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Breeding value and homeostaticity of the spike performance and its constituents in medium tall winter bread wheat (*Triticum aestivum* L.) accessions in relation to resistance to the pathogens of powdery mildew (*Blumeria graminis* (DC.) E.O. Speer f. sp*. tritici* Em. Marchal) and Septoria leaf blotch (*Septoria tritici* Rob. et Desm.)

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Identification of sources of group resistance in winter bread to the pathogens *B. graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal and *S. tritici* Rob. et Desm. and of high performance of the spike and its constituents is a necessary and relevant step towards the creation of comprehensively valuable and adaptable genotypes. The paper presents the results of evaluation of the breeding value and homeostaticity of the spike performance and its constituents in medium tall winter bread wheat in relation to resistance to powdery mildew and Septoria leaf blotch. New sources of consistently high group resistance to the powdery mildew and Septoria leaf blotch pathogens have been identified: Kyivska 17, Zorianka, Sicheslava, and Svitiaz (UKR). We have selected accessions with high performance of the spike and its constituents in combination with high breeding value and homeostaticity of these characteristics: the kernel weight per spike (Kyivska 17 (Sc = 1.8; Hom = 21.9) (UKR)); the kernel number per spike (Svitohliad (Sc = 37.8; Hom = 554.1), Stritenska (Sc = 36.4; Hom = 452.5), Svitiaz (Sc = 35.8; Hom = 451.8), MIP Lada (Sc = 33.6; Hom = 572.7) (UKR), and Manella (Sc = 33.1; Hom = 460.8) (NLD)); and the thousand kernel weight (Kyivska 17 (Sc = 42.9; Hom = 1053.7), Sicheslava (Sc = 42.6; Hom = 873.2) (UKR), and Turanus (Sc = 41.3; Hom = 707.5) (AUT)). It was found that the percentage of accessions with high homeostaticity of the thousand kernel weight, the kernel number per spike and the kernel weight per spike was 63.6%, 31.8%, and 22.7%, respectively. In the medium tall winter bread wheat accessions, there were strong positive correlations between the breeding value of the kernel weight per spike and resistance to Septoria leaf blotch ($r = 0.77$, $P < 0.01$) and between the kernel number per spike and resistance to powdery mildew ($r = 0.71$, $P < 0.01$). Significant positive correlations were observed between the breeding value of the thousand kernel weight and resistance to Septoria leaf blotch ($r = 0.61$, $P < 0.01$), between the homeostaticity of the thousand kernel weight and resistance to Septoria leaf blotch ($r = 0.51$, $P < 0.01$) and between the breeding value of the kernel number per spike and resistance to Septoria leaf blotch ($r = 0.56$, $P < 0.01$). The selected sources of high group resistance to powdery mildew and Septoria leaf blotch, high performance of the spike and its constituents in combination with the breeding value and homeostaticity of these traits are valuable starting materials to create highly promising winter bread wheat cultivars, which would be adaptable to limiting biotic factors.

Key words: *winter bread wheat, epiphytotic, spike performance, breeding value, homeostaticity, source.*

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Introduction

The effectiveness of agrarian production intensification is determined by successful breeding in terms of increased performance, adaptability and quality of agricultural crops, including winter bread wheat. Among the existing diversity of cereals, common wheat (*Triticum aestivum* L.) plays a rather important role in ensuring the food security in many countries due to its nutritional value and various uses (Gulyanov, 2003; Cherenkov et al., 2014; Ning, Wang, 2018).

The breeding values for major constituents of the yield, which include the number of productive stems per unit area, the kernel weight per spike, the kernel number per spike, and the thousand kernel weight are crucial for increasing the gross yield of grain (Gulyanov, 2003; Samofalov, 2005). Spike performance (kernel weight per spike), as an integrated trait, is determined by expression of its constituents, which are influenced by environmental stressors at different stages of ontogenesis. Kernel weight per spike is closely correlated with the kernel number per spike and is moderately correlated with the thousand kernel weight (Samofalov, 2005). It is also known that, in medium tall and semi-dwarf accessions, the percentage of sources with high breeding value (Sc) for yield is 50% and 385 %, respectively (Yarosh, Riabchun, 2021).

Harvesting high and stable yields as well as realizing the genetic potential of performance is limited by different biotic and abiotic factors of the environment (Morhun et al., 2014). Among the biotic factors, fungal diseases play the leading role, as losses from them may amount to 25–50 % (Trybel, 2006; Retman, 2007; Morhun et al., 2014). Application of different fungicides to control foliar diseases enhances the pesticide load, contributing to environmental pollution and emergence of new pathogen races (Kang et al., 2020; Li et al., 2020). Through the lens of the need for ecologically safe products in the global market, alternative plant protection, which is based on introduction of new cultivars with genetic resistance to pathogens of foliar diseases, is becoming increasingly relevant, as it has a number of economic and ecological advantages (Liu et al., 2017; Petrenkova et al., 2018; Wu et al., 2021).

