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THE LEVEL OF ADAPTATION OF THE GENOTYPES OF SOFT WINTER WHEAT FROM CHINA UNDER ORGANIC CULTIVATION

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Abstract

The results of three-stages of experimental study conducted under different agroclimatic conditions are presented. The adaptability of Chinese soft winter wheat genotypes was evaluated across three experimental phases: the initial stage involved 124 samples, the second stage focused on 50 samples, and the final stage examined the 12 most promising samples under organic farming conditions. The study identified advanced genotypes with valuable breeding traits, including high productivity, for subsequent hybridization efforts. This process aimed to integrate the genetic potential of both Ukrainian and Chinese wheat varieties to develop improved genotypes. The research distinguished semi-dwarf (60-85 cm) and short-stemmed (85-105 cm) wheat varieties According to indicators of homeostaticity, stability, selection value, plasticity, these genotypes are suitable for originating new varieties adapted to the cultivation under organic farming conditions. The selected best genotypes of wheat varieties from China were transferred to the National Center of Genetic Resources of Ukraine and breeding institutions.

Key words*: organic agriculture, resistance to diseases, elements of productivity, selection value, homeostaticity.*

INTRODUCTION

Wheat is one of the most highly cultivated cereal crops in the world. Like other agricultural crops, the successful cultivation of wheat and the obtaining of maximum yields are significantly affected by abiotic and biotic stresses (Rahman et al., 2013; Litvinov et al., 2020). The main requirement for the creation of new varieties is to increase their resistance to environmental stress factors, which significantly affect the formation of grain productivity and quality (Li et al., 2022; Karpenko et al., 2022). The success of measures to improve yield largely depends on the identification of the best genotypes for cultivation under specific agro-climatic conditions. It is achieved by assessing the variability of genotype productivity relative to environmental changes (determining adaptability) and the level of productivity relative to environmental factor changes over time (determining stability). Breeders use different methods to analyze the genetic stability of varieties/genotypes - linear regression models (b_i) and deviation from the regression mean square (S_{di}), coefficient of variability (CV) among indicators of stability/adaptation (Vlasenko et al., 2019; Karbivska et al., 2022a). The effect of the adaptive potential of varieties is especially evident in years with unfavorable agro-climatic conditions for the cultivation of agricultural crops, when the yield varies greatly from year to year. Therefore, at the last stage of the breeding process, special attention is paid not only to increasing productivity, but also to researching the ecological adaptability of varieties. Such a comprehensive evaluation of the source material according to the parameters of adaptability and stability allows to determine advanced genotypes based on various characteristics (Karbivska et al., 2022b; Radchenko et al., 2024a). They have the greatest value in agricultural production, as they are able to give high-quality crops in different soil and climatic zones, minimally react to weather and agricultural conditions (Sobko et al., 2023; Radchenko et al., 2024b). Nowadays, agricultural producers are interested in those varieties that do not significantly reduce the yield and quality of grain due to significant instability of climatic conditions. Adaptability is considered as the genotype ability to maintain a characteristic phenotypic expression of a trait under certain environmental conditions, and

stability is the ability of the regulatory mechanisms of a plant organism to maintain a specific phenotype under different environmental conditions. The highest adaptability of the genotype can be achieved due to such a property of some features, which in turn determine the stability of the manifestation of others (Manukyan et al., 2021; Verma & Singh, 2021; Tanchyk et al., 2021).

Intensive varieties with high productivity genetic potential should be grown under more favorable conditions. Under problematic soil and climatic conditions, varieties with greater adaptability potential should be grown (Stoyanova et al., 2021; Eduardo Carlos et al., 2021). Thus, taking into account the sharp changes and fluctuations of climatic conditions all over the world, the selection of the best varieties and the evaluation of their ecological adaptability is of great importance both for Ukraine and for other countries of the world, since the newly created varieties must have an effective response to the changing environment and a positive response to conditions of organic agriculture. It especially applies to regions with favorable conditions for the pathogen development in combination with stressful conditions for the wheat development. Only due to its genetic/adaptive features, soft wheat can produce high yields under such circumstances without reacting to stressful conditions (Bakumenko et al., 2019; Tykhonova et al., 2021; Kovalenko et al., 2022; Mishchenko et al., 2024).

Therefore, the aim of our work was to investigate in further work the adaptive potential of Chinese varieties under organic farming conditions, as well as to select superior specimens with a set of characteristics related to selection (including productivity) for crossing and to obtain comprehensive genetic potential improved Genotypes of Ukrainian and Chinese ancestry.

MATERIALS AND METHODS

The prospects of soft winter wheat genotypes of Chinese origin as breeding sources of adaptability were determined in three stages of experimental research and under different agro-climatic conditions (Figure 1). The Remeslo Myronivka Wheat Research Institute is located in the central forest-steppe zone of Ukraine on the right bank of the Dnieper, Ross and Rossava watersheds (southeast of the Kiev region) (Vlasenko et al., 2018).

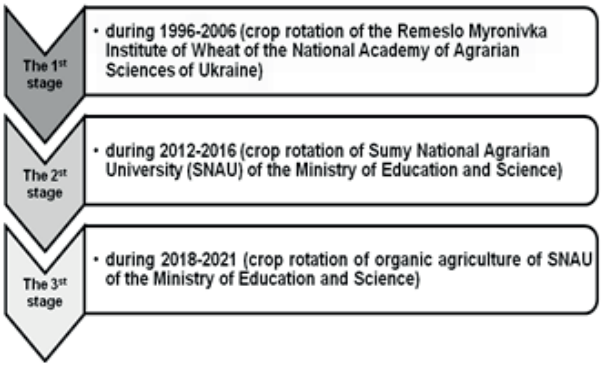


Figure 1. Stages of experimental research conducting

The terrain of the area is a wide plateau (approximately 150 m above sea level) - the so-called "Dnieper-Kaniv tongue", divided by a deep gorge at the confluence of the Ross River in the Northeast and Northwest - the Rosava River. Geographical coordinates - 49.64 north latitude, 31.08 longitude. The territory's microtopography is characterized by shallow depressions of 0.2-1.0 ha in elongated shape.

The soil cover of the experiment field of the Remeslo Myronivka Institute of Wheat is mainly with represented with low-humus, coarse loam and sandy-loam, low-acid and middle-acid chernozems. The intensity of the humus horizon is 38-40 cm, contents of humus - 3.58-4.18%. The depth of the carbonate layer is 45-65 cm, and the depth of groundwater is 50-60 m, which does not affect the soil-forming process. These soils have a high and medium supply of mineral nutrition elements and they are characterized by a slightly acidic, close to neutral reaction of the soil solution (saline pH - 5.3-6.4), which has a good effect on the productivity of winter wheat (Vlasenko et al., 2019; Debuschewitz & Sanders, 2022).

