Universal Journal of Agricultural Research 10(3): 228-239, 2022 http://www.hrpub.org
DOI: 10.13189/ujar.2022.100305

Ways to Improve the Adaptability of Winter Wheat in the Eastern Part of the Northern Steppe of Ukraine

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Received November 18, 2021; Revised May 12, 2022; Accepted June 21, 2022

Cite This Paper in the following Citation Styles

(a): *[1] Oleksander Vinyukov, Hanna Chuhrii, Anatoliy Gyrka, Roman Vyskub, Olha Bondareva , "Ways to Improve the Adaptability of Winter Wheat in the Eastern Part of the Northern Steppe of Ukraine," Universal Journal of Agricultural Research, Vol. 10, No. 3, pp. 228 - 239, 2022. DOI: 10.13189/ujar.2022.100305.*

(b): *Oleksander Vinyukov, Hanna Chuhrii, Anatoliy Gyrka, Roman Vyskub, Olha Bondareva (2022). Ways to Improve the Adaptability of Winter Wheat in the Eastern Part of the Northern Steppe of Ukraine. Universal Journal of Agricultural Research, 10(3), 228 - 239. DOI: 10.13189/ujar.2022.100305.*

Abstract The research was conducted to study the impact of new nutrient complexes on improving the yield of winter wheat and its adaptability in the eastern part of the Northern Steppe of Ukraine. The article aimed to determine the adaptive properties of winter wheat plants of various breeding centers in the eastern Northern Steppe of Ukraine, as well as to improve the technology of growing winter wheat through the use of new nutrient complexes. To achieve this goal, an algorithm of graphical analysis was used. It is established that the introduction of a new nutrient Complex 3 into the winter wheat cultivation technology, which includes: Sizam (250 g/t), Phosphoenterin (133.3 g/t), Diazophyte (133.3 g/t) Biopolicide (133.3 g/t) in the conditions of the eastern part of the Northern Steppe of Ukraine provides a yield increase on a mineral ($N_{30}P_{30}K_{30}$) nutrition background of 1.22 t/ha, on organo-mineral ($N_{15}P_{15}K_{15}$+biohumus (250 kg/ha)) — 0.78 t/ha and organic (biohumus — 250 kg/ha) nutrition background compared to the control. There was also a significant improvement in biometrics and the structure of winter wheat yields. A method for analysing the elements of productivity and plasticity of winter wheat is proposed, which allows the selection of drought-resistant varieties suitable for cultivation in the Northern Steppe of Ukraine. Also, it is determined that using a patented graphical algorithm for analyzing the level of ecological plasticity of cereal varieties due to the uniformity of environmental factors on the productivity of cereals allows for determining the most adapted plants. Thus, the varieties of winter wheat Bohynia and Oleksiivka were identified as the most flexible.

Keywords Biopreparations, Plant Growth Regulators, Winter Wheat, Adaptability, Nutrient Complex

1. Introduction

In 2020, the sown area of winter wheat in Ukraine amounted to 6.2 million hectares, which is 4.7% less than in 2019 [6, 21, 22].

The yield of new varieties of winter wheat in the experiments is in the range of 10-12 t/ha, but in the field the potential yield of these varieties is reduced by 30-50%, decreasing to 24-26% and even 20% in some years. For example, in the Netherlands, the potential of varieties is used by 70%, in Denmark and Sweden — by 50-60% [5, 7]. Although there is a yearly increase in yield in our country, it remains quite low compared to the European Union.

Adverse climatic conditions associated with global climate change are a major cause of declining yields and winter wheat cultivation. The climate change in the steppe zone of Ukraine has led to an increase in the frost-free period in winter and drought in spring and summer [12, 13]. As a result, under the influence of drought in the critical periods of earing, flowering and grain formation, the yield of winter wheat decreases due to the inhibition of growth processes.

Weather conditions, namely the amount of precipitation, play an extremely important role in forming the harvest of winter wheat. So, the lack of moisture in the 10-centimeter layer of soil leads to delayed seed germination, late unfriendly and sparse shoots, and the formation of an underdeveloped root system of winter wheat plants [5, 15-17]. In addition to unfavourable climatic conditions, the yield of winter wheat is negatively affected by the cultivation technology, namely the intensive use of mineral fertilizers and plant protection products of chemical origin. Therefore, it is necessary to look for opportunities for adaptation of winter wheat to climate change not only through the invention of new adaptive varieties, but also through the cultivation technology.

In the experiment, we examine the adaptability of the crop variety, as this is one of its most important properties. The adaptability of plants is considered a manifestation of forms of reliability of biological systems — biogeocenoses, populations, species and organisms, the realization of their adaptive potential in phylogenetic and ontogenetic changes to environmental conditions [27].

