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## **ENHANCING THE YIELD POTENTIAL AND ADAPTABILITY OF *Triticum aestivum* L. VARIETIES CULTIVATED IN UKRAINE**

**Introduction.** *Soft winter wheat (Triticum aestivum L.) remains the primary food crop in global agriculture. Recent increases in air temperature and reductions in precipitation have led to more frequent droughts, posing significant ecological and economic challenges, including declining grain yields.*

**Problem Statement.** *These climatic shifts have underscored the urgent need to develop fundamentally new wheat varieties that combine high productivity, grain quality, and broad-spectrum resistance to biotic and abiotic stresses.*

**Purpose.** *The study aims to assess yield improvements in leading winter wheat varieties widely cultivated in Ukraine and to evaluate the variability of key agronomic traits in relation to adaptability and breeding value.*

**Materials and Methods.** *The plant material comprised winter wheat varieties developed at the Institute of Plant Physiology and Genetics, National Academy of Sciences of Ukraine. Field trials, laboratory assessments, breeding evaluations, statistical analyses, and cluster analysis were employed. Hierarchical cluster membership was determined, and valuable traits were analyzed to assess adaptability and selection potential.*

**Results.** *Hierarchical clustering has grouped the studied varieties into six distinct clusters based on valuable traits. The total yield potential has increased significantly – from 49.0 c/ha (Ukrainka 0246, released in the early 20th century) to 85.0 c/ha (Horodnytsia, released in the early 21st century). Strong correlations have been established between general tillering and productive tillering ( $r = 0.91$ ), spike length and grain mass per plant ( $r = 0.74$ ), spike mass and grain mass in the spike ( $r = 0.99$ ), grain number per plant ( $r = 0.78$ ), and 1000-grain mass ( $r = 0.88$ ). Varieties with high breeding value have been identified, including Smuglianka for spike length and Favoritka for total spikelet number and grain mass per main spike.*

**Conclusions.** *Under current climate change conditions, the identified yield potential of regionalized varieties such as Smuglianka, Favoritka, and Horodnytsia offers a valuable genetic resource for developing new cultivars intended for industrial-scale cultivation and contributes to strengthening food security in Ukraine.*

*Keywords: varieties, Triticum aestivum L., potential, yield, adaptability.*

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Hunger and food insecurity remain pressing global challenges affecting human health and well-being. According to the Food and Agriculture Organization (FAO) of the United Nations, approximately 12.5% of the world's population suffers from hunger daily, while around 17.0% experience deficiencies in essential micronutrients [1]. Ensuring global food security is a multifaceted issue that transcends economics and enters the realm of geopolitics. Bread is not merely a staple food – it also represents national security and state stability [2].

Soft winter wheat (*Triticum aestivum* L.) is the most important food crop in global agriculture. It is cultivated in many countries, with annual production reaching approximately 770 million tons [3], which still falls short of meeting the world's growing demand [4]. Thus, increasing both production and productivity of this cereal crop has become an urgent necessity [5]. A significant rise in wheat yield occurred during the Green Revolution of the 1960–1970s, primarily through the introgression of semi-dwarfing genes. These genetic improvements enhanced assimilative capacity during stem elongation, increased grain number per spike, and ultimately led to higher yields [6].

In recent years, however, there has been a steady trend of rising air temperatures, resulting in more frequent extreme weather events [7]. Reduced precipitation and declining humidity levels have led to increased aridity. Droughts now affect entire countries and have emerged as an ecological crisis of not only regional but also global significance [8]. Climate change has negatively impacted the productivity of many crops, including wheat [9, 10].

To ensure yield stability and enhancement in cereal crops, researchers worldwide have implemented not only intensive but also digital technologies into agricultural production systems [11]. Expanding wheat yield potential across diverse soil and climatic zones has relied heavily on varietal resources, whose importance has been well-documented by numerous scientific studies [12–14]. Genotypes resistant to environmental stress factors but with limited agronomic traits have also

been developed, contributing to increased adaptability and the realization of high yield potential in cereal production, as well as supporting the diversification of crop farming systems [15].

However, as yields have increased, so too has the need to protect crops from diseases, pests, and other adverse environmental factors [16]. As noted by academician Volodymyr Vasylovych Morgun of the National Academy of Sciences of Ukraine (NAS), author of more than 200 registered plant varieties and hybrids [17], there is now an acute need to develop a fundamentally new generation of soft winter wheat varieties that combine high productivity, superior grain quality, and comprehensive resistance to diseases and drought.

Modern breeding efforts have focused on the targeted selection of unique parental forms, with in-depth investigation into their biological properties and mechanisms of agronomic trait expression. In this context, the development of high-yielding and promising soft winter wheat cultivars necessitates a comprehensive analysis of available genetic material, including the evaluation of samples from diverse ecological and geographical origins for their adaptability and selection value.

Recent research has shown that increasing grain production is a strategic priority for Ukraine's agricultural sector, where winter wheat plays a leading role [18]. Ukraine shall consistently harvest no less than 80 million tons of grain annually, given that the agronomic potential of its chernozem soils is estimated at 100 million tons per year. Academician of the National Academy of Sciences of Ukraine (NAS), V.V. Morgun [2], has emphasized that such yields are essential to securing Ukraine's economic future in Europe and ensuring the prosperity of its population.

