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VARIABILITY OF YIELD COMPONENTS IN WINTER WHEAT VARIETIES AND BREEDING LINES UNDER ENVIRONMENT OF THE FOREST-STEPPE OF UKRAINE

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Topicality. *The main task of winter wheat breeding is to increase productivity, therefore, the development and introduction of new varieties of winter wheat with high productivity potential being well adapted to changing growing conditions into agricultural production is an urgent area of research. 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. Breeding work is determined by many factors, among which the search and development of new genetic sources with high performance indicators. Therefore, the peculiarities of yield potential realization and the study of the mechanisms of productivity element formation under changing meteorological conditions are important for establishing the response rate and selecting the most stable productive genotypes and their further involvement in breeding programs.* ***Purpose.*** *To identify the best varieties and breeding lines of winter wheat in terms of productivity elements in the environment of the Forest-Steppe of Ukraine for their involvement in crossbreeding programmes.* ***Methods.*** *Visual – phenological observations; laboratory-field – determination of biometric indicators; mathematical and statistical – establishing the reliability of the obtained data.* ***Results.*** *It was found that the maximum realisation of the yield potential of winter wheat plants by structural elements occurred under optimal growing conditions such as in years with higher moisture availability and sowing on 5 October. Yield formation was significantly influenced by the weather conditions of the year, genotype and unaccounted factors. Sowing dates had a significant effect only on the manifestation of the plant height trait. There was a minor variation (3.8 %÷5.5 %) in plant height in all varieties and breeding lines. Different levels of variability were found for the following traits: number of productive stems varied from Cv=16.4 % (the second sowing date in the dry 2019/20) to Cv=27.6 % (first sowing date in the favourable 2020/21); main spike grain content and thousand grain weight – Cv=10.7÷17.6 % and Cv=8.8÷16.9 %, respectively. Regardless of varietal characteristics, the main spike length had insignificant (Cv=5.6÷8.8 %) phenotypic variability with a range of variation of 0.2–2.0 cm. There were determined the variability levels of traits by the spikelet number per spike (Cv=5.7 %÷ 8.6 %), by grain weight per spike (Cv=13.1÷20.5 %) and per plant (Cv=20.5÷36.3 %).* ***Conclusions.*** *The varieties MIP Assol, Hratsiia MYR, MIP Dniprianka, MIP Yuvileina and breeding lines LUT 55198, LUT 37519 consistently formed a high level of productivity elements regardless of sowing dates and conditions of the growing year, which indicates their high adaptive capacity. They are recommended for breeding programmes as valuable parental components.*

Key words*: productivity parameters, trait, variation, sowing date, year conditions*

Introduction. The development of highly productive grain varieties with stable yields has always been and remains the main task of breeding. Winter wheat (*Triticum aestivum* L.) yield is determined by the nature of the manifestation of structural elements of its productivity, which are highly variable under the influence of biotic and abiotic environmental factors. Results of their formation most fully represent the influence of plant growing conditions in the process of ontogenesis. The main indicators that affect the level of productivity are the productive stem density and the spike productivity, 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 and their productivity [1–4].

Wheat breeding is focused on increasing yield by improving the spike productivity, which has always been a priority and has been addressed by breeders in various ways.

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Some scientists associate the solution to the problem with an increase in the number of kernels, while others prefer grain size. Breeders may not always be satisfied with the effectiveness of selections for these traits, as the level of their manifestation varies under the influence of environmental conditions. Therefore, we need to understand the peculiarities of the formation and manifestation of traits, determine the impact of each trait on total productivity and the relationship between them. The breeders are working to create varieties with a successful combination of high parameters of all the main productivity elements in one genotype, which will maximise grain yield [5–7]. An understanding of the patterns of variability in the manifestation of valuable traits is the basis for breeding work, as it allows us to focus on working with forms that have wide opportunities for improvement.

Research is aimed at selecting the winter wheat varieties and breeding lines by productivity elements for their involvement in breeding programmes as source material in the Forest-Steppe of Ukraine.