Sumy National Agrarian University is located on the outskirts of the city of Sumy, part of the Forest Steppe on the left bank of northeastern Ukraine. The eographical equals - north latitude 50.88, east longitude 34.77. The megacity is located on the banks of the Psel River at its convergence with the River Sumka.

The geographic coordinates - latitude north 50.88, longitude east 34.77. The northern part of the area lies within the borders of the Novgorod

- Siversky Polissia and the southern part is part of the forested steppe zone. The average content of humus in farmland is 4.1% (Vlasenko et al., 2019; Tonkha et al., 2021).

In general, it can be stated that the soil conditions of the experimental fields of the Remeslo Myronivka Institute of Wheat and Sumy National Agrarian University are typical for the zones, which makes it possible to determine the hereditary productivity potential of wheat sortess and to determine their adaptive potential for use in further breeding work.

The analysis of weather conditions by stages of research (Table 1), conducted on the basis provided by the Myroniv Weather Station of Kyiv region and the Weather Station of the Institute of Agriculture of the Northeast of Sumy region.

The weather conditions during the winter wheat growing season varied from the long–term average in terms of temperature and precipitation and their distribution by months. It is important to observe the deviation of temperatures from the long-term average, as well as the fluctuation of precipitation patterns over time (decrease/increase relative to the long-term average). Thus, it contributed to a comprehensive assessment of the studied material for adaptive capacity in the conditions of the Forest-Steppe of Ukraine.

Table 1. Climatic norm for the years of research

Years of research	Autumn		Winter		Spring		Summer	
	deviation from the optimum air temperature (± ^{0}C)	the amount of precipitation to the norm (%)	deviation from optimum air temperature (± ^{0}C)	the amount of precipitation to the norm (%)	deviation from the optimum air temperature (± ^{0}C)	the amount of precipitation to the norm (%)	deviation from the optimum air temperature (± ^{0}C)	the amount of precipitation to the norm (%)
the 1st stage of research								
1996-1997	0.8	143	1.3	101	0.5	115	0.0	171
1997-1998	0.3	146	-1.2	110	2.9	113	0.6	115
1998-1999	-0.7	100	0.1	124	1.7	127	2.4	65
1999-2000	1.4	117	3.6	102	1.0	107	1.0	149
2000-2001	0.4	116	-3.0	44	1.0	199	2.0	110
2001-2002	0.5	238	-2.1	81	4.8	65	1.8	151
2002-2003	0.2	149	1.5	114	-1.7	51	1.7	103
2003-2004	1.4	141	1.1	119	0.7	72	0.3	110
2004-2005	0.5	97	-1.2	114	0.0	103	1.3	107
2005-2006	-	-	-	-	0.1	112	0.6	128
the 2nd stage of research								
2012-2013	2.8	119	1.0	99	1.3	126	2.2	72
2013-2014	1.6	148	1.5	44	3.2	77	2.2	96
2014-2015	0.4	73	2.3	106	1.4	168	2.3	74
2015-2016	1.9	92	2.5	122	1.8	189	2.1	125
the 3rd stage of research								
2018-2019	1.9	-85	1.7	52	2.6	-30	3.0	-121
2019-2020	2.8	-34	4.9	-7	0.8	-12	2.7	-74
2020-2021	3.9	-64	0.7	-32	0.1	-13	3.5	-31

The material for research was soft winter wheat varieties of Chinese origin, which came from the expedition meetings conducted by Vlasenko in China in the provinces of Sichuan, Henan, Hebei (period 1996-2005), and Hebei and Hansu (2000-2018). When researching the Chinese assortment at the Remeslo Myronivka Institute of Wheat (1996-2006), Myronivs'ka 61, Myronivs'ka early-ripening and Kryzhynka varieties were used as a standard. At Sumy National Agrarian University during 2012-2021, the Podolianka variety was used as a standard to compare, which currently has the largest commercial crops in the Forest Steppe of Ukraine. The seed sowing rate was 5 million seeds ha^{-1}. The plot area is 1 m^2. Research at Sumy National Agrarian University at the 3rd stage differed from the 1st and the 2nd stages, they were conducted under organic farming conditions - without the use of mineral nutrition and chemical plant protection agents. At the first and second stages of the research, intensive farming conditions were observed. Sowing was carried out at the optimal time (third decade of September) with a SR-1 manual seeder in triple repeatability. The fully ripe grain was manually harvested from the plants. The study employed a combination of fieldwork, laboratory experiments, mathematical modeling, and statistical analysis. Standardized techniques

were used for phenological observations, data recording and evaluation, and harvesting (Volkodav, 2003; Vlasenko et al., 2020).

In order to assess the adaptability of the Chinese variety, the study calculated the average yield, as well as the maximum and minimum values and the range of variability. The study also determined the ripening groups to which the varieties belonged, their winter hardiness, and disease resistance (Babayants, 2011; Hryhoriv et al., 2022), and we also calculated indicators of selection value (S_c), homeostaticity (H_{om}), plasticity (b_i) and stability (S^2_{di}) (Hangildin & Litvinenko, 1981). Statistical analysis of research results was performed by the method of disperse analysis and variation statistics according to Dospekhov (1985), using statistical software package Exell, Statistica 6.0.

RESULTS AND DISCUSSIONS

According to the results of the first stage of research (1996-2006) (Vlasenko et al., 2018), in the selective crop rotation of the Remeslo Myronivka Institute of Wheat, there were distinguished (genotypes with satisfactory winter hardiness, overwintering score 7-9) Jimai 24, 97-13, Jimai 30, 97-46, Handan 4564, Dongfeng 1, 89 Zhong 1, Yumai 14, FAN 20. Most Chinese-origin plant varieties have poor winter hardiness when grown in the field. This is particularly true for varieties from the eastern and central provinces of China.

Based on plant height, at the first stage of research, a significant amplitude of fluctuations was revealed. The studied varieties were both dwarf (51-60 cm) and medium-sized (106-120 cm) forms (Figure 2), 14% of forms belong to the group of varieties that exceeded Myronivska 61 by 9-26 cm.

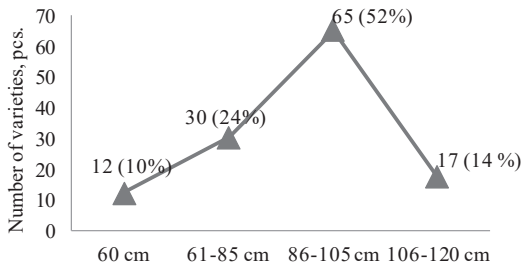


Figure 2. Allocation of the Chinese wheat assortment according to the plant height (Remeslo Myronivka Institute of Wheat, 1997-2005)

The plant height in the range of 86-105 cm is typical for most (52%) of the studied set of varieties. 24% of the studied samples belong to the group of 2-gene dwarfs (short-stemmed samples) with the plant height of up to 85 cm. The group of 3-gene dwarfs (up to 60 cm) included Ren 117, Ren 119, CAT 9933, Jimai 24, 97-03, Xin Dong 20, number 2919 and others.

