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VARIABILITY OF PERFORMANCE AND YIELD CONSTITUENTS IN WINTER BREAD WHEAT ACCESSIONS

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Abstract. This paper is focused on the study of the performance constituent variability in 104 new winter bread wheat cultivars from 10 countries worldwide, which was carried out in 2016-2019 at the Plant Production Institute named after V.Ya. Yuriev of NAAS of Ukraine. Research results revealed that spike length was the least variable parameter depending on the growing conditions (CV = 2.0–19.2%) and that the following characteristics responded most strongly to changes in the growing conditions: kernel number per spike (CV = 3.5–30.6%), spike weight (CV = 2.3–47.1%), and kernel weight per spike (CV = 1.2–55.1%). According to the variability degree, it was established that cv. Ladyzhynka, Polianka, and Apertus were most responsive to changes in the growing conditions, while cv. Dobirna, Darynka Kyivska, MIP Asol, and Cappelle Desprez were stable in terms of expression of the performance constituents and yield.

Key words: winter bread wheat, spike performance constituents, yield, variability.

INTRODUCTION

Wheat with its annual gross harvest of over 780 million tons has become one of the main cereals in the world (USDA, 2022). In our country, wheat has long had the absolute dominant position as the main cereal, satisfying primarily bakery needs. Therefore, performance increasing is one of the mainstreams in winter bread wheat breeding. The yield potential of a cultivar is always used as its most important characteristic; therefore, studies of performance constituents and their influence on yield have been conducted for a long time.

Hence, the creation of highly productive wheat cultivars is the ultimate objective of every breeder, as performance increasing is one of the most difficult challenges associated with its considerable complexity and entanglements.

The yield amount, the most important feature of bread wheat, is determined by plant performance and density. Spike length, spikelet and kernel numbers per spike, spike weight, kernel weight per spike, and thousand kernel weight (TKW) represent the most important constituents of the bread wheat performance. Their expression depends on the genetic characteristics of a cultivar, farming techniques, and weather factors (Tishenko et al., 2018).

Zhemela and Bahan (2007) reported that a very strong variability was intrinsic to the spike length, depending on the weather during the formation of spike parts. Alabushev (2013) also believed that the spike length depended on cultivar features, but that meteorological conditions had a greater impact on this characteristic. However, the data presented by Burlachenko and Sydorova (2022) attested to a slight variability of this characteristic.

The spikelet number per spike is characterized by insignificant variability; the coefficients of variation for this trait expression in the studied cultivars did not exceed 10%, which was confirmed in a study by Lozinskyi (2018). At the same time, according to Bazalii and Boichuk's data (2016), the kernel number per spike depended on the spikelet number and fertile flower number, which greatly decreased under the influence of environmental conditions, causing significant variations in the kernel number per spike.

The kernel number per spike is closely associated with yield and determined by environmental conditions; Khomenko and Shtanko (2019) published data suggesting that there might be considerable variations in this trait. In a study carried out by Bahan et al. (2012), the kernel number per spike represented a significantly variable parameter, with the coefficient of variation of 20.0–25.2%.

The kernel weight per spike is another important constituent of the plant performance. It depends on many factors, in particular on the spike length, kernel number per spike and spike size (test weight), as well as on cultivation conditions, and many scientists demonstrated that enhancement in this characteristic expression was one of the most effective ways to breed more productive wheat cultivars (Orlyuk, 2012).

From Blyzniuk et al.'s data (2019), it is known that TKW depended not only on characteristics of a cultivar, but also on environmental conditions during the growing period and farming techniques. Demydov et al. (2021) found a considerable variability of this parameter depending on hydrothermal conditions. Environmental conditions had also the greatest impact on this parameter according to the experiments performed by Kolomiiets, et al. (2012), Skudra and Ruža (2016), Twizerimana et. al. (2020). However, according to the results obtained by Li et al. (2021), TKW was more dependent on genotype.

Although information on this issue is widely available from studies of many scientists, it is ambivalent. Hence, studies on the variability of the spike performance and yield of new winter bread cultivars are relevant.

Our purpose was to study the variability of spike performance and yield of winter bread wheat.

MATERIALS AND METHODS

The study was carried out in the Laboratory of Genetic Resources of Cereals of the Plant Production Institute named after V.Ya. Yuriev of NAAS of Ukraine in 2016–2019. One hundred and four new winter bread wheat cultivars from 10 countries worldwide were studied. The largest number of cultivars were bred in Ukraine (66), much fewer in Russia (16), Germany (10), Kyrgyzstan (3), Turkey, Romania and France (2 in each), Azerbaijan, Slovakia and Hungary (1 in each).

