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Influence of Eco-Safe Growth-Regulating Substances on the Phytosanitary State of Agrocenoses of Wheat Varieties of Various Types of Development in Non-Irrigated Conditions of the Steppe Zone

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ABSTRACT
The article is devoted to establishing the influence of multifunctional environmentally friendly growth-regulating preparations on the phytosanitary state of agrocenoses of various types of wheat varieties and their productivity under non-irrigated conditions of the steppe zone of Ukraine. Field studies were conducted over 2016–2020 in two agroclimatic points of the steppe zone: such as in the experimental field of the Kherson State Agrarian and Economic University (GPS: 46.743447, 32.481064 Kherson, Ukraine – point 1) and the land use of the farm "Svetlana" (GPS: 47.635522, 32.099772 Vossiyatskoye Village, Mykolaiv region, Ukraine-point 2) under non-irrigated conditions. The implementation of the scientific research program was carried out by laying three – factor experiments in these agroecological points, where Factor A was the varieties of winter wheat – Khersonska 99, Kirena, Askaniyska, Mudrist, Clarissa, Khutoryanka; variants of Factor B: growth-regulating preparations – VuksalMicroplant, Helafit Combi, Phytomare, without cultivation (control); variants of factor C: terms of sowing winter wheat – 10.09, 20.09, 30.09 and 10.10. Studies established that the use of multifunctional growth-regulating preparations helped to reduce the level of plant damage by pathogenic microflora at all sowing periods and varieties of winter wheat. Phytomare and Helafit Combi were the most effective in this respect, under various growing conditions. In most cases, they reduced the degree of damage to winter wheat plants by pathogenic microflora by 40–50% or more. All applied growth regulators increased the mass of grain from the ear and the mass of 1000 grains at different sowing times. It was found that for five years of field research, the greatest increase in yield under different research conditions and different varieties was shown by the Helafit Combi preparation. When it was applied in the experimental field of the Kherson State Agrarian and Economic University, the yield was additionally formed from 0.22 up to 0.5 t/ha, in the field of FG "Svetlana", respectively, it was formed 0.14 up to 0.36 t/ha.

Keywords: winter wheat, growth regulators, agrocenosis productivity, pathogens, fungicides.

INTRODUCTION

The intensification of agriculture and global warming contribute to an increase in agricultural production in Ukraine and the EU countries. With global food demand predicted to grow by 50–80% by 2050, timely strategies are required to best adapt to the projected changes in agriculture (Collins et al. 2021). However, such processes negatively affect the agroecosystem, the environment and public health. It is possible to eliminate the negative impact on agrophytocenoses by transferring the business structures of the agricultural sector of the economy to an environmentally safe direction of development using nature-saving technologies, equipment and organization of production processes. In the context of further intensification of agriculture, it is necessary to introduce environmentally friendly production of agricultural products, the essence of which is to ensure the reproduction of natural resources (soil, water, etc.) in a state close to natural or not exceeding the maximum permissible levels of pollution (Pichura et al., 2020; 2021; Panfilova, 2021).

Warming conditions for the growing season of agricultural crops negatively affect the phytosanitary condition of crops characterized by the development of fungal diseases in the autumn – winter period (winter crops) and a high number of insect pests in the spring-summer period, in addition to the manifestation of viral diseases. Arid conditions negatively affect the development of agricultural crops and contribute to contamination of crops. Taking into account the changes in the climate in recent years, especially significant warming and lengthening of the autumn period in the steppe and forest – steppe zones, it is recommended to shift the optimal time for sowing winter crops by 5–7 days towards late ones. However, it is necessary to warn against too late sowing dates, which reduce not only the resistance to adverse environmental conditions, but they also decrease the yield of grain crops (Urbatzka et al., 2012; Zimmermann et al., 2017).

Under the conditions of intensive agricultural production, pathogens of pathogenic microflora, harmful entomofauna and weed spread are the main significant factors that hinder the growth of yields of all agricultural crops without exception. The development of such processes also has a negative impact on the gross yield of crop production (Domaratsky et al., 2018; 2021). In the world, diseases and pests cause winter wheat crop shortages every year, averaging 14.1% (Zhang et al., 2022). In the years of severe epiphytotic diseases, these indicators increase significantly. In Ukraine, the potential losses of wheat crops from pathogens of harmful diseases amount up to 25% or more annually (Fischer et al., 2018; Domaratsky et al., 2020).

Among the technological innovations is the introduction of a system for protecting grain crops from diseases (a biochemical mixture of fungicides, mordants and the use of the method of induced immunity). The induced immunity method provides a convincing increase in yield compared to the chemical fungicide protection methods. The use of chemicals leads to the "destruction" of plant immunity, leading to a constant increase in the use of fungicides and an increase in the chemical load on agrophytocenoses. In addition, the essence of the method of induced immunity is reduced to spraying agricultural crops with the preparations containing the fungus *Trichoderma lignorum*. It has a significant advantage over classical methods of protecting plants from diseases (Daguerre et al., 2014; Liu et al., 2022).