Most of the Chinese varieties that were involved in the experiment kept their biological feature - dwarfness and early maturity. Out of the entire set, 27% of the forms were marked as early ripening (which were eared 11-14 days earlier than Myronivs'ka 61 and 3 days earlier than Myronivska early ripening) (Figure 3). Approximately 36% of the samples in the studied assortment of wheat from China entered the earing stage 3-10 days earlier than Myronivska 61, with a similar early ripening level.

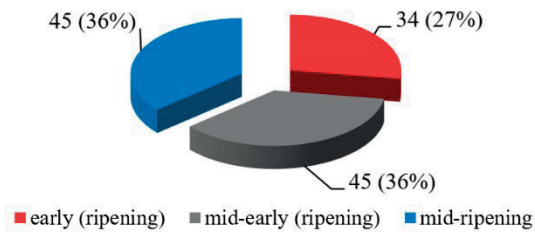


Figure 3. Allocation of wheat varieties of Chinese origin by the length of the vegetation period the (Remeslo Myronivka Institute of Wheat, 1997-2005)

Furthermore, it is worth noting that precocious forms accounted for almost two-thirds of the introduced assortment of wheat from China in general.

According to Table 2, the majority of the Chinese wheat material tested was susceptible to powdery mildew and showed instability in this regard. Specifically, 66% of the studied samples were found to be vulnerable to Blumeria graminis, and during the years 1999-2000, this index approached 90%, leading to significant plant damage that affected the ears and awns/ear tips (and not just the awns). Several genotypes, including 97-14, 97-13, Xindong 18, Xindong 20, 90-109, 90-17, and others, were found to be relatively resistant to powdery mildew at the standard level, with a score ranging from 5-6 (equivalent to Myronivs'ka 61). In 2005, under the conditions of moderate spread of powdery mildew, no genotypes with high resistance were detected when the lesion was at an average level.

Under the conditions of the Remeslo Myronivka Institute of Wheat, the studied genotypes were significantly affected by the phytopathogen *Puccinia recondita*, 12% of samples were found to be resistant to brown rust, at the standard level and above, and only one genotype was characterized by high resistance. Lesion with the phytopathogen *Septoria tritici* (47%) was found to be less than *Blumeria graminis* and *Puccinia recondita*, however, in general, high resistance to the phytopathogen was not detected. So, according to the resistance to leaf diseases, the studied Chinese assortment was generally characterized negatively. However, it was possible to isolate several genotypes resistant to phytopathogens.

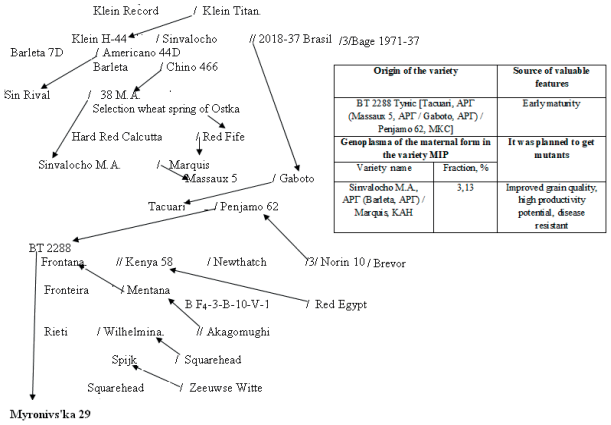
Table 2. Allocation of wheat varieties introduced from China by the resistance to leaf diseases (Remeslo Myronivka Institute of Wheat, 1997-2005)

No.	Phytopathogen	Number of samples, pcs.	Number of samples in groups of the resistance to the pathogens (score)		
			(score) 7-9*, pcs./%	(score) 5-6** middle, pcs./%	score 2-4*** low, pcs./%
1	*Blumeria graminis*	124	0 (0%)	42 (34%)	82 (66%)
2	*Puccinia recondita*	59	1 (2%)	7 (12%)	51 (86%)
3	*Septoria tritici*	89	0 (0%)	42 (47 %)	47 (53%)

Note: *high, **middle, ***low resistance to the pathogen

Due to the precocity, Chinese wheats resisted July droughts under the conditions of the Remeslo Myronivka Institute of Wheat and thereby formed a relatively complete grain, if no other limiting factor affected it. During certain years, some of the studied samples formed ears with over 70 grains, which is higher than the standard range of 40-70 grains. However, despite the higher grain count, the 1000-grain weight did not exceed 42 g even with the larger grain size. The high variability of ear productivity parameters indicates the low adaptive capacity of Chinese varieties and breeding forms studied in the Remeslo Myronivka Institute of Wheat. Practically none of the studied forms significantly exceeded the yield standard. The main valuable characteristics of Chinese wheat in the breeding for adaptability are precocity and shortness. However, in general, the assortment of Chinese whea, which was studied in the Remeslo Myronivka Institute of Wheat, quite clearly maintained the general characteristics according to the main breeding characteristics. Therefore, one of the priority directions of breeding work of the Remeslo Myronivka Institute of Wheat is the creation in terms of new winter wheat cultivars and lines, despite the inclusion of genetic diversity from valuable trait sources in China. Specifically, during the competitive variety test, the line Lutescens 23449 and several lines (Lutescens 32408, Lutescens 32948, and Lutescens 32946) developed with its involvement proved to be the most promising breeding sources, particularly from China. However, these lines were unable to compete with the top-performing lines of the Remeslo Myronivka Institute of Wheat.

The results of research conducted at the Remeslo Myronivka Institute of Wheat indicated that the most significant changes in global wheat breeding involved the development of short-stemmed varieties in the dwarf and semi-dwarf categories, which are now the most abundant types in China's overall wheat breeding (Vlasenko, 2008). Developing resistance in plants to leaf diseases, particularly powdery mildew and septoria disease, continues to present challenges in breeding. It is evident that the lack of Ukrainian germplasm in the genotypes studied from China's assortment has led to a lower adaptive capacity and decreased effectiveness in the breeding process. The Myronivs'ka 29 variety serves as an example of efforts to blend germplasm from Ukrainian and foreign breeding varieties, including wheat genotypes from China. Myronivs'ka 29 was created with the participation of breeding material of bread spring wheat BT-2288 from Tunisia by the method of thermal mutagenesis. The share of the genoplasm of the primary parental form (Chino 466) from China in the Myronivs'ka 29 variety (Figure 4) is 3.13%. Since 1990, the Myronivs'ka 29 variety has undergone the State variety test (formula of the gliadin spectrum - 12.2.1.3.1.1., variety - *erythrospermum*), but at the initiative of the originator it was withdrawn from further testing after 2 years. Nevertheless, Myronivs'ka 29 remains a valuable source for breeding winter wheat in Ukraine due to its short-stemmed, early-ripening characteristics and high ability to generate new varieties.