Numerous high-yielding winter wheat varieties have been developed. Each variety is genetically unique, representing a distinctive combination of genes. However, many factors prevent the full realization of their genetically determined potential. As open biological systems, varieties in field conditions are inevitably influenced by uncontrolled abiotic and biotic environmental stressors [19].

Some varieties with high yield potential and adaptability have already achieved productivity levels of up to 10.0 t/ha (100.0 c/ha). Nevertheless, in recent years, winter crops have increasingly suffered from severe droughts, making it more difficult to stabilize and express their genetic yield potential under increasingly unstable climatic conditions [12]. The development of new, more productive varieties capable of withstanding unfavorable growing conditions is thus critical for improving wheat productivity [20].

Through prolonged and targeted breeding efforts, researchers at the Institute of Plant Physiology and Genetics (IPPG) of the NAS of Ukraine have developed cultivars with high ecological plasticity, capable of realizing their genetic yield potential under variable conditions. For example, the variety *Favoritka* initially produced only 7.3 t/ha (73.0 c/ha) during trials from 2000 to 2004. By 2007–2009, it had reached 11.8 t/ha (117.7 c/ha) on the experimental fields of IPPG, and in 2008/09, a commercial field of 136 hectares in the Cherkasy region (AF *Ladis*) yielded 13.2 t/ha (131.8 c/ha) [2]. In the 2020 state and ecological trials, the variety *Horodnytsia* reached 12.4 t/ha (124.0 c/ha), while *Sofia Kyivska* yielded 11.9 t/ha (119.3 c/ha) [21]. In 2023, record-breaking grain yields were achieved: 13.5 t/ha (135.0 c/ha) for *Horodnytsia* and 14.4 t/ha (144.0 c/ha) for *Sofia Kyivska*, marking the highest performance recorded for food-grade wheat [22].

These results have confirmed that the key to achieving high yields lies in the use of innovative, next-generation wheat cultivars. Despite the challenges posed by climate change, such varieties have demonstrated their ability to dynamically express high genetic yield potential when combined with a complex of adaptive traits and modern cultivation technologies [23].

The aim of this study has been to determine the increase in yield potential of soft winter wheat (*Triticum aestivum* L.) varieties cultivated within the framework of the *Crop Rotation History* experiment. These varieties have historically occupied the largest sown areas in Ukraine and have

made a significant contribution to national grain production. The research has also aimed to assess the variability of valuable agronomic traits, their interrelationships, and to evaluate the adaptability and breeding value of the varieties under study.

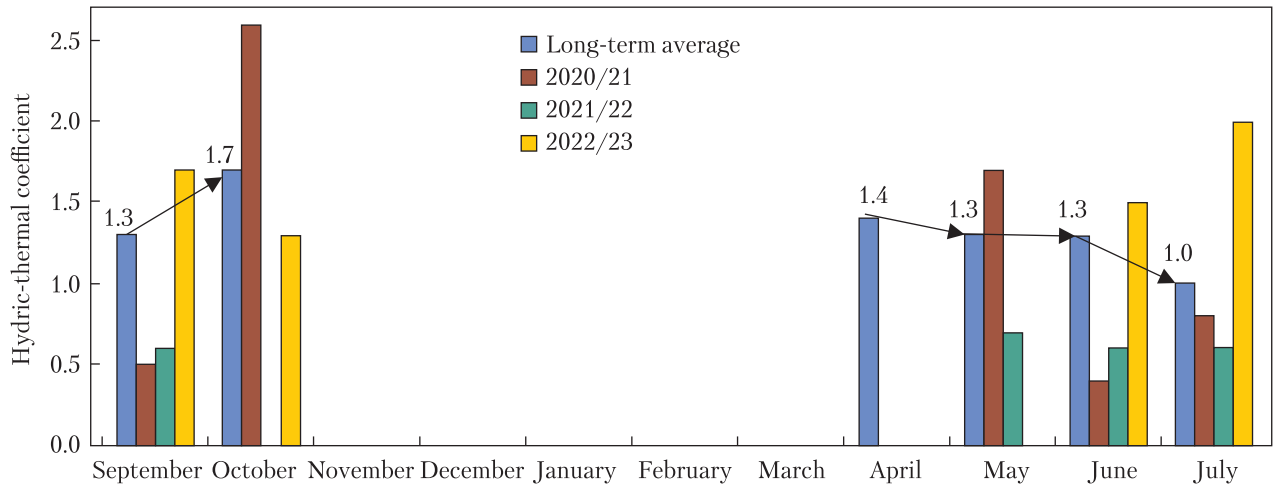
The research has been conducted during 2020–2023 at the Department of Genetic Improvement of Plants, Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine (IPPG NASU), based at the Experimental Agricultural Production Unit of IPPG NASU (Hlevakha township, Fastiv district, Kyiv Oblast).

