phytocide-R biological products was examined on the winter wheat varieties under study. Azotophyt-R is a natural biostimulator of growth, which actively fixes molecular atmospheric nitrogen, synthesises growth-stimulating substances, improves seed germination, stimulates the development of the root system and plants, improves the absorption of nutrients, and increases crop yield. Phytocide-R is a biological fungicide against fungal and bacterial diseases that protects plants from a wide range of fungal and bacterial pathogens, stimulates plant growth and development, increases resistance to adverse environmental conditions and improves the quality of crop production. The preparations are used for seed treatment before sowing at the rate of 0.8 and 1.0 L/t, respectively. Accounting of crop density was determined on test sites with an area of 1 m^2 twice during the growing season, which were placed diagonally across the registered area of the plot. For the first time, counting is conducted in the phase of full shoots, and for the second time – before harvesting.

The coefficient of productive tillering was determined by the ratio of the number of productive stems to the number of plants in a snip sample taken from an area of 1 m^2. The mass of grain from one ear was determined by dividing the mass of grain from the sheaf by the number of productive stems in the sheaf sample. 1000 grain weight was determined according to DSTU ISO 520:2015 (2015). Winter wheat harvesting was conducted with a SAMPO-500 combine harvester with each repetition. After threshing each section, the combine's threshing machine was turned off, the collected grain was weighed separately and transferred to standard humidity (14%) and purity (100%).

The obtained results in the form of analytical digital material were subjected to statistical and mathematical processing, which was performed by the method of variance and correlation analysis using Microsoft Exel and Agrostat computer programmes by the method of variation, correlation, and variance analysis.

RESULTS AND DISCUSSION

The productivity of winter wheat is influenced by many factors, including varietal characteristics, biological products for pre-sowing seed treatment and cultivation technology. Plant density is the main indicator for the formation of the future yield. According to the results of the conducted studies, it was established that the density of winter wheat plants was influenced by both varietal characteristics and the pre-sowing treatment of seeds with the examined biological products. Thus, the highest density of plants per 1 m^2 was formed by plants of the Rosynka variety – 384-424 pcs./m^2 depending on the treatment of seeds with biological products, and on average according to these biological products, the density was 398 pcs./m^2 (Table 1).

Table 1. *Plant density of winter wheat varieties in the phase of full grain ripeness, depending on seed treatment with biological products (average for 2020-2022), pcs./m^2*

No.	Factor A (varieties)	Factor B (biological products)				
		Control (water treatment)	Azotophyt-R	Phytocide-R	Azotophyt-R + Phytocide-R	Average
1	Ovidii	287	291	276	357	**303**
2	Rodzynka odeska	375	373	362	422	**383**
3	Rosynka	384	393	389	424	**398**
4	Spadshchyna odes`ka	380	392	394	415	**395**
5	Khersons'ka 99	366	396	401	414	**394**
6	Antonivka	366	367	348	405	**372**

Table 1, Continued

No.	Factor A (varieties)	Factor B (biological products)				
		Control (water treatment)	Azotophyt-R	Phytocide-R	Azotophyt-R + Phytocide-R	Average
7	Versiia odes`ka	358	370	392	410	**383**
8	Vidpovid odes'ka	353	379	375	409	**379**
9	Duma odes`ka	295	299	292	396	**321**
10	Liha odes'ka	349	375	383	409	**379**
	Average	**351**	**364**	**361**	**406**	**371**
	HIP_{05} for factor A (pcs./m²) – 2.01					
	HIP_{05} for Factor B (pcs./m²) – 5.04					

Source: *compiled by the authors*

The lowest density of plants was formed by plants of the Ovidii variety – from 276 pcs./m² in the version with the biological product Phytocide-R up to 357 pcs./m² in the version with the combined use of biological products Azotophyt-R and Phytocide-R. The coefficient of productive tillering of the examined winter wheat varieties ranged from 1.7 to 2.4, depending on the examined biological products (Table 2).