Materials and Methods. The research was conducted at the Winter Wheat Breeding Laboratory of the V. M. Remeslo Myronivka Institute of Wheat of NAAS of Ukraine in a breeding crop rotation in 2018/19–2020/21. Contrasting weather conditions during the growing season of winter wheat reflected the instability of climatic conditions in the central Forest-Steppe zone of Ukraine, which allowed obtaining objective results and identifying highly productive winter wheat genotypes by yield structure elements. Agrotechnical practices were in line with the generally accepted recommendations for winter wheat cultivation in this region. Sowing was carried out after the soybean in two dates (on 5 and 15 October). In the full ripeness stage, 25 plants were harvested with roots and structural analysis was carried out in the laboratory for the following elements: plant height, productive tillering, length of the main spike, number of spikelets and kernels per spike, grain weight per spike and per plant, and 1000 seed weight. The material for the research was winter wheat varieties (Podolianka variety-standard, MIP Assol, Hratsiia Myronivska (MIR), MIP Dniprianka, MIP Lada, MIP Yuvileina) and breeding lines (ER 55023, LUT 55198, LUT 37519) of Myronivka selection. Research included the following methods: field (phenological observations, records), laboratory (determination of yield structure indicators), and statistical. A comparative evaluation based on the average values of quantitative valuable traits of the samples was carried out, considering the degree of their variability in response to changes in agroclimatic conditions. The following statistical parameters were calculated: arithmetic mean ($\overline{x}$); minimum (x_{min}) and maximum (x_{max}); range of variation ($R = x_{max} - x_{min}$); coefficient of variation (Cv, %) [8]. The characteristics of environmental conditions for the formation of winter wheat productivity were determined with regard to the hydrothermal coefficient (HTC) according to the method [9].

Results and Discussion. Effective management of winter wheat productivity requires the development of varieties with high genetic yield potential, resistant to abiotic and biotic stressors and able to use favourable environmental conditions. The yield is the result of a complex dynamic equilibrium of numerous processes, the influence of which is multidirectional. The research results evidence a significant effect of both weather conditions and genotype on the formation of yield structure elements (Table 1, 2). Breeding and genetic research pays great attention to plant height, which plays an important role in the formation of a high yield [10]. Depending on the environmental conditions, the manifestation level of the trait varied from 74.0 cm (LUT 37519, ER 55023; for II and I sowing dates in 2019/20, respectively) to 121.4 cm (LUT 55198; for I sowing date in 2020/21). The minimum indicators (74.0±1.04÷96.9±1.14 cm) for both sowing dates were observed in acutely dry (HTC = 0.60) conditions of 2019/20, the adaptive norm (average for the experiment) was the lowest (Table 1, 2).

In favourable 2021, the maximum (88.8±0.82÷121.4±1.16 cm) indicator was at HTC = 1.03. Changes in plant height of varieties and breeding lines depending on the sowing date and weather conditions led to changes in plant groups: MIP Assol, MIP Hratsiia, MIP Yuvileina, LUT 55198, as well as the standard, belonged to the group of medium-stemmed (101–120 cm) in 2019 (5 October, first sowing date) and 2021, and to short-stemmed – in 2019 (the second sowing date) and 2020.

In 2019, 2021, the MIP Dniprianka variety

Table 1. Parameters of variation of yield structure elements of winter wheat varieties (2018/19–2020/21)