The experimental material included winter wheat varieties representing the *Varietal Rotation History* collection within the Preliminary Trials nursery: *Ukrainka 0246*, *Bilotserkivska 198*, *Myronivska 808*, *Kyiyanka*, *Podolyanka*, *Smuglianka*, *Favoritka*, *Zolotokolosa*, *Astarta*, *Buzhanka*, and *Horodnytsia*. The varieties were sown in 10 m<sup>2</sup> plots. In the Comparative Trials, varieties with the largest cultivation area in Ukraine – such as *Podolyanka*, *Bohdana*, *Favoritka*, *Smuglianka*, and *Horodnytsia* – were included. In these plots, the accessions were sown in rows of 1.5 meters in length. Sowing was carried out within the optimal time-frame of September 20–30.

Harvesting and yield assessment were performed in accordance with the Methodology for Testing Grain Crop Varieties for Suitability for Dissemination in Ukraine [24]. The national standard variety *Yednist* and the reference line UK 065 were used as yield benchmarks. All trials were conducted in three replications.

Climatic data and long-term average weather parameters were obtained from the official meteorological archives of the Borys Sreznevskiy Central Geophysical Observatory for the Kyiv region [25]. The evaluation of hydrological growing conditions for winter wheat was performed using the Selyaninov Hydrothermal Coefficient (HTC) during the active vegetation period (defined by an average daily air temperature  $\geq +10$  °C) along with the Drought Intensity Index [26].

Biometric parameters and the degree of correlation between yield components are determined



**Fig. 1.** Hydric-thermal coefficient during the active vegetation period of winter wheat in 2020–2023 as compared with the long-term average

based on the average values of 25 plants per plot in three replications. The samples are selected at the onset of full grain maturity. The correlation coefficient is calculated using the following formula:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

To determine the strength of the relationship between traits, the following scale was applied:  $r < 0.3$  – weak correlation;  $0.3 < r < 0.5$  – moderate;  $0.5 < r < 0.7$  – substantial;  $0.7 < r < 0.9$  – strong;  $r > 0.9$  – very strong, approaching a functional dependence [27].

Cluster analysis was performed using the hierarchical method [28]. Euclidean distance in the dendrogram was calculated using the following formula:

$$d_{ij} = \sqrt{\sum_{k=1}^m (z_{ik} - z_{jk})^2}$$

Calculations are carried out using the *STATISTICA 6* software package via the *Cluster Analysis* function.

To assess the variability of traits in winter wheat, the following indicators were used: stress tolerance (min – max), plasticity (min + max/2), coefficient of variation (*Cv*) [29], homeostasis index (Hom), and breeding value [30]. Statistical processing and data analysis are conducted accor-

ding to the method described in [31] using Microsoft Excel 2007.

Under Ukrainian growing conditions, hydrological factors – primarily temperature and moisture – are the main environmental limitations for winter wheat cultivation. The moisture availability varies significantly across years compared to long-term climatic norms. Therefore, during 2020–2023, the moisture conditions during the crop’s vegetation period are assessed based on the hydrothermal coefficient (HTC). The HTC values recorded during the active growth phase of winter wheat are presented in Fig. 1.

The obtained data indicate that during the autumn seasons of 2020–2022, the vegetation of winter wheat was characterized by significant fluctuations in moisture availability. In October – when wheat seedlings successfully root and initiate tillering – an excess of moisture was observed in 2020 (HTC = 2.6), whereas in the same period of 2021, there was a complete lack of precipitation (HTC = 0.0). In contrast, autumn 2022 presented favorable moisture conditions with HTC = 1.7 in September and HTC = 1.3 in October.

Researchers have established [32] that a clear relationship exists between plant development and the formation of yield components. Particular attention should be paid to the correlation with orga-

nogenesis stages. The second stage of organogenesis marks the plant's initial step toward reproduction and determines the potential spike size in wheat. A delay in development at this stage leads to an increased number of rachis segments and, consequently, more spikelets. As demonstrated by Protopish, I. [33], spikelet primordia formation already begins at the third stage of organogenesis. A significant positive correlation ( $r = +0.91$ ) has been established between the number of spikelets and the duration of the second and third stages of organogenesis in winter wheat.

Similar patterns were observed during the spring seasons of 2020–2023. According to long-term climatic data, the transition of the average daily air temperature above +10 °C typically occurs in April. However, HTC records indicate that such active thermal conditions were only observed in May during these years. Extended cool spring periods prolonged the third and fourth organogenesis stages, during which spike length was formed, internode elongation occurred, and floret initiation took place within the spikelets [34]. Consequently, the most favorable conditions for the formation of reproductive organs of the shoot apices were recorded in spring 2023. Despite a severe drought in May 2023, subsequent vegetative growth occurred under adequate (HTC = 1.5) and even excessive (HTC = 2.0) moisture supply, which promoted grain filling and ultimately increased winter wheat productivity.

Thus, the active vegetation period of winter wheat during the last three years has predominantly occurred under drought stress. Severe droughts were recorded in 2020/21 during September (HTC = 0.5), June (HTC = 0.4), and a moderate drought in July (HTC = 0.8). In 2021/22, drought conditions persisted throughout the year – from an extreme drought in October (HTC = 0.0) to moderate drought in May (HTC = 0.7). Only in 2022/23 did the severe May drought (HTC = 0.0) have no significant impact on crop development.