The most common foliar diseases of winter bread wheat in Ukraine include powdery mildew and Septoria leaf blotch, which are caused by *Blumeria graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal and *Septoria tritici* Rob. et Desm., respectively (Retman, 2007; Afanasieva et al., 2010). Symptoms of these diseases largely depend on the resistance of a genotype to the pathogens as well as on the hydrothermal conditions in spring and summer, which can contribute to the development and spread of fungal infections and epiphytotics (Yevtushenko et al., 2004). *B. graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal is an obligate highly specialized parasite, which develops mainly on young plants that grow and develop intensively. Its systematics is as follows: class Ascomycetes, order Erysiphales, family Erysiphaceae. The systematics of *S. tritici* Rob. et Desm. is as follows: class Deuteromycetes, order Sphaeropsidalec, family Sphaeropsidaceae. By nutrition type, it is a facultative parasite, which is able to develop saprotrophically until plant remains macerate completely (Retman, 2007).

Among the existing genetic diversity of *T. aestivum* L., there are genotypes with group resistance to pathogens (Afanasieva et al., 2010; Petrenkova et al., 2018; Khomenko, Sandetska, 2018; Pilet-Nauel et al., 2017). However, because of adaptation of the pathogen to the host plant, the pathogen race composition changes, so plant cultivars become susceptible; therefore, the search for new sources of resistance to pathogens should be routine and continuous (Shylyna, Hushcha, 2004; Ning, Wang, 2018; Qie et al., 2019; Kang et al., 2020).

The stability of physiological processes that are influenced by environmental conditions reflects the level of homeostasis, which is understood as the ability of a genotype to minimize the effects of environmental stressors (Khangildin, 1979; Kochmarskyi et al., 2016). It is closely related to variability, which is characterized by the ability of organisms to acquire new traits during individual development and is the cause of inter-individual variations in a species. By evaluating the homeostaticity (Hom) and breeding value (Sc), researchers revealed that the higher they were, the more stable and important the genotype was under changing conditions of cultivation (Demydov et al., 2019).

Therefore, the identification of sources of group resistance to *B. graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal and *S. tritici* Rob. et Desm. and of high performance of the spike and its constituents is a necessary and relevant step towards the creation of comprehensively valuable and adaptable genotypes. Despite the considerable number of studies, issues regarding the breeding value and homeostaticity of the spike performance and its constituents in medium tall winter bread wheat in relation to resistance to the pathogens of powdery mildew and Septoria leaf blotch remain open to date.

Our purpose was to determine the breeding value and homeostaticity of the spike performance (kernel weight per spike) and its constituents (kernel number per spike and thousand kernel weight) in medium tall winter bread wheat accessions in relation to resistance to the pathogens of powdery mildew and Septoria leaf blotch as well as to select sources of group resistance to these pathogens and high performance of the spike.

Materials and methods

Twenty-two medium tall winter bread wheat (*Triticum aestivum* L.) accessions were investigated. They come from nine countries: nine accessions from Ukraine, five from the USA, two from Austria, and one each from Poland, Hungary, the Netherlands, Azerbaijan, Turkey, and Canada. The study was conducted in the Laboratory of Genetic Resources of Cereals of the National Center for Plant Genetic Resources of Ukraine (NCPGRU) of the Plant Production Institute named after V.Ya. Yuriev of NAAS in 2017–2020. The experiments were designed in accordance with the requirements of field experiments in breeding (Dospekhov, 1985). The wheat accessions were sown after fallow within the optimal timeframe at the seeding rate of 4,500,000 seeds/ha with a SSFK-7 seeder in plots of 5 m^2 in three replications. In the spring, the plots were fertilized with ammonium nitrate (N_{40}). Podolianka was taken as a check cultivar; it was sown between every 20 accessions. The accessions were evaluated by Merezhko's method (Merezhko et al., 1999) and in compliance with the classifier of the genus *Triticum* L. (CMEA's extended harmonized classifier of the genus *Triticum* L., 1989). Resistance to foliar diseases was evaluated on a 9-point scale, where 1 point represents very low resistance (very severe damage, > 50%), 3 points – low resistance (severe damage, 26–50 %), 5 points – moderate resistance (moderate damage, 5–25 %), 7 points – high resistance (mild damage, < 5%), and 9 points – very high resistance (no damage, 0%).

The homeostaticity (Hom) of the winter bread wheat accessions was determined by Khangildin's method (Khangildin, 1979), which is based on experimentally established patterns of lower variability of the investigated characteristics and their smaller decrease in highly homeostatic accessions under adverse conditions. The breeding value (Sc) was also calculated by this method, which allows one to identify genotypes that combine high or medium yield with its stability under changing conditions of cultivation (Khangildin, 1979). The data were statistically processed, as recommended by B.A. Dospekhov (Dospekhov, 1985). The Chaddock scale (Chaddock, 1952) was used to qualitatively assess the correlation coefficients, i.e. the strength of the correlations between the traits under investigation.

In order to achieve the purpose, we used the following methods: general scientific (analysis and synthesis) – for differentiation and generalization of the obtained results, field – for evaluation of the resistance of the accessions to the fungal pathogens, and dispersive – for determination of the breeding value and homeostaticity of the spike performance and its constituents as well as for determination of the significance of the experimental data.

Results and Discussion

Having analyzed the weather conditions during the growing periods in 2017–2020, we can conclude that various values of the hydrothermal coefficient (HTC) contributed to the differentiation of the winter bread wheat accessions by resistance to the pathogens of foliar diseases and by spike performance constituents. The autumn was very dry in 2018 (HTC = 0.49) and rather wet in 2017 (HTC = 1.09) and 2019 (HTC = 1.46). The meteorological conditions during the spring and summer vegetation periods of the study differed significantly in terms of wetting and temperature: very dry in 2018 (HTC = 0.42), sufficiently wet in 2019 (HTC = 0.98) and excessively wet in 2020 (HTC = 1.66).