Adaptation of plants is associated with the specific influence of environmental factors depending on their variety, dosage, time of exposure on the one hand, and the biological characteristics of the variety, and its functional state on the other hand. In case of deviation of environmental conditions from optimal ones at different stages of vegetation, there is self-regulation of separate plants and ripening, which is manifested by standstill and decreased individual growth. In this case, the lack in some parts of the product is partially offset by an increase in the other parts. For example, the rarefaction of grain productive stems can be compensated under favourable conditions by increased concentration of plants, ear size and grain fullness, as well as insufficient grain size of the ear — by the kernel weight, and so on. Besides, these processes last throughout the growing season, thereby increasing the plant's adaptability.

The issue of transition to adaptive cultivation technologies based on differentiated use of natural resources and adaptive potential of varieties is especially topical. Such technologies cannot be permanent and fixed, and can change depending on environmental conditions, and the economic situation in the market, taking into account the country's economic condition. Adaptation and yield of wheat can be improved by developing and implementing adaptive and flexible technologies that use established scientific methods and research results to ensure the differentiation of agricultural technologies based on cultivation conditions [28].

The advantage of adaptive cultivation technology over traditional cultivation methods is that technical decision-making algorithms contain information beyond the knowledge of individual experts, being the collective experience of many experts in different fields, such as different fields of knowledge, science and quantitative models of processes influencing the productivity; the ability to quickly adjust decision-making algorithms to new information that needs to be taken into account; erroneous actions of the process engineer are excluded; subjectivity is significantly reduced when choosing the parameters of a set of agrotechnical measures [29].

This is why the aim of our research was to improve the technology of growing winter wheat through the use of new nutrient complexes, as well as to study the adaptive properties of winter wheat plants of different breeding centres in the eastern Northern Steppe using a graphical algorithm analysis (the process of determining the computational complexity of algorithms, that is the amount of time, memory or other resources required to perform algorithms). The analysis in the algorithm contributes to the ideal solution of urgent scientific and practical problems in relation to the formation and use of the fixed assets at the enterprise. The procedure of the analyst, the sequence of stages of analysis of fixed assets in the enterprise allows investigating and drawing conclusions about the state and efficiency of the use of fixed assets by stages.

Crop production is the area that requires decisions in the context of incompleteness and inaccuracy of input information, where the actual figures may differ. Algorithms of analysis are developed for particular cultivated crops, in our case — winter wheat. They will help to create an individualized approach and make agronomic decisions that take into account the specifics of the growing crop, allow the farmer to prioritize tasks at a particular stage of development, and provide relevant and timely information to take the necessary measures.

2. Materials and Methods

The research was conducted from 2015to 2018 in the research field of the Donetsk State Agricultural Research Station of the National Academy of Agrarian Sciences of Ukraine, which is located in the central part of the Donetsk region. The area of the plot is 80.0 m^2. The experiments were repeated three times. The placement of plots is systematic. The soil is common low-humus heavy-loam chernozem. Gross content of basic nutrients: N — 0.28-0.31%, P_2O_5 — 0.16-0.18%, K_2O — 1.8-2.0%, humus content in the arable layer is 4.5%, pH — 6.9. The winter wheat growing technology is generally accepted for the region.

The research was conducted to study the effectiveness of new nutrient complexes, which included biopreparations, plant growth regulators for the growth and development of winter wheat Kraplyna on three nutrition backgrounds: Background 1 — $N_{30}P_{30}K_{30}$, Background 2 — $N_{15}P_{15}K_{15}$ + boihumus (250 kg/ha), Background 3 — boihumus (250 kg/ha). The microbiological complex of biopreparations is a mixture of Phosphoenterin (133.3 g/t), Diazophyte (133.3 g/t) and Biopolycid (133.3 g/t). The design of the experiment consisted of the following options (Table 1).