The study titled *Crop Rotation History* included wheat varieties that have made a significant con-

tribution to grain production in Ukraine and have occupied extensive cultivation areas not only within Ukraine but also in neighboring countries and globally. As emphasized by the prominent plant breeder and academician of the National Academy of Sciences of Ukraine, V.V. Morgun [2], while folk selection in the early 20th century delivered cereal varieties yielding around 7 c/ha, scientific breeding had already developed varieties with a genetic yield potential of up to 100 c/ha by the end of the century. Therefore, in 2020, the grain yield obtained from the historical set of varieties was analyzed in comparison with the years in which these varieties were registered in the State Register of Plant Varieties Suitable for Distribution in Ukraine [35]. The data are presented in Fig. 2.

The data presented in the figure confirm that, based on the 2020 yield results from the *Crop Rotation History* study, there has been a progressive increase in the genetic yield potential of soft winter wheat varieties – from the lowest recorded value of 49.0 c/ha for the variety *Ukrainka 0246* registered in the early 20th century [34], to 85.0 c/ha for the variety *Horodnytsia*, listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine in 2017 [35]. By prioritizing productivity in breeding programs and enhancing the genetic improvement of crops, the breeders at the Institute of Plant Physiology and Genetics (IPPG) of the NAS of Ukraine have developed unique varieties such as *Podolyanka*, *Smuglianka*, *Favoritka*, *Zolotokolosa*, and others, with yields ranging from 64.0 to 66.0 c/ha. For the first time in the history of Ukrainian wheat breeding, these varieties have achieved record yields of 124.0 to 131.8 c/ha [2].

A critical task in the development of breeding material is the identification of yield structure components that should be targeted for improvement in wheat productivity breeding. These include productive tillering, the grain mass of the main spike, thousand-kernel mass, and other traits that, although genetically determined, are significantly influenced by environmental factors. Therefore, biometric indicators of yield structure were determined for the studied varieties, and correla-

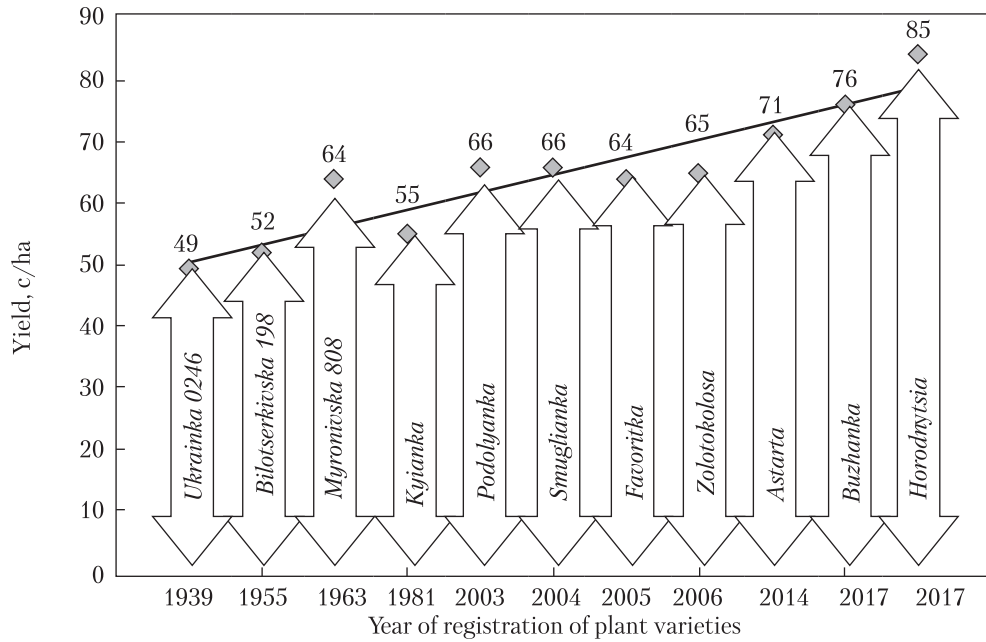
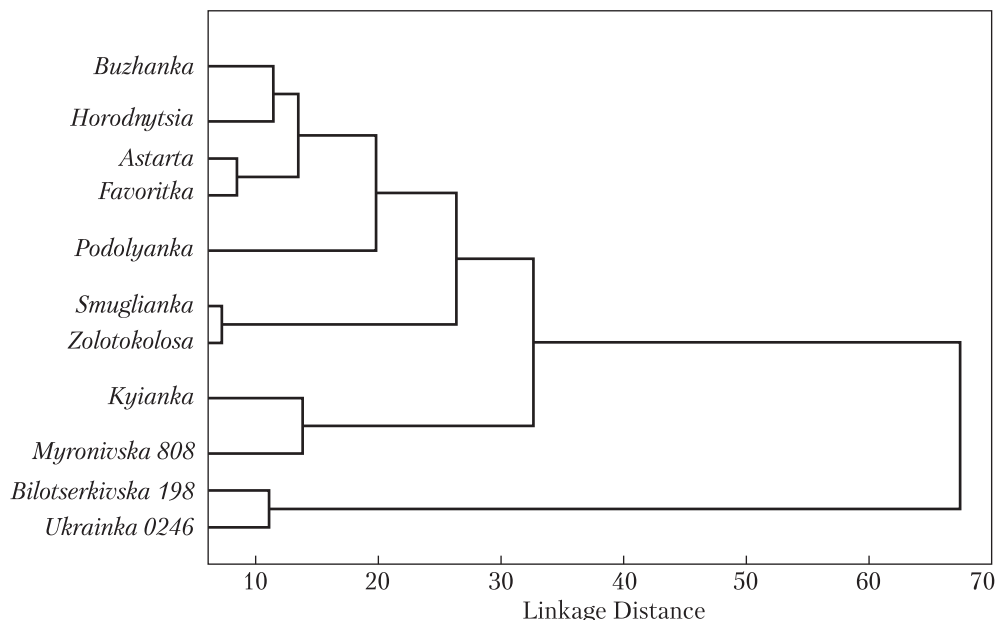