Origin of the variety		Source of valuable features
BT 2288 Tytic [Tacuari, APT (Massaux 5, APT / Gaboto, APT) / Penjamo 62, MKC]		Early maturity
Genoplasma of the maternal form in the variety MIP		It was planned to get mutants
Variety name	Fraction, %	
Sinvalocho M.A., APT (Barleta, APT / Marquis, KAH	3,13	Improved grain quality, high productivity potential, disease resistant

Figure 4. 29 Lineage of Myronivs'ka 29 soft winter wheat

Next (the second) stage of our research (2012-2016), 50 Chinese varieties of winter wheat were studied under the conditions of Sumy National Agrarian University (Vlasenko et al., 2019). These varieties were divided into four groups according to the length of the vegetation period:

I - ultra-early ripening (218 days and less) - RS 412, DF 526, RS 6079, RS 526, RS 6075;

II - early ripening (219-222 days) - DF581, Jinan 17, Lankao 906, DF529, Zhongmai 9, CA0175, Jimai 22, Jing 411, Shixin 733, Shimai 12, RS 718, Jimai 19, Lunxuau 518, DF549, Shi 4185, DF425, RS 6076, Duto 1081, DF 401, RS 6125, RS 6024, RS 6052, DF 549, Pekin KMS-2012, RS 6049, DF412, RS 6102;

III - mid-early ripening (223-226 days) - Longzhong 9, Jingdong 8, Zhongmai 19, Longzhong 10, Jingdong 8, RS 987;

IV - mid-ripening (227-230 days) - Longzhong 1, Longzhong 11, Longzhong 3, RS6018, Longzhong 4, Longzhong 6, Longzhong 2, Longzhong 7, NSA 97-2082, , Longzhong 5, Longzhong 12, Longzhong 8.

The standard mid-ripening Podolianka variety in the studied area had a vegetation period of 229 days. In terms of winter hardiness, all groups of introduced varieties exhibited lower performance compared to the standard, despite achieving a significant index level ranging from 6.4 to 7.9 on a 9-point scale. The genotypes that were almost not inferior (score <0.1) to the standard according to the overwintering were assigned to the group of mid–ripening samples. In terms of adapting to winter conditions in the Forest Steppe of Ukraine, the early ripening variety Lankao 906 outperformed Podolianka and achieved the highest score (9.0) in the experiment. On the other hand, the ultra-early ripening variety RS 6075 had the lowest level of tolerance to unfavorable winter conditions with a score of 3.0. Overall, the Chinese assortment tested under the field conditions of Sumy National Agrarian University showed relatively satisfactory winter hardiness. Among the studied samples, 52% were able to survive the winter at the standard level with a score of 8 points. This included 2% ultra-early ripening, 20% early ripening, 8% mid-early ripening, and 22% mid-ripening. In addition to winter hardiness, the studied genotypes were also evaluated for callous characteristics and other important vegetative traits for breeding.

Our study revealed a wide range of plant heights, from dwarf forms (30-50 cm) to medium-sized forms (81-110 cm), with a significant amplitude of fluctuations. Among the studied forms, 22% were medium-sized and were on par with Podolianka. The majority of the Chinese varieties under Sumy National Agrarian University conditions (64%) had a semi-dwarf stature, with plant heights ranging between 51-80 cm. A total of 14% of the studied samples belonged to the dwarf group. Varieties with strong and short stems are necessary to realize the high genetic potential of over 8-10 t ha^{-1}. The optimal plant height that provides the highest productivity and resistance to unfavorable environmental conditions is around 91-100 cm, as indicated by Lytvynenko (1993). Our research has confirmed that within the med-high variety group, there is a higher score for winter hardiness (7.9-8.0), which decreases as the plant height decreases. This trend is also linked to the maturity group of the varieties, as there is a direct correlation (as indicated by the r index) between the maturity group, plant height (r = 0.96), overwintering resistance (r = 0.78), and maturity group again (r = 0.92). In other words, genotypes with a shorter vegetation period tend to have lower plant height and overwintering scores. Furthermore, our experiment yielded a correlation coefficient close to +1, indicating a strong linear correlation (almost functional) between maturity group, plant height, and winter hardiness.

The significance of the contributions of factors that influenced the manifestation of yield and disease resistance traits was determined using analysis of variance. This allowed us to assess

the extent to which the factors of interest - such as genotype and ecogradient - accounted for variation in the observed traits. By quantifying the degree of variation attributable to each factor, we were able to identify which factors were most important in shaping the observed phenotypic differences among the wheat varieties. Different reaction rates of varieties depending on the groups of ripeness, yield and disease resistance under the influence of different ecogradient over the years were revealed. Table 3 shows that the object's disease resistance and yield were significantly influenced by different genotypes and the conditions of the year, with a probability close to 100%. This suggests that the factors of genotype and ecogradient have a significant impact on the object under study.

Table 3. Resistance to leaf diseases and yield of bread winter wheat varieties of Chinese origin under Sumy National Agrarian University conditions, average 2012-2016

Maturity group of variety	Number of varieties in group, pcs.	Resistance to diseases, score				Yield, t ha^{-1}			
		Powdery mildew	Septoria disease	Brown rust	$\overline{X}$	$\overline{X}$ according to the groups	limits		R
							min.	max.	
Podolinka (St)	St	6.1	5.5	6.1	5.9	5.9	5.5	6.0	0.5
Ultra-early ripening	5	5.8	2.8	3.3	4.0	6.1	5.8	6.4	0.6
Early ripening	27	5.9	4.9	6.3	5.7	5.7	5.2	6.3	1.1
Mid-early ripening	6	6.5	5.6	6.9	6.3	6.4	5.9	6.9	1.0
Mid- ripenng	13	7.1	6.4	6.4	6.7	7.9	7.6	8.1	0.5
MAR	-	6.4	4.9	5.7	5.8	6.4	6.0	6.7	0.7
LSD_{05} / p-level	*Genotype influence*	0.54 / 0.00	0.47 / 0.00	0.69 / 0.00		0.36 / 0.00			
	Ecogradiend influence	0.18 / 0.00	0.16 / 0.00	0.23 / 0.02		0.12 / 0.00			
	Interaction ecogradient+ genotype	0.93 / 0.94	0.82 / 0.77	1.19 / 0.99		0.63 / 0.36			

