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Realization of the adaptive yield potential of the assortment of winter wheat in the Steppe zone under different growing conditions

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Abstract. Climate changes in recent decades have increased the degree of risks in crop production. The consequence of such processes is an increase in the temperature regime against the background of a significant moisture deficit in critical periods of plant growth and development. Accordingly, research aimed at establishing the adaptability of plants to such climatic changes is relevant and timely. The purpose of the research is to establish the principles of implementing the adaptive potential of new varieties of winter wheat of different types of development in the Steppe zone under the conditions of climate change. Records and their assessment were carried out according to the generally accepted methods of Ukrainian variety testing with mandatory statistical and dispersion analysis of the results of field experiments. The establishment of indicators of the stability of quantitative traits and plasticity was carried out using the Eberhard-Russell algorithm, which is based on a regression analysis of the dependence of the grain yield of winter wheat of different varieties on the environmental index. The results of the research

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established that universal type varieties with a stem length of 85-90 cm are the most suitable for irrigated and non-irrigated conditions. Regression analysis of the data on the plasticity and stability of the elements of the crop structure in different varieties of winter wheat proved that their variability directly depends on the genotype and ecological gradients. According to the results of the assessment of the adaptive potential, it was established that the parameters of plasticity (b_i=0.804-0.989) and yield (7.33-7.63 t/ha exceed the standard by 10.4-14.9%) showed winter wheat varieties of the universal type - Askaniyska, Askaniyska Bereginya, Perlyna, Znahidka Odeska, while Khersonska 99, Kirena, Yaroslavna, Kuyalnyk, etc. were characterized by an intensive type of development. Varieties of the universal type were more plastic and stable in the formation of ear productivity, compared to short and tall biotypes. The scientific significance of the research lies in the substantiation of scientific principles, practical recommendations for improving varietal agricultural technology of winter wheat, which had different genetic and ecological origins, in irrigated and non-irrigated conditions of the Steppe zone

Keywords: climate changes; variety; stability; plasticity; morphobiotype; productivity

INTRODUCTION

The last three decades have been characterized by an increase in the average annual temperature in Ukraine by 1.2°C (Pichura *et al.*, 2021). According to weather observations since the 1890s, the period from the end of the 20th century to today is considered the warmest in Ukraine in the entire history of monitoring (Pichura *et al.*, 2021). Such climatic transformations of recent years have increased the degree of risks related to the technological processes of crop production: establishing optimal sowing dates and sowing rates, growing varieties and hybrids of grain crops of different degrees of intensity and maturity groups, optimizing the application of mineral fertilizers, etc. They are caused by an increase in the temperature regime of the environment, the unevenness of precipitation or its complete absence in critical phases of the development of field crops (Pichura *et al.*, 2021). The rate of change in average, as well as maximum and minimum temperatures for the period 1961-2013 was 0.3°C every ten years (Didovets *et al.*, 2020). The last two decades have been characterized by a fairly dangerous trend from the point of view of the impact on crop production - the spread of heat waves. Their appearance leads to the formation of extremely difficult conditions for the vegetation of agricultural plants not only in the whole world, but also in the Steppe zone of Ukraine in particular. According to NASA, in the summer of 2021, a heat wave with a record temperature of +49°C was recorded in the city of Lytton in Canada. In the summer of 2022, large-scale heat waves were observed throughout the European continent, as a result of which massive forest fires were recorded in Central, Western and Southern Europe. All this led to considerable human casualties and the loss of biodiversity in large areas. The intensification of the field of crop production due to modern regional and global climate changes with their negative consequences requires not only an increase in the full productivity of the assortment of grain crops, but also their ecological stability of agrocenoses. Selection and varietal agrotechnics of agricultural crops are of primary importance in solving these problems. According to the results of research by Ukrainian and international scientists, the increase in the yield of winter wheat due to the introduction of certain technological innovations and the improvement of agricultural cultivation techniques is up to 60%, and due to the fate of modern high-yielding varieties of intensive direction with appropriate varietal agricultural techniques – up to 40% (Domaratskiy, 2021; Williamson *et al.*, 2022). The absence of high-intensity varieties of winter wheat with an increased positive reaction to the nutrient regime of the soil would nullify the use of modern approaches in the intensification of crop production, namely: the introduction of increased doses and norms of mineral fertilizers, the use of new stimulators and plant growth regulators, etc. Conducting high-quality seed production and variety renewal are the most profitable and environmentally safe factors for increasing the gross harvest of winter wheat grain (Domaratskiy, 2021; Williamson *et al.*, 2022).