Major abiotic stresses, such as heat, drought, salinity, heavy metal, light, pesticide, and cold are considered the great threat for the food and environmental security of the increasing population (Hossain et al., 2022). In the process of their vital activity, plants produce their own growth regulators, but under stressful situations (drought, exposure to high temperatures, wind, phytotoxicity), the production of their own hormones is significantly reduced. This leads to a weakening of plants, disruption of the internal development program of plant organisms, making them significantly sensitive to the effects of diseases and other negative environmental factors. Growth-regulating preparations can be successfully used to normalize the vital activity of the plant organism under stress conditions, for directed effects on the plant (Ababaf et al., 2021; Panfilova et al., 2019; Panfilova et al., 2021).

Growing varieties of different degrees of intensity, genetically and biologically heterogeneous, allows more effective use the agroclimatic potential of each zone, each field and ultimately increase the yield, and stabilization of the bull grain harvest. Knowledge of the reaction of different winter wheat varieties to biotic and abiotic environmental factors, the nature of manifestation and the relationship of quantitative characteristics is the basis for the targeted use of these varieties in the adaptive crop production program.

MATERIALS AND METHODS

For the implementation of the research program, a number of field experiments were conducted over 2016–2020 in two agroclimatic points of the steppe zone: such as in the experimental field of the Kherson State Agrarian and Economic University (GPS: 46.743447, 32.481064 m. Kherson, Ukraine – point 1) and the land use of the farm "Svetlana" (GPS: 47.635522, 32.099772 s. Vossiyatskoye, Mykolaiv region, Ukraine-point 2) under non-irrigated conditions (Figure 1).

The soils of the points within the land use of which experimental studies were conducted are characterized by the following indicators: Experimental field of Kherson State Agrarian and Economic University (Point 1) – dark chestnut medium loam medium solonetz with humus content in the arable layer at the level of 2.34–2.60%.

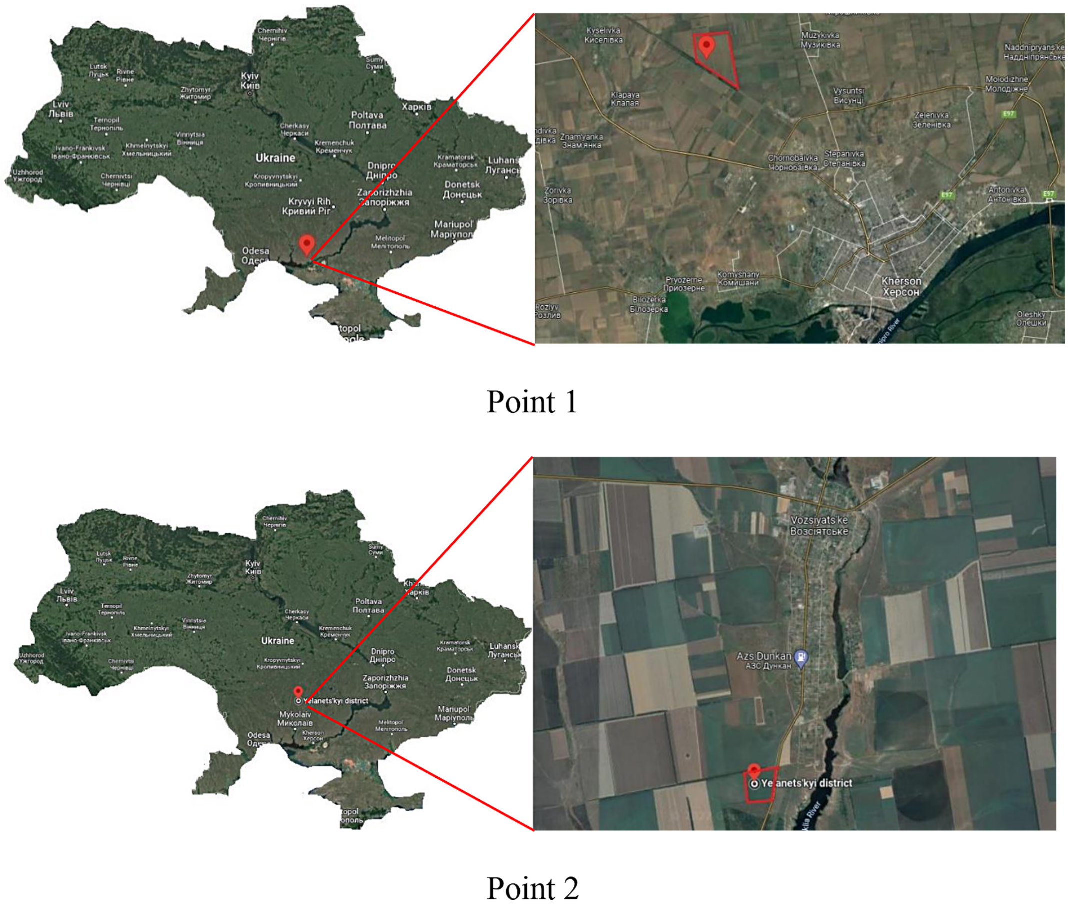

Fig. 1. The location of research

The content of mobile forms of mineral nutrition elements: nitrogen content is 17–20 mg/kg of soil; phosphorus is 49–65; potassium is 280–360 mg/kg of soil, pH is 6.9–7.2. The occurrence of ground water is at a depth of 7.5–13 m.