Table 1. Design and variants of the experiment

Variant	Complex used for treatment
Background 1 – $N_{30}P_{30}K_{30}$	
CONTROL	without seed treatment and crop spraying
Chemical protection of crops	seed treatment with Vitavax 200FF (3 l/t) and crop spraying with Borey insecticide (0.1 l/ha) and Falcon fungicide (0.6 l/ha)
Biological protection of crops	seed inoculation with microbiological complex (400 g/t)
Complex 1 *	seed treatment with Rost-forte (0.5 l/t) in a mixture with a complex of amino acids, spraying of plants in the tillering and earing phases with a mixture of Rost-concentrate 15.7.7. (1 l/ha) + amino acid complex + Helatin (2 l/ha) + microbiological complex (400 g/ha);
Complex 2 **	seed treatment with Aidar (2 l/t), spraying of plants in the tillering and earing phases with a mixture of Aidar (2 l/ha) and microbiological complex (400 g/ha)
Complex 3 ***	seed treatment with Sizam (250 g/t) in a mixture with a microbiological complex (400 g/t), spraying of plants in the tillering phase with a mixture of Sizam (250 g/ha) and microbiological complex (400 g/ha)
Background 2 – $N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha)	
CONTROL	without seed treatment and spraying
Chemical protection of crops	seed treatment with Vitavax 200FF (3 l/t) and crop spraying with Borey insecticide (0.1 l/ha) and Falcon fungicide (0.6 l/ha)
Biological protection of crops	seed inoculation with microbiological complex (400 g/ha) t)
Complex 1 *	seed treatment with Rost-forte (0.5 l/t) in a mixture with amino acid complex, spraying plants in the tillering and earing phases with a mixture of Rost-concentrate 15.7.7 (1 l/ha) + amino acid complex + Helatin (2 l/ha) + microbiological complex (400 g/ha)
Complex 2 **	seed treatment with Aidar (2 l/t), spraying of plants in the tillering and earing phases with a mixture of Aidar (2 l/ha) and microbiological complex (400 g/ha)
Complex 3 ***	seed treatment with Sizam (250 g/t) in a mixture with a microbiological complex (400 g/t), spraying of plants in the tillering phase with a mixture of Sizam (250 g/ha) and microbiological complex (400 g/ha)
Background 3 – biohumus (250 kg/ha)	
CONTROL	without seed treatment and crop spraying
Chemical protection of crops	seed treatment with Vitavax 200FF (3 l/t) and crop spraying with Borey insecticide (0.1 l/ha) and Falcon fungicide (0.6 l/ha)
Biological protection of crops	seed inoculation with microbiological complex (400 g/t)
Complex 1 *	seed treatment Rost-forte (0.5 l/t) in a mixture with amino acid complex, spraying of plants in the tillering and earing phases with a mixture of Rost-concentrate 15.7.7. (1 l/ha) + amino acid complex + Helatin (2 l/ha) + microbiological complex (400 g/ha)
Complex 2 **	seed treatment with Aidar (2 l/t), spraying of plants in the tillering and earing phases with a mixture of Aidar (2 l/ha) and microbiological complex (400 g/ha)
Complex 3 ***	seed treatment with Sisam (250 g/t) in a mixture with a microbiological complex (400 g/t), spraying of plants in the tillering phase with a mixture of Sizam (250 g/ha) and microbiological complex (400 g/ha).

When studying the adaptive properties of winter wheat plants of different breeding centres in the eastern part of the Northern Steppe, a graphical algorithm of analysis was used in terms of increasing the level of ecological plasticity of varieties when grown in agro-climatic conditions of the region [18, 20]. This algorithm involves graphing: on the axis of ordinates the basic features of plant productivity are applied in pairs, the increase of which directly affects the increase in yield — the number of grains in the ear and the weight of 1,000 grains (A, B); on the abscissa axis, productivity indicators are applied in pairs, the increase of which indirectly affects the increase in yield, causing an increase in the values of two basic indicators — the number of productive stems and ear length (C, D). Points C and D are connected by vector lines with points A and B, thus demonstrating the nature of the relationships of increase of values for the indicators under consideration. Statistical analysis was also used to analyse the results of field experiments.

3. Results

Analysis of the depth of the tillering node of winter wheat plants at the time of cessation of autumn vegetation, with different nutrition backgrounds and nutrient complexes showed that it varied from 3.3 cm to 5.1 cm (Table 2).

Table 2. Condition of winter wheat plants of Kraplyna variety at the end of autumn vegetation (average for 2015–2018)