The yield indicator implements the effect of a set of factors on the plant organism during its growing season, and the yield is the result of a compromise between productivity and resistance to biotic and abiotic factors of the environment (Herrera *et al.*, 2021). For maximum harvest indicators, the characteristics of productivity and stability must be selected and adjusted in such a way that in each individual case they best correspond to the conditions of the external environment (Domaratskiy *et al.*, 2020; Panfilova *et al.*, 2021).

Increasing the yield of winter wheat depends, first of all, on the connection between individual components of productivity and establishing the main patterns of crop formation (Domaratskiy *et al.*, 2019; Panfilova *et al.*, 2020). Many scientists (Sewenet *et al.*, 2021; Ge *et al.*, 2022) indicate the important role of the linear relationship between the variability of traits and environmental conditions, this opens up new opportunities for studying quantitative traits, and also allows predicting the adaptive reactions of varieties during cultivation them in different conditions.

The purpose of the article is to establish and highlight the principles of implementing the adaptive potential of new varieties of typical winter and alternative wheat in the Steppe zone of Ukraine under the conditions of climate change.

MATERIALS AND METHODS

The research program included a comprehensive study of new varieties of the universal type under different growing conditions (irrigated, non-irrigated, sowing dates and rates). The researched varieties of soft winter wheat (Askaniyska Bereginya, Khersonska bezosta, Perlyna, Askaniyska, Zahidna Odeska) had different genetic and ecological origins, and were also included in the State Register of plant varieties suitable for distribution in Ukraine. Field experiments were carried out in 2017-2021 in the conditions of the experimental field of the Kherson State Agrarian and Economic University (GPS: 46.743447, 32.481064, Kherson, Ukraine – point 1) and the Askaniysk DSDS of the National Academy of Sciences of the National Academy of Sciences (GPS: 46.55209, 33.82216, 40 Rokiv Peremohy Str., 16, Tavrychanka village, Kherson region, Ukraine - point 2), which are part of the Southern Steppe of Ukraine (Fig. 1).

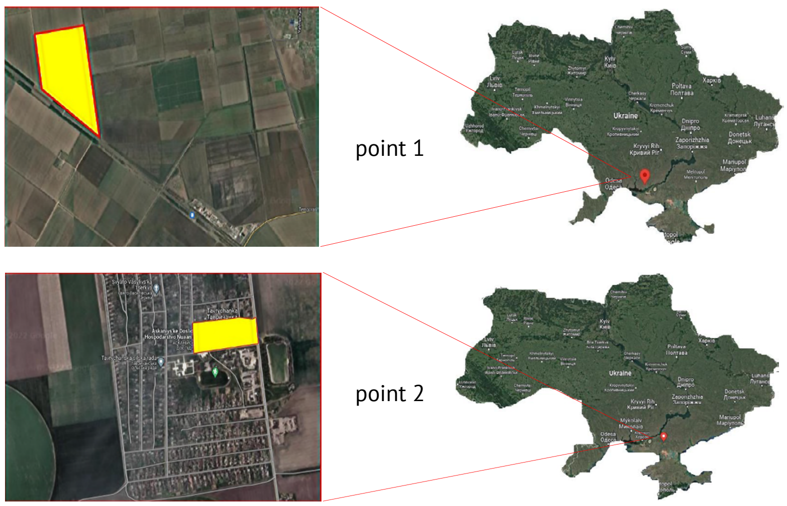

Figure 1. *Points of field research*

Notes*: Point 1 – GPS: 46.743447, 32.481064 Kherson, Ukraine; Point 2 – GPS: 46.55209, 33.82216 40 Rokiv Peremohy Str., 16, Tavrychanka village, Kherson region, Ukraine*

Assessment of winter wheat assortment, necessary records and observations were carried out in accordance with generally accepted methods of state variety testing. Statistical and dispersion analyzes were performed according to methodological instructions (Dospekhov, 1979; Lytun *et al.*, 1996).