Table 2. *Coefficient of productive tillering of plants of winter wheat varieties in the phase of full grain ripeness, depending on seed treatment with biological products (average for 2020-2022), pcs./m²*

No.	Factor A (varieties)	Factor B (biological products)				
		Control (water treatment)	Azotophyt-R	Phytocide-R	Azotophyt-R + Phytocide-R	Average
1	Ovidii	2.0	2.1	2.1	2.0	**2.1**
2	Rodzynka odeska	2.0	2.0	1.9	1.8	**1.9**
3	Rosynka	1.9	1.7	1.8	1.7	**1.8**
4	Spadshchyna odes`ka	1.8	1.9	1.8	1.8	**1.8**
5	Khersons'ka 99	1.9	1.8	1.8	1.7	**1.8**
6	Antonivka	1.8	1.8	1.9	1.7	**1.8**
7	Versiia odes`ka	2.0	2.0	1.9	2.0	**2.0**
8	Vidpovid odes'ka	2.1	2.0	2.1	1.9	**2.0**
9	Duma odes`ka	2.0	2.4	2.1	1.8	**2.1**
10	Liha odes'ka	2.1	2.0	2.0	1.9	**2.0**
	Average	**2.0**	**1.9**	**1.9**	**1.8**	**1.9**
	HIP_{05} for factor A (pcs./m²) – 0.01					
	HIP_{05} for Factor B (pcs./m²) – 0.02					

Source: *compiled by the authors*

This indicator was higher (2.0) on average for varieties in the control version, and lower (1.8) in the version with the combined use of biological products Azotophyt-R and Phytocide-R. It was determined that pre-sowing treatment of seeds with biological products reduced the coefficient of productive bushiness of plants on average for the examined varieties by 0.1-0.2 pcs./m². It is established that the varieties Ovidii and Duma odes'ka formed the highest coefficient of productive tillering – 2.1, which is 0.1 more than the varieties Versiia odes'ka and Vidpovid odes'ka; 0.2 more than the variety Rodzynka odes'ka; 0.3 – than the varieties Rosynka, Spadshchyna odes'ka, Khersons'ka 99, and Antonivka.

The number of productive stems per unit area – an important indicator characterising winter wheat's productive stem. It determines the formation of the winter wheat crop in the South of Ukraine more than other indicators of productivity elements. The conducted studies determined that the number of productive stems depended on varietal characteristics and the examined biological products. Thus, this indicator is more formed in the variety Vidpovid odes'ka – 804 pcs./m², which is 9-179 pcs./m² is higher than that of other varieties examined (Table 3).

Table 3. *The number of productive stems of winter wheat varieties in the phase of full grain ripeness, depending on seed treatment with biological products (average for 2020-2022), pcs./m²*

No.	Factor A (varieties)	Factor B (biological products)				
		Control (water treatment)	Azotophyt-R	Phytocide-R	Azotophyt-R + Phytocide-R	Average
1	Ovidii	566	619	570	750	**626**
2	Rodzynka odeska	787	785	724	801	**774**
3	Rosynka	761	708	740	762	**743**
4	Spadshchyna odes`ka	723	785	749	789	**762**
5	Khersons'ka 99	732	753	762	744	**748**
6	Antonivka	709	696	697	729	**708**
7	Versiia odes`ka	752	776	785	861	**794**
8	Vidpovid odes'ka	777	795	825	818	**804**
9	Duma odes`ka	609	652	637	601	**625**
10	Liha odes'ka	768	787	805	818	**795**
	Average	**718**	**736**	**729**	**783**	**742**
	HIP_{05} for factor A (pcs./m²) – 17.2					
	HIP_{05} for factor B (pcs./m²) – 22.3					

Source: *compiled by the authors*

A higher density of productive stem (783 pcs./m²) was formed plants of winter wheat varieties in the version with the pre-sowing treatment of seeds with biological products Azotophyt-R and Phytocide-R, and the smallest amount – 718 pcs./m² in the control version with seed treatment before sowing with water. The best option in terms of the number of productive stems of winter wheat was the Vidpovid odes'ka variety for seed treatment with Phytocide-R – 825 pcs./m². The smallest number of productive stems is formed by plants of winter wheat of the Ovidii variety (560 pcs./m²) in the control version (seed treatment with water).

The second important indicator that characterises the productivity of winter wheat is the mass of grain per ear. According to the results of the study, this indicator was formed from 0.61 g/ear in the variety Versiia odes'ka for seed treatment with water to 0.93 g/ear in the varieties Duma odes'ka for seed treatment with Azotophyt-R, and Ovidii in the variant with the biological product Phytocide-R (Table 4).