The cultivars were sown in the experimental fields of scientific crop rotation of the Institute. The soil was black soil. Bare fallow preceded winter bread wheat. The farming techniques were conventional for the Eastern Forest-Steppe of Ukraine. The cultivars were evaluated by traditional methods (Dospehov, 1985; Studying the World Collection of Wheat, 1984; Merezhko et al., 1999) and in compliance with „CMEA Extended Harmonized Classifier of the genus *Triticum L.*" (1989). The cultivars were sown at the seeding rate of 450 seeds/m2 to a depth of 4-6 cm within the optimal timeframe with a SN-10Ts-01 planter in three replications with a plot area of 2 m2. The inter-row distance was 15 cm. Bunchuk was taken as the control cultivar for the intensive and universal groups; Podolianka was the control cultivar for the semi-intensive accessions. The check cultivars were sown between every 20 accessions.

For structural analysis of spikes, material was gathered 1-2 days prior to harvesting for further measurements in the laboratory (spike length, spikelet number per spike, spike weight, kernel weight and number per spike, TKW). The following parameters were calculated from the obtained data: spike density (spikelet number/spike length * 10) and spike performance index (kernel weight per spike/spike weight).

The coefficient of variation was calculated using the following formula:

$$V=\sigma \ / \ M \times 100 \ \%,$$

Where: σ – standard deviation;
M – arithmetic mean.

Variability is considered low if the coefficient of variation (CV) does not exceed 10%, medium if 20%<CV>10%, and high if CV is higher than 20%.

RESULTS AND DISCUSSIONS

The weather varied in the study years. September in 2016 and 2018 had less precipitation (14.7 and 35.5 mm, respectively) compared to the multi-year average (43.5 mm), which negatively affected the emergence, making sprouts uneven. In September 2017, 90.5 mm fell, contributing to the uniform emergence of seedlings on day 10 (Table 1).

Winter wheat plant ceased to vegetate during the tillering phase in November: within the second 10 days in 2016 and 2018, and within the third 10 days in 2017. Vegetation resumed within the third 10 days of March in 2017 and 2019 and in the first 10 days of April in 2018.

May, the month when the vast majority of the cultivars began to form spikes, had a sufficient amount of precipitation (35.6, 43.4, and 50.9 mm in 2017, 2018, and 2019, respectively); temperature in May was 0.7oC lower than the multi-year average in 2017 and 3.8 and 2.3° C higher in 2018 and 2019, respectively.

Table 1. *Weather during the growing period of winter bread wheat*

Month	Temperature, °C				Precipitation, mm			
	2016-2017	2017-2018	2018-2019	Multi-year average	2016-2017	2017-2018	2018-2019	Multi-year average
September	14.9	17.7	18.9	14.5	14.7	90.5	35.5	43.5
October	6.8	8.5	11.4	7.5	52.8	44.3	19.1	39.32
November	0.1	1.1	–0.6	0.6	67.3	60.5	20.8	43.0
December	-5.5	2.4	-3.5	-3.7	48.1	62.9	76.5	43.5
January	-6.5	-3.8	-5.1	-6.5	34.5	48.0	49.8	38.3
February	-4.3	-5.6	-0.8	-5.8	19.5	35.9	4.4	30.5
March	5.1	-3.4	4.2	-0.3	24.5	109.3	7.9	28.3
April	9.5	12.4	11.5	9.6	41.0	20.1	44.5	35.5
May	15.4	19.9	18.4	16.1	35.6	50.9	43.4	43.7
June	20.4	21.6	24.8	20.2	18.6	43.5	15.2	63.3
July	21.7	23.0	21.4	21.4	31.6	28.7	38.8	71.7

During the seed setting, filling and ripening, the temperature was 20.4 and 21.7°C in June and July 2017, respectively; in June and July 2018 – 21.6 and 23.0°C, respectively; and in 2019 – 24.8 and 21.4° C, respectively. The multi-year averages are 20.2 and 21.4°C in June and July, respectively. The precipitation amount in June and July 2017 was 18.6

and 31.6 mm, in 2018 – 43.5 and 28.7 mm, and in 2019 – 15.2 and 38.8 mm, respectively. The multi-year average precipitation amounts are 63.3 and 71.7 mm in June and July, respectively. The weather during this period in 2018 and 2019 was somewhat similar and resulted in shorter spikes with fewer kernels per spike, with less fullness compared to those in 2017.

Therefore, 2017 was more favorable for winter bread wheat cultivation than 2018 and 2019.