Farm "Svetlana" of the Elanetsky District of the Mykolaiv region (item 2) – ordinary shallow, low-humus, slightly washed chernozem. The humus content in the arable soil layer is 3.17–3.41%, and the amount of humus gradually decreases down the profile. In the lower part of the soil profile, the amount of humus is 1.89%, the pH of the water extract is 7.0 in the arable layer, down the profile it gradually increases and the pH of the soil solution becomes slightly alkaline. These soils are medium-rich in easily soluble forms of phosphorus and highly rich in exchange potassium. The amount of P_2O_5 is 50 up to 100 mg/kg of soil, K2O is 110–150 mg/kg of soil. Ground water occurrence is at a depth of 12.7–16 m.

The program of scientific research provided for the study of the influence of multifunctional growth-regulating preparations on the phytosanitary state of agrocenoses, seed productivity and quality of products obtained when growing wheat varieties of various types of development. The implementation of the scientific research program was carried out by laying three-factor experiments in these agroecological points, where Factor A was the varieties of winter wheat, such as Khersonska 99, Kirena, Askaniyska, Mudrist, Clarissa, Khutoryanka; variants of Factor B: such growth-regulating preparations as VuksalMicroplant, Helafit Combi, Phytomare, without cultivation (control); variants of factor C: winter wheat sowing dates – 10.09, 20.09, 30.09 and 10.10.

These multifunctional eco-safe preparations were introduced in the form of foliar treatment of crops in the tillering phase in spring, when the average daily temperatures were above +10°C. VuksalMicroplant is a complex suspension with a high content of a wide range of trace elements. Additionally, it contains magnesium, sulfur, potassium and nitrogen to prevent plant nutrition imbalances and increase the intensity of photosynthesis. The preparation is manufactured in Germany at the AglukonSpezialdünger GmbH & Co KG plant. Chelafit Combi contains organic fertilizers (a set of trace elements in chelated form), as well as amino acids, polysaccharides with fragments of vitamins, growth stimulants of biological origin, spores and mycelium of the fungus *Trichoderma lignorum*, spores of bacterial culture *Bacillus subtilis*. The preparation is manufactured in Ukraine. Phytomare is a unique fertilizer based on *Ascophyllumnodosum* seaweed extract obtained using the exclusive technology of Atlantica Agricola (Spain), containing the highest concentration of natural nutrients and biostimulants.

The versatility of the studied preparations lies in the fact that in addition to growth-stimulating properties, they also have a fungicidal effect. At the control variant, no preparations were applied, and the plants were treated with clean water. Experimental plots of winter wheat were established in field experiments by using the method of split plots, sowing was carried out with a grain seeder with a row spacing of 15 cm. The registered area of the plots is 25 m^2. Repeatability was four times. The predecessor for soft winter wheat was black fallow. All necessary assessments, records and observations were carried out according to generally accepted methods of state variety testing. Statistical and variance analysis of research results data was performed according to the Acutis methodology (Acutis et al., 2012).

RESULTS AND DISCUSSION

A scientifically based nutrition system necessarily includes foliar nutrition with macro- and microelements, the use of growth stimulants which have a multifunctional purpose. Due to the use of growth regulators in winter wheat crops, the redistribution of nutrients is optimized, which contributes to better absorption of nutrients and moisture from the soil, and the length, diameter and weight of the wheat root system increases. There is stimulation of secondary root embedding, strengthening and thickening of the main roots, additional accumulation of sugars, phosphorus, potassium, nitrogen, which provides additional initial growth of the plants weakened during overwintering as well as increases the resistance to adverse weather conditions and stress factors (Blandino et al., 2009; Macholdt et al., 2021). The specific effect of plant growth regulators is that they are able to influence processes, direction and intensity which cannot be adjusted using agrotechnical cultivation measures (Blandino et al., 2009; Macholdt et al., 2021). Analysis of the weather conditions of 2016–2020 studies allows classifying them as medium – arid typical for this growing zone. The main long-term average data on the weather and climatic conditions of each of the agroecological research points are shown in Figure 2.

By themselves, growth-regulating preparations do not increase the productivity of crops, but only activate the biological processes of plant organisms and enhance the permeability of intercellular membranes, which contributes to a more complete disclosure of their biological productivity potential (Arikan et al., 2022). In the conducted studies, the use of growth-regulating preparations under various growing conditions of winter wheat significantly reduced the degree of damage to the most harmful diseases (brown rust, powdery mildew) (Table 1).

As it can be seen from the data in Table 1, the degree of fungal disease damage tended to decrease with later sowing dates. The use of multifunctional growth-regulating preparations reduced the degree of damage to plants by brown rust, powdery mildew at all sowing periods and winter wheat varieties, regardless of their genotypically determined resistance to diseases. All the preparations used in the studies contributed to a decrease in the phytopathogenic activity of diseases, but Phytomare and Helafit Combi showed greater effectiveness in this respect under different growing conditions. In most cases, they reduced the degree of damage to winter wheat plants by 40 up to 50% or more.