2019 and 2020 were the favorable years for high values of the kernel weight per spike, the kernel number per spike and the thousand kernel weight. In 2018, their levels were mostly lower than in the previous years. 2020 was the most suitable year to select sources of resistance to powdery mildew (*B. graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal) and Septoria leaf blotch (*S. tritici* Rob. et Desm.); in 2019, the background was slightly less suitable for evaluating resistance to foliar diseases; and 2018 showed the lowest differentiation capacity.

Thus, the weather during the growing periods allowed for differentiation of the medium tall winter bread wheat accessions by group resistance to the pathogens of powdery mildew and Septoria leaf blotch, kernel weight and number per spike, and thousand kernel weight as well as for determination of their breeding values and homeostaticity in relation to resistance to the foliar disease pathogens in the Eastern Forest-Steppe of Ukraine.

In 2017–2022, the resistance of the investigated winter bread wheat accessions to the pathogens of powdery mildew and Septoria leaf blotch ranged 1 to 9 points. As a result of the study, we selected eight winter bread wheat sources with high resistance to powdery mildew (7–9 points), i.e. 36.4% of the studied sample. They were Kyivska 17, Zorianka, Sicheslava, Stritenska, Svitiaz, MIP Darunok (UKR); Dominikus (AUT); and Manella (NLD) (the resistance of Podolianka, the check cultivar, was estimated as 6 points) (Table 1). Of the studied accessions, the following ones were moderately resistant (4–6 points): Svitohliad, MIP Lada, Henichanka (UKR); MV Sed (HUN); Turanus (AUT); Loma (USA); and Broadview (CAN), which accounted for 31.8%. Seven cultivars (31.8%), viz: Smuga (POL); Ruzi 84 (AZE); Yayla 302 (TUR); Northern, Judee, Vanguard, and Vargorse (USA), were susceptible (1–3 points) to *B. graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal.

The coefficient of variation (CV, %) showed that the variability of resistance to the powdery mildew pathogen ranged 5.9% to 96.4%. Having analyzed the variation series, we revealed that low variability (CB ≤ 10.0%) was intrinsic to Kyivska 17, Zorianka, Sicheslava, Stritenska, Svitiaz (UKR), and MV Sed (HUN), accounting for 27.3% (Table 1). Four cultivars (18.2%) were moderately variable (CV = 11.0% – 20.0%), viz: MIP Lada, Svitohliad, MIP Darunok (UKR), and Dominikus (AUT). High variability (CV > 20.0%) was recorded for Henichanka (UKR); Smuga (POL); Turanus (AUT); Manella (NLD); Ruzi 84 (AZE); Yayla 302 (TUR); Northern, Judee, Warhorse, Vanguard, Loma (USA), and Broadview (CAN).

Table 1. Resistance of the medium tall winter bread wheat accessions to the pathogens of powdery mildew (*B. graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal) and Septoria leaf blotch (*S. tritici* Rob. et Desm.), 2017–2020

Accession	Country of origin	Resistance to the pathogens, score							
		Powdery mildew				Septoria leaf blotch			
		Range of variation series		$\bar{\bar{X}}$	CV, %	Range of variation series		$\bar{\bar{X}}$	CV, %
		max	*min*			*max*	*min*		
Podolianka [1)]	UKR	8.0	5.0	6.3	24.1	6.0	4.0	5.0	20.0
Kyivska 17	UKR	9.0	8.0	8.5	5.9	8.0	7.0	7.3	7.9
Zorianka	UKR	9.0	8.0	8.5	5.9	8.0	7.0	7.7	7.5
Sicheslava	UKR	9.0	8.0	8.3	6.9	8.0	7.0	7.3	7.9
Stritenska	UKR	9.0	8.0	8.3	6.9	7.0	5.0	5.7	20.4
Svitiaz	UKR	8.0	7.0	7.3	7.9	9.0	8.0	8.3	6.9
MIP Darunok	UKR	8.0	6.0	7.0	14.3	8.0	6.0	7.0	14.3
MIP Lada	UKR	7.0	5.0	6.0	16.7	9.0	5.0	7.0	28.6
Svitohliad	UKR	7.0	6.0	6.0	16.7	6.0	4.0	5.2	20.2
Henichanka	UKR	6.0	4.0	5.2	20.2	4.0	1.0	2.3	65.5
Smuga	POL	3.0	2.0	2.7	21.7	6.0	4.0	5.0	20.0
MV Sed	HUN	7.0	6.0	6.3	9.1	4.0	2.0	3.0	33.3
Dominikus	AUT	9.0	7.0	8.0	12.5	9.0	8.0	8.3	6.9
Turanus	AUT	7.0	5.0	5.7	20.4	8.0	7.0	7.7	7.5
Manella	NLD	9.0	6.0	7.3	20.8	5.0	3.0	4.3	26.7
Ruzi 84	AZE	3.0	1.0	2.0	50.0	4.0	3.0	3.3	17.3
Yayla 302	TUR	5.0	1.0	3.2	71.2	6.0	3.0	4.0	43.3
Loma	USA	7.0	5.0	6.0	26.7	4.0	1.0	2.3	65.5
Northern	USA	7.0	1.0	3.3	96.4	4.0	2.0	2.7	43.3
Judee	USA	6.0	1.0	3.3	75.5	5.0	2.0	3.0	57.7
Vanguard	USA	4.0	2.0	3.3	34.6	7.0	5.0	6.0	16.7
Warhorse	USA	3.0	1.0	2.0	50.0	7.0	5.0	6.0	16.7
Broadview	CAN	5.0	3.0	4.3	26.7	6.0	1.0	3.3	75.5
$LSD_{0.05}$		–	–	0.9	–	–	–	0.8	–

Note: [1)] check cultivar.