Table 4. *Grain weight per 1 ear of winter wheat plants depending on the variety and seed treatment with biological products (average for 2020-2022), g*

No.	Factor A (varieties)	Factor B (biological products)				
		Control (water treatment)	Azotophyt-R	Phytocide-R	Azotophyt-R + Phytocide-R	Average
1	Ovidii	0.90	0.92	0.93	0.78	**0.88**
2	Rodzynka odeska	0.72	0.69	0.72	0.72	**0.71**
3	Rosynka	0.68	0.77	0.72	0.77	**0.74**
4	Spadshchyna odes`ka	0.72	0.70	0.72	0.72	**0.72**
5	Khersons'ka 99	0.71	0.71	0.70	0.74	**0.72**
6	Antonivka	0.71	0.74	0.72	0.72	**0.72**
7	Versiia odes`ka	0.61	0.65	0.59	0.60	**0.61**
8	Vidpovid odes'ka	0.60	0.63	0.58	0.75	**0.64**
9	Duma odes`ka	0.90	0.93	0.91	0.79	**0.88**
10	Liha odes'ka	0.73	0.73	0.70	0.70	**0.72**
	Average	**0.73**	**0.75**	**0.73**	**0.73**	**0.74**
	HIP_{05} for factor A (g) – 0.02					
	HIP_{05} for Factor B (g) – 0.06					

Source: *compiled by the authors*

The largest mass of grain per ear (0.75 g/ear) was formed on average for varieties in the variant with pre-sowing seed treatment with Azotophyt-R biological product, which is 2.7% more compared to the control variant.

All these indicators also affected the formation of winter wheat grain yield, which depended on varietal characteristics and biological products. Thus, the highest grain yield (6.09 t/ha) was formed by the Duma odes'ka variety in the version with pre-sowing seed treatment with Azotophyt-R and Phytocide-R biological products, and the smallest – 4.49 t/ha. Thus, on average, for factor B (biological products), a higher grain yield (5.85 t/ha) was formed in the Duma odes'ka variety, which is 0.19-1.09 t/ha more than in other varieties examined. Varieties Ovidii, Rodzynka odes'ka, Rosynka, Khersons'ka 99, Antonivka formed an average yield – 5.45; 5.30; 5.35; 5.26; 5.04 t/ha, respectively.

Table 5. *Yield of winter wheat grain depending on the variety and seed treatment with biological products, (average for 2020-2022), t/ha*

No.	Factor A (varieties)	Factor B (biological products)				
		Control (water treatment)	Azotophyt-R	Phytocide-R	Azotophyt-R + Phytocide-R	Average
1	Ovidii	5.10	5.71	5.29	5.71	**5.45**
2	Rodzynka odeska	5.00	5.33	5.18	5.67	**5.30**
3	Rosynka	5.07	5.35	5.22	5.76	**5.35**
4	Spadshchyna odes`ka	5.13	5.44	5.29	5.59	**5.36**
5	Khersons'ka 99	5.09	5.30	5.22	5.43	**5.26**
6	Antonivka	4.89	5.10	4.97	5.18	**5.04**
7	Versiia odes`ka	4.49	4.96	4.52	5.07	**4.76**
8	Vidpovid odes'ka	4.55	4.89	4.72	5.11	**4.82**
9	Duma odes`ka	5.46	6.08	5.76	6.09	**5.85**
10	Liha odes'ka	5.52	5.68	5.58	5.84	**5.66**
	Average	**5.03**	**5.38**	**5.18**	**5.55**	**5.29**
		HIP_{05} for factor A (t/ha) – 0.14				
		HIP_{05} for factor B (t/ha) – 0.21				

Source: *compiled by the authors*

On average, for the examined biological products, a higher grain yield was formed on average for varieties in the variant with the combined use of biological products Azotophyt-R and Phytocide-R – 5.55 t/ha, which is 0.17 t/ha more than in the variant with the biological product Azotophyt-R, 0.37 t/ha more than in the variant with the biological product Phytocide-R and 0.52 t/ha more than in the control variant (Fig. 1).