An analysis of four maturity groups revealed that genotypes in the mid-early and mid-ripening categories exhibited the highest level of resistance (over 3) to powdery mildew, with scores ranging from 6.5 to 7.1, compared to the standard variety. However, ultra-early and early-ripening varieties showed lower resistance to the standard, with scores ranging from 0.2 to 0.3 and the average value according to the experiment by score 0.5-0.6. The same results were found as for septoria diseaseThe early-ripening group showed improved resistance to brown rust compared to the standard variety, with a score of 0.2, while the mid-early and mid-ripening groups exhibited even greater resistance with scores of 0.8 and 0.3, respectively. Podolianka, the standard variety, demonstrated above-average resistance to powdery mildew. In fact, 61.5% of the varieties studied exhibited higher resistance than the standard, including 5.8% ultra-early ripening, 26.9% early ripening, 7.7% mid-early ripening, and 21.2% mid-ripening varieties. Regarding resistance to brown rust, 59% of the genotypes studied surpassed the standard, including 1.9% ultra-early ripening, 32.7% early ripening, 9.6% mid-early ripening, and 15.4% mid-ripening varieties. According to the resistance to septoria disease 46.2% of studied genotypes were better than Podolianka, including 19.2% early-ripening, 7.7% mid-early ripening, and 19.2% mid-ripening varieties. Thus, early maturity did not result in increased resistance to leaf diseases.

The most valuable genotypes for modern breeding are those that exhibit a high level of resistance, or immunity, to a variety of leaf diseases. Out of the samples that were studied, those that exhibited high resistance to the group of diseases were: early ripening - DF529, Lankao 906, DF581, CA0175, Shi 4185, Shixin 733, Zhongmai 9, Shimai 12, Jimai 22; mid-early ripening - Shijiazhuang 8, Zhongmai 19, Longzhong 10; mid-ripening - Longzhong 1, Longzhong 3, Longzhong 2, Longzhong 7, Longzhong 4, Longzhong 12. By using such varieties, the farmers can reduce their use of pesticides, which can lower their costs and minimize the negative impact on the environment. Furthermore, the use of disease-resistant varieties can help to maintain crop productivity and quality, even in unfavorable weather conditions. By incorporating these varieties into breeding programs, the genetic diversity of the crop can be expanded, and more resistant and productive varieties can be developed.

Next (the third) stage of our research was conducted under the conditions of Sumy National Agrarian University organic farming on the 12 best introduced samples of the Chinese winter wheat assortment. The main aim of repeated research was to determine the adaptive potential of genotypes from China under extreme agro-climatic conditions of the 2018-2021 agricultural years as for ecologically safe cultivation technology. The hydrothermal moisture coefficient (HMC) during this research period was within 0.6-1.2. That is, the vegetation years of the research differed quite significantly according of moisture and heat availability of the winter wheat growing area. Due to HMC, it is possible to determine what part of evaporation is compensated by atmospheric precipitation, the lower HMC indicators the drier area is. The 2018-2019 agricultural year was characterized by average aridity (HMC 0.63), for 2019-2020 and 2020-2021 - sufficient humidity (1.2 and 1.1, respectively).

To assess the adaptability of the Chinese assortment to three diseases resistance, a significant contribution of factors was assigned according to the results of three–year studies (Table 4). A different rate of genotype reaction to the agro-climatic conditions in different years of variety cultivation (ecogradient) was found out. Confidence level (p-level) was within 0.027-0.042 of the significance level for both factors of three diseases. Later, the genotype and year conditions statistically significantly influence the resistance to powdery mildew, brown rust and septoria disease.

Table 4. Resistance to leaf diseases in winter wheat varieties introduced from China, Sumy National Agrarian University (2018-2021)

Variety	Septoria disease		Powdery mildew		Brown rust		Resistance average value to 3 diseases
	($\bar{x} \pm S\bar{x}$), score	CV, %	($\bar{x} \pm S\bar{x}$), score	CV, %	($\bar{x} \pm S\bar{x}$), score	CV, %	
Podolianka (St)	6.33±0.33	9.12	7.00±0.58	14.29	6.33±0.33	9.12	6.55
Longzhong 3	6.67±0.33	8.66	6.67±0.33	8.66	8.00±0.58	12.50	7.11
Longzhong 4	6.33±0.33	9.12	8.00±0.00	0.00	7.33±0.88	20.83	7.22
Longzhong 6	7.00±0.58	14.29	7.33±0.67	15.75	6.33±0.33	9.12	6.89
Longzhong 8	7.33±0.33	7.87	7.67±0.67	15.06	8.00±0.58	12.50	7.67
Longzhong 9	6.67±0.33	8.66	8.00±0.58	12.50	7.33±0.88	20.83	7.33
Longzhong 10	6.67±0.33	8.66	6.67±0.33	8.66	7.00±0.58	14.29	6.78
Longzhong 12	7.67±0.33	7.53	8.00±0.58	12.50	7.67±0.88	19.92	7.78
RS 6075	7.33±0.67	15.75	8.67±0.33	6.66	8.33±0.67	13.86	8.11
RS 6076	7.00±0.58	14.29	7.67±0.33	7.53	8.33±0.67	13.86	7.67
Zhongsi 1048	5.33±0.33	10.83	6.67±0.33	8.66	5.00±0.58	20.00	5.67
DF401	6.00±0.58	16.67	8.00±0.58	12.50	7.67±0.88	19.92	7.22
Tanmin 2013	5.67±0.33	10.19	6.33±0.33	9.12	6.00±0.58	16.67	6.00
$\bar{x}$	6.62		7.44		7.18		7.08
p-level	0.027		0.038		0.042		
Fisher's criterion actual / tabular	2.45 / 2.15		2.28 / 2.15		2.23 / 2.15		
LSD_{05}	1.24		1.35		1.93		

Note: $\bar{x}$ - mid-arithmetic mean; $S\bar{x}$ - standard drawback; p-level - confidence level; CV - coefficient of variation.

