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VARIABILITY IN INDICATORS OF YIELD ATTRIBUTES OF BREAD SPRING WHEAT COLLECTION SAMPLES IN THE CONDITIONS OF THE FOREST-STEPPE OF UKRAINE

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Topicality. *An important area of spring wheat breeding work is to increase yields by improving head productivity, which is always a relevant area of research.* ***Purpose.*** *To identify the peculiarities in variability of the productivity attributes of bread spring wheat collection samples and to involve them as source material in breeding programmes.* ***Materials and Methods.*** *The research was carried out during 2020–2022 at the V. M. Remeslo Myronivka Institute of Wheat of NAAS of Ukraine. The material for the research was 105 samples of bread spring wheat, the variety Elehiia Myronivska was used as a standard. Laboratory and field, mathematical and statistical methods were used.* ***Results.*** *It was found that the formation of the head length was determined by the genotype and meteorological conditions of the year. During the years of research, the number of kernels per head was characterised by an average level of variability (Cv = 12.2–14.1 %) and varied from 33.6±1.6 to 48.9±1.9 pcs. It should be noted that the average value of grain weight per head was at the level: in 2020 – 1.6±0.08 g, 2021 – 1.5±0.07 g, 2022 – 1.9±0.1 g. The coefficient of variation had an average level of variability of 13.8–14.7 %. It was found that the kernel weight per head depended more on the conditions of the year of cultivation than on genotypic characteristics. Over the years of research, the 1000 grain weight, depending on the genotypes, varied from 29.7±0.7 g in the Stepnaia 50 sample (Kazakhstan) to 43.2±1.4 g in the MIP Oleksandra (Ukraine). The genotypes differed slightly in terms of response rate. The highest range of variation was observed in 2021 (11.7 g), and the lowest in 2020 (6.9 g). It was found that the 1000 grain weight varied depending on the conditions of the year of cultivation and genotype.* ***Conclusions.*** *Samples with a complex of traits are of practical interest for breeding work: MIP Oleksandra, MIP Svitlana, Bozhena, MIP Solomiia, Oksamyt Mironivskyi (Ukraine), Lamys, Amina (Kazakhstan), Matthus, Melissos, Quintus (Germany), Alicia (Czech Republic), BAV 92/SERI (Mexico), Tianmin 198 (People's Republic of China), Licamero (France), which are recommended as parental components for crosses. Determination of the correlation coefficients of phenotypic productivity elements revealed that the yield level is influenced to varying degrees by the elements of the head structure, allowing identification of genotypes for introduction into breeding programmes as source material.*

Key words: *bread spring wheat, collection samples, productivity attributes, yielding capacity, correlation coefficients*

Introduction. Increasing productivity is the main focus of spring wheat (*Triticum aestivum* L.) breeding, so the current research area is the development and implementation of new varieties with high potential for productivity and grain quality, well adapted to changing cultivation conditions [1−8]. Wheat breeding for productivity is challenging because of the complexity of this trait. The development of genetics and breeding is the fundamental direction and the determining powerful biological basis for yield growth [9]. Quantitative productivity traits are controlled by polymeric genes, and the degree of gene expression and development of quantitative traits is largely dependent on environmental conditions. The main elements that affect the yield level are the productive stem density and the head productivity, the values of which are determined by light and temperature conditions, soil moisture supply, etc.

All these factors are closely and constantly interrelated and determine the intensity of plant growth and development at different stages of the growing season, as well as crop producti-

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vity [10]. An important direction in wheat breeding is increasing the grain yield of varieties by improving the head productivity, which has been addressed by breeders in different ways Some associate the head productivity with increased grain number, while others prefer grain size. Breeders may not always be satisfied with the effectiveness of selection for these traits because in most cases they change differently under the influence of environmental conditions. Therefore, for this reason, we need to understand the peculiarities of formation and manifestation of traits, and determine the impact of each trait on the total productivity and establish the relationship between these traits. Breeders' efforts are aimed at developing varieties with a successful combination of high parameters of all the main productivity elements in one genotype, which will maximise grain yield [11–15].

This research was aimed at revealing the peculiarities of variability of the yield attributes of spring wheat collection samples and their involvement in breeding programmes as a source material for the conditions of the Forest-Steppe of Ukraine.