The percentage of accessions with considerable variability in resistance to the powdery mildew pathogen was determined to be 54.5%. The powdery mildew resistance variability in Podolianka (check cultivar) was considerable (CV = 24.1%).

High resistance to Septoria leaf blotch (7–9 points) was noted in eight cultivars, accounting for 36.4% of the tested sample. These were MIP Darunok, MIP Lada, Kyivska 17, Sicheslava, Svitiaz, Zorianka (UKR); Turanus, and Dominikus (AUT) (Podolianka's resistance was 5 points). Low-medium to high-medium resistance (4–6 points) was observed in Svitohliad, Stritenska (UKR); Smuga (POL); Manella (NLD); Yayla 302 (TUR); Vanguard, and Warhorse (USA), accounting for 36.4%. Henichanka (UKR); MV Sed (HUN); Ruzi 84 (AZE); Northern, Loma (USA), and Broadview (CAN), accounting for 31.8%, were susceptible (1–3 points) to *S. tritici* Rob. et Desm.

The variability in resistance to *S. tritici* Rob. et Desm. (CV, %) was 6.9–75.5 %. Analysis of the variation series showed that Kyivska 17, Zorianka, Sicheslava, Svitiaz (UKR), Dominikus, and Turanus (AUT) were little variable (CV ≤ 10.0%); their percentage was 27.3% (Table 1). Five cultivars (22.7%) were moderately variable (CV = 11.0% – 20.0%) in terms of resistance to *S. tritici* Rob. et Desm.; they were MIP Darunok (UKR); Smuga (POL); Ruzi 84 (AZE) Vanguard, and Warhorse (USA).

High variability (CV > 20.0%) was noted for Svitohliad, Stritenska, MIP Lada, Henichanka (UKR); MV Sed (HUN); Manella (NLD); Yayla 302 (TUR); Northern, Judee, Loma (USA), and Broadview (CAN). The percentage of accessions with considerable variability in resistance to *S. tritici* Rob. et Desm. was 50.0%. The variability in resistance to Septoria leaf blotch in Podolianka (check cultivar) was medium (CV = 20.0%).

As a result of the study, based on low levels of variability, we identified sources of high and stable resistance to the pathogens of powdery mildew and Septoria leaf blotch in the tested group of medium tall winter bread wheat accessions. These include Ukrainian accessions: Kyivska 17, Zorianka, Sicheslava, and Svitiaz.

In order to determine the breeding value and homeostaticity of the spike performance and its constituents in the medium tall winter bread wheat accessions in relation to resistance to the pathogens of powdery mildew and Septoria leaf blotch, we evaluated the accessions differentiated by resistance to these pathogens for kernel weight and number per spike and thousand kernel weight.

Owing to the 2017–2020 study of the medium tall winter bread wheat accessions, we identified sources of high performance of the spike (kernel weight per spike > 2 g): Svitiaz, Zorianka, Sicheslava, Kyivska 17, Svitohliad (UKR); and Dominikus (AUT) (in Podolianka, the check cultivar, this parameter was 1.9 g) (Table 2). The kernel weight per spike ranged 1.4 to 2.3 g across the tested sample.

We revealed that the breeding value (Sc) for the kernel weight per spike was 0.9–1.8, while the homeostaticity (Hom) varied 6.4 to 24.5 in the medium tall accessions. Having evaluated the breeding values of the medium tall winter bread wheat accessions, we selected sources with values above the mean of the experiment (Sc = 1.4): Kyivska 17 (Sc = 1.8), Svitiaz (Sc = 1.7), Zorianka (Sc = 1.7), Sicheslava (Sc = 1.7), Stritenska (Sc = 1.5), MIP Gift (Sc = 1.5) (UKR); Turanus (AUT); Vanguard (Sc = 1.7), and Warhorse (Sc = 1.7) (USA) (for Podolianka, the check cultivar, Sc = 1.4) (Table 2). Therefore, the proportion of sources selected by breeding value for the kernel weight per spike was 40.9%.

The ability of a genotype to maintain low variability of a trait during the study period is the criterion of its homeostaticity. The close relationship between homeostaticity (Hom) and coefficient of variation (CV) clearly reflects the trait's stability under changing environmental conditions. The medium tall accessions that were highly homeostatic (CV ≤ 10.0%) in terms of the kernel weight per spike included Kyivska 17 (Hom = 21.9) (UKR); Warhorse (Hom = 24.5), Vanguard (Hom = 23.1), Judee (Hom = 22.5), and Northern (Hom = 18.6), (USA), accounting for 22.7%.