Variant	Plant height, cm	Depth of tillering node, cm	Tillering rate	The number of secondary roots, pcs.	Sugar content in plants, %
Background 1 – $N_{30}P_{30}K_{30}$					
Control	17.1	3.9	1.1	0.5	30.01
Chemical protection of crops	15.6	4.8	1.4	0.9	40.54
Biological protection of crops	15.5	3.6	1.3	0.3	32.58
Complex 1*	12.7	3.9	1.3	0.5	35.72
Complex 2**	12.2	3.4	1.2	0.7	33.47
Complex 3***	14.8	3.8	1.5	1.2	40.62
HIP_{05}	0.1-0.6	0.3-0.9	0.02-0.05	0.01-0.03	1.3-2.1
Background 2 – $N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha)					
Control	14.7	4.4	1.3	0	34.08
Chemical protection of crops	15.0	4.9	1.8	0.8	42.49
Biological protection of crops	12.0	3.4	1.2	0.9	24.17
Complex 1*	12.3	3.5	1.9	1.0	30.23
Complex 2**	12.3	3.3	2.0	1.0	32.78
Complex 3***	13.7	3.3	2.1	1.4	33.42
HIP_{05}	0.4-0.7	0.1-0.3	0.09-0.10	0.01-0.05	1.0-1.3
Background 3 – biohumus (250 kg/ha)					
Control	15.1	4.9	1.0	0.1	32.93
Chemical protection of crops	16.8	5.1	1.2	0.8	42.59
Biological protection of crops	13.1	4.4	1.0	0.6	33.26
Complex 1*	13.0	4.6	1.2	0.9	24.38
Complex 2**	13.0	4.2	1.1	0.8	25.01
Complex 3***	13.8	4.6	1.4	1.1	26.47
HIP_{05} for: variant of the experiment	0.5–0.6	0.1–0.4	0.01–0.03	0.02–0.04	1.3–1.6
nutrition background	0.1–0.3	0.3–0.5	0.01–0.02	0.06–0.08	0.9–1.1
interaction	0.8–0.9	0.6–0.7	0.04–0.05	0.11–0.12	1.9–2.1

The tillering rate and the number of secondary roots differed significantly between the variants by nutrition backgrounds, but Complex 3 preparations proved their high performance on all nutrition backgrounds. These were seed treatment with Sisam (250 g/t) in a mixture with a microbiological complex (400 g/t), spraying of plants in the tillering phase with a mixture of Sizam (250 g/ha) and microbiological complex (400 g/ha). These indicators exceeded the control by 0.4 and 0.7 pieces on the mineral background; by 0.8 and 1.4 pieces on the organo-mineral background; by 0.4 and 1.0 pieces on an organic nutrition background, respectively.

The deepest occurrence of the tillering node (4.8 cm, 4,9 cm and 5.1 cm) was recorded for all mineral nutrition backgrounds when treating seeds with Vitavax 200FF (3 l/t), spraying crops with Borey insecticide (0.1 l/ha) and Falcon fungicide (0.6 l/ha). The components of Complex 2 performed the worst and the figure was 3.4 cm, 3.3 cm and 3.3 cm, respectively, according to the background.

Comparing the development of winter wheat plants depending on the nutrition background, it was found that plants where the organo-mineral nutrition background was used had the best biometric indicators at the time of the cessation of autumn vegetation. As for the sugar content in plants, regardless of the nutrition background and treatments, the number of carbohydrates was sufficient for good wintering of plants, but it was greatest when using chemical protection of winter wheat crops.

At the end of the tillering phase, plants were selected for biometric analysis. It was found that the use of the nutrient Complex 3 (Table 3) on the mineral nutrition background provided the largest increase in the values of plant indicators relative to the control. Therefore, the tillering rate exceeded the control variant by 0.3, and the number of secondary roots — by 1.1 pieces.

Table 3. Condition of winter wheat plants of Kraplyna variety at the end of the tillering phase (average for 2015–2018)

Variant	Plant height, cm	Tillering rate	Secondary roots rate
Background 1 – $N_{30}P_{30}K_{30}$			
Control	41.4	3.9	2.3
Chemical protection of crops	45.2	3.2	2.6
Biological protection of crops	41.3	3.6	2.4
Complex 1*	38.7	3.3	2.0
Complex 2**	40.8	2.8	2.0
Complex 3***	43.6	4.2	3.4
Background 2 – $N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha)			
Control	40.8	3.3	1.9
Chemical protection of crops	39.8	3.2	1.7
Biological protection of crops	37.5	3.2	2.0
Complex 1*	39.0	3.6	2.1
Complex 2**	40.6	3.4	2.4
Complex 3***	41.3	3.8	2.9
Background 3 – biohumus (250 kg/ha)			
Control	43.8	3.0	1.5
Chemical protection of crops	38.9	2.8	1.6
Biological protection of crops	35.2	2.0	1.0
Complex 1*	37.0	2.4	1.3
Complex 2**	41.5	2.8	1.7
Complex 3***	38.2	2.8	1.8

On the organo-mineral nutrition background, the most significant increase in the tillering coefficient compared to the control was obtained using Complexes 1 and 3. So, this indicator increased by 0.3 and 0.5, respectively. The number of secondary roots was higher than the control variant by 1.0 pieces when using nutrient Complex 3.