Yield structure element	Year of harvest	Sowing date	$\bar{x} \pm sx$[1]	Lim (min÷max)[2]	R[3]	Cv, %[4]	LSD_{05}[5]
Height of plant, cm	2019	5.10	104.5±0.95	100.0–110.0	10.0	3.9	2.62
		15.10	97.5±1.03	89.0–103.0	14.0	4.0	
	2020	5.10	85.9±1.09	75.2–99.0	23.8	5.0	2.48
		15.10	90.1±1.04	83.6–96.9	13.3	4.9	
	2021	5.10	92.5±0.84	105.1–118.7	13.6	3.7	2.02
		15.10	105.3±0.73	92.8–115.3	22.5	3.5	
	$\bar{X}$[6]		**96.3**	**75.2–118.7**	**43.5**	**4.2**	
Number of productive stems, pcs	2019	5.10	4.2±0.20	3.8–4.7	0.9	18.2	0.33
		15.10	4.4±0.18	4.0–5.4	1.4	18.0	
	2020	5.10	3.3±0.13	3.3–3.4	0.2	18.7	0.61
		15.10	3.3±0.14	3.0–3.6	0.6	16.4	
	2021	5.10	3.9±0.22	3.3–4.4	1.1	27.3	0.50
		15.10	4.0±0.17	3.7–4.4	0.7	22.5	
	$\bar{X}$		**3.8**	**3.0–5.4**	**2.4**	**20.2**	
Main spike: length, cm	2019	5.10	10.2±0.17	9.6–10.5	0.9	6.7	0.34
		15.10	10.4±0.18	9.6–11.6	2.0	5.6	
	2020	5.10	8.5±0.09	7.9–8.9	1.0	7.8	0.28
		15.10	8.8±0.10	8.0–9.3	1.3	6.7	
	2021	5.10	9.3±0.12	8.5–9.9	1.4	5.8	2.20
		15.10	9.0±0.15	8.6–9.9	1.3	6.6	
	$\bar{X}$		**9.4**	**7.9–11.6**	**3.7**	**6.5**	
Main spike: number of spikes, pcs	2019	5.10	18.1±0.32	17.8–18.7	0.9	7.5	0.65
		15.10	18.6±0.30	17.0–20.9	3.9	5.7	
	2020	5.10	16.2±0.26	15.8–16.8	1.0	7.4	0.73
		15.10	16.3±0.22	16.2–16.6	0.4	7.5	
	2021	5.10	17.5±0.24	17.2–18.2	1.0	8.0	0.90
		15.10	16.9±0.32	16.1–18.2	2.1	8.1	
	$\bar{X}$		**17.3**	**15.8–20.9**	**5.1**	**7.4**	
Main spike: number of kernels, pcs	2019	5.10	49.7±1.60	45.2–51.3	7.6	12.2	3.32
		15.10	50.5±1.45	44.3–56.5	12.2	13.6	
	2020	5.10	34.9±0.57	31.0–37.3	6.3	14.2	2.44
		15.10	34.0±0.77	32.5–35.5	3.0	13.8	
	2021	5.10	45.7±1.22	42.2–48.8	6.3	10.7	3.92
		15.10	42.7±1.25	37.3–50.2	12.9	13.3	
	$\bar{X}$		**42.9**	**31.0–56.5**	**25.5**	**12.9**	
Main spike: grain weight, g	2019	5.10	2.3±0.06	2.0–2.6	0.6	13.1	0.19
		15.10	2.2±0.07	2.0–2.5	0.5	15.9	
	2020	5.10	1.4±0.04	1.3–1.6	0.3	17.6	0.11
		15.10	1.4±0.04	1.2–1.6	0.4	18.5	
	2021	5.10	1.9±0.07	1.7–2.2	0.5	13.4	0.20
		15.10	1.8±0.08	1.5–2.1	0.6	19.0	
	$\bar{X}$		**1.8**	**1.2–2.6**	**1.4**	**16.2**	
Grain weight per plant, g	2019	5.10	6.0±0.26	5.2–6.4	1.2	20.5	0.77
		15.10	5.9±0.29	5.4–6.4	1.0	20.9	
	2020	5.10	2.9±0.19	2.4–3.6	1.2	30.6	0.51
		15.10	2.9±0.17	2.4–3.7	1.3	29.4	

Table 1 continuation

		15.10	4.8±0.25	4.1–5.7	1.6	36.3	
	X̄		**4.2**	**1.5–6.7**	**5.2**	**27.8**	
1000 grain weight, g	2019	5.10	49.6±1.79	46.7–51.2	4.5	15.3	4.30
		15.10	46.3±1.73	42.9–48.8	5.9	16.9	
	2020	5.10	35.6±0.94	31.8–39.0	7.2	10.4	2.40
		15.10	35.9±0.97	31.8–38.5	6.7	10.3	
	2021	5.10	43.7±1.09	41.7–47.1	5.4	13.1	2.70
		15.10	42.8±1.20	39.1–47.1	8.0	15.9	
	X̄		**42.3**	**31.8–51.2**	**19.4**	**13.6**	

Notes: 1. $\bar{x}$±sx – average; 2. min, max – minimum and maximum values; 3. R – range of variation; 4. Cv – coefficient of variation, %; 5. LSD_{05} – the smallest significant difference at the 95% significance level; 6. $\bar{X}$ – average for 2018/19–2020/21.