Medium homeostaticity (CV = 11.0% – 20.0%) was recorded for Sicheslava (Hom = 18.7), Zorianka (Hom = 16.3), Svitiaz (Hom = 15.9), Stritenska (Hom = 15.4), MIP Darunok (Hom = 12.9), Svitohliad (Hom = 11.1) (UKR); MV Sed (Hom = 12.9) (HUN); Turanus (Hom = 13.6), Dominikus (Hom = 10.9) (AUT); Manella (Hom = 7.5) (NLD); Ruzi 84 (Hom = 10.2) (AZE); and Broadview (Hom = 8.5) (CAN) (for Podolianka, the check cultivar, Hom = 12.1). The percentage of moderately homeostatic accessions in terms of the spike performance was 54.5%.

Low homeostaticity (CV > 20.0%) was observed in five cultivars: MIP Lada (Hom = 9.2), Henichanka (Hom = 7.4) (UKR); Smuga (Hom = 8.3) (POL); Yayla 302 (Hom = 6.4) (TUR); and Loma (Hom = 6.5) (USA), accounting for 22.7%.

Thus, Kyivska 17, a Ukrainian cultivar, is a genotype that is noticeable for high performance of the spike (kernel weight per spike) in combination with its breeding value and homeostaticity. This accession is a valuable starting material to create new breeding-valuable and stable genotypes with high performance of the spike.

The vast majority of the accessions examined (81.8%) had large numbers of kernels per spike (>- 36), viz: Kyivska 17, Svitohliad, MIP Lada, Henichanka, Zorianka, Sicheslava, Svitiaz, MIP Darunok, Stritenska (UKR); Smuga (POL); Turanus, Dominikus (AUT); Manella (NLD); Northern, Judee, Loma, Vanguard, and Warhorse (USA) (the check cultivar, Podolianka had 40.0 kernels per spike) (Table 2). The kernel number per spike varied from 33.8 to 46.7 among the investigated cultivars. The breeding value (Sc) for the kernel number per spike varied from 25.9 to 37.8, while the homeostaticity (Hom) ranged 198.3 to 572.7.

Having assessed the breeding value of the medium tall winter bread wheat accessions for the kernel number per spike, we selected sources, in which the breeding value exceeded the mean of the experiment (Sc = 31.7). These were nine cultivars (40.9%): Svitohliad (Sc = 37.8), Zorianka (Sc = 37.8), Stritenska (Sc = 36.4), Svitiaz (Sc = 35.8), Kyivska 17 (Sc = 34.4), Sicheslava (Sc = 33.8), MIP Lada (Sc = 33.6) (UKR); Dominikus (Sc = 34.8) (AUT); Manella (Sc = 33.1) (NLD), and the check cultivar, Podolianka (Sc = 33.6) (Table 2).

Table 2. Breeding value and homeostaticity of the kernel weight and number per spike in the medium tall winter bread wheat accessions, 2017–2020

Accession	Country of origin	Kernel weight per spike, g						Kernel number per spike					
		max	*min*	$\overline{\overline{X}}$	Sc	CV, %	Hom	*max*	*min*	$\overline{\overline{X}}$	Sc	CV, %	Hom
Podolianka [1)]	UKR	2.2	1.7	1.9	1.4	15.5	12.1	43.5	36.5	40.0	33.6	8.8	457.1
Kyivska 17	UKR	2.3	1.9	2.1	1.8	9.8	21.9	48.0	38.5	42.9	34.4	11.2	381.9
Zorianka	UKR	2.5	1.9	2.2	1.7	13.7	16.3	52.5	42.5	46.7	37.8	11.2	418.5
Sicheslava	UKR	2.4	1.9	2.2	1.7	11.6	18.7	48.5	37.5	43.7	33.8	12.9	339.3
Stritenska	UKR	2.2	1.7	1.9	1.5	12.8	15.4	48.0	39.5	44.2	36.4	9.8	452.5
Svitiaz	UKR	2.5	1.9	2.3	1.7	14.2	15.9	47.5	39.5	43.0	35.8	9.5	451.8
MIP Darunok	UKR	2.1	1.6	1.9	1.5	14.9	12.9	44.0	35.5	40.2	32.4	10.7	374.3
MIP Lada	UKR	2.3	1.6	1.9	1.3	20.3	9.2	40.5	35.5	38.3	33.6	6.7	572.7
Svitohliad	UKR	2.3	1.6	2.1	1.4	18.0	11.1	47.5	40.5	44.3	37.8	8.0	554.1
Henichanka	UKR	2.0	1.4	1.6	1.1	21.7	7.4	42.0	30.5	37.2	26.9	16.1	231.6
Smuga	POL	2.3	1.6	1.8	1.3	22.0	8.3	42.5	32.0	39.2	29.2	15.9	246.9
MV Sed	HUN	1.7	1.4	1.5	1.2	11.6	12.9	42.5	31.0	35.5	25.9	17.3	205.1
Dominikus	AUT	2.3	1.6	2.1	1.4	18.6	10.9	49.0	39.5	43.2	34.8	11.8	364.9
Turanus	AUT	2.3	1.7	2.0	1.5	15.0	13.6	45.0	33.5	40.2	29.9	14.9	270.5
Manella	NLD	1.8	1.3	1.5	1.1	19.7	7.5	42.0	35.5	39.2	33.1	8.5	460.8
Ruzi 84	AZE	1.8	1.4	1.5	1.2	15.1	10.2	38.5	33.0	34.8	29.9	9.1	382.1
Yayla 302	TUR	1.8	1.2	1.4	0.9	22.4	6.4	38.5	31.5	34.0	27.8	11.5	296.0
Loma	USA	1.9	1.3	1.5	1.0	23.1	6.5	40.0	35.0	37.7	32.9	6.7	563.8
Northern	USA	1.6	1.4	1.5	1.3	7.9	18.6	44.5	35.0	40.8	32.1	12.5	326.5
Judee	USA	1.6	1.4	1.5	1.3	6.7	22.5	44.0	33.0	36.3	26.4	18.3	198.3
Vanguard	USA	2.1	1.8	2.0	1.7	8.7	23.1	43.5	32.5	37.3	27.9	15.1	248.0
Warhorse	USA	2.1	1.8	1.9	1.7	7.9	24.5	45.0	33.0	39.0	28.6	15.4	253.5
Broadview	CAN	1.8	1.3	1.5	1.1	17.6	8.5	38.0	31.5	33.8	28.1	10.7	316.5
$LSD_{0.05}$		–	–	0.1	–	–	–	–	–	1.6	–	–	–
min		1,6	1.2	1.4	0.9	6.7	6.4	38.0	30.5	33.8	25.9	6.7	198.3
max		2,5	1.9	2.3	1.8	23.1	24.5	52.5	42.5	46.7	37.8	18.3	572.7
Mean		2,1	1.6	1.8	1.4	15.2	13.7	44.1	35.3	39.6	31.7	11.9	363.8