More aligned plants in terms of development were obtained from the organic nutrition background. The same tillering coefficients were obtained (2.8) when using chemical protection of crops, Complex 2 and Complex 3. The number of secondary roots in the same variants was the largest – 1.6 pcs; 1.7 pcs and 1.8 pcs, respectively.

Plants in the variants of the experiment, which involved nutrient Complex 1 and biological protection of crops, formed the number of secondary roots which was lower than the control by 0.2 pcs and 0.5 pcs, respectively.

The greatest influence of mineral and organo-mineral nutrition backgrounds on the biometric indicators of winter wheat was found at the beginning of the earing phase (Table 4).

Table 4. Biometric indicators of winter wheat of Kraplyna variety at the beginning of the earing phase when using nutrient complexes (average for 2015–2018)

Variant	Plant height, cm	Number of stems, pcs/m^2		Tillering rate	
		total	productive	total	productive
Background 1 – $N_{30}P_{30}K_{30}$					
Control	56.2	565.5	477.5	1.73	1.46
Chemical protection of crops	70.0	555.5	464.0	2.07	1.72
Biological protection of crops	69.6	572.0	451.0	1.76	1.39
Complex 1*	71.1	570.5	473.5	1.71	1.42
Complex 2**	70.4	618.0	487.0	1.73	1.36
Complex 3***	69.4	645.5	540.0	1.72	1.44
Background 2 – $N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha)					
Control	67.5	543.0	431.0	1.72	1.37
Chemical protection of crops	69.8	545.0	489.0	1.97	1.55
Biological protection of crops	68.7	555.0	424.0	1.89	1.44
Complex 1*	70.0	616.0	487.5	1.94	1.53
Complex 2**	69.2	657.5	520.0	2.13	1.68
Complex 3***	69.2	596.0	456.0	1.84	1.41
Background 3 – biohumus (250 kg/ha)					
Control	66.7	541.0	424.0	1.83	1.44
Chemical protection of crops	69.8	508.0	432.0	1.85	1.58
Biological protection of crops	69.2	568.5	425.0	1.67	1.25
Complex 1*	68.0	558.0	443.5	1.77	1.40
Complex 2**	69.0	584.0	469.0	1.62	1.30
Complex 3***	68.2	570.0	427.5	1.86	1.39

When using the mineral nutrition background, none of the presented variants of crop complexes provided a significant increase in the total tillering compared to the control, except for variants with chemical and biological protection of crops.

When using the organo-mineral nutrition background in all variants, the total and productive tillering were higher than the control variant, but the best indicators were obtained through the use of Complex 2 (2.13 and 1.68, respectively, by 0.41 and 0.31 above the control).

On the organic nutrition background, only one variant — Complex 3 — exceeded the control in terms of the total tillering rate — (+0.03), and the variant with chemical crop protection (+0.14) – in terms of the productive tillering coefficient.

When comparing three nutrition backgrounds, we can conclude that the greatest effect of nutrient complexes was obtained through an organo-mineral background. That is the coefficients of total and productive tillering obtained on the organo-mineral nutrition background significantly exceeded the control variant.

When studying the impact of agricultural cultivation techniques provided by different variants of the experiment on the indicators of winter wheat yield structure, it was found that elements of yield structure were improved in terms of control over all indicators on mineral and organo-mineral nutrition backgrounds (Complex 3). Ear length increased by 1.5 and 1.1 cm compared to the control; the number of grains in the ear — by 0.9 and 2.0 pieces, and the weight of 1,000 grains — by 3.02 and 1.15 g, respectively (Table 5).

Table 5. Indicators of the structure of winter wheat yield of Kraplyna variety when using nutrient complexes (average for 2015–2018)

Variant	Ear length, cm	Number of grains in the ear, pcs	Weight of 1000 grains, g	Grain unit, g/l
Background 1 – $N_{30}P_{30}K_{30}$				
Control	8.3	27.0	35.21	691.3
Chemical protection of crops	8.9	27.5	37.62	721.1
Biological protection of crops	8.5	27.3	37.20	719.0
Complex 1*	9.2	27.8	38.06	728.3
Complex 2**	9.4	27.7	37.88	743.4
Complex 3***	9.8	27.9	38.23	751.4
$HIP_{0,5}$	0.03-0.10	0.05-0.12	0.5-1.4	1.7-2.4
Background 2 – $N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha)				
Control	8.0	26.4	40.08	701.1
Chemical protection of crops	7.9	27.4	33.88	724.4
Biological protection of crops	8.4	27.5	41.34	736.1
Complex 1*	8.4	27.8	33.35	728.3
Complex 2**	8.3	28.0	34.07	730.5
Complex 3***	9.1	28.4	41.23	745.6
$HIP_{0,5}$	0.02-0.09	0.1-0.4	0.01-0.07	1.5-2.2
Background 3 – biohumus (250 kg/ha)				
Control	7.5	26.2	38.62	686.6
Chemical protection of crops	7.8	26.4	37.09	698.4
Biological protection of crops	8.0	26.7	37.28	683.1
Complex 1*	8.3	26.8	37.02	700.2
Complex 2**	8.5	26.6	34.87	705.7
Complex 3***	8.5	27.1	40.74	711.4
HIP_{05} for: variant of the experiment	0.1–0.2	0.1–0.2	2.12–2.18	4.4–5.1
nutrition background	0.1–0.2	0.1–0.3	2.28–2.34	6.3–6.7
interaction	0.2–0.3	0.2–0.4	2.62–2.74	8.1–8.3