Having analyzed spike performance and its constituents in the winter bread wheat accessions under investigation, it was found out that, on average across the study years, SWW 1-904 (TUR) formed the longest spikes (13.5 cm) and Viglanka (SVK) – the shortest ones (7.3 cm). The mean values in the control cultivars, Bunchuk and Podolianka, were 8.3 and 8.7 cm, respectively.

SWW 1-904 (TUR) had the greatest number of spikelets per spike (21.7), and Polianka (UKR) had the smallest number of spikelets per spike (14.7). In the control cultivars, Bunchuk and Podolianka, this parameter was 18.4 and 18.5, respectively.

The highest spike density among the studied cultivars was noted in cv. Zluka (UKR) (25.0 spikelets/10 cm), and the loosest spike was recorded by Chornozerna cultivar (UKR) (15.2 spikelets/10 cm).

In the control cultivars, Bunchuk and Podolianka, this characteristic was 21.3 and 22.5 spikelets/10 cm, respectively.

SWW 1-904 (TUR) had the greatest number of kernels per spike (66), and Obriad (UKR) – the smallest number of kernels per spike (34 pcs). The control cultivars, Bunchuk and Podolianka, had 43 and 49 kernels per spike, respectively (Table 2).

Table 2. *Bread winter wheat spike performance constituents and yield, 2017-2019*

Accession, country of origin	Spike length, cm	Spikelet number per spike	Spike density, spikelets/10 cm	Kernel number per spike	Spike weight, g	Kernel weight per spike, g	TKW, g	Performance index	Yield, g/m2
Intensive, universal									
Bunchuk, control cv.	8.3	18.4	22.5	49	2.2	1.8	36.9	0.80	691
Polianka, UKR	8.4	14.7	17.4	40	2.7	1.9	45.8	0.72	624
Obriad, UKR	7.6	15.9	20.9	34	2.0	1.5	42.3	0.72	749
Hnom, UKR	8.3	16.4	19.8	42	1.9	1.5	36.6	0.79	477
Yunona, RUS	7.7	17.4	22.2	53	2.4	1.9	36.4	0.82	641
Kuma, RUS	8.6	16.2	18.9	41	2.0	1.7	41.0	0.82	570
Vid, RUS	7.7	16.7	21.6	40	2.5	1.7	39.4	0.68	740
SWW 1-904, TUR	13.5	21.7	16.1	66	4.2	3.4	54.2	0.80	433
Viglanka, SVK	7.3	18.1	24.7	45	2.6	2.1	45.8	0.80	712
Gneys, KGZ	9.2	18.8	20.5	51	2.3	1.8	33.4	0.75	601
Semi-intensive									
Podolianka, control cv..	8.7	18.5	21.3	43	2.5	2.1	47.8	0.81	693
Zluka, UKR	7.7	19.3	25.0	41	2.6	2.0	48.8	0.77	711
Serpanok Kyivskyi, UKR	9.4	17.2	18.4	49	2.9	2.4	48.8	0.82	764
Chornozerna, UKR	11.9	18.0	15.2	47	2.9	2.2	46.2	0.76	574
Darynka Kyivska, UKR	8.7	16.1	18.4	42	2.5	1.8	46.7	0.71	903

SWW 1-904 (TUR) had the highest weight of the spike and the kernel weight per spike (4.2 g and 3.4 g, respectively), and the smallest values of these traits were recorded for Hnom (UKR) (1.9 g and 1.5 g, respectively). As to the control cultivars, these parameters were 2.2 g and 1.8 g in Bunchuk, respectively, and 2.5 g and 2.1 g in Podolianka, respectively.

The greatest TKW was recorded for SWW 1-904 (TUR) (54.2 g), and the smallest – for Gneys (KGZ) (33.4 g). In the control cultivars, the corresponding values were as follows: Bunchuk – 36.9 g, Podolianka – 47.8 g.

The highest value of the spike performance index was observed in cv. Serpanok Kyivskyi (UKR), Yunona (RUS), Kuma (RUS) (0.82), while the lowest index was noted for Vid (RUS) (0.68). The control cultivars, Bunchuk and Podolianka, had the index of 0.8 and 0.81, respectively.

Among the studied cultivars, the semi-intensive cv. Darinka Kyivska (UKR) gave the highest yield (903 g/m2), and SWW 1-904 (TUR) was the most low-yielding accession (433 g/m2). The control cultivars, Bunchuk and Podolianka, yielded 691 g/m2 and 693 g/m2, respectively.