Fig. 2. Increase in the yield of soft winter wheat varieties by year of registration in the state register of plant varieties approved for cultivation in Ukraine, 2020 harvest

Table 1. Correlation Between Economically Valuable Traits in Soft Winter Wheat Varieties from the Crop Rotation History Trial, 2020 Harvest

Properties	Plant height to main spike, cm	Total tillering, pcs.	Productive tillering, pcs.	Main spike						Grain mass per plant, g	Thousand grain mass, g
				Length, cm	Mass, g	Quantity			Grain mass, g		
						Productive spikelets, pcs	Unproductive spikelets, pcs	Grains, pcs.			
<i>r</i>	1	2	3	4	5	6	7	8	9	10	11
1	1.00	—	—	—	—	—	—	—	—	—	—
2	0.58	1.00	—	—	—	—	—	—	—	—	—
3	0.35	<b>0.91</b>	1.00	—	—	—	—	—	—	—	—
4	0.05	0.45	0.63	1.00	—	—	—	—	—	—	—
5	0.18	0.05	0.02	0.43	1.00	—	—	—	—	—	—
6	-0.05	0.20	0.15	0.25	-0.22	1.00	—	—	—	—	—
7	0.16	-0.19	-0.14	-0.06	-0.28	0.22	1.00	—	—	—	—
8	-0.13	0.09	0.07	0.47	0.57	0.41	-0.18	1.00	—	—	—
9	0.16	-0.02	-0.05	0.40	<b>0.99</b>	-0.20	-0.22	0.59	1.00	—	—
10	0.29	0.60	0.62	<b>0.74</b>	<b>0.78</b>	0.06	-0.27	0.55	<b>0.73</b>	1.00	—
11	0.23	0.04	0.06	0.29	<b>0.88</b>	-0.51	-0.13	0.20	<b>0.88</b>	<b>0.67</b>	1.00



**Fig. 3.** Hierarchical cluster dendrogram of soft winter wheat varieties based on the interaction of valuable traits, yield 2020

tion relationships among economically valuable traits were analyzed (Table 1).

Structural analysis of the studied wheat varieties has revealed strong correlations between the following traits: total tillering and productive tillering ( $r = 0.91$ ), length of the main spike and grain mass per plant ( $r = 0.74$ ), and main spike mass with the mass of its grain ( $r = 0.99$ ), grain mass per plant ( $r = 0.78$ ), and thousand-kernel mass ( $r = 0.88$ ).

Based on the biometric indicators obtained from this structural analysis of the soft winter wheat varieties in the *Crop Rotation History* trial (2020 yield), cluster analysis was applied. The criterion for determining similarity of economically valuable traits and distinguishing clusters was the dendrogram distance. The hierarchical cluster membership of the studied varieties was identified (Fig. 3).

The data indicate that the hierarchical dendrogram, constructed based on economically valuable traits of soft winter wheat varieties that have made a significant contribution to grain production in Ukraine, grouped the varieties into six clusters. The greatest linkage distance, reflecting the ac-

cumulation of genetic yield potential traits, was 38 steps, connecting the weakly associated cluster of varieties *Ukrainka 0246* and *Bilotserkivska 198* with the strongly linked cluster comprising *Myronivska 808* and *Kyianka*. The smallest distance of very strongly linked traits, measuring 1.5 steps, was observed between the clusters of the variety groups *Astarta* and *Favoritka* and *Buzhanka* and *Horodnytsia*.

As a genetic system, soft winter wheat specifically responds to external environmental factors. Researchers [37, 38] have noted that adaptability parameters such as stress resistance, plasticity, and coefficient of variation can be used to assess the stability of varieties under varying environmental influences.

For a detailed evaluation of the formation of adaptability parameters in the studied winter wheat varieties, the varieties *Podolyanka*, *Bohdana*, *Favoritka*, *Smuglianka*, and *Horodnytsia* — which occupy the largest sowing areas in Ukraine — are selected. Due to prolonged and cool springs over the past three years, which differently affected the duration of reproductive organ formation during

wheat ontogenesis, these varieties have been examined for the development of an important agronomic trait: the length of the main spike. The results are presented in Table 2.

The obtained data indicate that under the climatic conditions of 2021–2023, among the studied varieties, *Favoritka* developed the greatest main spike length of 11.3 cm and exhibited high plasticity  $((\min + \max)/2) = 11.6$ . The variety *Podolyanka* showed the least stress response for this trait  $(\min - \max) = -1.6$ , with a low coefficient of variation ( $Cv = 8.5$ ), indicating its suitability for cultivation under diverse climatic conditions.