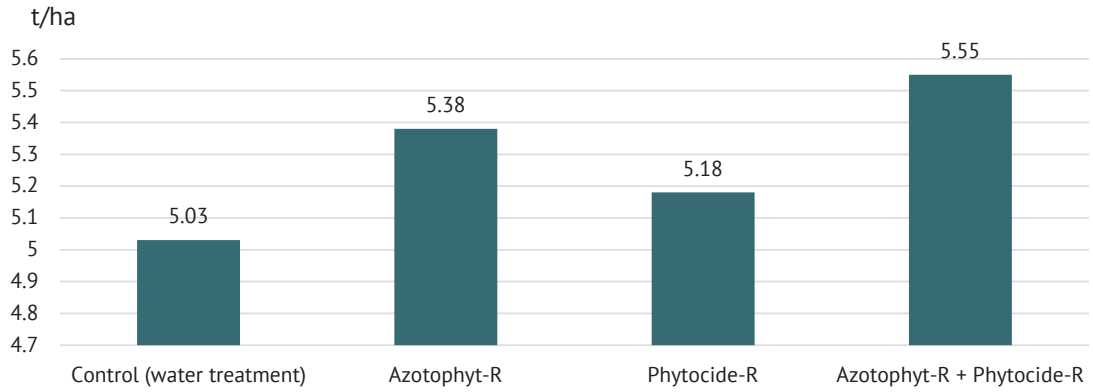

Figure 1. *Winter wheat grain yield depending on biological products (average for varieties and average for 2020-2022), t/ha*

Source: *compiled by the authors*

The lowest grain yield on average for varieties was formed in the control version – 5.03 t/ha, namely when growing the Versiia odes'ka variety, where the yield was 4.49 t/ha. The 1000 grain weight of winter wheat ranged from 30.9 g in the control version when growing the Vidpovid odes'ka variety to 45.3 g in the version with the combined use of Azotophyt-R and Phytocide-R biological products in the Ovidii variety (Table 6).

Table 6. *1000 grain weight of winter wheat, depending on the variety and seed treatment with biological products (average for 2020-2022), g*

No.	Factor A (varieties)	Factor B (biological products)				
		Control (water treatment)	Azotophyt-R	Phytocide-R	Azotophyt-R + Phytocide-R	Average
1	Ovidii	40.1	42.2	41.6	45.3	**42.3**
2	Rodzynka odeska	38.9	39.4	39.1	40.6	**39.5**
3	Rosynka	35.0	35.2	34.9	36.1	**35.3**
4	Spadshchyna odes`ka	35.1	35.9	35.6	36.8	**35.9**
5	Khersons'ka 99	34.0	34.3	33.9	34.8	**34.3**
6	Antonivka	35.9	36.1	35.3	36.5	**36.0**
7	Versiia odes`ka	40.0	40.6	40.1	41.0	**40.4**
8	Vidpovid odes'ka	30.9	33.2	32.6	33.9	**32.7**
9	Duma odes`ka	36.6	37.1	36.8	38.2	**37.2**
10	Liha odes'ka	35.7	36.4	35.9	37.2	**36.3**
	Average	**36.2**	**37.0**	**36.6**	**38.0**	**37.0**
		HIP_{05} for factor A (g) – 0.3				
		HIP_{05} for factor B (g) – 0.5				

Source: *compiled by the authors*

On average, the largest 1000 grain weight was formed by the Ovidii variety – 42.3 g, and the smallest – 32.7 g. Thus, on average for larger varieties, this indicator (38.0 g) is formed in the variant with joint seed treatment before sowing with Azotophyt-R and Phytocid-R biological products, which is 1.8 g more than in the control version, 1.0 g more than in the variant using Azotophyt-R biological products, and 1.4 g more than in the variant with the Phytocid-R biological products.

The formation of winter wheat grain yield was influenced by the interaction of productivity factors, mainly the number of productive straws, the mass of a thousand grains, and the size and quality of grains in ears (Olkhovsky *et al.*, 2019; Tsvey *et al.*, 2021). M. Lozinskiy *et al.* (2021) determined that the grain mass of a single ear, i.e. its productivity, is the result of the action and interaction of many hereditary factors that determine its components, so the main ear plays an extremely important role in shaping the productivity of wheat plants and grain yield.

Based on the results of a study conducted during 2015-2017 in the Lublin Voivodeship (Poland), it was determined that winter wheat, regardless of the year of the study, generated the highest yield of soft winter wheat varieties – 7.69 t/ha (Rachon *et al.,* 2020). In addition, a higher yield (5.91 t/ha) was obtained by research in the period 2016-2022 on average for winter wheat varieties (Korkhova *et al.*, 2023).