The genetic yield potential of modern winter wheat varieties increased up to 8.0–12.0 t/ha over the past 10 years, but under production conditions their yield averaged only 2.62 t/ha, that is, it barely reached 25–30% of the potential genetic level. Winter wheat productivity can always be high if differentiated sowing dates are met for each variety (Ewert, 2009; Shah et al., 2020). Modern growth regulators help to increase the yield of wheat grain by 0.42 up to 0.60 t/ha (12.0 up to 17.3%). They not only increase the yield of the crop, but they also improve the quality of grain (they enhance the level of gluten content by 2.4 up to 2.6%, they increase the number of productive stems by 0.3 up to 1.1 PCs, the length of the ear, the weight of grain from the ear increase by 0.3 – 0.8 g, a larger and fuller grain is formed (the weight of 1000 seeds increases by 2.0 up to 2.7 g). Calculations of a number of scientists indicate that with the introduction

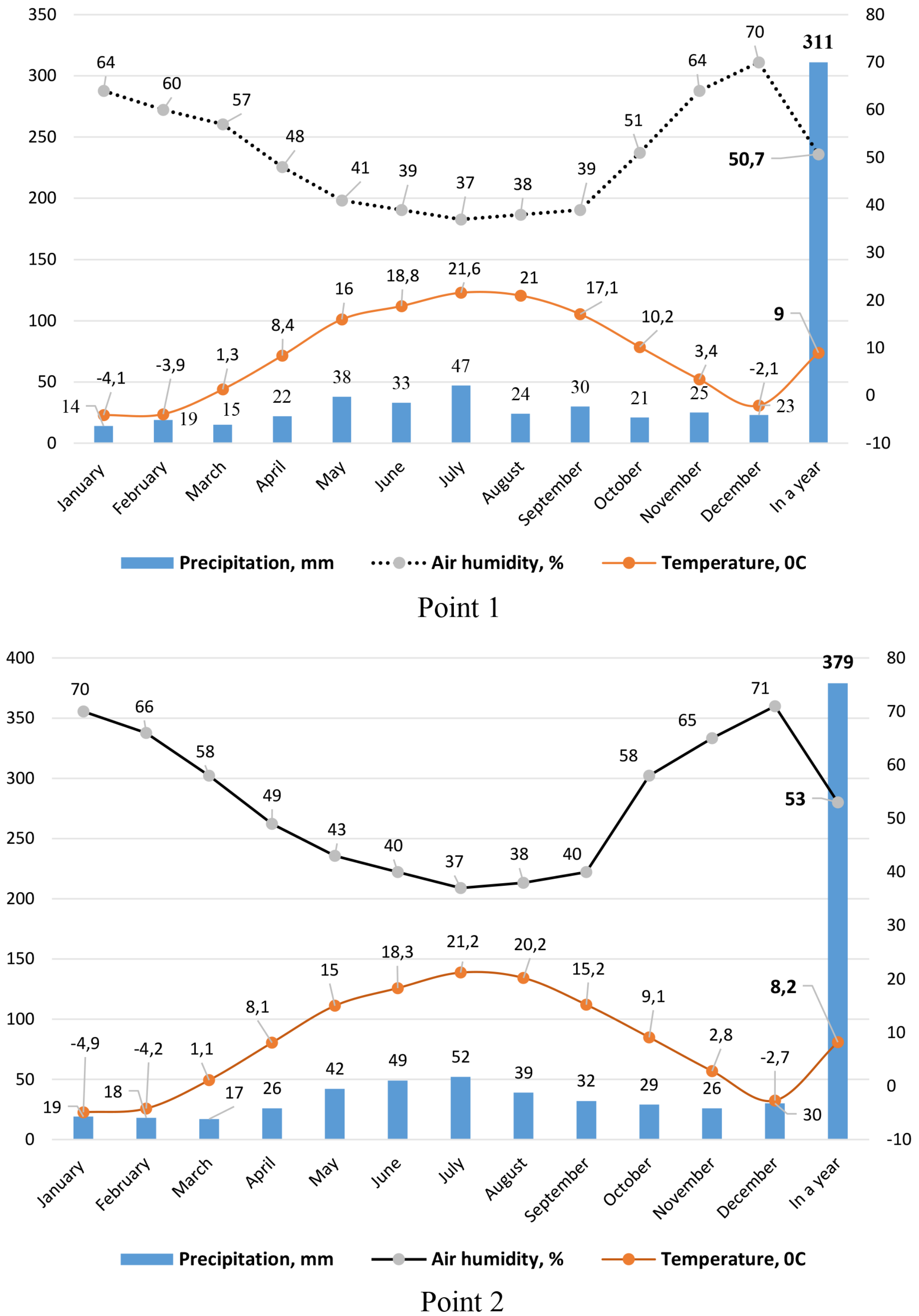

Fig. 2. Weather and climatic conditions of agroecological research points

of plant growth regulators on the vast majority of crops in our country, it would allow obtaining products additionally worth six billion hryvnias (Domaratsky et al., 2020). Today, as a result of generalizing long-term studies, more than a hundred different plant growth regulators were studied, but not all of them had advantages in terms of influencing the increase in yield and improving the quality of grain products. Therefore, they need to be purposefully studied for each zone, subzone and under different climatic and agrotechnical growing conditions.