Homeostasis refers to the plant’s ability to maintain stability in physiological process parameters throughout ontogenesis despite changing environmental conditions [39]. Homeostatic capacity allows the determination of a genotype’s reaction norm to limiting environmental factors based on

biometric indicators. High homeostatic stability is characteristic of varieties that consistently express the studied traits [40]. Therefore, during 2021–2023, homeostatic capacity for main spike length was assessed in the studied varieties (Fig. 4).

The data obtained over three years indicate that among the studied varieties, the cultivar *Podolyanka* has been distinguished by the economically valuable trait of main spike length, exhibiting a high homeostasis index ( $Hom = 74.4$ ).

For the studied varieties, one of the key productivity traits – the total number of spikelets formed on the main spike – was evaluated, and adaptive variability indicators for this trait were calculated (Table 3).

It has been demonstrated that over the course of three years, the variety *Horodnytsia* has developed the highest average number of spikelets on the main spike – 21.0 spikelets – and exhibits a

Table 2. Adaptive Indicators of Soft Winter Wheat Varieties Based on Main Spike Length During 2021–2023

Variety	Main spike length, cm			$\bar{x}$	min – max	min + max 2	Cv, %
	2021	2022	2023				
<b>UK line 065, st</b>	9.5 ± 0.2	9.1 ± 0.2	10.8 ± 0.2	9.8	-1.7	10.0	9.1
<i>Podolyanka</i>	9.8 ± 0.2	9.6 ± 0.2	11.2 ± 0.1	10.2	<b>-1.6</b>	10.4	<b>8.5</b>
<i>Bohdana</i>	9.8 ± 0.2	9.5 ± 0.2	11.7 ± 0.2	10.3	-2.2	10.6	11.7
<i>Favoritka</i>	9.8 ± 0.2	10.6 ± 0.1	13.4 ± 0.3	<b>11.3</b>	-3.6	<b>11.6</b>	16.7
<i>Smuglianka</i>	10.8 ± 0.3	10.4 ± 0.2	12.3 ± 0.2	11.2	-1.9	11.4	8.9
<i>Horodnytsia</i>	9.3 ± 0.1	10.8 ± 0.2	12.7 ± 0.2	10.9	-3.4	11.0	15.6

Table 3. Adaptive Parameters of Winter Wheat Varieties Based on the Total Number of Spikelets Formed on the Main Spike During 2021–2023

Variety	Total number of spikelets, pcs.			$\bar{x}$	min – max	min + max 2	Cv, %
	2021	2022	2023				
<b>UK line 065, st</b>	21.5 ± 0.5	17.4 ± 0.4	23.0 ± 0.6	20.6	-5.6	20.2	14.1
<i>Podolyanka</i>	19.8 ± 0.4	18.5 ± 0.5	20.7 ± 0.4	19.7	-2.2	19.6	5.6
<i>Bohdana</i>	20.0 ± 0.3	18.8 ± 0.4	20.8 ± 0.3	19.9	-2.0	19.8	5.1
<i>Favoritka</i>	20.5 ± 0.3	19.8 ± 0.6	20.8 ± 0.4	20.4	<b>-1.0</b>	20.3	<b>2.5</b>
<i>Smuglianka</i>	20.8 ± 0.4	18.5 ± 0.5	22.3 ± 0.5	20.5	-3.8	20.4	9.3
<i>Horodnytsia</i>	20.5 ± 0.3	19.5 ± 0.6	23.0 ± 0.6	<b>21.0</b>	-3.5	<b>21.3</b>	8.6

high plasticity index  $((\min + \max) / 2) = 21.3$ . The variety *Favoritka* showed the least response to stress for this trait  $(\min - \max) = -1.0$ , with a very low coefficient of variation ( $Cv = 2.5$ ), enabling the stable realization of its genetically determined yield potential.

Homeostasis for the total number of spikelets formed on the main spike was also calculated for the wheat varieties. The results are presented in Fig. 5.

It has been established that among the studied varieties, with respect to the economically valuable trait of total spikelet number formed on the main spike, the variety *Favoritka* stood out with a high homeostasis index ( $Hom = 808.1$ ), even under drought conditions.

Within the yield structure components of the varieties, the grain mass of the main spike occupies a significant position. During 2021–2023, adaptive parameters for grain mass from the main spike have been evaluated across the varieties (Table 4).

It should be noted that over the three years of research, the variety *Favoritka* has demonstrated the highest grain mass of the main spike at 4.0 g, a low stress response  $(\min - \max)$  of  $-0.8$  with a moderate coefficient of variation ( $Cv$ ) of 13.3, and a high genetic plasticity index  $(\min + \max / 2)$  of 4.2.

For the studied winter wheat varieties, the homeostasis index for grain mass of the main spike has been calculated (Fig. 6).