N.V. Pinchuk *et al.* (2022) determined that in the variants where pre-sowing inoculation of winter wheat seeds of the Skagen variety was conducted with biological products, the stem density was higher compared to the data obtained in the control variant. When using Azotophyt-R biological product for pre-sowing inoculation of seeds, the stem density was 586 pcs./m^2, which is 28.8% more than the results of studies conducted when using this biological product on average for varieties. The yield of winter wheat grain during pre-sowing seed treatment with Azotophyt-R was 5.64 t/ha, which is 6.2% less compared to the results obtained when growing the Duma odes'ka variety.

V. Gamayunova *et al.* (2022) argue that the use of biological products substantially affects the 1000 grain weight and the yield of winter wheat. The highest 1000 grain weight was obtained at 38.7 g when treated with organic balance biological products when growing the Duma odes'ka variety, which is an increase of 1.1% compared to the variant growing a similar variety with the combined use of Azotophyt-R and Phytocide-R biological products on average over the years of the study.

The studies, conducted at the Agricultural Academy of Vytautas Magnus University (Lithuania) in 2019-2020 by D. Jodaugiene *et al.* (2022), determined that the use of biological products did not substantially affect the germination of winter wheat seeds, but contributed to

an increase in plant tillering and the number of productive stems. When using biological products, there was a tendency to increase 1000 grain weight, the number of grains in the ear, the mass of grain from the ear, and the yield of winter wheat substantially increased compared to the control option.

V. Gamayunova *et al.* (2022) determined that the use of biological products affects the productivity of winter wheat. The highest yields were obtained in the variant for growing a crop of the Duma odes'ka variety with soil steaming and treatment with organic balance biological product and amounted to 7.19 t/ha, which is 1.67 t/ha or 30.3% more compared to the control version.

According to R. Vozhehova & A. Kryvenko (2019), the effectiveness of Azotophyt-R in Southern chernozems depends on the average level of their fertility. The highest efficiency was recorded on variants without fertiliser application (increments ranged from 0.18 to 0.30 t/ha), with a minimal application for the worse predecessor (an increase of 0.35 t/ha) and for background $N_{64}P_{64}K_{64}$ when growing the Knopa Variety with soil steaming (increment of 0.19-0.26 t/ha).

M. Korkhova *et al.* (2022) determined that on average for five years of the study (2018-2022), among 20 varieties of winter wheat, bearded varieties (Ozerna, Staleva, Mudrist odes'ka, Duma odes'ka, Koshova, Mariia, Zdobn, Dyvo, MIP Valensiia, Pamiati Girka, Kraievyd, Centurion) formed a 5.8% higher grain yield than unbearded – Kvitka poliv, Legenda bilotserkivs'ka, MIP Assol, Katarina, Felix, Ponticus, Faustus, and Hlaukus. Medium-early varieties (Ozerna, Staleva, Kvitka poliv, Mudrist odes'ka, Zdobna, Dyvo, and Centurion).

O.G. Berdnikova & E.M. Kucherak (2021) argue that the choice of variety is a key factor in obtaining technical indicators of high grain yield and quality. The introduction of new varieties of winter wheat into production is one of the ways to increase the profitability of its cultivation, but the average yield of this crop in Ukraine is 2.5 times lower than in Western Europe. This situation is caused by various factors, one of which is the use of low-selection and outdated varieties that do not meet the requirements of modern high-intensity agriculture.

D. Jodaugiene *et al.* (2022) determined that the use of the biological preparation did not have a substantial effect on seed germination, but contributed to tillering, an increase in winter wheat plant leaf surface area, the number of productive stems, 1000 grain weight, the ear, the mass of grain in the ear, and an increase in grain yield compared to the control.

A study by V.V. Bazalii *et al.* (2019) proved that in the conditions of the south of Ukraine, it is necessary to grow flexible wheat varieties with increased crop stability (Khersons'ka unbearded, Khersons'ka 99, Znakhidka odes'ka, Askaniys'ka, Clarysa), if strict stress limits are expected in the environmental conditions. M.K. Bondarenko & M.M. Nazarenko (2022) argue that highly productive genotypes developed yields due to additional ears, had higher resistance to lodging due to lower plant height and grain weight from the ear, respectively, and spent fewer nutrients on stem formation.

Thus, biological products for pre-sowing seed treatment under study substantially impact the productivity of winter wheat varieties, namely, the number of productive stems, the mass of grain per ear, the yield, and 1000 grain weight.