Table 1. The nature of damage to winter wheat varieties by brown rust and powdery mildew under different growing conditions, depending on growth-regulating preparations, average for (2016–2020)

Variety	Sowing period	Brown rust, %				Powdery mildew, %			
		Without treatment	Phytomare	Vuksal Microplant	Helafit Combi	Without treatment	Phytomare	Vuksal Microplant	Helafit Combi
Khersonska 99	10.09	25.5	15.5	20.0	15.0	30.5	15.5	20.8	15.0
	20.09	19.3	10.5	15.5	10.0	26.7	10.5	15.5	10.5
	30.09	15.5	10.0	15.0	10.5	25.0	15.8	20.0	15.5
	10.10	15.0	5.0	10.0	5.0	20.0	10.0	15.5	10.5
Kirena	10.09	30.5	18.5	25.0	15.0	36.5	20.5	25.0	25.0
	20.09	25.0	15.5	20.0	15.0	30.5	15.5	20.0	18.5
	30.09	20.5	10.0	15.0	10.5	25.5	15.0	18.5	15.5
	10.10	20.0	5.0	10.0	10.0	20.0	10.5	15.0	15.0
Mudrist	10.09	30.5	15.8	25.5	20.5	35.5	20.5	28.0	20.0
	20.09	25.5	15.0	20.0	15.5	30.5	20.0	25.5	15.5
	30.09	25.0	15.5	20.0	15.0	30.0	15.5	20.0	20.0
	10.10	20.5	10.0	15.5	10.5	25.5	15.0	20.5	15.5
Askaniyska	10.09	15.5	10.0	15.0	10.5	20.0	10.0	15.0	10.5
	20.09	10.0	5.0	5.0	5.0	25.0	10.0	20.5	15.0
	30.09	10.0	5.0	10.0	5.0	20.0	10.0	15.0	5.0
	10.10	10.0	0.0	5.0	0.0	15.5	5.5	10.0	5.0
Clarissa	10.09	15.0	5.0	10.0	5.0	20.0	10.5	15.0	10.0
	20.09	10.0	0.0	5.0	5.0	15.0	10.0	15.0	5.5
	30.09	10.0	5.0	5.0	5.0	15.0	5.0	10.0	5.5
	10.10	5.5	0.0	5.0	0.0	10.5	5.0	10.0	0.0
Khutoryanka	10.09	25.5	15.5	20.5	10.0	30.0	15.5	20.0	15.0
	20.09	20.5	10.5	15.0	10.0	25.0	10.5	15.0	5.0
	30.09	20.0	10.0	15.0	10.0	20.5	10.0	15.5	5.0
	10.10	15.5	5.5	10.0	10.0	20.0	5.0	10.5	5.0

Table 2. Formation of a productive stem in plants of winter wheat varieties using growth regulators under various growing conditions, (average for 2016–2020)

Variety	Sowing period	Number of productive stems, PCs							
		Point 1				Point 2			
		Without treatment	Phytomare	Vuksal Microplant	Helafit Combi	Without treatment	Phytomare	Vuksal Microplant	Helafit Combi
Khersonska 99	10.09	3.1	3.4	3.2	3.3	3.0	3.4	3.3	3.4
	20.09	2.8	3.0	3.4	3.6	2.7	2.9	3.0	3.0
	30.09	2.4	2.8	2.8	3.0	2.4	2.6	2.8	2.8
	10.10	1.9	2.1	2.4	2.2	1.6	1.9	2.0	2.0
Kirena	10.09	3.2	3.4	3.4	3.6	3.1	3.2	3.4	3.6
	20.09	2.9	3.0	3.2	3.3	2.8	3.0	3.1	3.2
	30.09	2.3	2.8	2.8	2.7	2.2	2.6	2.5	2.8
	10.10	2.0	2.2	2.4	2.4	1.6	2.0	2.1	2.2
Mudrist	10.09	3.4	3.8	4.0	4.0	3.1	3.4	3.6	3.4
	20.09	3.9	4.1	4.2	4.4	3.6	3.8	3.8	4.0
	30.09	3.4	3.8	3.9	4.0	3.0	3.2	3.4	3.6
	10.10	2.6	2.9	3.4	3.4	2.2	2.8	2.8	3.0
Askaniyska	10.09	2.9	3.1	3.1	3.2	2.6	2.8	2.8	3.0
	20.09	2.4	2.6	2.8	2.8	2.4	2.6	2.8	2.6
	30.09	2.1	2.4	2.6	2.8	2.2	2.4	3.0	2.9
	10.10	1.4	1.6	1.8	1.7	1.3	1.5	1.8	1.9
Clarissa	10.09	3.6	3.6	3.8	3.7	3.6	3.8	3.9	3.6
	20.09	4.2	4.2	4.4	4.4	3.9	4.0	4.0	3.9
	30.09	3.5	3.8	4.0	4.2	3.1	3.6	3.8	4.0
	10.10	2.9	3.3	3.6	3.8	2.8	3.3	3.4	3.6
Khutoryanka	10.09	3.2	3.4	3.8	4.0	3.1	3.4	3.6	3.6
	20.09	3.6	3.7	4.0	4.2	3.6	3.8	4.0	4.1
	30.09	3.0	3.2	3.6	3.8	2.8	3.1	3.6	3.4
	10.10	2.5	2.7	2.9	2.9	2.4	2.6	2.8	3.0