The agricultural technique of growing winter wheat in the experiment was generally accepted for the south of Ukraine, which provides for the maximum accumulation and preservation of moisture in the seed layer of the soil at the time of sowing. This approach makes it possible to sow winter wheat every year at the end of the optimal period (in the last decade of September), even in non-irrigated conditions. The precursor for winter wheat in the experiment was black steam, both under irrigated conditions and without irrigation. The researched varieties were sown at the rate of 3.5 million similar seeds per hectare. Weeding of crops was controlled by spring application of a herbicide with the active substance tribenuron-methyl in the interphase period at the end of tillering - exit into the tube. Fungicidal protection against pathogenic microflora involved only the treatment of seed material before sowing with preparations containing the active ingredient tebuconazole 750 g/kg. To establish indicators of plasticity of varieties and stability of quantitative traits, the S.A. Eberhart & W.A. Russell (1966) algorithm was used. This algorithm is based on a regression analysis of the dependence of the grain yield of varieties on the environmental index.

RESULTS AND DISCUSSION

The productivity of the ear had a well-expressed genetic specificity in the formation of the crop as a whole according to the experiment. Over the years of research under different growing conditions, the highest mass of grain from an ear of corn was formed by the varieties Kirena, Khersonska 99, Askaniyska, Solomiya, Askaniyska Bereginya. These varieties were characterized by high ear productivity, mainly due to the increased intensity of grain filling, compared to other varieties of winter wheat. Variability of growing conditions did not have a significant impact on ear productivity indicators. This indicator was genetically determined and reached a high level. The highest mass of grain from the ear was formed by the studied varieties in the variant of sparse sowing during the late sowing period. From the point of view of yield formation under such conditions, the lower productive stalk was compensated by the higher productivity of the ear.

The studied varieties of winter wheat had their own specificity in terms of compensatory features in crop formation. Thus, winter wheat varieties Viktoriya Odeska, Znahidka Odeska, Askaniyska, Askaniyska Bereginya formed a highly productive ear (1.60-2.06 g) almost regardless of the density of the plants. As for Odeska semidwarf, Istok, Khersonska 99 and Kuyalnyk varieties, these varieties had a tendency to decrease the ear productivity index due to the increase in sowing rates. The decrease in the stem density in these varieties had a significant effect on the increase in the weight of the grain from the ear.

As for the number of grains in the ear of the studied varieties, this indicator increased in the late sowing period, similar to the overall productivity of the ear. Some variety types were distinguished by different reactions to the variability of growing conditions. Analyzing the results of the experiment on the parameters of plasticity and stability of the elements of the crop structure in winter wheat varieties under different growing conditions, it was established that their variability was dependent on the genotype and environmental gradients (Table 1).

Table 1. *Character of manifestation of structural elements in the ear of winter wheat varieties under different growing conditions*

Sort	x ±S x	Regression coefficient, b_i	Dispersion, S^2d
Askaniyska Berehynia	1.87±0.03	0.612	0.006
Khersonska bezosta	1.58±0.03	1.614	0.034
Perlyna	1.78±0.02	0.836	0.007
Askaniyska	1.74±0.02	0.759	0.005
Zakhidna Odeska	1.56±0.03	0.760	0.026
The number of grains in an ear. pcs.			
Askaniyska Berehynia	43.7±0.65	0.501	3.00
Khersonska bezosta	41.81±0.85	1.824	12.16
Perlyna	46.41±0.53	0.623	5.56
Askaniyska	48.77±0.65	0.814	4.84
Zakhidna Odeska	42.10±0.31	1.018	6.14
Length of ear, cm			
Askaniyska Berehynia	10.1±0.06	0.466	0.08
Khersonska bezosta	10.0±0.10	2.342	0.46
Perlyna	10.2±0.06	0.166	0.09
Askaniyska	10.7±0.07	0.648	0.11
Zakhidna Odeska	9.4±0.06	0.843	0.13

Source: *developed by authors*

From the results of the research, it was established that among the genotypes that were studied in the field experiment based on the indicator of grain weight from the ear, only one variety (Khersonska bezosta) was characterized by a significant reaction to the change in growing conditions (b_1=1.614). As for other new universal varieties (Askaniyska Bereginya, Askaniyska, Perlyna), they had a sufficiently high level of plasticity (b_1=0.612-0.836). Under such conditions, these varieties can also be considered stable in the formation of ear productivity (S^2d=0.005-0.006).