Materials and Methods. The research was conducted at the V. M. Remeslo Myronivka Institute of Wheat of NAAS of Ukraine in 2020-2022. The collection samples of spring wheat were sown with a cassette seeder SKS-6-10 with three repetitions. The plot area was 1 sq. m. The predecessor was soybean. The standard was the Elehiia Myronivska variety, which was sown every 25 numbers. The material for the research was 105 samples of bread spring wheat. Phenological observations were carried out according to the methodology of the State Variety Testing of Crops [16]. The hydrothermal coefficient (HTC) was calculated to qualitatively characterise the favourable environmental conditions and the formation of plant productivity, which was determined by the method of G. T. Selianinov [17]. The statistical parameters were calculated according to the method of breeding experiment (in crop production) [18].

Results and Discussion. During the study period (2020–2022), hydrothermal conditions differed from long-term averages in terms of temperature, precipitation and their distribution in certain stages of plant growth and development. It is known that the intensity and time of precipitation in spring and summer determines the level of spring wheat yield. The average daily temperature during the sowing - seedling period ranged from +5.8 °C (2020) to +7.8 °C (2022) compared to the long-term average of +7.1 °C (Table 1). The amount of precipitation during this period plays an essential role in getting good sprouts, so a shortage of moisture can significantly affect the subsequent harvest. In general, the amount of precipitation was sufficient to obtain good sprouts, although their amount (16.6 mm) in 2020 was lower compared to the average long-term average (37 mm). The hydrothermal coefficient corresponded to a sufficient moisture content (1.18) in 2020 and excessive moisture content in 2021 and 2022 (2.72 and 3.02, respectively).

The temperature regime during the period of seedling – stem elongation in 2020 was lower (+11.3 °C) and was equal to the average long-term indicators (+12.5 °C) in 2022. Moisture availability during this period was characterised by excessive moisture content in 2020, 2021 (HTC = 2.64; 2.38, respectively) and optimal moisture content in 2022 (HTC = 1.35).

During the stem elongation – heading period, the temperature regime was lower than the long-term average (+16.4 °C) in 2020 (+12.6 °C) and higher in 2021 and 2022 (+18.0 and +19.8 °C, respectively). The amount of precipitation over the years of research was below the long-term average. The years 2020 and 2021 were excessively wet (HTC = 6.63 and 2.73, respectively), and 2022 was dry (HTC = 0.66).

During the years of research, the temperature regime during the heading – full grain ripeness period was higher than the average long-term data.

The amount of precipitation was lower in 2020 and 2022, while excessive precipitation was observed in 2021, which did not contribute to the grain filling of bread spring wheat. The hydrothermal coefficient in 2021 was 2.52, which corresponds to an excessive moisture level, which negatively affected the formation of high-yielding genotypes.

Thus, the meteorological conditions of 2020–2022 were very different, which allowed us to evaluate and identify high-yielding bread spring wheat collection samples.

Promising samples of bread spring wheat were identified by the elements of the spike productivity (Table 2). According to the data

Table 1. Hydrothermal conditions during the growing season of spring wheat, 2020–2022

Period	Parameters	2020	2021	2022	Average long-term data of MIW
Sowing – seedling	Sowing date	12.03	01.04	24.03	-
	Seedling date	5.04	25.04	10.04	-
	Duration, days	25	25	15	-
	Total precipitation, mm	16.6	45.3	42.8	37.0
	∑t (actual), °C	140.7	166.6	141.8	156.5
	Average t, °C	5.8	6.9	7.8	7.1
	HTC	1.18	2.72	3.02	2.36
Seedling – stem elongation	Seedling date	5.04	25.04	10.04	-
	Date of stem elongation	28.05	05.06	25.05	-
	Duration, days	53	42	46	-
	Total precipitation, mm	162.7	133.8	72.1	58.0
	∑t (actual), °C	615.7	562.4	533.0	397.6
	Average t, °C	11.3	12.6	11.2	12.5
	HTC	2.64	2.38	1.35	1.46
Stem elongation – heading	Date of stem elongation	28.05	05.06	25.05	-
	Heading date	3.06	12.06	04.06	-
	Duration, days	7	8	11	-
	Total precipitation, mm	43.2	39.3	13.0	48.0
	∑t (actual), °C	65.2	144.2	195.6	259.3
	Average t, °C	12.6	18.0	18.0	16.4
	HTC	6.63	2.73	0.66	1.85
Heading – full maturity	Heading date	3.06	12.06	04.06	-
	Date of full maturity	10.07	25.07	20.07	-
	Duration, days	38	48	47	-
	Total precipitation, mm	78.8	251.1	92.8	128.0
	∑t (actual), °C	851.3	996.4	957.6	765.8
	Average t, °C	22.4	22.4	20.4	19.6
	HTC	0.93	2.52	0.97	1.67
∑t (actual), C for the active growing season		1672.9	1703.0	1828.0	1579.2
Duration of active growing season, days		98	98	104	-
Growing season, days		123	123	119	-
HTC		1.80	2.49	1.21	1.72