The real grain yield of various varieties of winter wheat is realized by a complex of productivity elements that can be compensated if one of them is formed in more favorable conditions during the growing season. The formation of a productive stem is one of the main elements of winter wheat yield. In the conducted studies, there was one general pattern in the fact that the number of productive stems on the plant in all the studied varieties of winter wheat decreased from early sowing to late, but their unequal formation was revealed when using various multifunctional growth-regulating preparations (Table 2). As it can be seen from the data in Table 2, all the growth regulators used had a positive effect on increasing the productive stem of various varieties of winter wheat. There was a tendency to increase it at later sowing dates. This is especially true for the "typical" winter wheat of the Askaniyska variety and the alternative Clarissa variety. In other varieties with a late sowing period (10.10), the increase in productive stem, regardless of the test point, under the influence of growth regulators ranged from 0.3 up to 0.8 PCs and, accordingly, in the Clarissa variety it was 0.5 up to 0.9 PCs of productive stems per plant. Similar results were obtained when forming the main elements of productivity: such as the mass of grain from the main ear and the mass of 1000 grains (Table 3).

In almost all the studied wheat varieties, ear productivity and grain size increased at later sowing dates, which can be explained by the formation of a smaller number of stems per unit area. All the used growth regulators increased the mass of grain from the ear and the mass of 1000 grains at different sowing times, especially in this aspect. It is necessary to note the Helafit Combi multifunctional preparation, which under almost all growing conditions showed significant effectiveness in increasing the mass index of 1000 grains. According to the increase in the mass of grain from the ear, in comparison with the control and other growth-regulating preparations, the effect of the Phytomare preparation was greater. To ensure sustainable production of winter wheat grain, it is necessary to further improve the growing technology of such most important food crop. Recently, in the technology of growing of winter wheat, as in many other crops, plant growth regulators of a new type were widely used, which in very moderate doses

Table 3. The nature of the manifestation of productivity elements in wheat varieties of different types of development, depending on the use of growth regulators, (average for 2016–2020)

Variety	Sowing period	Grain weight per ear, g				Weight of 1000 grains, g			
		Without treatment	Phytomare	Vuksal Microplant	Helafit Combi	Without treatment	Phytomare	Vuksal Microplant	Helafit Combi
Khersonska 99	10.09	1.28	1.30	1.34	1.32	38.1	38.4	38.4	39.2
	20.09	1.31	1.39	1.46	1.44	39.5	40.2	39.9	40.4
	30.09	1.84	1.86	1.90	1.86	41.4	42.1	41.2	41.8
	10.10	1.65	1.72	1.76	1.74	40.9	41.9	40.9	41.8
Kirena	10.09	1.32	1.38	1.39	1.40	36.5	38.4	37.4	38.4
	20.09	1.24	1.29	1.36	1.36	38.1	39.1	40.4	40.1
	30.09	1.78	1.80	1.81	1.79	40.4	41.2	41.8	42.4
	10.10	1.64	1.69	1.71	1.70	40.8	40.9	41.0	41.9
Mudrist	10.09	1.54	1.59	1.67	1.64	37.9	38.1	39.1	38.6
	20.09	1.48	1.50	1.57	1.58	39.1	40.2	41.0	40.6
	30.09	1.78	1.79	1.82	1.80	42.4	42.8	43.1	44.2
	10.10	1.70	1.74	1.78	1.72	41.4	44.9	43.0	43.1
Askaniyska	10.09	1.28	1.31	1.37	1.34	35.1	36.0	36.1	36.8
	20.09	1.32	1.40	1.46	1.44	36.9	37.1	37.4	37.2
	30.09	1.54	1.59	1.61	1.60	38.4	39.1	40.2	40.1
	10.10	1.50	1.55	1.60	1.57	34.2	35.4	35.9	36.1
Clarissa	10.09	1.28	1.32	1.36	1.36	36.4	38.1	39.0	39.4
	20.09	1.32	1.39	1.44	1.46	35.4	36.0	35.9	36.2
	30.09	1.68	1.74	1.79	1.78	41.2	42.8	41.9	44.1
	10.10	1.65	1.70	1.74	1.76	40.4	42.9	42.0	42.2
Khutoryanka	10.09	1.34	1.41	1.46	1.42	36.4	36.9	36.8	37.1
	20.09	1.48	1.54	1.60	1.59	37.2	38.1	37.9	38.0
	30.09	1.68	1.72	1.76	1.74	36.4	37.2	37.0	37.2
	10.10	1.60	1.68	1.78	1.74	35.2	36.4	36.0	36.1

Table 4. Yield of winter wheat varieties when using growth stimulants under various growing conditions, t/ha (average for 2016–2020 yrs)