According to research results, varieties introduced from China showed a high level of resistance to leaf diseases. Their characteristics corresponded to the indicators of the standard (Podolianka) and exceeded it. According to the resistance to septoria disease above score 6.3 were Longzhong 3, Longzhong 4, Longzhong 6, Longzhong 8, Longzhong 9, Longzhong 10, Longzhong 12, RS 6075, RS 6076. Over three years of research, the average resistance index (score 7.1) of Chinese varieties to three diseases was. With resistance score more than 7.0 to powdery mildew the following varieties were found out: Longzhong 4, Longzhong 6, Longzhong 8, Longzhong 9, Longzhong 12, RS 6075, RS 6076, DF 401. Resistance to brown rust above score 6.3 was recorded in the following varieties: Longzhong 3, Longzhong 4, Longzhong 6, Longzhong 8, Longzhong 9, Longzhong 10, Longzhong 12, RS 6075, RS 6076, DF401. The varieties were most affected by the causative agent of seproria disease. The average resistance score to this disease over the years of research was 6.6. The most favorable year for the development of septoria disease (score 6.2) was in 2020. The variation coefficient to septoria disease resistance was recorded withing 7.5-15.7%, which indicates a

low and medium trait variation by the year. The varieties that, over the years of research, were distinguished by comprehensive resistance (score above 7.0) to phytopathogens - causative agents of septoria disease, powdery mildew, brown leaf rust - Longzhong 8, Longzhong 12, RS 6075, RS 6076 deserve attention.

Winter wheat varieties currently registered and allowed for commercial cultivation in Ukraine differ significantly according to the plant height. This trait has a genetic basis and high heritability (Orliuk et al., 2006; Radchenko et al., 2022). With the intensive technology of wheat cultivation, plant height acts not only as a varietal, morphological trait, but also as an indicator of the plant resistance and phytocenoses to lodging (Panchenko, 2003). In many countries of the world, with the level of agriculture increasing the height of plants decreased by about 15 cm every 50 years. The increase in wheat yield is associated with a decrease in the height of plants from 130 cm to 60-85 cm due to a reduction in the size of all stem internodes, an increase in the size and productivity of the ear. So, with an unchanged total biological yield of crops, the yield increase of modern wheat varieties is associated precisely with its redistribution in the plant at the expense of straw into the grain part. Increasing of the wheat plant resistance to lodging is achieved by reducing the stem height and increasing its strength (Lytvynenko & Honcharuk, 1993).

In different years of cultivation, the studied varieties manifested themselves in different ways according to the plant height (Table 5). The increasing in plant height was observed in 2021 in all studied varieties. Then it was 85 cm on average according to the experiment. A lower average plant height was observed in 2019. The evaluated varieties fall into the group: semi-dwarf (60-85 cm) and short-stemmed (85-105 cm). The analysis of plant height in the studied varieties indicated its significant variability - from 74 to 92 cm. The average plant height in the experiment under the conditions of the northeastern forest-steppe was 80 cm, which is practically the same as the variety of Ukrainian breeding (standard) - Podolianka (83 cm). Individually, on average, the lowest plant height (74 cm) had Longzhong 12, which indicates the prospects of its use in breeding for short stemness. The highest plant height (93 cm) over the years of research was observed in DF401. It should be noted that at the previous stage of research, the selected varieties also werein the group of the semi-dwarf and mid-hight group. It should be mentioned separately that Longzhong 12 had the lowest plant height (74.67±0.33) on average over the years of research, and at the same time, the smallest range of its variation, which indicates the high genotype adaptability. Having analyzed the statistical indicators that characterize the varieties according to the plant height, it is possible to choose out those that are valuable for the breeding process by this trait. With a narrow reaction rate, low dispersion and insignificant variability over the years, the following varieties were: Tanmin 2013, RS 6075, Longzhong 12. One of the most important elements of ear productivity is the number of grains in the ear, which has a close correlation with the yield of winter wheat. As shown in Table 5, the conditions of 2020 were favorable for earing of the studied varieties (average - 45.9 pcs.). This indicator was lower in 2019 (average 36.6 grains/ear) and in 2021 (41.2). The number of grains in an ear varied from 21.8 to 61.8 pcs. The average value of the indicator was 41.2 pcs./ear over the years of research. The coefficient of the trait variation characterizes its stability in a specific genotype. This indicator was the lowest in RS 6075 (3.7%). In general, the variation coefficient (3.7-9.9%) indicates that the variability of the studied trait in most varieties is insignificant. However, varieties with a significant variation rate (10.7-26.9%) of the number of grains in an ear were noted. All varieties have a wide reaction rate according to this this trait. Having analyzed the statistical data that characterize the potential of varieties by the number of grains from the ear, it is possible to highlight valuable sources for breeding. On average, during the years of research, the varieties Longzhong 4, Longzhong 8, Zhongsi 1048 turned out to be significantly better than the standard variety Podolyinka.

There is an opinion (Bazalii, 2000; Samofalov, 2005) that the increase in the yield of new wheat varieties occurred due to a decrease in vegetative biomass and an increase in the 1000 grain weihts, the number of grains in an ear and the weight of grain from an ear. However, the grain size indicator for wheat seeds is not regulated by the national standard of Ukraine, although it is

partially taken into account when determining seed quality according to DSTU 4138-2002 (DSTU 4138-2002). Thus, the seed that passed through the 1.7 x 20 mm seed sieve during the sifting process is considered small and belongs to waste. The seed that remained on the sieve is counted as seed, without dividing it by size. However, in the standards of other countries, grain size is taken into account, for example, in Germany, the mass of 1000 grains should be 43-55 g (Kyrpa, 2013). Studying organic farming the largest mass of 1000 grains in 2019 was found out in the vast majority of varieties. The conditions this year were the most favorable for the majority of studied varieties. Analysis of variance by 1000 grain weihts of the Chinese assortment by year indicates a high significant difference ($p<0.035$) between them. The value of this trait varied from 41.6 to 48.1 g. The average value over the years of the study was 46.4 g. On average, the 1000 grain weihts of the standard variety (45.2 g) significantly exceeded only one variety - Longzhong 9 (48.7 g). The coefficient of variation (1.97-8.3%) indicates low variability of the trait. Its lowest value was observed in Longzhong 6. This variety shows high adaptability. After analyzing the statistical indicators calculated by us, which characterized the potential of the varieties according to the 1000 grain weihts, we find out the ones that are valuable for breeding according to this trait. Thus, during the years of research, varieties that exceeded the average population value (46.4 g) were distinguished - Longzhong 3, Longzhong 9, Longzhong 10, Longzhong 12, RS 6076, Zhongsi 1048, DF401.

The productivity of the ear had a well-expressed genetic specificity in the formation of the yield. Over the years of research, the genotypes Longzhong 4, Longzhong 8, Longzhong 9, Longzhong 12, RS 6075, RS 6076, Zhongsi 1048, DF 401 turned out to be significantly better according to the grain weight than the standard variety (Table 5). The coefficient of variation (4.5-14.2%) indicates that the variability of the analyzed trait is both low and medium. In Longzhong 4, Longzhong 9, RS 6075, Zhongsi 1048, the coefficient of variation was more than 10%, which indicates the average value of the indicator. It indicates a significant potential for grain weight from the ear of Chinese genotypes under optimal growing conditions.