Note: [1)] check cultivar.

Seven cultivars (31.8%) were remarkable for high homeostaticity (CV ≤ 10.0%) of the kernel number per spike: MIP Lada (Hom = 572.7), Svitohliad (Hom = 554.1), Stritenska (Hom = 452.5), Svitiaz (Hom = 451.8) (UKR); Manella (Hom = 460.8) (NLD); Ruzi 84 (Hom = 382.1) (AZE), and Loma (Hom = 563.8) (USA), while in the check cultivar, Podolianka, Hom = 457.1.

Medium homeostaticity (CV = 11.0% – 20.0%) was intrinsic to 15 accessions, the proportion of which was 68.2%. These were Zorianka (Hom = 418.5), Kyivska 17 (Hom = 381.9), MIP Darunok (Hom = 374.3), Sicheslava (Hom = 339.3), Henichanka (Hom = 231, 6) (UKR); Smuga (Hom = 246.9) (POL); MV Sed (Hom = 205.1) (HUN); Dominikus (Hom = 364.9), Turanus (Hom = 270.5) (AUT); Yayla 302 (Hom = 296.0) (TUR); Northern (Hom = 326.5), Warhorse (Hom = 253.5), Vanguard (Hom = 248.0), Judee (Hom = 198.3) (USA), and Broadview (Hom = 316.5) (CAN). There were no accessions with low homeostaticity (or with considerable variability CV > 20.0%) of the kernel number per spike.

Thus, the accessions with large numbers of kernels per spike, high breeding value and homeostaticity for this characteristic are mainly Ukrainian genotypes: Svitohliad, Stritenska, Svitiaz, MIP Lada (UKR), and Manella (NLD).

Table 3. Breeding value and homeostaticity of the thousand kernel weight in the medium tall winter bread wheat accessions, 2017–2020

Accession	Country of origin	Thousand kernel weight, g					
		max	*min*	$\bar{\bar{X}}$	Sc	CV, %	Hom
Podolianka [1)]	UKR	44.5	39.0	42.2	36.9	6.7	625.4
Kyivska 17	UKR	48.5	44.5	46.8	42.9	4.4	1053.7
Zorianka	UKR	43.5	38.5	41.3	36.6	6.2	665.9
Sicheslava	UKR	49.5	44.5	47.3	42.6	5.4	873.2
Stritenska	UKR	46.5	38.5	42.3	35.1	9.5	446.9
Svitiaz	UKR	47.5	43.5	45.0	41.2	4.8	929.1
MIP Darunok	UKR	48.5	38.8	43.8	35.0	11.1	394.6
MIP Lada	UKR	46.5	41.5	43.7	38.9	5.9	743.2
Svitohliad	UKR	45.5	37.0	41.8	34.0	10.4	400.6
Henichanka	UKR	46.5	38.5	42.3	35.1	9.5	446.9
Smuga	POL	44.0	35.5	40.5	32.7	10.9	369.1
MV Sed	HUN	42.5	34.5	39.0	31.7	10.5	371.6
Dominikus	AUT	45.5	37.5	42.0	34.6	9.7	431.0
Turanus	AUT	49.5	43.5	47.0	41.3	6.6	707.5
Manella	NLD	42.5	31.5	37.3	27.7	14.8	252.3
Ruzi 84	AZE	41.0	32.5	37.2	29.5	11.6	320.4
Yayla 302	TUR	44.5	37.5	41.3	34.8	8.6	481.2
Loma	USA	42.5	38.0	39.8	35.6	5.9	671.0
Northern	USA	39.0	31.5	34.5	27.9	11.5	299.1
Judee	USA	45.5	40.0	42.2	37.1	6.9	606.9
Vanguard	USA	47.0	37.5	43.5	34.7	12.0	362.5
Warhorse	USA	42.0	37.5	39.8	35.6	5.7	703.0
Broadview	CAN	44.5	38.0	41.5	35.4	7.9	525.3
$LSD_{0.05}$		–	–	1.4	–	–	–
min		39,0	31.5	34.5	27.7	4.4	252.3
max		49,5	44.5	47.3	42.9	14.8	1053.7
Mean		45,1	38.2	41.8	35.5	8.5	551.3

Note: [1)] check cultivar.