Variety (A)	Sowing period (B)	Pointof research (C)							
		Point 1				Point 2			
		Growth stimulator (D)							
		Without treatment	Vuksal Microplant	Phytomare	Helafit Combi	Without treatment	Vuksal Microplant	Phytomare	Helafit Combi
Khersonska 99	10.09	3.52	3.65	4.77	4.88	3.33	3.54	3.61	3.73
	20.09	3.96	4.15	4.19	4.35	3.89	3.98	4.12	4.23
	30.09	3.99	4.16	4.28	4.39	4.03	4.16	4.32	4.44
	10.10	3.70	3.83	3.94	4.14	3.68	3.85	3.95	4.15
Kirena	10.09	3.50	3.67	3.77	3.91	3.26	3.45	3.56	3.70
	20.09	3.85	4.01	4.12	4.24	3.82	4.00	4.11	4.25
	30.09	3.81	3.95	4.03	4.13	3.82	4.05	4.13	4.33
	10.10	3.48	3.66	3.81	3.95	3.35	3.60	3.71	3.86
Askaniyska	10.09	3.44	3.69	3.78	3.98	3.50	3.72	3.82	3.99
	20.09	4.07	4.37	4.44	4.60	4.06	4.21	4.33	4.41
	30.09	4.31	4.48	4.59	4.73	4.21	4.34	4.40	4.58
	10.10	4.22	4.40	4.51	4.72	4.16	4.31	4.44	4.58
Clarissa	10.09	3.18	3.44	3.53	3.66	3.09	3.31	3.42	3.57
	20.09	3.51	3.80	3.92	4.05	3.68	3.87	4.10	4.23
	30.09	4.20	4.35	4.49	4.57	4.11	4.35	4.39	4.58
	10.10	4.37	4.52	4.65	4.75	4.39	4.55	4.66	4.76
Mudrist	10.09	3.22	3.60	3.72	3.86	3.31	3.47	3.64	3.79
	20.09	3.87	4.01	4.09	4.32	3.72	3.91	3.97	4.12
	30.09	4.07	4.21	4.36	4.43	3.98	4.18	4.26	4.38
	10.10	3.48	3.66	3.79	3.93	3.62	3.64	3.76	3.88
Khutoryanka	10.09	3.47	3.64	3.79	3.96	3.49	3.62	3.70	3.82
	20.09	3.86	4.05	4.21	4.24	3.70	3.84	3.98	4.10
	30.09	4.04	4.16	4.25	4.39	3.94	4.09	4.18	4.31
	10.10	3.38	3.56	3.66	3.81	3.60	3.78	3.87	4.02
LSD_{05}, t/ha: A – 0,07-0,14; B – 0,04-0,11; C – 0,05-0,08; D – 0,05-0,11; ABCD – 0,37-0,78									

can increase yields and positively affect the quality of grain. Today, in the most economically developed countries, up to 20–30% of agricultural products are additionally produced by introducing plant growth-regulators into technological schemes for growing crops. Such growth-regulators of biological origin contribute to an increase in the yield of winter wheat by 12–20%, which leads to an additional yield of 0.6 up to 0.8 t/ha of grain. In the southern steppe zone of Ukraine, the use of such preparations on winter wheat crops was studied poorly. Foliar treatment of plants with biologics had different effects on the yield of winter wheat varieties under different growing conditions (Table 4). Regardless of the points of research and different sowing dates, the use of growth-regulating preparations had a positive effect, which was expressed in an increase in yield. Therefore, on average, for five years of field research, the greatest increase in yield under different research conditions and different varieties was shown by the Helafit Combi preparation. When it was applied in the experimental field of the Kherson State Agrarian and Economic University, the yield was enhanced by additional 0.22 up to 0.5 t/ha, while in the field of FG "Svetlana", it was improved by 0.14 up to 0.36 t/ha. It was characteristic of all used biologics that there were no significant fluctuations in the increase in yield in the context of different sowing periods and wheat varieties.

CONCLUSIONS

The results of field studies proved that the use of multifunctional growth-regulating preparations helped to reduce the level of plant damage by pathogenic microflora at all sowing periods and varieties of winter wheat. Phytomare and Helafit Combi were the most effective in this respect under various growing conditions. In most cases, they reduced the degree of damage to winter wheat plants by 40–50% or more.

In the context of individual years of research, regardless of the points of research, different sowing dates and studied varieties of winter wheat, almost identical results were observed, which were obtained on average over five years of research. All applied growth regulators increased the mass of grain from the ear and the mass of 1000 grains at different sowing times. However, it is necessary to note the variety of “typical” winter wheat Askaniyska and alternative variety Clarissa, which at a late sowing period (10.10) form a yield at the level and above the optimal period (20.09), under the influence of growth-regulating Helafit Combi and Phytomare preparations, compared to other varieties of winter wheat and sowing periods formed a large increase in yield at a late sowing period.