Table 5. Indicators of the main productivity elements of winter wheat varieties introduced from China, Sumy National Agrarian University (2018-2021)

Variety	The plant height, cm	Number of grains in an ear		1000 grain weihts		Weight of grains from an ear	
	($\bar{x} \pm S\bar{x}$)	($\bar{x} \pm S\bar{x}$), pcs.	CV, %	($\bar{x} \pm S\bar{x}$), g	CV, %	($\bar{x} \pm S\bar{x}$), g	CV, %
Podolianka (St)	82.67±4.18	37.39±2.86	13.25	45.17±1.48	5.68	1.68±0.07	6.91
Longzhong 3	75.33±4.37	28.44±4.43	26.96	46.50±2.23	8.30	1.65±0.08	7.93
Longzhong 4	77.67±5.24	47.32±1.51	5.53	45.07±1.43	5.48	2.09±0.16	13.16
Longzhong 6	80.33±2.96	39.98±1.33	5.78	46.03±0.52	1.97	1.85±0.05	4.54
Longzhong 8	75.00±2.89	46.91±2.91	10.73	41.60±0.72	3.01	2.12±0.11	9.12
Longzhong 9	82.00±4.04	45.15±2.57	9.87	48.67±0.88	3.14	2.07±0.14	11.67
Longzhong 10	80.00±5.00	37.40±2.75	12.75	47.00±1.00	3.69	1.88±0.05	4.52
Longzhong 12	74.67±0.33	46.40±1.00	3.73	48.07±0.64	2.29	2.11±0.10	8.53
RS 6075	82.00±1.73	43.78±0.94	3.70	47.98±1.04	3.77	2.08±0.14	11.80
RS 6076	85.67±2.73	41.05±5.31	22.43	46.50±0.8	3.03	1.93±0.11	9.68
Zhongsi 1048	81.00±3.06	49.42±7.14	25.02	47.78±1.42	5.16	1.99±0.16	14.24
DF401	92.67±2.19	45.48±1.25	4.75	47.67±1.34	4.86	2.07±0.06	4.83
Tanmin 2013	75.00±1.73	27.37±1.10	6.94	45.57±1.28	4.88	1.47±0.07	8.69
$\bar{x}$	80.31	41.24		46.43		1.92	
p-level	0.039	0.001		0.035		0.002	
Fisher's criterion actual / tabular	2.26 / 2.14	4.62 / 2.14		2.31 / 2.14		3.77 / 2.14	
LSD_{05}	9.73	9.34		3.50		0.31	

Note: $\bar{x}$ - mid-arithmetic mean; $S\bar{x}$ - standard drawback; p-level - confidence level; CV - coefficient of variation.

Among the examined genotypes from China, yields varied between 5.5 and 9.2 ha, depending on the year (Table 6).

Table 6. Characteristics of winter wheat varieties of Chinese origin according to the yield, Sumy National Agrarian University (2018-2021)

Variety	Yield, t ha^{-1} ($\bar{x} \pm S\bar{x}$)	CV, %	H_{om}	S_c	S^2_{di}	b_i
Podolianka (St)	6.24±0.56	15.64	39.90	5.19	-	-
Longzhong 3	6.02±0.86	24.82	24.25	5.01	0.043	0.098
Longzhong 4	9.08±0.16	3.01	302.01	7.55	0.039	0.512
Longzhong 6	7.02±0.19	4.67	150.29	5.84	0.193	0.947
Longzhong 8	7.65±0.41	9.22	82.97	6.36	0.151	0.389
Longzhong 9	8.62±1.26	25.39	33.96	7.17	0.101	0.102
Longzhong 10	6.83±0.68	17.23	39.62	5.68	0.191	0.262
Longzhong 12	9.16±0.51	9.70	94.42	7.62	0.133	0.290
RS 6075	8.72±0.86	17.09	51.03	7.26	0.143	0.179
RS 6076	7.35±0.62	14.68	50.02	6.11	0.164	0.265
Zhongsi 1048	7.83±0.87	19.17	40.88	6.52	0.026	0.076
DF401	9.13±1.35	25.58	35.70	7.60	0.042	0.062
Tanmin 2013	5.46±0.71	22.51	24.25	4.54	0.034	0.106
Middle yield of varieties 7.62; p–level – 0.017						
Yield Fisher's criterion actual / tabular – 2.66 / 2.14						
Yield LSD_{05} – 2.22						

Note: $\bar{x}$ - mid-arithmetic mean; $S\bar{x}$ - standard drawback; CV - coefficient of variation; H_{om} - manifestation of homeostasis; S_c - breeding value; S^2_{di} - quadratic deviation of the actual productivity indicators; bi - intensity indicator variety.

The average population value for this trait was 7.6 tons per hectare. This indicator indicates the adaptive optimum of crop productivity represented by varieties of Chinese origin under organic farming conditions in the left-bank Northeastern Forest-Steppe region of Ukraine. Exceeding it indicates that the genotype has a higher level of fitness under the conditions of the study because it is closer to a level of genetic potential more fully realized. Therefore, the varieties DF401, Zhongsi, 1048, RS 6076, RS 6075, Longzhong 12, Longzhong 9, Longzhong 8, Longzhong 4 were found out at the level of the average population value. At the same time, none of the studied genotypes of Chinese breeding was significantly inferior to the Podolyanka standard - 6.24 t ha^{-1} (for LSD_{05} - 2.22 t ha^{-1}). It indicates that, despite insufficient adaptive properties, the Chinese assortment is characterized by a high enough level of potential productivity. The researched genotypes can be recommended for further breeding work as sources of high productivity, which have consistently high productivity indicators according to previous studies (the second stage). One of the important indicators in assessing the ecological adaptability of varieties is the coefficient of plasticity bi (linear regression). The yield plasticity coefficient shows the reaction of varieties to the growing condition changes. Genotypes with a value of bi close to 1 are considered the most suitable for growing under organic farming, the change in the yield of Chinese genotypes corresponds to the growing condition fluctuations. If bi is significantly higher than 1, then these varieties are classified as intensive. These varieties have shown a significant response to improved growing conditions, but unfavorable weather conditions can have a negative impact on their productivity. If bi is significantly less than 1, it suggests that such varieties are best suited for cultivation using extensive farming techniques. During the second stage of research on the Chinese assortment Longzhong 7 and Longzhong 12 were found to be the most plastic. These varieties demonstrated high intensity (bi = from 0.9 to 1.4) when grown under the conditions of the North-Eastern Forest Steppe of Ukraine. When determining the ecological adaptability of varieties from China under organic cultivation, in drier years (2018-2021, Table 1), 12 studied varieties had a positive b_i indicator, which was less than 1 (from 0.06 to 0.94).