had a stem height of 103.0±1.04÷113.2±1.25 cm, and in 2020 – 95.6±1.27 cm. Despite the conditions of the cultivation year, the MIP Lada variety had a plant height of 83.8±0.69÷92.8±0.76 cm at sowing date of 15 October, 103.0±1.33 and 105.1±0.66 cm at sowing date of 5 October in years with sufficient precipitation (2021, 2019), respectively, and 75.2±0.69 cm in the dry year of 2020 (HTC = 0.60). The breeding line LUT 37519 formed a stem with different heights: when sown in the first sowing date its height was 100.0±0.82 cm (2019), 81.0±0.98 cm (2020) and 105.1±0.66 cm (2021), and in the second sowing date it was 86.0±0.86 cm, 74.0±1.04 cm, 92.8±0.76 cm, respectively, evidencing its high sensitivity to environmental conditions. Regardless of the sowing dates in years with optimal moisture supply (2019, 2021), the breeding line ER 55023 was consistently included in the short-stemmed group, and in the dry year 2020 – in the semi-dwarf group (Table 3). Insignificant variation in plant height was revealed in all varieties and breeding lines of winter wheat. The coefficient of variation ranged from 3.4 to 6.6 %, which corresponds to a low variability (Table 1, 2). According to the analysis of variance, the factors "year" and "genotype" had the highest influence on the manifestation of the trait (46.9 % and 29.2 %, respectively), the sowing dates had a significantly less influence (5.9 %).

The number of productive stems per plant varied from 3.0 (ER 55023 and standard; the second sowing date; 2020) to 5.4 (Hratsiia MIR; the second sowing date; 2019). Varieties (Hratsiia MIR, MIP Dniprianka, MIP Lada) and breeding lines (LUT 37519, LUT 55198), with this indicator exceeded the standard at both sowing dates of each year and on average in the experiment, were identified. The Hratsiia MIR variety annually formed the maximum value of the indicator when sown on 15 October, and the LUT 37519 breeding line – on 5 October. The minimum number of productive stems was observed in the breeding line ER 55023 at both sowing dates, except for the first date (5 October) in 2018/19. The biological ability to form a high number of productive stems was in the varieties Hratsiia MIR (4.4±0.18), MIP Dniprianka (4.1±0.18) and the breeding line LUT 37519 (4.1±0.18). The manifestation of the trait at the average level in the experiment (3.8 stems) was observed in the breeding line LUT 55198 (3.9±0.16) and varieties MIP Lada (3.8±0.15), MIP Assol (3.6±0.18). The highest average variability in the number of productive stems was observed in the variety Hratsiia MIR (3.4÷5.4 stems; Cv=22.68 %) and the breeding line LUT 37519 (3.3÷5.1 stems; Cv=22.06 %), the lowest – in EP 55023 (3.0÷4.7 stems; Cv=17.58 %). It was found that the formation of productive tillering was more dependent on the weather conditions of the year (52.3 %) and varietal characteristics (23.6 %) than on the sowing dates. Average level of variability of this trait was in 2018/2019–2019/2020 (except for the second sowing date of 2019 for breeding lines, Cv=22.9 %) and significant level in 2020/2021 (except for the second sowing date for breeding lines, Cv=18.6 %).

Spike productivity is one of the main features that determine the yield of winter wheat and is significantly determined by growing conditions.

Spikes with the greatest length and number of spikelets are formed under moderate air tem-

Table 2. Parameters of variation of productivity structure elements of winter wheat breeding lines (2018/19–2020/21)