The presented data indicate that among the studied varieties, the variety *Favoritka* stood out for grain mass of the main spike, exhibiting a high

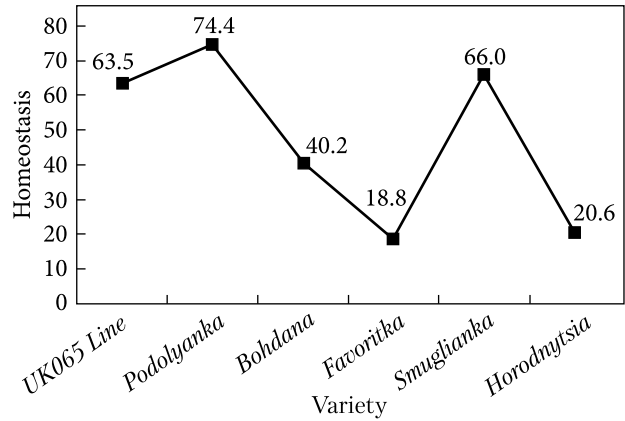


Fig. 4. Homeostasis of winter wheat varieties based on main spike length 2021–2023

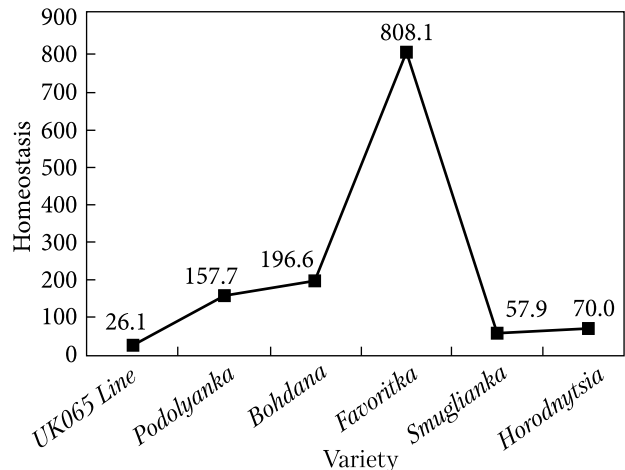


Fig. 5. Homeostasis of Soft Winter Wheat Varieties Based on the Number of Spikelets Formed on the Main Spike During 2021–2023

Table 4. Adaptive Indicators of Winter Wheat Varieties Based On the Grain Mass of the Main Spike During 2021–2023

Variety	Main spike grain mass, g			$\bar{x}$	min – max	min + max 2	Cv, %
	2021	2022	2023				
<i>UK line 065, st</i>	3.6 ± 0.2	2.6 ± 0.1	4.2 ± 0.2	3.5	-1.6	3.4	23.1
<i>Podolyanka</i>	3.5 ± 0.2	1.9 ± 0.1	4.0 ± 0.2	3.1	-2.1	3.0	35.5
<i>Bohdana</i>	3.6 ± 0.2	1.9 ± 0.1	4.0 ± 0.2	3.2	-2.1	3.0	35.0
<i>Favoritka</i>	3.6 ± 0.2	3.8 ± 0.2	4.6 ± 0.3	<b>4.0</b>	<b>-0.8</b>	<b>4.2</b>	<b>13.3</b>
<i>Smuglianka</i>	3.7 ± 0.2	2.6 ± 0.1	4.2 ± 0.2	3.5	-1.6	3.4	23.4
<i>Horodnytsia</i>	3.4 ± 0.2	2.8 ± 0.1	4.4 ± 0.2	3.5	-1.6	3.6	23.1

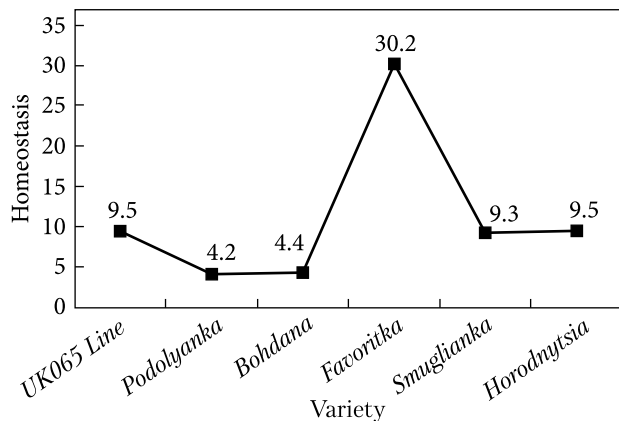


Fig. 6. Homeostatic stability of winter wheat varieties based on the grain mass of the main spike during 2021–2023

homeostasis index (Hom = 30.2), which reflects its strong adaptive capacity.

Breeding value of varieties is crucial for assessing the degree of stability of a given genotype. The breeding value index reflects the transformation of yield stability into measurable units. Therefore, under the extreme weather conditions of 2021–2023, characterized by frequent droughts and the expression of economically valuable traits of winter soft wheat, the breeding value of the studied varieties has been determined (Table 5).

It has been established that under drought conditions over the past three years, the varieties occupying the largest sown areas in Ukraine have demonstrated significant breeding value in reali-

Table 5. Breeding Value (Sc) of Soft Winter Wheat Varieties Based on Key Agronomic Traits During 2021–2023

Variety	Main spike of variety		
	Sc by length	Sc by total number of spikelets	Sc by the grain mass
<b>UK line 065, st</b>	8.3	15.6	2.2
<i>Podolyanka</i>	8.7	17.6	1.5
<i>Bohdana</i>	8.4	18.0	1.5
<i>Favoritka</i>	8.3	<b>19.4</b>	<b>4.0</b>
<i>Smuglianka</i>	<b>9.8</b>	17.0	2.2
<i>Horodnytsia</i>	8.0	17.8	2.2

zing yield potential. Specifically, the variety *Smuglianka* has shown high value for the trait of main spike length (9.8), while the variety *Favoritka* has been valuable for the total number of spikelets (19.4) and grain mass of the main spike (4.0).