obtained, it was found that the samples formed a longer ear in 2022 (9.6±0.6 cm) compared to 2020 (8.5±0.4 cm) and 2021 (8.4±0.4 cm), which were characterised by high moisture supply during spike formation, which led to the development of a shorter spike. We selected such collection samples as MIP Svitlana (Ukraine) (10.5±0.9 cm), MIP Oleksandra (Ukraine) (10.3±0.8 cm), Melissos (Germany) (10.1±0.8 cm), Matthus (Germany) (10.0±0.8 cm), MIP Solomiia (Ukraine) (10.0±0.8 cm), Oksamyt Myronivskyi (Ukraine) (9.9±0.7 cm), Lamis (Kazakhstan) (9.8±0.7 cm), Amina (Kazakhstan) (9.7±0.7 cm), Quintus (Germany) (9.5±0.6 cm), Tianmin 198 (People's Republic of China) (9.4± 0.6 cm), BAV 92/SERI (Mexico) (9.3±0.5 cm), Matthus (Germany) (9.2±0.5 cm), Licamero (France) (9.1±0.5 cm), which outperformed the Elehiia Myronivska variety-standard (9.0±0.5 cm) by this indicator, which makes it possible to obtain highly productive genotypes.

The coefficient of variation makes it possible to compare the variability of traits, i.e. the degree of phenotypic expression of plant genes depending on environmental conditions. According to the data obtained, the spike length had a slight phenotypic variability (Cv = 6.3–8.1 %) with a range of variation of 4.7–7.7. It was established that the formation of the spike length (quantitative trait) was determined by the

Table 2. Parameters of spike productivity of collection samples of bread spring wheat, 2020–2022

Productivity elements of the spike	Year	Average, X±Sx	Lim (min-max)	Range of variation, R	Coefficient of variation, Cv, %
Spike length, cm	2020	8.5±0.4	5.5−10.2	4.7	7.8
	2021	8.4±0.4	5.3−10.4	5.1	8.1
	2022	9.6±0.6	6.3−13.0	6.7	6.3
Number of kernels per spike, pcs	2020	37.1±1.1	29.3−44.1	14.8	13.4
	2021	33.6±1.0	28.9−43.8	14.9	14.1
	2022	48.9±1.7	39.0−62.7	23.7	12.2
Grain weight per spike, g	2020	1.6±0.08	1.1-1.90	0.8	13.8
	2021	1.5±0.07	1.0-2.0	1.0	14.7
	2022	1.9±0.1	1.3-2.8	1.5	13.6
1000 grain weight, g	2020	34.6±1.0	29.9-36.8	6.9	15.8
	2021	32.7±0.9	27.5-39.2	11.7	16.4
	2022	38.3±1.2	33.1-43.2	9.0	14.9

genotype and meteorological conditions of the year.

An important element of the spike productivity is the number of kernels per spike, which was characterised by an average level of variability (Cv = 12.2–14.1 %). Over the years of research, this trait was at the level of 33.6±1.6–48.9±1.9 kernels with a range of variation of 14.8–23.7. The highest grain content (standard – 40.9 ± 1.3 kernels), on average for three years, regardless of the conditions of the cultivation year, was found in collection samples of spring wheat MIP Oleksandra (Ukraine) (45.4 ± 1.5), Lamis (Kazakhstan) (44.7±1.4), Bozhena (Ukraine) (44.4±1.4), MIP Solomiia (Ukraine) (44.1±1.4), MUCUY (Mexico) (43.7±1.4), MIP Svitlana (Ukraine) (43.5±1.4 pcs.), Quintus (Germany) (42.5±1.3), FITIS (Mexico) (42.1±1.3), Tianmin 198 (People's Republic of China) (41.6±1.3), Tianmin 168 (People's Republic of China) (41.1±1.3), Alicia (Czech Republic) (41.0±1.3), which characterises them as genotypes with a high level of productivity. It was found that the collection samples responded differently to environmental conditions in a certain period of their development and, as a result, all this affected the grain content of the head.