Similar results were also found in the formation of the number of grains in an ear. Thus, winter wheat varieties Askaniyska Bereginya, Askaniyska, Perlyna were characterized by higher indicators of plasticity (b_i=0.501-0.814) and stability (S^2d=3.00-5.56) in the manifestation of this characteristic of productivity under different growing conditions (Table 1). The variety Znahidka Odeska needs special attention, which is characterized by a significantly high level of reaction to the variability of growing conditions (b_i=1.018) and showed a high level of stability (S^2d=6.14) according to this characteristic, while the variety Khersonska bezosta with the greatest reaction to improvement (deterioration) growing conditions (b_i=1.824) was significantly unstable in the formation of the number of grains in the ear (S^2d=12.16).

The structural analysis of productivity elements proved that the number of grains and the mass of grain from the ear increased in all varieties at a lower plant density and later sowing dates.

Conducting a dispersion analysis of the mentioned characteristics makes it possible to state that they are largely modified by environmental conditions (46.5-53.2%). The rate of sowing had practically no influence on the variation of these characteristics (1.4-4.2%), the timing of sowing, on the contrary, was characterized by a significant influence (9.5-20.8%). The mass of grain from an ear is due to genotypic variability to a greater extent (25.6%) than the number of grains in an ear (14.1%).

Carrying out dispersion analysis of other important subcomponents of ear productivity (ear length, number of ears) made it possible to establish their significant dependence on the genetic properties of one or another variety and environmental gradients.

The indicator of spike length undergoes more significant modifications under the influence of environmental conditions (49.9%) with a slight manifestation of genetic variability (17.1%) compared to the number of spikelets in a spike. The last indicator had an average variability (28.3%) for a sufficiently high genotypic variability (55.6%).

The increase in the absolute expression of the length of the ear and the number of ears in it occurred against the background of the increase in the response of winter wheat varieties to a decrease in the density of sowing, which was formed under the influence of different norms and terms of sowing the crop.

The processes of formation of winter wheat varieties with a productive stem largely depend on the growing conditions and the indicator of the hydrothermal coefficient. A decrease in the number of productive stems in plants per unit area caused by a decrease in sowing rates, a late sowing period and unfavorable weather conditions of the year is a general pattern. But the modification of this feature was largely determined by the architecture of the varieties.

New universal varieties (stem length 85-90 cm) Askaniyska, Askaniyska Bereginya, Perlyna formed significantly more productive stems compared to medium-growing varieties Khersonska bezosta, Dryada, Kirena, which was the result of their formation of higher productivity in all periods and sowing rates. This is primarily due to their biological morphological features, as well as the reaction of a certain variety to irrigation conditions (Bazaliy *et al.*, 2020).

With a late sowing period, the advantage of these varieties over medium-sized ones is even more obvious. Thus, in this case, due to the additional spring bushing of plants and the synchronicity of earing, the productivity of universal varieties decreased to a lesser extent than that of medium-sized varieties.

With an increase in the sowing rate, a general tendency to increase the productivity of varieties was observed, especially for the late sowing period. For plants of universal type varieties, this is explained by the synchronicity of stem formation and occurs as a result of an increase in spike-bearing shoots. On average, in different years of the tests, the largest yield was formed under optimal test conditions. The evaluation of varieties at different stem densities showed that a significant increase in productivity was observed in them with its increase.

The results of the research established that only during the late sowing period, the studied varieties had a positive reaction to the increase in the sowing rate, during other periods its increase did not have a reliable effect on the yield change. This dependence is especially typical for tall and medium-growing varieties of winter wheat (Dniprovska 847, Yaroslavna, Khersonska bezosta and Kirena). These varieties, in most cases, had a mathematically proven decrease in productivity with an increase in sowing rates up to 7 million grains/ha (Bazaliy *et al.*, 2020).

The difference between varieties of intensive and semi-intensive type of development is that the former require a higher level of agrobackground, moisture supply, agrotechnical conditions, etc. Deterioration of these conditions and their significant qualitative fluctuation leads to the impossibility of maximum realization of one's productivity potential. Along with this, the high sensitivity of intensive-type varieties to favorable growing conditions often limits their range of distribution in other agro-ecological zones, in which these varieties may not form high productivity indicators. Accordingly, the creation of universal varieties, which are characterized by an increased level of adaptive potential, is the main direction of winter wheat breeding in the conditions of further increasing the productivity of the agrocenosis. All this will guarantee the ecological stability of a specific variety.