The smaller the quadratic deviation of the actual productivity indicators from the theoretically expected ones (S^2_{di}), the more stable the trait is manifested in the variety. At the background of organic farming of the Chinese assortment, the stability of the S^2_{di}, indicator was revealed. All varieties showed high stability under the studied conditions and had a positive indicator of S^2_{di} = 0.1 and below.

The smallest variability of yield under changing environmental conditions is related with the high homeostaticity manifestation. In those cases where homeostasis will be manifested, plants can develop normally, regardless of the unfourable environmental conditions. In our studies, high homeostaticity (H_{om} = 24.25-302.01) was recorded in all selected genotypes. The maximum indicator was found in Longzhong 4. It should be noted that this indicator is fully correlated with yield and coefficient of variation. That is, the higher the productivity and the lower the variation index, the higher the variety homeostaticity. Measuring the homeostaticity of varieties enables not only the assessment of their productivity in terms of average yield, but also the determination of their

responsiveness to environmental factors that may limit growth and development. All selected varieties showed a positive result (Sc = from 4.54 to 7.55) in terms of breeding value under organic cultivation. Longzhong 4 exhibited the highest breeding value among all the studied varieties, attributed to its high yield and the highest coefficient of trait variation. In general, under organic farming varieties from China responded poorly to drought weather conditions during the years of research and had a high enough yield, stability and adaptability, indicating that these varieties are more adapted to drought conditions and organic cultivation, as the change in their yield fully corresponds to growing conditions.

So, on the basis of the conducted three-stage studies of the Chinese assortment, the value of a number of winter wheat varieties was confirmed. The best genotypes for selection work were singled out for genetic, selection value, adaptability, homeostatic and stability. These results demonstrate the significance of genotypes sourced from China, and provide a foundation for their utilization in the breeding process to develop new and modern varieties suitable for cultivation in Ukraine and other regions around the world.

Organic agriculture is considered a particularly ecologically clean way of farming, based on interrelated principles of ecology, health, and moral ideal (IFOAM, 2021; Debuschewitz & Sanders, 2022). Feeling the unfavorable effects of cost-driven synthetic agriculture, the concept of organic agriculture is gaining global momentum. Almost 31 million hectares of land are currently managed organically by more than 600,000 farmers worldwide, representing 0.7 percent of agricultural land (Manzoor et al., 2021).

Therefore, one of the important aspects of the transition to organic agriculture is the cultivation of varieties with high adaptive potential. At the same time, there is a need to increase disease resistance and productivity of wheat varieties, especially under organic agriculture, which is limited by the lack of varieties adapted to an environmentally friendly way of growing. The rapid development of conventional agriculture over the past 60 years, exemplified by the increase in grain production, has depended on significant and continuous investment in plant breeding. Breeders created hundreds of varieties of different genetic origin, which can be traced through their parentage. All genotypes are adapted to the classical variety in the agriculture and it is important to occupy significant areas of land. However, the productivity of the most varieties mainly depends on large planted areas, significant fuel costs for processing and caring for crops, which in turn contributed to limiting the impact of the changing environment on the adaptive potential of varieties. Though, climate change combined with rising oil prices is now beginning to affect the development of traditional plant breeding and cultivation, including wheat.

During this time, organic agriculture developed much more slowly, suspending investment in breeding on the one hand, there are problems of overcoming extreme environmental variability and on the other hand, so the need to adapt varieties to various environmental conditions is now extremely important for organic agriculture.

These positions must be taken into account at the initial stages of breeding, starting with the selection of highly adapted parental forms. Although organic agriculture is well developed in most European countries, specialized breeding of varieties for organic farming systems is not well developed.

In this paper, we argue that there is a need for different approaches to plant breeding to improve organic farming systems and the quality of organic produce compared to current traditional practices

CONCLUSIONS

During the period of 1997-2005, under the conditions of the MIW (Mironivka Institute of Wheat) at the National Academy of Agrarian Sciences of Ukraine, a total of 124 samples of the Chinese variety were studied, some of which remain sources of breeding-valuable traits for the creation of modern early-ripening and short-stemmed genotypes. Samples Jimai 24, Jimai 30, 97-13, 97-46, Dunfen 1, Handan 4564, FAN 20, Yumai 14, 89 Zhong 1 were selected as valuable breeding sources. They were involved in hybridization with varieties of this institute, resulting in the creation of lines, which are at different stages of the breeding process.

From 2012 to 2016, a study was conducted on 50 new varieties of Chinese origin under the conditions of the left-bank region of the Forest-Steppe in Ukraine, which helped identify the Chinese assortment, which better realized its genetic potential - Longzhong 2, Longzhong 3, DF529, Longzhong 4, Longzhong 7, Shijiazhuang 8, Longzhong 10 , Longzhong 12. These varieties are recommended to breeding institutions of Ukraine as valuable original source for the creation of new genotypes for intensive agricultural technologies. The studied samples proved to be highly intensive in the growing region (b_i = 0.9-1.4), extensive varieties (b_i = from minus 0.3 to minus 4.5). The study also revealed high stability (S^2di = 0.2) and homeostasis (Hom = from 54.5 to 868.4) among the analyzed samples.

A repeated experiment was conducted between 2018 and 2021 in the Left-Bank region of the Forest-Steppe in Ukraine, in accordance with organic farming conditions. The study focused on the 12 best varieties of Chinese origin identified in previous research. They represented the following groups: semi-dwarf (60-85 cm) and short-stemmed (85-105 cm) genotypes. The varieties Longzhong 4, Longzhong 8, Zhongsi 1048 turned out to be significantly better than the standard variety Podolianka according to the number of grains in an ear. Longzhong 3, Longzhong 9, Longzhong 10, Longzhong 12, RS 6076, Zhongsi 1048, DF401 were the best by weight of 1000 seeds. The genotypes – Longzhong 4, Longzhong 8, Longzhong 9, Longzhong 12, RS 6075, RS 6076, Zhongsi 1048, DF 40 showed significantly better weight of grains from the ear than the standard. Longzhong 8, Longzhong 12, RS 6075, RS 6076 were distinguished by complex resistance (above 7.0) to phytopathogens - causative agents of septoria disease, powdery mildew, brown leaf rust. According to the yield, at the level of average population meaning there were the varieties DF401, Zhongsi, 1048, RS 6076, RS 6075, Longzhong 12, Longzhong 9, Longzhong 8, Longzhong 4. According to indexes of homeostaticity, stability, breeding value, plasticity these genotypes are suitable for creating new varieties adapted for growing under organic farming conditions. The best genotypes of wheat varieties from China were transferred to the National Center of Genetic Resources of Ukraine and breeding institutions..

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