It should be noted that the collection samples formed a significant number of kernels per spike in 2022, which was characterised by more favourable moisture conditions at the stage of grain filling and ripening (HTC = 1.05) compared to dry conditions of 2020 (HTC = 0.93) and excessive moistening of 2021 (HTC = 2.52). The average grain weight per spike was 1.6±0.08 g in 2020, 1.5±0.07 g in 2021, and 1.9±0.1 g in 2021. It was found that this indicator in most of the samples in 2020–2022 exceeded the standard variety by 1.5±0.07 g. The coefficient of variation varied within 13.6–14.7 %, which is confirmed by the limits min – max (0.8–1.5). The following spring wheat samples were identified during the years of research: MIP Oleksandra (Ukraine) (1.9±0.1 g), MIP Svitlana (Ukraine) (1.8±0.1 g), Lamis (Kazakhstan) (1.8±0.1 g), Melissos (Germany) (1.7±0.1 g), Bozhena (Ukraine) (1.7±0.1 g), MIP Solomiia (Ukraine) (1.6±0.08 g), Matthus (Germany) (1.6±0.08 g), Oksamyt Myronivskyi (Ukraine) (1.6±0.08 g), Amina (Kazakhstan) (1.6±0.08 g), Tianmin 198 (People's Republic of China) (1.5±0.07 g), BAV 92/SERI (Mexico) (1.5±0.07 g), which formed the grain weight per spike with a high stability. It was found that genotypic characteristics did not significantly affect the formation of grain weight, which depended to a greater extent on the conditions of the cultivation year.

The highest 1000 grain weight of spring wheat samples was formed in 2022 (38.3±1.2 g) compared to 2020 (34.6±1.0 g) and 2021 (32.7±0.9 g). Over the years of research, this indicator varied depending on the genotypes, ranging from 29.7±0.7 g in Stepnaia 50 (Kazakhstan) to 43.2±1.4 g in MIP Oleksandra (Ukraine), and 33.4±0.8 g in the standard variety. High 1000 grain weight was formed by MIP Svitlana (Ukraine) (43.1±1.4 g), Lamis (Kazakhstan) (42.8±1.4 g), Matthus (Germany) (41.6±1.3 g), Bozhena (Ukraine) (41.2±1.3 g), MIP Solomiya (Ukraine) (40.9±1.3 g), Melissos (Germany) (40.7±1.3 g), Oksamyt Myronivskyi (Ukraine) (40.5±1.3 g), Alicia (Czech Republic)

(40.1±1.3 g), Amina (Kazakhstan) (39.6±1.2 g), BAV 92/SERI (Mexico) (38.5±1.2 g), Tianmin 198 (People's Republic of China) (38.1±1.2 g), Quintus (Germany) (37.9±1.2 g), Licamero (France) (37.8±1.2 g). The calculations of the statistical characteristics of the variability show that it responds to changes in hydrothermal conditions to an average extent. This is confirmed by the coefficient of variation (14.9–16.4 %). The response rate of the genotypes differed slightly. The highest range of variation was observed in 2021 (11.7) that the limits min – max (27.5–39.2) are confirmed, and the lowest – in 2020 (6.9). It was found that the 1000 grain weight varied depending on the conditions of the cultivation year and genotype.

Thus, the collection samples of spring wheat with different ecological and geographical origin by the complex of studied traits represent a practical interest for breeding work: MIP Oleksandra, MIP Svitlana, Bozhena, MIP Solomiia, Oksamyt Mironivskyi (Ukraine), Lamis, Amina (Kazakhstan), Matthus, Melissos, Quintus (Germany), Alicia (Czech Republic), BAV 92/SERI (Mexico), Tianmin 198 (People's Republic of China), Licamero (France), which are recommended as parental components for crossing in breeding programmes for varieties with high productivity potential.

In breeding, the level of variability of quantitative plant traits and the relationships between them play an important role. In experimental studies, perfect functional relationships are not possible with exactly the same dependence of the values of one trait on another; therefore, the study of correlations between valuable economic traits in varieties as a source material for breeding is especially relevant [19]. The correlation between the yield and spike productivity of collection samples were analysed (Table 3).