Cultivated plants are constantly affected by adverse factors of the external environment, as a result of these processes there is a depression in the productivity of both individual plant organisms and agrocenoses as a whole. The degree of negative reaction of the investigated agrocenoses is characterized by the presence or absence of homeostasis mechanisms. At the same time, the inconsistency of growing conditions with the adaptive potential of plants is directly proportional to the expenditure of assimilation products on protective and compensatory reactions, which in turn must be lost precisely on crop formation. Such processes have a negative impact on the level of crop yield. The integral physiological indicator determines the general resistance of plants to negative environmental factors, it also affects the dispersion in the formation of agrocenosis productivity (Basu *et al.*, 2021).

The indicator of stability (ecological stability) should be understood as the ratio under stressful conditions to yield under optimal conditions. According to this formula for determining stability, we calculated indicators of yield stability in winter wheat varieties (Table 2).

Table 2. *Indicators of yield stability in winter wheat varieties under different growing conditions (2017-2021)*

Sort	Irrigation	No irrigation	Irrigation/ No irrigation
Khersonska bezosta	0.71	0.79	0.54
Khersonska 99	0.73	0.80	0.52
Khersonska ostista	0.76	0.79	0.54
Cyrene	0.64	0.71	0.49
Yaroslavna	0.57	0.68	0.43
Askaniyska	0.77	0.71	0.49
Askaniyska Berehynia	0.78	0.82	0.57
Perlyna	0.79	0.84	0.59
Odesa 267	0.79	0.83	0.58
Albatross Odesskyi	0.56	0.70	0.51
Kuyalnik	0.57	0.73	0.48
Znahidka Odeska	0.72	0.71	0.48

Source: *developed by authors*

As can be seen from Table 2, the varieties partially differed in indicators of ecological stability. Despite the fact that they have different genetic origins and belong to different ecological groups, the stability of their plants in terms of yield is higher under conditions of non-irrigated agriculture, which provided less intensive vegetation growth than under irrigation conditions, and this, in turn, led to smaller energy costs for the protection of compensatory reactions.

It should also be noted that in conditions of insufficient soil moisture, the varieties of universal type Askaniyska, Askaniyska Bereginya, Perlyna and Znahidka Odeska stood out in terms of absolute productivity and ecological stability. In 2021, Obriy, Odeska 162 varieties suffered from difficult factors of overwintering, mainly from frosts in autumn and early spring. The weather and climate conditions of a specific growing year have a significant impact on the realization of the potential productivity of winter wheat varieties. This especially applies to risky farming zones in the south of Ukraine, including the Kherson region. The analysis of meteorological data for the last 30 years in the Kherson region shows high variability of the amount of precipitation by year (from 283 to 627 mm) and during the growing season from 59 to 255 mm. (Bazaliy *et al.*, 2021). It is appropriate to consider the variety as a biological system through the prism of its reaction to environmental conditions. The ability of the variety to realize its genetic yield potential depends on this, thanks to the parameters of plasticity and its stability (Table 3).

Table 3. *Character of manifestation of yield and plasticity parameters in winter wheat varieties under irrigation conditions (2017-2021)*

Sort	Years of study	Height of plants, cm	Yeld of corn		Coefficient of plasticity, b_i
			t/ha	Regarding standard, %	
Khersonska bezosta	5	106	6.64	-	1.120
Khersonska 99	5	108	6.78	102.1	1.018
Khersonska ostista	5	110	6.65	100.0	1.203
Cyrene	5	106	6.84	103.0	1.314
Yaroslavna	5	108	6.64	100.0	0.980
Askaniyska	5	95	7.05	106.2	0.989
Askaniyska Berehynia	4	90	7.23	110.4	0.814
Perlyna	3	96	7.63	114.9	1.018
Odesa 267	5	110	6.24	93.5	1.105
Albatross Odesskyi	5	108	6.04	91.0	1.314
Kuyalnik	5	106	6.79	102.2	1.140
Znahidka Odeska	5	96	7.06	113.2	0.804

Source: *developed by authors*

According to the results of the assessment of the adaptive potential, it was established that the parameters of plasticity (bi=0.804-0.989) and yield (7.33-7.63 t/ha exceed the standard by 10.4-14.9%) showed winter wheat varieties of the universal type – Askaniyska, Askaniyska Bereginya, Perlyna, Znahidka Odeska, while Khersonska 99, Kirena, Yaroslavna, Kuyalnyk, etc. were characterized by an intensive type of development.