On the organic nutrition background, the longest ear (8.5 cm) was obtained when using nutrients Complexes 2 and 3, which exceeded the control variant by 1.0 cm. The number of grains in the ear and the grain unit were greater when using Complex 3 (+0.9 and +24.8 g/l, respectively). The largest weight of 1,000 grains was obtained in the variant using nutrient Complex 3 (+2.12 g relative to control).

When comparing the influence of nutrient backgrounds on the crop structure, it was found that the mineral nutrient background contributed to the increase in the ear length, the weight of 1,000 grains and grain unit, and the organo-mineral background provided the highest grain size.

The grain yield of winter wheat using different nutrient complexes on different nutrient backgrounds is shown in Table 6.

Table 6. Winter wheat grain yield when using different nutrient complexes (average for 2015–2018)

Variant	Grain yield, t/ha	Increase	
		t/ha	%
Background 1 – $N_{30}P_{30}K_{30}$			
Control	4.54	-	-
Chemical protection of crops	4.80	0.26	10.2
Biological protection of crops	4.58	0.04	1.6
Complex 1*	5.01	0.47	18.5
Complex 2**	5.11	0.57	22.4
Complex 3***	5.76	1.22	48.0
Background 2 – $N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha)			
Control	4.56	-	-
Chemical protection of crops	4.54	-0.02	-0.78
Biological protection of crops	4.82	0.26	10.2
Complex 1*	4.52	-0.04	-1.56
Complex 2**	4.96	0.40	15.6
Complex 3***	5.34	0.78	30.5
Background 3 – biohumus (250 kg/ha)			
Control	4.29	-	-
Chemical protection of crops	4.23	-0.06	-2.6
Biological protection of crops	4.23	-0.06	-2.6
Complex 1*	4.40	0.11	4.8
Complex 2**	4.35	0.06	2.6
Complex 3***	4.72	0.43	18.8
HIP_{05}, t/ha for: nutrition background – 0.02-0.07; variant of treatment – 0.07-0.11; interaction – 0.10-0.19			

The use of Complex 3 on the mineral nutrition background provided the highest increase in yield compared to the control (1.22 t / ha, or 48.0%) on average over the years of research. Biological crop protection provided the smallest increase in yield (0.04 t/ha, or 1.6%).

On the organo-mineral nutrition background, plants treated with Complex 3 (+0.78 t/ha, or 30.5% compared to the control) were also more productive. However, not all variants of this nutrition background provide a significant increase in grain yield compared to the control. The application of chemical protection of crops and Complex 1 contributed to a decrease in the grain productivity level compared to the control by 0.02 t/ha (-0.78%) and 0.04 t/ha (-1.56%), respectively.

On the organic nutrition background, all the proposed nutrient complexes contributed to the increase in grain yield. Complex 3 provided a significant increase in the grain productivity relative to control (+0.43 t/ha, or 18.8%). Complex 2 had the lowest increase (0.06 t/ha compared to the control).

In general, the level of grain yield depended to a greater extent on the nutrition background, in particular, winter wheat plants formed the highest level of yield on the mineral background, and slightly lower on the organo-mineral background. Although in general, the degree of plant development during the growing season and the formation of grain yields by plants using the proposed nutrient complexes indicates the correctness of the chosen direction of research.

Points A, B, C, and D in the graph show the percentage increase in the values of individual plant productivity relative to the standard (Donetsk 48) for winter wheat varieties Epocha, Bohynia, Oleksiivka and Alliance (Figure 1).