CONCLUSIONS

Studies conducted in the conditions of the South of Ukraine in the period 2020-2022 show that the yield of soft winter wheat grain largely depends and varies under the influence of pre-sowing seed treatment with biological products and varietal characteristics of the crop.

The formation of winter wheat grain yield is determined by the interaction of plant productivity elements, particularly the number of productive stems formed, the mass of grain from the ear, etc., which, in turn, depended on the examined factors. Thus, according to the number of productive stems of winter wheat, the best version was determined to be the Vidpovid odes'ka variety with seed treatment with Phytocide-R – 825 pcs./m^2. A large mass of grain per ear (0.75 g/ear) was formed on average for the examined varieties in the variant with the pre-sowing treatment of seeds with Azotophyt-R biological preparation.

The maximum grain yield of winter wheat varieties was formed by joint pre-sowing treatment of seeds with Azotophyt-R and Phytocide-R biological products. Thus, for the cultivation of winter wheat, on average for the examined varieties, 5.55 t/ha of grain was obtained for this variant of the experiment, which exceeded the indicators of other variants of the experiment by 0.17-0.52 t/ha or by 3.1-9.4%.

Varietal characteristics also affected the yield of the examined crop. Thus, on average, according to the options for pre-sowing seed treatment, the Duma odes'ka winter wheat variety formed a grain yield of 5.85 t/ha, which exceeded the indicators of other examined varieties by 3.2-18.6%.

Among the examined biological products, the highest yield was obtained by joint treatment with Azotophyt-R and Phytocide-R biological products when growing the Duma odes'ka winter wheat variety and amounted to 6.09 t/ha, and the lowest yield was formed in the Versiia odes'ka variety in the control version – 4.49 t/ha. The conducted studies confirm the feasibility of pre-sowing seed treatment with biological products to optimise the nutrition of winter wheat varieties to obtain a high grain yield.

In the future, it is planned to analyse the influence of biological products and varietal characteristics of winter wheat on the quality indicators of grain, which will give a more complete description of the examined varieties of winter wheat.

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CONFLICT OF INTEREST

None.

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Продуктивність пшениці озимої залежно від сортових особливостей та передпосівної обробки насіння біопрепаратами

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Анотація. Пшениця озима є основною продовольчою культурою у степовій зоні та основною сільськогосподарською культурою в багатьох країнах світу. Питання інтенсифікації виробництва зерна невіддільні від виробництва та використання нових ефективних біопрепаратів для передпосівної обробки насіння, які позитивно впливають на ріст та розвиток рослин пшениці озимої. Метою роботи було встановити вплив обробки насіння перед сівбою біопрепаратами на продуктивність сортів пшениці озимої. У ході проведення дослідження використовували загальноприйняті методи: системний підхід і системний аналіз,

аналіз та синтез, польовий та статистичний метод. У статті наведено дані про результати дослідження 10 сортів пшениці озимої за обробки насіння біопрепаратами в умовах Навчально-практичного центру Миколаївського національного аграрного університету з 2020 по 2022 роки. Було проаналізовано вплив обробки насіння біопрепаратами та сортових особливостей пшениці озимої на продуктивність. Встановлено, що рівень урожаю залежав та змінювався залежно від взятого для передпосівної обробки насіння біопрепарату та досліджуваного сорту. За роки досліджень біопрепарати вплинули на густоту рослин, коефіцієнт продуктивного кущення, кількість продуктивних стебел, масу зерна з одного колосу, масу 1000 зерен та врожайність сортів пшениці озимої. Найкращі результати було отримано при сумісному використанні досліджуваних біопрепаратів Азотофіт-р та Фітоцид-р. Проведеними дослідженнями підтверджено доцільність передпосівної обробки насіння біопрепаратами для оптимізації живлення рослин сортів пшениці озимої з метою формування високої врожайності зерна. Отримані наукові досягнення сприятимуть широкому застосуванню біопрепаратів для обробки насіння, забезпечать швидкий і повноцінний ріст і розвиток сортів пшениці озимої, сприятимуть подальшому збільшенню виробництва та валового збору зерна

Ключові слова: пшениця м'яка озима; урожайність зерна; коефіцієнт продуктивного кущення; маса 1000 зерен; маса зерна з 1 колосу