The analysis of breeding lines of winter wheat of different genetic origin revealed that in a year with favorable weather conditions, genotypes with different plant heights have high yields, but the most optimal stem length for realizing productivity is 80-95 cm. This pattern was more evident in unfavorable growing conditions, when it was observed a sharp decrease in plant height. Thus, the study of identical lines under unfavorable growing conditions made it possible to differentiate them into only two groups based on plant height with a maximum stem length of 85-90 cm. These morphobiotypes were characterized by higher productivity of crop structure elements and yield than lines with lower plant height.

The creation of morphobiotypes with a stem length of 85-90 cm by crossing short forms with each other does not cause difficulties, because the output of taller genotypes in hybrid populations occurs in a mass order. This significantly increases the possibility for targeted individual selection of highly productive morphobiotypes, in addition, such biotypes are usually characterized by a greater expression of adaptive traits compared to stunted forms of identical, genetic origin. The results of experimental studies revealed that under optimal conditions of moisture supply, morphobiotypes of winter wheat were characterized by a high absolute manifestation of grain mass from the main ear and ears of the second order and grain size.

Characteristically, the ratio of these elements of the crop structure during splicing was closer than under conditions without splicing. Thus, the exaggeration of the weight of the grain from the main ear to the weight of the ears of the second order under the conditions of splicing was 27.3-34.4%, and without splicing 32.6-41.0%, according to the weight of 1000 grains, respectively, 10.9-24.5% and 17.1-33.0%. So, in the conditions of splicing, the realization of indicators of the elements of the crop structure is significantly higher than in less favorable conditions (without splicing), therefore, the selection of genotypes resistant to adverse environmental conditions should be carried out only after their high potential productivity has been proven in favorable growing conditions.

An increase in the mass of grain from an ear, as one of the main elements of winter wheat productivity, depends on the stability of the manifestation of the number of grains and their size. These signs have different variability under the influence of limiting factors of the external environment and from the genetic origin of breeding lines of winter wheat. Morphobiotypes that were selected from the hybrid populations Znahidka Odeska / NS 314, Askaniyska / Victoria Odeska, Khersonska bezosta / Perlyna and others showed the greatest stability of high ear productivity traits. The parameters of productivity traits in these hybrid populations are average in severity but quite stable in manifestation.

Thus, selection lines were selected from these hybrid populations, which in terms of ear productivity exceeded the standard Kherson seedless variety by 10-15%, which was mainly ensured by an increase in the number of grains in the ear and grain size.

The yield of winter wheat largely depends on the duration of the growing season, but in the southern Steppe of Ukraine, in the late-earing morphobiotypes, the process of grain formation occurs in less favorable conditions, compared to early-ripening forms, so they form low ear productivity and thin grain. In early- and mid-ripening hybrid populations, the selection of morphobiotypes with a longer period of grain formation (38-46 days) provided higher productivity under the conditions of splicing.

However, the theoretical justification and effectiveness of the selection of such morphobiotypes under the conditions of growth did not always confirm their high productivity when grown in unfavorable and unirrigated conditions.

Only forms with early earing (the first and second decades of May) and a long period of grain formation in some hybrid populations retained their advantage over other selection lines of different maturity groups, their high productivity was formed mainly due to an increase in grain size and ear productivity.

Late maturing selection lines practically did not confirm their high productivity in extreme growing conditions and without splicing.

Thus, there should be a differentiated approach to highly productive forms with a longer period of grain formation, and their use only after studying in the conditions of varietal agrotechnics. A difficult problem arose before the selection of winter wheat – the creation of varieties of a universal type, but at the moment it is impossible to create such varieties for all ecological zones and production conditions. The authors of the article established that high-yielding varieties are more adapted to favorable growing conditions, and low-yielding varieties and local morphobiotypes are more productive in stressful conditions, this coincides with the opinion of scientists S. Ceccarlli & S. Grando (1991), I. Stoeva & E. Penchev (1999), S. Boroevich (1984). A number of Ukrainian scientists and scientists of the European Union (Chuhrii *et al.*, 2022; Keser *et al.*, 2022) claim that despite the deterioration of growing conditions, selection for high potential productivity is necessary, because the higher the potential capabilities of the variety, the weaker it responds to environmental, weather and other changes in environmental conditions.