Yield structure element		Year of harvest	Sowing date	$\bar{x} \pm sx$[1]	Lim (min÷max)[2]	R[3]	Cv, %[4]	LSD_{05}[5]
Height of plant, cm		2019	5.10	99,3±0,76	90,0–108,0	18,0	3,4	2,66
			15.10	88,0±0,57	86,0–92,0	6,0	4,6	
		2020	5.10	82,7±0,65	74,1–93,0	18,9	6,6	3,62
			15.10	80,1±1,0	74,0–90,1	16,1	5,7	
		2021	5.10	107,4±0,81	95,8–121,4	25,6	3,7	2,44
			15.10	97,4±0,55	88,8–110,6	21,8	4,1	
		$\bar{X}$[6]		**92,4**	**74,0–121,4**	**47,4**	**4,7**	
Number of productive stems, pcs		2019	5.10	4,6±0,19	4,1–5,1	1,0	19,0	0,45
			15.10	4,1±0,13	3,6–4,5	0,9	22,9	
		2020	5.10	3,4±0,14	3,2–3,6	0,4	18,5	0,61
			15.10	3,2±0,13	3,0–3,4	0,4	16,8	
		2021	5.10	3,9±0,21	3,3–4,4	1,1	27,6	0,40
			15.10	3,8±0,16	3,5–4,1	0,6	18,6	
		$\bar{X}$		**3,8**	**3,0–5,1**	**2,1**	**20,6**	
Main spike	length, cm	2019	5.10	10,5±0,19	9,5–11,2	1,7	8,2	0,50
			15.10	10,1±0,16	9,2–10,9	1,7	7,9	
		2020	5.10	7,4±0,13	6,9–8,0	1,1	7,2	0,30
			15.10	7,8±0,16	7,7–7,9	0,2	7,8	
		2021	5.10	9,9±0,19	9,5–10,4	0,9	8,1	3,40
			15.10	9,7±0,15	8,8–10,8	2,0	8,8	
		$\bar{X}$		**9,2**	**6,9–11,2**	**4,3**	**8,0**	
	number of spikes, pcs	2019	5.10	18,6±0,33	17,3–20,4	3,1	7,1	0,83
			15.10	17,8±0,30	16,6–18,7	1,8	6,4	
		2020	5.10	15,4±0,24	15,0–15,9	0,9	6,8	0,81
			15.10	15,3±0,23	15,1–15,6	0,5	8,6	
		2021	5.10	17,7±0,26	17,3–18,3	1,0	7,6	0,82
			15.10	17,4±0,25	16,5–18,4	1,9	8,1	
		$\bar{X}$		**17,0**	**15,0–20,4**	**5,4**	**7,4**	
	number of kernels, pcs	2019	5.10	50,1±1,63	44,0–55,7	11,7	14,4	4,80
			15.10	47,2±1,46	41,5–51,3	9,8	17,6	
		2020	5.10	31,1±0,86	28,1–34,3	6,2	12,9	2,22
			15.10	30,6±1,10	30,1–31,3	1,2	14,0	
		2021	5.10	47,0±1,77	48,0–51,3	3,3	14,5	4,60
			15.10	44,8±1,50	41,5–50,3	8,8	15,9	
		$\bar{X}$		**41,8**	**28,1–55,7**	**27,6**	**14,9**	
	grain weight, g	2019	5.10	2,3±0,09	2,0–2,6	0,6	16,3	0,23
			15.10	2,2±0,09	1,9–2,5	0,6	18,2	
		2020	5.10	1,2±0,04	1,0–1,4	0,4	18,3	0,13
			15.10	1,1±0,05	1,1–1,2	0,1	19,4	
		2021	5.10	2,1±0,09	1,9–2,2	0,3	16,6	0,28
			15.10	2,1±0,07	1,8–2,5	0,7	20,5	
		$\bar{X}$		**2,0**	**1,0–2,6**	**1,6**	**18,2**	
Grain weight per plant, g		2019	5.10	6,1±0,29	5,3–6,7	1,4	20,7	0,75
			15.10	5,8±0,22	5,3–6,3	1,0	20,5	
		2020	5.10	2,0±0,17	1,5–2,4	0,9	26,1	0,47
			15.10	2,0±0,18	1,8–2,1	0,3	28,1	
		2021	5.10	4,5±0,31	3,8–5,2	1,4	34,9	0,90
			15.10	4,8±0,25	4,1–5,7	1,6	36,3	
		$\bar{X}$		**4,2**	**1,5–6,7**	**5,2**	**27,8**	

Table 2 continuation

1000 grain weight, g	2019	5.10	49,6±1,79	46,7–51,2	4,5	15,3	4,30
		15.10	46,3±1,73	42,9–48,8	5,9	16,9	
	2020	5.10	35,6±0,94	31,8–39,0	7,2	10,4	2,40
		15.10	35,9±0,97	31,8–38,5	6,7	10,3	
	2021	5.10	43,7±1,09	41,7–47,1	5,4	13,1	2,70
		15.10	42,8±1,20	39,1–47,1	8,0	15,9	
	$\bar{X}$		**42,3**	**31,8–51,2**	**19,4**	**13,6**	

Notes: 1. $\bar{x}\pm sx$ – average; 2. min, max – minimum and maximum values; 3. R – range of variation; 4. Cv – coefficient of variation, %; 5. LSD_{05} – the smallest significant difference at the 95% significance level; 6. $\bar{X}$ – average for 2018/19–2020/21.