Having evaluated the variations of the spike performance and its constituents, it was established that a slight variability of the spike length was typical for more than half of the cultivars (53). The lowest coefficients of variation were recorded for cv. Colonia (FRA) (2.0%), Viglanka (SVK) (2.1%), MIP Asol (UKR) and Dobirna (UKR) (2.3%), Darynka Kyivska (UKR) (2.4%), Gubernator (RUS) and Petrovchanka (RUS) (3.1%). The remaining cultivars (51) showed a moderate variability of this characteristic (Table 3).

The variability of the spikelet number per spike was recorded by 80 cultivars; the lowest values of this trait were recorded by Darynka Kyivska (UKR) (0.7%), Viglanka (SVK) Adele (RUS) (0.8%), and Colonia (FRA) (0.9%). In 24 cultivars, this trait was moderately variable.

Table 3. *Variability of the winter bread wheat cultivars by spike performance constituents and yield, 2017-2019*

Parameter	Number of accessions		
	CV ≤ 10 %	CV 10–20 %	CV ≥ 20%
Spike length	53	51	-
Spikelet number per spike	80	24	-
Spike density	98	6	-
Kernel number per spike	2	48	54
Spike weight	12	12	80
Kernel weight per spike	11	1	92
TKW	50	50	4
Spike performance index	89	15	-
Yield	53	38	13

Spike density in the majority of cultivars (98) showed a low variability; moderate variability of this characteristic was seen in 6 accessions: Fito 542/14 (UKR) (10.2%), Estivus (DEU) (10.6%), Petrovchanka (RUS) (11.3%), Khyst (UKR) (13.3%), and Sotnytsia (UKR) (13.9%).

Cv. Adel (RUS) and Colonia (FRA) showed a low variability of the kernel number per spike (5.0% and 7.1%, respectively). A moderate variability was observed in 48 cultivars, and a high variability – 54 cultivars. Cv. Ortegus and Ponticus (DEU) had the highest coefficient of variation (30.6 and 29.9%, respectively).

The variability of the spike weight and the kernel weight per spike was significant in most of the cultivars, amounting to 20.2–47.1% and 20.1–55.1%, respectively.

The TKW was found to be low-variable in 50 cultivars; the same number of cultivars showed a moderate variability of this characteristic. A high variability was observed in cv. Lehenda Myronivska (UKR) (21.4%), Colonia (FRA) (21.6%), and Talisman (UKR) (21.7%).

The variability of the spike performance index in the majority of cultivars (89) was low (0.3–9.8%). A moderate variability (10.2–16.3%) was observed in the remaining cultivars. The yield was low variable in 53 cultivars, with the lowest coefficients of variation in cv. Colonia (FRA) (1.2%), Feonia (RUS) (1.2%), Obriad (UKR) (1.7%), and Lebidka Odeska (UKR) (1.9%). The highest variation coefficients of the spike performance, indicating a significant variability, were recorded by cv. Apertus (DEU) (34.2%), Arktis (DEU) (26.7%), SWW 1-904 (TUR) (26.7%), and Dalnytska (UKR) (26.0%).

As for the spike performance constituents and yield, the most variable cultivars were Ladyzhynka (CV = 6.88–49.2%), Polianka (CV = 5.59–48.3%), Apertus (CV = 3.27–55.1%), while the least variable ones – Dobirna (CV = 0.80–14.8%), Darynka Kyivska (CV = 0.72–13.1%), MIP Asol (CV = 2.29–14.4 %) and Cappelle Despez (CV = 1.13–11.9 %).

Thus, cv. Ladyzhynka, Polianka, and Apertus are the most responsive to changes in the growing conditions, while cv. Dobirna, Darynka Kyivska, MIP Asol, and Cappelle Desprez are stable in terms of expression of the spike performance constituents and yield.

CONCLUSIONS

Research results established that the spikelet number per spike, spike density, and spike performance index showed the smallest variations year-to year in the winter bread wheat cultivars. In the vast majority of cultivars, the coefficient of variation was low (<10%). Kernel number per spike, spike weight, kernel weight per spike turned out to be the traits that responded most strongly to changes in the growing conditions. Cv. Ladyzhynka, Polianka, and Apertus were revealed to be most responsive to changes in the growing conditions, while Dobirna, Darynka Kyivska, MIP Asol, and Cappelle Desprez were stable in terms of expression of the performance constituents and yield. The semi-intensive cv. Darynka Kyivska distinguished itself by combining a high yield (903 g/m^2) with stable expression the spike performance constituents and yield stability (CV = 0.72–13.1%).

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Conflict of interests

The authors declare that they have no conflict of interests.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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