Australian scientists D. Cann *et al.* (2023) also dealt with the problem of realizing the adaptive potential of winter wheat during 2018-2022. In their research, they established that morphobiotypes of winter wheat, which have an accelerated type of development, had a higher level of adaptation to adverse factors of the external environment, compared to ordinary varieties. Such conclusions completely coincide with the opinion of the authors of the article, this type of development is characteristic of winter wheat varieties studied in the field experiment. Australian researchers claim that under such conditions, phenology is already of secondary importance for the process of plant adaptation.

A team of Polish scientists M. Rapacz *et al.* (2022) based on their own six-year field research developed empirical models on the adaptive potential of winter wheat under climate change conditions until 2040, 2060 and 2080 under different scenarios. According to the forecasting results, it was established that the main problem of realizing the adaptive potential of agrocenoses will be cold deacclimatization associated with climate warming, which will be more important for the resistance of plants to adverse environmental factors than the general increase in winter temperatures. This conclusion coincides with the opinion of the team of authors of the article and indicates that resistance to deacclimatization should be included in the programs of creation and breeding of winter wheat varieties as a feature important for winter hardiness of plants in future winters, at least in Central Europe.

A team of US scientists consisting of scientists K. Kothari *et al.* (2019) conducted field studies to assess the impact of climate change on winter wheat production in the state of Texas. As well as evaluate potential strategies for plant adaptation to new conditions. These studies were conducted under irrigation conditions. Scientists see that there are certain expectations regarding the features of irrigation of field crops in the future, namely: the use of total volumes of water for irrigation of winter wheat will decrease due to the increase in the efficiency of water use due to the increased concentration of CO_2 in the atmosphere and the reduction of the duration of the growing season, as a consequence of increasing the temperature regime. These expectations are also confirmed by the results of the authors' observations.

Dryland yields are expected to tend to increase due to improved crop water use efficiency. Among the created virtual predictive models of the US scientists, tested for adaptation to climate change, it was found that an increase in the potential number of grains and the development of a stronger root system were the most desirable traits, as such varieties had higher yields and required less irrigation water than the control variety. Research has established that under the specified conditions, varieties with a longer growing season, whose leaf apparatus remained green longer, turned out to be impractical due to significantly more use of water for irrigation than the control variety. Overall, research results indicated that winter wheat production in the Texas region could benefit from climate change under milder climate conditions (average growing season temperature <13°C). In this case, the realization of the adaptive potential of the researched varieties and the increase in the level of productivity occurred due to the improvement of the architecture of the root system of plants.

To date, the research of the authors of the article is aimed at the creation and study of winter wheat varieties of the universal type, which could be grown both by intensive and conventional technologies. On the other hand, well-known Ukrainian breeders (Orlyuk *et al.*, 2002; Bazaliy *et al.*, 2020) believe that it is far from always possible to obtain a variant - a variety for characteristic specific conditions. Its productivity can vary greatly from year to year in the same farm, when grown according to the same predecessor, using similar agricultural techniques and other identical conditions. It is expected that in the future, our country will face a double problem: food and water security, which are already relevant today and will probably intensify in the future under the influence of further climate changes. The varieties of grain crops that use soil moisture and irrigation water most economically will be especially in demand, accordingly, the coefficient of use of irrigation water when growing such varieties will be in the optimal range. Such an approach can be considered key in solving these problems.

Analyzing the results of our own research and the work of other scientists, it is necessary to note that climate changes will most likely directly affect the development of agriculture in general and the field of crop production in particular. This poses a number of tasks for scientists to establish the dependence of the implementation of the adaptive potential of agricultural crops on such climatic changes, accordingly, the creation of a new assortment of grain crops and the study of such morphobiotypes which will have the highest degree of plasticity and yield stability, today are the most relevant and priority areas of crop production development in the countries of the European Union.