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Of the accessions under investigation, three cultivars with great weights of thousand kernels (> 46 g) were distinguished: Kyivska 17, Sicheslava (UKR), and Turanus (AUT) (Table 3). The thousand kernel weight variation limits in the studied accessions were from 34.5 g to 47.3 g. The breeding value (Sc) for the thousand kernel weight varied from 27.2 to 42.9, while the homeostaticity (Hom) was within 252. 3 – 1053.7.

We selected sources with values higher than the average breeding value of the experiment (Sc = 35.5) for the thousand kernel weight. These were the following cultivars: Kyivska 17 (Sc = 42.9), Sicheslava (Sc = 42.6), Svitiaz (Sc = 41.2), MIP Lada (Sc = 38.9), Zorianka (Sc = 36,6) (UKR); Turanus (Sc = 41.3) (AUT); Judee (Sc = 37.1), Loma (Sc = 35.6), Warhorse (Sc = 35.6) (USA), and the check cultivar, Podolianka, (Sc = 36.9). The proportion of the selected cultivars was 40.9%.

Fourteen cultivars (63.6%) were characterized by high homeostaticity (CV $\leq$ 10.0%) of the thousand kernel weight: Kyivska 17 (Hom = 1053.7), Svitiaz (Hom = 929.1), Sicheslava (Hom = 873.2) , MIP Lada (Hom = 743.3), Zorianka (Hom = 665.9), Stritenska (Hom = 446.9), Henichanka (Hom = 446.9) (UKR); Turanus (Hom = 707.5), Dominikus (Hom = 431.0) (AUT); Yayla 302 (Hom = 481.2) (TUR); Warhorse (Hom = 703.0), Judee (Hom = 606.9), Loma (Hom = 671.0) (USA); Broadview (Hom = 525.3) (CAN), and the check cultivar, Podolianka, (Hom = 625.4) (Table 3).

Medium homeostaticity (CV = 11.0% – 20.0%) was observed in eight accessions, the proportion of which was 36.4%. These were Svitohliad (Hom = 400.6), MIP Darunok (Hom = 394.6) (UKR); Smuga (Hom = 369.1) (POL); MV Sed (Hom = 371.6) (HUN); Manella (Hom = 252.3) (NLD); Ruzi 84 (Hom = 320.4) (AZE); Vanguard (Hom = 362.5), and Northern (Hom = 299.1) (USA). There were no accessions with low homeostaticity (or with considerable variability CV > 20.0%) of the thousand kernel weight.

Based on the study results, we selected genotypes with large weights of thousand kernels, high breeding value and homeostaticity of this characteristic: Kyivska 17, Sicheslava (UKR), and Turanus (AUT).

Having analyzed relationships between the investigated traits in the medium tall winter bread wheat accessions, we found positive correlations with significance of 99% (P<0.01): very strong – between the breeding value for the kernel weight per spike and resistance to Septoria leaf blotch (r = 0.77), between the kernel number per spike and resistance to powdery mildew (r = 0.71); strong – between the breeding value for the thousand kernel weight and resistance to Septoria leaf blotch (r = 0.61), between the thousand kernel weight homeostaticity and resistance to Septoria leaf blotch (r = 0.51), between the breeding value for the kernel number per spike and resistance to Septoria leaf blotch (r = 0.56); moderate – between the homeostaticity of the kernel number per spike and resistance to powdery mildew (r = 0.47), between the breeding value for the thousand kernel weight and resistance to powdery mildew (r = 0.42), between the thousand kernel weight homeostaticity and resistance to powdery mildew (r = 0.38) (Table 4).

Table 4. Correlations (r) of the breeding value and homeostaticity of the kernel weight and number per spike and the thousand kernel weight with resistance to powdery mildew and Septoria leaf blotch in the medium tall winter bread wheat accessions, 2017–2020

Trait		Kernel weight per spike		Kernel number per spike		Thousand kernel weight	
		Sc	Hom	Sc	Hom	Sc	Hom
Resistance to the diseases	Powdery mildew	0.35 [1)]	0.04	0.71 [2)]	0.47 [2)]	0.42 [2)]	0.38 [2)]
	Septoria leaf blothc	0.77 [2)]	0.32 [1)]	0.56 [2)]	0.21	0.61 [2)]	0.51 [2)]

Note: [1)] P < 0.05; [2)] P < 0.01.

There were moderate positive correlations with 95% significance (P < 0.05) between the breeding value for the kernel weight per spike and resistance to powdery mildew (r = 0.35) as well as between the homeostaticity of the kernel weight per spike and resistance to Septoria leaf blotch (r = 0.32). There were weak positive correlations between the homeostaticity of the kernel number per spike and resistance to Septoria leaf blotch (r = 0.21) as well as between the homeostaticity of the kernel weight per spike and resistance to powdery mildew (r = 0.04).

Thus, to successfully introduce breeding-valuable, promising winter bread wheat cultivars, with high adaptability to biotic environmental stressors, into production, one should to pay special attention to group resistance to the pathogens of the most common foliar diseases of winter bread wheat in Ukraine – *Blumeria graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal and *Septoria tritici* Rob. et Desm.