Table 3. Correlation coefficients (r) of yield with spike productivity elements of bread spring wheat collection samples, 2020–2022

Trait	Spike length	Number kernels per spike	Grain weight per spike	1000 grain weight
Yield	0.33±0.06	0.50±0.10	0.53±0.09	0.44±0.10
Spike length	x	0.62±0.10	0.31±0.06	0.27±0.05
Number kernels per spike	-	x	0.59±0.09	0.29±0.05
Grain weight per spike	-	-	x	0.52±0.10
1000 grain weight	-	-	-	x

The correlation analysis data indicate that there is a moderate relationship between yield and spike length (r = 0.33±0.06), kernel number per spike (r = 0.50±0.10), 1000 grain weight (r = 0.44±0.10); spike length and grain weight per spike (r = 0.31±0.06). A significant correlation was observed between yield and grain weight per spike (r = 0.53±0.09); spike length and number of kernels per spike (r = 0.62±0.10); number of kernels per spike and grain weight per spike (r = 0.59±0.09); grain weight per spike and 1000 grain weight (r = 0.52±0.10). A weak correlation was established between the spike length and the 1000 grain weight (r = 0.27±0.05); number of kernels per spike and the 1000 grain weight (r = 0.29±0.05). Thus, the correlation coefficients of productivity indicators showed that the yield level is variously influenced by the spike attributes. On this basis, we have identified genotypes for their involvement as source material in breeding programmes.

Conclusions. During the period of research in 2020-2022, meteorological conditions were contrasting and differed from long-term indicators in terms of temperature, precipitation and their distribution by months, which allowed evaluating and identifying highly productive collection samples of bread spring wheat. According to the parameters of variability of the productivity elements of the spike, we identified samples of different ecological and geographical origin for their involvement in breeding programmes as source material as follows: MIP Oleksandra, MIP Svitlana, Bozhena, MIP Solomiia, and Oksamyt Myronivskyi (Ukraine), Lamis, Amina (Kazakhstan), Matthus, Melissos, Quintus (Germany), Alicia (Czech Republic), BAV 92/SERI (Mexico), Tianmin 198 (People's Republic of China), Licamero (France). It was established a different degree of phenotypic correlation coefficients between productivity and yield of spring wheat, which is the basis for assessing the influence of individual studied traits on the formation of yield level.

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Актуальність. Важливим напрямком селекційної роботи з пшеницею м'якою ярою є збільшення рівня урожайності, головним фактором якої є підвищення продуктивності колоса, що завжди є актуальним напрямом досліджень. **Мета.** Виявити особливості прояву мінливості елементів структури продуктивності колекційних зразків пшениці м’якої ярої та залучити їх в селекційні програми в якості вихідного матеріалу. **Матеріали і методи.** Дослідження проводили протягом 2020–2022 рр. у Миронівському інституті пшениці імені В. М. Ремесла НААН України. За стандарт використовували сорт Елегія миронівська. Матеріалом для досліджень слугували 105 зразків пшениці м’якої ярої. Використовували лабораторно-польові та математично-статистичні методи. **Результати.** Встановлено, що формування ознаки «довжина колоса» обумовлено генотипом та метеорологічними умовами року. За роки досліджень кількість зерен з колоса відзначилась середнім рівнем мінливості (Cv = 12,2–14,1 %) та змінювалась в межах від 33,6±1,6 до 48,9±1,9 шт. Слід відзначити, що середнє значення ознаки «маса зерна з колоса» знаходилося на рівні: у 2020 р. – 1,6±0,08 г, 2021 р. – 1,5±0,07 г, 2022 р. – 1,9±0,1 г. Коефіцієнт варіації мав середній рівень мінливості (13,8–14,7 %). Встановлено, що маса зерна з колоса більшою мірою залежала від умов року вирощування, аніж від генотипових особливостей. За роки досліджень маса 1000 зерен залежно від генотипів варіювала від 29,7±0,7 г у зразка Степная 50 (Казахстан) до 43,2±1,4 г – МІП Олександра (Україна). За нормою реакції генотипи дещо різнилися між собою. Найвищий розмах варіювання відмічено у 2021 р. (11,7 г), а найменший – 2020 р. (6,9 г). Виявлено, що маса 1000 зерен варіювала залежно від умов року вирощування та генотипу. **Висновки.** Практичний інтерес для селекційної роботи становлять зразки за комплексом ознак: МІП Олександра, МІП Світлана, Божена, МІП Соломія, Оксамит миронівський (Україна), Ламис, Амина (Казахстан), Matthus, Melissos, Quintus (Німеччина), Alicia (Чехія), BAV 92/SERI (Мексика), Tianmin 198 (Китайська народна республіка), Licamero (Франція), що рекомендовані як батьківські компоненти для схрещувань. Визначення коефіцієнтів кореляції фенотипових елементів продуктивності дало змогу виявити, що на рівень врожайності різною мірою впливають елементи структури колоса, це дозволило виділити генотипи для залучення в селекційні програми в якості вихідного матеріалу.

Ключові слова: *пшениця м’яка яра, колекційні зразки, елементи структури продуктивності, урожайність, коефіцієнти кореляції*