CONCLUSIONS

The analysis of the manifestation of the parameters of plasticity and stability of the elements of the crop structure revealed that under different growing conditions in winter wheat varieties, their variability and absolute manifestation depended on both the genotype and environmental gradients. Varieties of the universal type (plant height 85-90 cm) were more plastic and stable in the formation of ear productivity, compared to short and tall biotypes, they respectively formed a higher and more stable yield.

A variety, as a biological system, should be considered through the prism of its reaction to environmental conditions and the ability to realize its genetic potential. The analysis of the results of research on the adaptive potential of winter wheat allowed us to draw a conclusion about the high degree of homeostaticity and high value of the universal type varieties Askaniyska, Askaniyska Bereginya, Perlyna, Znahidka Odeska.

Under different growing conditions, morphobiotypes with integral interaction of valuable ear productivity sub-characteristics were selected from winter wheat hybrid populations characterized by resistance or tolerance to adverse environmental conditions.

Studies have proven that a one-sided increase in the level of a separate characteristic increased its variability under the influence of limiting factors of the external environment, accordingly, the character of the manifestation of productivity elements in the complex has an average value. An inversely proportional dependence of the absolute individual manifestation of subcharacteristics with the adaptive capacity of morphobiotypes has been established. It is possible to break the specified negative relationship under conditions of activation of the work of the entire genetic and physiological system of homeostasis, which in turn significantly affects the complex manifestation of symptoms.

Under different growing conditions (splicing, without splicing) and environmental weather conditions, the advantage of good selection lines of the universal type compared to the standard variety Khersonska bezosta was steadily maintained within the range of 0.34-0.64 t/ha.

The prospect of further research is the development and improvement of the elements of varietal agrotechnics for the cultivation of new promising winter wheat varieties of the universal type under the conditions of global climate change, as well as the maximum realization of the genetic potential of each variety in the harsh climatic conditions of the Steppe zone of Ukraine.

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CONFLICT OF INTEREST

The authors declare that the study was conducted in the absence of any commercial or financial relationships that could be interpreted as a potential conflict of interest.

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Реалізація адаптивного потенціалу урожайності сортиментом пшениці озимої в зоні Степу за різних умов вирощування

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Анотація. Зміни клімату останніх десятиліть посилили ступінь ризиків у веденні рослинництва. Наслідком таких процесів є підвищення температурного режиму на фоні істотного дефіциту вологи в критичні періоди росту і розвитку рослин. Відповідно, дослідження спрямовані на встановлення пристосованості рослин до таких кліматичних змін є актуальними та своєчасними. Метою досліджень є встановлення принципів реалізації адаптивного потенціалу нових сортів пшениці озимої різних типів розвитку в зоні Степу за умов зміни клімату. Обліки та їх оцінку проводили відповідно загальноприйнятих методів українського сортовипробування з обов'язковим статистичним і дисперсійним аналізом результатів польових дослідів. Встановлення показників стабільності кількісних ознак і пластичності проводилося за допомогою алгоритму Еберхарда-Рассела, в основу якого покладено регресійний аналіз залежності врожайності зерна пшениці озимої різних сортів від індексу довкілля. Результатами досліджень встановлено, що для умов зрошення і без зрошення найбільш пристосовані сорти універсального типу з довжиною стебла 85-90 см. Регресійним аналізом даних пластичності і стабільності елементів структури врожаю у різних сортів пшениці озимої доведено, що їх мінливість має пряму залежить від генотипу та екологічних градієнтів. Відповідно результатів оцінки адаптивного потенціалу встановлено, що за параметрами пластичності (bi = 0.804-0.989) і врожайності (7.33-7.63 т/га перебільшення стандарту на 10.4-14.9%) показали сорти пшениці озимої універсального типу – Асканійська, Асканійська Берегиня, Перлина, Знахідка одеська, інтенсивним типом розвитку характеризувалися сорти Херсонська 99, Кірена, Ярославна, Куяльник та ін. Сорти універсального типу були більш пластичними і стабільними в формуванні продуктивності колоса, порівняно з низькорослими і високорослими біотипами. Наукова значимість досліджень полягає в обґрунтуванні наукових принципів, практичних рекомендацій щодо вдосконалення сортової агротехніки пшениці озимої, які мали різне генетико-екологічне походження, в зрошуваних та незрошуваних умовах зони Степу

Ключові слова: зміни клімату; сорт; стабільність; пластичність; морфобіотип; урожайність