peratures and intense lighting. On average, over the years of research, plants of varieties and breeding lines, as well as the standard, reached an average spike length of 9.3 cm. This trait varied from 7.4±0.10 cm (ER 55023 breeding line; the first sowing date; 2019/20) to 11.6±0.15 cm (Hratsiia MIR variety; the second sowing date; 2018/19). The maximum average values of the indicator, regardless of the sowing date, were in the conditions of 2018/19. The minimum indicators were in 2019/20 against the background of precipitation deficit in April (HTC = 0.35) with a large (12) number of days with air temperature above +10 ºC that accelerated the development of the spike and its elements and negatively affected the spike length. In 2018/19 and 2019/20, the plants of the second sowing date had a longer spike compared to the first one, and in 2020/21 – vice versa. The winter wheat development period from the growth resumption to the beginning of grain filling (III–VIII stage of organogenesis) was the shortest in 2020/21, while the formation of the spike in plants of the second sowing date occurred at a lower average daily air temperature than in the first one. The spike length of the standard (9.3±0.14 cm) exceeded the breeding line LUT 55198 (9.7±0.20 cm) and varieties MIP Dniprianka (9.6±0.14 cm), MIP Lada (9.6±0.16 cm), MIP Assol (9.5±0.11 cm). The MIP Assol variety had the lowest (Cv=5.83 %) degree of variability in the experiment. The minimum spike length (8.6±0.11 cm) was in the short-stemmed breeding line ER 55023. Regardless of the varietal characteristics, this trait had a slight phenotypic variability (Cv=5.6–8.8 %) with a variation range of 0.2–2.0 cm. It was determined that the length of the main spike as a quantitative trait depends on the weather conditions of the year (59.5 %) and genotype (8.4 %).

The formation of the number of spikelets in the spike occurs in the III-IV stages of organogenesis. The trait varied from 15.0±0.26 pcs (LUT 37519; I sowing date; 2019/20) to 20.9±0.25 pcs (Hratsiia MIR; II sowing date; 2018/19). The experimental data revealed that sowing dates had no significant effect on the number of spikelets per spike.

It should be noted that the maximum number of spikelets per spike was in 2018/19 at both sowing dates and reached 18.3 pcs. In the vast majority of the studied varieties and breeding lines, the number of spikelets per spike exceeded the standard (16.9 pcs). The level of variability was weak, which was due to the response rate of the genotype: the maximum (8.27; 8.48 %) was in the standard and the breeding line LUT 55198, respectively, and the minimum (6.53 %) was in the Hratsiia MIR variety. It was found that the formation of the number of spikelets in the main spike was more determined by the conditions of the cultivation year (54.4 %) than by the genotype (10.4 %) and sowing dates (0.5 %).

The number of grains in the main spike is also a significant element of the yield structure. Grain formation occurs at the X stage of organogenesis. Lack of moisture in the VI and IX stages of organogenesis, when plants are very sensitive to adverse weather conditions, leads to a significant deterioration of the spike grain content and a lower yield [10], which was observed in 2019/20: 33.2±1.63 (I sowing date) and 32.9±1.50 (II sowing date), the range of variation was 28.1–36.3 and 30.1–35.5, respectively. Significant reduction in the number of kernels in semi-dwarf breeding lines was observed under moisture deficit within the group of genotypes studied: LUT 37519 (28.1±0.81 pcs; I sowing date and 30.4±1.39 pcs; II sowing

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Table 3. Biometric parameters of winter wheat varieties and breeding lines, average 2018/19–2020/21