Conclusions

As a result of this study, new sources of high and stable group resistance to the pathogens of powdery mildew and Septoria leaf blotch were identified: Kyivska 17, Zorianka, Sicheslava, and Svitiaz (UKR). We distinguished the genotypes with high performance of the spike and its constituents combined with the breeding value and homeostaticity of these traits: kernel weight per spike – Kyivska 17 (Sc = 1.8; Hom = 21.9) (UKR); kernel number per spike – Svitohliad (Sc = 37.8; Hom = 554.1), Stritenska (Sc = 36.4; Hom = 452.5), Svitiaz (Sc = 35.8; Hom = 451.8), MIP Lada (Sc = 33.6; Hom = 572.7) (UKR), and Manella (Sc = 33.1; Hom = 460.8) (NLD); thousand kernel weight – Kyivska 17 (Sc = 42.9; Hom = 1053.7), Sicheslava (Sc = 42.6; Hom = 873.2) (UKR), and Turanus (Sc = 41.3; Hom = 707, 5) (AUT). The proportions of medium tall accessions with high homeostaticity of the thousand kernel weight, kernel number per spike, and kernel weight per spike were 63.6%, 31.8%, and 22.7%, respectively.

In the medium tall winter bread wheat accessions, there were very strong positive correlations between the breeding value for the kernel weight per spike and resistance to Septoria leaf blotch ($r = 0.77$, $P < 0.01$) as well as between the kernel number per spike and resistance to powdery mildew ($r = 0.71$, $P < 0.01$). Strong positive correlations were found between the breeding value for the thousand kernel weight and resistance to Septoria leaf blotch ($r = 0.61$, $P < 0.01$), between the thousand kernel weight homeostaticity and resistance to Septoria leaf blotch ($r = 0.51$, $P < 0.01$) as well as between the breeding value for the kernel number per spike and resistance to Septoria leaf blotch ($r = 0.56$, $P < 0.01$).

The selected sources with high levels of group resistance to powdery mildew and Septoria leaf blotch, high performance of the spike and its constituents, combined with the breeding value and homeostaticity of these traits, are valuable starting materials for creating new, highly promising winter bread wheat cultivars that would be adaptable to limiting biotic factors.

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Рівень селекційної цінності та гомеостатичності продуктивності колосу та її структурних елементів у середньорослих генотипів пшениці м’якої озимої (*Triticum aestivum* L.), в залежності від стійкості до збудників борошнистої роси (*Blumeria graminis* (DC.) E.O. Speer f. sp. *tritici* Em. Marchal) та септоріозу листя (*Septoria tritici* Rob. et Desm.)

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У роботі представлені результати вивчення рівня селекційної цінності та гомеостатичності продуктивності колосу та її структурних елементів у середньорослих генотипів пшениці м’якої озимої, в залежності від стійкості до збудників борошнистої роси та септоріозу листя. Виділено нові джерела високої та стабільної групової стійкості до збудників борошнистої роси та септоріозу листя – Київська 17, Зорянка, Січеслава, Світязь (UKR). Визначено генотипи, які відзначаються формуванням високої продуктивності колосу та її структурних елементів у поєднанні із селекційною цінністю та гомеостатичністю даних ознак: маси зерна з колосу – Київська 17 (Sc = 1,8; Hom = 21,9) (UKR); кількості зерен у колосі – Світогляд (Sc = 37,8; Hom = 554,1), Стрітенська (Sc = 36,4; Hom = 452,5), Світязь (Sc = 35,8; Hom = 451,8), МІП Лада (Sc = 33,6; Hom = 572,7) (UKR) та Manella (Sc = 33,1; Hom = 460,8) (NLD); маси 1000 зерен – Київська 17 (Sc = 42,9; Hom = 1053,7), Січеслава (Sc = 42,6; Hom = 873,2) (UKR) та Turanus (Sc = 41,3; Hom = 707,5) (AUT). Визначено, що частка генотипів з високою гомеостатичністю маси 1000 зерен складала 63,6%, кількості зерен у колосі – 31,8% та маси зерна з колосу – 22,7%. Встановлено, що у середньорослих генотипів пшениці м'якої озимої високий позитивний зв'язок мають селекційна цінність маси зерна з колосу та стійкість до збудника септоріозу листя (r = 0,77, P < 0,01), а також кількість зерен у колосі та стійкість до збудника борошнистої роси (r = 0,71, P < 0,01). Значний позитивний зв'язок простежується між селекційною цінністю маси 1000 зерен та стійкістю до збудника септоріозу листя (r = 0,61, P < 0,01); між гомеостатичністю маси 1000 зерен та стійкістю до збудника септоріозу листя (r = 0,51, P < 0,01), а також між селекційною цінністю кількості зерен у колосі та стійкістю до збудника септоріозу листя (r = 0,56, P < 0,01). Виділені джерела високих рівнів групової стійкості до збудників борошнистої роси та септоріозу листя, високої продуктивності колосу та її структурних елементів, у поєднанні із селекційною цінністю та гомеостатичністю даних ознак, є цінним вихідним матеріалом для створення високоперспективних сортів пшениці м'якої озимої, адаптивних до лімітуючого впливу біотичних чинників.

Ключові слова: *пшениця м'яка озима, епіфітотії, продуктивність колосу, селекційна цінність, гомеостатичність, джерело.*

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