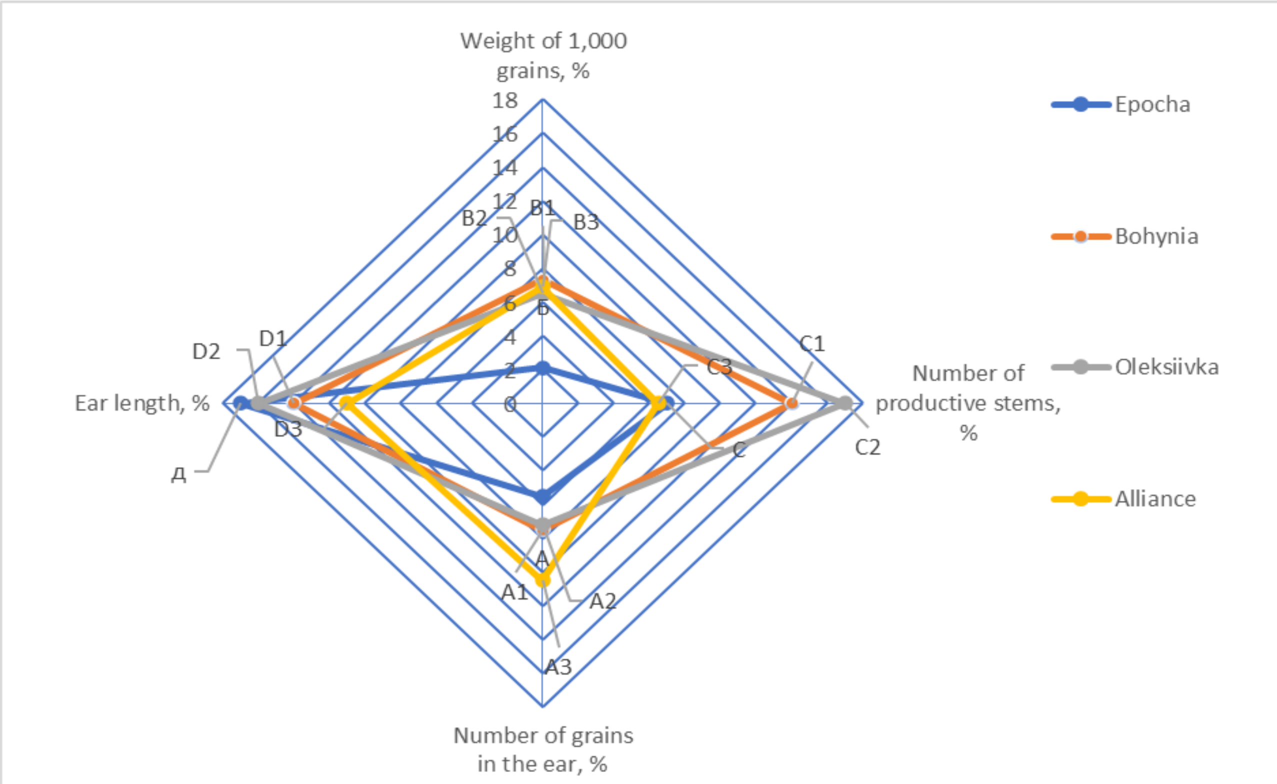

Figure 1. The value of relative indicators (%) of individual productivity of winter wheat varieties Epocha, Bohynia, Oleksiivka and Alliance (average for 2011-2015)

Analysis of the data obtained shows that depending on the agroecological characteristics of varieties, the efficiency of plant use of agrocenosis opportunities during the growing season differently influenced the increase in plant productivity indicators according to genetically determined features of the variety, which were enshrined during its creation. Thus, a much smaller increase in the weight of 1,000 grains was observed in the Epocha variety (2.23% vs. 7.26% for the Bohynia variety, 6.7% for Oleksiivka, and 6.94% for the Alliance). Regarding the indicator of the number of productive grains, the varieties Epocha (7.2%) and Alliance (6.5%) had a much smaller increase in this indicator compared to Bohynia (13.7%) and Oleksiivka (16.8%). In terms of the number of grains in the ear and the length of the ear, all varieties had approximately equal increase above the standard, only the Alliance variety had on average 4% more grains in the ear and 5% less ear length compared to other varieties.

The given principle of graphing allows determining the advantage of one or another variety in terms of plasticity. It is performed by calculating the ratio of the areas of two conditional triangles ABC and ABD within each graph. The sum of values of the growth of indicators as a percentage between the vertices A and B is used as the basis of triangles, and the increase in the values of OC and OD is as their height. When calculating the areas of conditional triangles for the Epocha variety, it was found that the difference between the areas was 36.53 abstract units: ΔABC — 27.1, and ΔABD – 63.63 abstract units. Accordingly, for the Bohynia variety, ΔABC is 99.74, and ΔABD is 101.19 abstract units, that is they are approximately the same. As for the Oleksiivka winter wheat variety, the areas of triangles, as well as in the Bohynia variety, are approximately equal: ΔABC — 115.08, and ΔABD — 110.97 abstract units. The situation was slightly worse in the Alliance variety, where the difference between the areas of triangles was 38.79 abstract units (ΔABC — 56.03, and ΔABD — 94.82 abstract units).