REFERENCES

1. Ababaf M., Omidi H., Bakhshanden A. 2021. Changes in antioxidant enzymes activities and alkaloid amount of Catharanthus roseus in response to plant growth regulators under drought condition. Industrial Crops and Products, 167, 113505.
2. Acutis M., Scaglia B., Confalonieri R. 2012. Perfunctory analysis of variance in agronomy, and its consequences in experimental results interpretation. European Journal of Agronomy, 43, 129–135.
3. Arikan B., Ozfidan-Konakci C., Alp F.N., Zengin G., Yildiztugay E. 2022. Rosmarinic acid and hesperidin regulate gas exchange, chlorophyll fluorescence, antioxidant system and the fatty acid biosynthesis-related gene expression in Arabidopsis thaliana under heat stress. Phytochemistry, 198, 113157.
4. Blandino M., Reyneri A. 2009. Effect of fungicide and foliar fertilizer application to winter wheat at anthesis on flag leaf senescence, grain yield, flour bread-making quality and DON contamination. European Journal of Agronomy, 30(4), 275–282.
5. Collins B., Chenu K. 2021. Improving productivity of Australian wheat by adapting sowing date and genotype phenology to future climate. Climate Risk Management, 32, 100300.
6. Daguerre Y., Siegel K., Edel-Hermann V., Steinberg Ch. 2014. Fungal proteins and genes associated with biocontrol mechanisms of soil-borne pathogens: a review. Fungal Biology Reviews., 28(4), 97–125.
7. Domaratskiy E.O., Zhuykov O.G., Ivaniv M.O. 2018. Influence of Sowing Periods andSeeding Rateson Yield of Grain Sorghum Hybridsunder Regional Climatic Transformations. Indian Journal of Ecology, 45(4), 785–789.
8. Domaratskyi Ye., Kozlova O., Domaratskyi O., Lavrynenko Iu., Bazaliy V. 2020. Effect of nitrogen nutrition and environmentally friendly combined chemicals on productivity of winter rapeseed under global climate change. Indian Journal of Ecology, 47(2), 330–336.
9. Domaratskiy Y., Kozlova O., Kaplina A. 2020. Economic Efficiency of Applying Environmentally Friendly Fertilizers in Production Technologies in the South of Ukraine. Indian Journal of Ecology, 47(3), 624–629.
10. Domaratskyi Y., Kaplina A., Kozlova O., Koval N., Dobrovolskyi A. 2020. Economic justification for the use of biological fungicides and plant growth stimulants for growing sunflower. Independent journal of management & production, 11(9), 2171–2184.
11. Domaratskiy Y. 2021. Leaf Area Formation and Photosyntetic Activity of Sunflower Plents Depending on Fertilizers and Growth Regulators. Journal of Ecological Engineering, 22(6), 99–105.
12. Ewert F. 1996. Spikelet and floret initiation on tillers of winter triticale and winter wheat in different years and sowing dates. Field Crops Research, 47(2–3),155–166.
13. Fischer R.A., Connor D.J. 2018. Issues for cropping and agricultural science in the next 20 years. Field Crops Research, 222, 121–142.
14. Hossain A., Pamanick B., Venugopalan V.K., Ibrahimova U., Rahman M.A., Siyal A.L., Maitra S., Chatterjee S., Aftab T. 2022. Chapter 1 - Emerging roles of plant growth regulators for plants adaptation to abiotic stress–induced oxidative stress. Emerging Plant Growth Regulators in Agriculture, Roles in Stress Tolerance, 1–72.
15. Liu B., Stevens-Green R., Johal D., Buchanan R., Geddes-McAlister J. 2022. Fungal pathogens of cereal crops: Proteomic insights into fungal pathogenesis, host defense, and resistance. Journal of Plant Physiology, 269, 153593.
16. Macholdt J., Hadasch S., Piepho H.-P., Reckling M., Taghizadeh-Toosi A., Christensen B.T. 2021. Yield variability trends of winter wheat and spring barley grown during 1932–2019 in the Askov Long-term Experiment. Field Crops Research, 264, 108083.
17. Panfilova A. 2021. Influence of stubble biodestructor on soil microbiological activity and grain yield of winter wheat (*Triticum aestivum* L.). Notulae Scientia Biologicae, 13(4), 11035.
18. Panfilova A., Gamayunova V., Smirnova I. 2020. Influence of fertilizing with modern complex organic-mineral fertilizers to grain yield and quality of winter wheat in the southern steppe of Ukraine. Agraarteadus, 31(2), 196–201.
19. Panfilova A., Mohylnytska A. 2019. The impact of nutrition optimization on crop yield of winter wheat varieties (*Triticum aestivum* l.) and modeling of regularities of its dependence on structure indicators. Agriculture and Forestry, 65(3), 157–171.
20. Pichura V.I., Potravka L.A., Skrypchuk P.M., Stratichuk N.V. 2020. Anthropogenic and climatic causality

of changes in the hydrological regime of the Dnieper river. Journal of Ecological Engineering, 21(4), 1–10.

21. Pichura V., Potravka L., Dudiak N., Vdovenko N. 2021. Space-Time Modeling of Climate Change and Bioclimatic Potential of Steppe Soil. Indian Journal of Ecology, 48(3), 671–680.
22. Shah F., Coulter J.A., Ye C., Wu W. 2020. Yield penalty due to delayed sowing of winter wheat and the mitigatory role of increased seeding rate. European Journal of Agronomy, 119, 126120.
23. Urbatzka P., Grab R., Haase T., Schüler Ch., Heb J. 2012. Influence of different sowing dates of winter pea genotypes on winter hardiness and productivity as either winter catch crop or seed legume. European Journal of Agronomy, 40, 112–119.
24. Zimmermann A., Webber H., Zhao G., Ewert F., Kros J., Wolf J., Britz W., Vries W. 2017. Climate change impacts on crop yields, land use and environment in response to crop sowing dates and thermal time requirements. Agricultural Systems, 157, 81–92.
25. Zhang Q., Men X., Hui C., Ge F., Ouyang F. 2022. Wheat yield losses from pests and pathogens in China. Agriculture, Ecosystems & Environment, 326, 107821.