Thus, under current climate change conditions, the varieties *Smuglianka*, *Favoritka*, and *Horodnytsia* have most notably increased their yield potential and have served as sources of valuable traits for developing new material with high productivity, adaptability, and grain quality. The large-scale implementation of these varieties in grain production is expected to ensure high yields, economic efficiency, and contribute to national food security.

### CONCLUSIONS

1. It has been proven that in the 2020 harvest, the genetic yield potential of winter soft wheat varieties from the *Crop Rotation History* experiment has increased from 49.0 c/ha (*Ukrainka 0246*, zoned in Ukraine at the beginning of the 20th century) to 85.0 c/ha (*Horodnytsia*, zoned at the beginning of the 21st century).

2. A strong correlation has been established among the following wheat traits: total plant tillering with productive tillering ( $r = 0.91$ ), main spike length with grain mass per plant ( $r = 0.74$ ), main spike mass with grain mass of the spike ( $r = 0.99$ ), grain mass per plant ( $r = 0.78$ ), and thousand-grain mass ( $r = 0.88$ ).

3. It has been revealed that the hierarchical dendrogram based on economically valuable traits has divided the winter soft wheat varieties into six clusters. The largest distances separate the clusters of *Ukrainka 0246* and *Bilotserkivska 198* from *Myronivska 808* and *Kyianka*, while the smallest distance unites the groups *Astarta* and *Favoritka* with *Buzhanka* and *Horodnytsia*.

4. It has been determined that over three years the variety *Favoritka* has formed the greatest main spike length (11.3 cm) with high plasticity (11.6), while the variety *Podolyanka* has shown the least stress response (−1.6) and high homeostasis (74.4) for this trait.

5. It has been proven that the variety *Horodnytsia* has formed the highest average number of spikelets on the main spike (21.0) with high plasticity (21.3), and *Favoritka* has exhibited a low stress response (–1.0) and high homeostasis (808.1) for this trait.

6. It has been revealed that the variety *Favoritka* has the greatest grain mass of the main spike

(4.0 g), with a low stress response (–0.8), high plasticity (4.2), and high homeostasis (30.2).

7. Under current climate change conditions, the yield potential of zoned varieties *Smuglianka*, *Favoritka*, and *Horodnytsia* as sources of valuable traits for creating new seed material for industrial grain production and ensuring the country's food security has been identified as essential.

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#### НАРОЩУВАННЯ ПОТЕНЦІАЛУ ВРОЖАЙНОСТІ ТА АДАПТИВНОСТІ СОРТАМИ *Triticum aestivum* L., ЩО ВИРОЩУЮТЬСЯ В УКРАЇНІ

**Вступ.** Пшениця м'яка озима (*Triticum aestivum* L.) — головна продовольча культура світового землеробства. Останніми роками спостерігається підвищення загальної температури повітря, зменшення кількості опадів, що призводить до тривалих посух, спричиняючи екологічну й економічну проблему глобального масштабу зі зниження урожайності цієї культури.

**Проблематика.** Актуальним є створення принципово нових сортів пшениці з поєднанням високої продуктивності, якості зерна, комплексного імунітету до хвороб і посухи.

**Мета.** Дослідити нарощування врожайності сортів пшениці озимої, що займають найбільші посівні площі в Україні, та встановити в них мінливість цінних ознак при визначенні адаптивності та селекційної цінності.

**Матеріали й методи.** Матеріалом слугували сорти пшениці озимої Інституту фізіології рослин і генетики НАН України. Застосовано польові, лабораторні, селекційні, статистичні методи та кластерний аналіз.

**Результати.** З'ясовано ієрархічний кластер досліджуваних сортів пшениці та проведено аналіз ознак з визначенням адаптивності та селекційної цінності зразків. Доведено нарощування загального потенціалу урожайності — від 49,0 ц/га (сорт 'Українка 0246', районований на початку ХХ ст.) до 85,0 ц/га (сорт 'Городниця', районований на початку ХХІ ст.) Встановлено сильний зв'язок ознак загальної кущистості рослин з продуктивною ( $r = 0,91$ ), довжини головного колосу з масою зерна з рослини ( $r = 0,74$ ) та маси головного колосу з масою зерна в ньому ( $r = 0,99$ ), зерна з рослини ( $r = 0,78$ ) і 1000 зерен ( $r = 0,88$ ). За цінними ознаками ієрархічна дендрограма поділила сорти на 6 кластерів. Виділено сорти з високою селекційною цінністю — 'Смуглянка' за довжиною головного колосу і 'Фаворитка' — за загальною кількістю колосків та масою зерна з головного колосу.

**Висновки.** За сучасних умов змін клімату виявлення потенціалу врожайності районованих сортів пшениці 'Смуглянка', 'Фаворитка', 'Городниця' є джерелом цінних ознак у створенні нового посівного матеріалу для промислового вирощування та формування продовольчої безпеки.

*Ключові слова:* сорти, *Triticum aestivum* L., потенціал, врожайність, адаптивність.