Analysis of the configuration of graphs, the ratio of the areas of triangles ABC and AVD and their height values (OC and OD) allows describing the varieties Bohynia and Oleksiivka as more plastic compared to the Epocha and Alliance varieties in arid conditions of the eastern part of the Northern Steppe of Ukraine. This is manifested due to the uniformity of the influence of environmental factors on the productivity of Bohynia and Oleksiivka winter wheat varieties.

4. Discussion

A study [8] showed that growing wheat on low-fertile soils with water deficit reduces its potential yield by 50-90%. In 2006, wheat yields in Australia fell by 46% compared to the yields of 50 last years. In 2012, total world wheat production decreased by 1.4% due to severe droughts in the United States, Europe and Central Asia [3, 4, 14]. So, we observe that drought is a key problem that reduces wheat yields [1, 2, 6, 7, 9-11, 19].

In order not to lose the yield of winter wheat in extreme weather conditions (drought), it is necessary to select drought-resistant varieties and introduce elements of biologization with the use of fertilizers and integrated plant protection growth regulators, as well as biological products into the cultivation technology. Our research has shown that the use of growth regulators and biopreparations improves biometrics and winter wheat yield structures, thus improving yields [23-26].

We can compare the study [30], where was studied the application of preparations on the quality of winter durum wheat grain depending on biologically active preparations and the mineral nutrition background. On a low mineral nutrition background, Biohumus + Aidar and Reakom-SR-grain performed best, and on a high background — Mars ELBi [30]. In our study, Aidar was part of Complex 2, which showed good performance on the studied indicators, especially in high yields, on all nutrient backgrounds.

The mineral background has a great impact on the action of preparations. For example, Zhuk [31] studied the insufficient supply of winter wheat plants with mineral nutrition, which entailed the ear length reduction of the main and side shoots. The number of grains in the ears of side shoots due to nutrient deficiency decreases greater than in the main shoot primarily because of the reduction of the lower and upper spikelets of the ear or flowers in them, and underdevelopment of the central grains of the spikelet. The content of basic mineral nutrients was N_{90} P_{90} K_{90} by active substance and $N_{32}P_{32}K_{32}$ [31].

The study [32] explored the application of mineral fertilizers and foliar fertilization of crops at the beginning of the spring vegetation and stooling of plants with Escort-Bio and Organic D_2. This provided the best conditions for plant growth and development and, as a result, more optimal indicators of crop structure and grain yield. Under these nutrition variants, the average number of productive stems in plants over the years of research averaged 556–601 units/m^2 [32]. In our experiment, the highest number of stems was 657.5 pcs/m^2 at $N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha) and seed treatment with Aidar (2 l/t), spraying of plants in the tillering and earing phases with a mixture of Aidar (2 l/ha) and microbiological complex (400 g/ha).

The summary of the results of 530 experiments conducted in different soil and climatic zones of Ukraine showed that in 46 experiments with winter wheat yields reached 6-9% due to the use of biofertilizers, confirming data on the technological role of biologically active substances as a reserve for increasing yields and quality of crops [33].

The efficiency of using biofertilizers on seed crops of the V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine, helped increase the weight of 1,000 seeds and improve the sowing quality of seeds [34].

5. Conclusions

The use of new nutrient complexes in the technology of growing winter wheat, as an element of biologization of agriculture, contributed to the improvement of plant development throughout the growing season and allowed obtaining a yield that significantly exceeded the control sample. So, the use of nutrient Complex 3 on mineral ($N_{30}P_{30}K_{30}$), organo-mineral ($N_{15}P_{15}K_{15}$ + biohumus (250 kg/ha)) and organic (biohumus — 250 kg/ha) nutrition backgrounds contributed to an increase in grain yield compared to the control by 1.22; 0.78 and 0.43 t/ha, respectively.

We proposed a method of analysing the elements of productivity and plasticity of winter wheat to identify drought-resistant wheat varieties suitable for cultivation in the Northern Steppe of Ukraine. The proposed method of analysis allows predicting and selecting additional technological measures for the cultivation of winter wheat and components of mixtures of biopreparations that would increase its growth.

The use of the mentioned method of selection of winter wheat variety with due regard to specific soil and climatic conditions of cultivation allows stabilizing grain yield through the use of varieties that are genetically highly adaptive.

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