Variety, breeding line	Statistical indicator *	Yield structure elements							
		plant height, cm	number of productive stems, pcs.	Main spike				grain weight per plant, g	1000 grain weight, g
				spike length, cm	number of spikelets per spike, pcs.	number of grains per spike, pcs.	grain weight per spike, g		
1	2	3	4	5	6	7	8	9	10
Podolianka standard	X̄[1]	104.4±0.88	3.5±0.16	9.3±0.14	16.9±0.31	41.4±1.07	1.7±0.05	4.1±0.25	42.5±0.83
	max[2]	118.7±1.03	3.9±0.15	10.2±0.20	17.8±0.37	48.9±1.36	2.2±0.07	5.4±0.36	50.2±1.27
	min[2]	91.1±0.83	3.0±0.15	8.5±0.13	16.2±0.36	34.6±0.61	1.5±0.03	2.8±0.25	39.1±0.82
	Cv[3]	3.94	20.57	6.57	8.27	11.67	13.76	28.62	8.79
LUT 55198	X̄	102.5±0.75	3.9±0.16	9.7±0.20	17.5±0.31	44.8±1.48	2.0±0.07	4.6±0.31	45.2±1.23
	max	121.4±1.16	4.5±0.15	10.9±0.22	18.7±0.36	51.3±1.52	2.5±0.08	6.3±0.24	51.0±1.75
	min	90.1±0.99	3.4±0.10	7.9±0.23	15.6±0.33	31.3±1.36	1.2±0.05	2.1±0.20	38.5±0.73
	Cv. %	3.98	21.76	9.61	8.48	15.29	15.71	26.10	12.23
MIP Assol	X̄	101.7±1.45	3.6±0.18	9.5±0.11	17.4±0.28	43.1±1.00	1.9±0.05	4.5±0.26	44.4±0.78
	max	109.7±0.92	4.5±0.26	10.7±0.15	18.2±0.25	50.5±1.12	2.3±0.06	6.2±0.33	48.8±0.87
	min	92.3±1.22	3.2±0.13	8.5±0.08	16.5±0.34	35.0±0.53	1.5±0.03	2.4±0.17	41.8±0.80
	Cv	4.36	20.31	5.83	8.00	10.17	12.96	26.52	8.63
MIP Dniprianka	X̄	103.8±1.09	4.1±0.18	9.6±0.14	17.7±0.28	44.5±1.34	1.9±0.06	4.5±0.27	44.9±1.17
	max	110.0±1.04	4.7±0.27	11.0±0.25	20.0±0.37	54.7±2.06	2.4±0.09	6.4±0.22	52.6±2.23
	min	94.2±1.40	3.4±0.15	8.8±0.10	16.3±0.20	33.5±0.61	1.4±0.04	2.8±0.14	41.2±0.91
	Cv	4.93	21.07	7.04	7.69	14.75	16.75	29.90	12.10
LUT 37519	X̄	89.9±0.85	4.1±0.18	9.2±0.17	17.3±0.27	42.2±1.44	1.9±0.08	4.2±0.23	42.0±1.41
	max	105.1±0.66	5.1±0.20	11.2±0.19	20.4±0.21	55.7±1.43	2.6±0.11	6.7±0.23	51.2±2.03
	min	74.0±1.04	3.3±0.11	6.9±0.09	15.0±0.26	28.1±0.81	1.0±0.04	1.5±0.20	31.8±1.06
	Cv	4.51	22.06	8.19	7.11	15.59	21.56	28.62	16.47
MIP Lada	X̄	91.5±0.96	3.8±0.15	9.6±0.16	17.4±0.23	43.9±1.07	1.8±0.07	4.4±0.22	43.4±1.32
	max	105.1±0.66	4.2±0.15	10.3±0.29	18.3±0.37	50.3±2.04	2.3±0.07	6.3±0.25	51.0±1.65
	min	75.2±1.47	3.3±0.16	8.6±0.10	15.4±0.26	31.0±0.63	1.3±0.05	2.2±0.14	36.6±1.37
	Cv	5.20	19.38	7.34	7.33	13.10	18.68	28.35	14.47

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Table 3 continuation

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
MIP Yuvileina	$\bar{X}$	97.7±0.77	3.6±0.16	9.2±0.13	16.8±0.26	42.0±1.21	1.8±0.06	4.2±0.21	42.9±0.90
	max	112.9±0.49	4.0±0.19	10.0±0.17	17.8±0.33	48.8±1.55	2.2±0.05	5.9±0.25	48.4±0.80
	min	85.9±0.99	3.2±0.14	8.3±0.09	15.9±0.13	34.3±0.81	1.4±0.04	2.5±0.15	39.0±0.87
	Cv	3.73	19.19	6.61	6.78	14.33	17.24	25.13	10.98
Hratsiia MIR	$\bar{X}$	96.1±1.09	4.4±0.18	9.1±0.12	17.4±0.23	42.5±1.21	1.8±0.08	4.0±0.28	43.0±1.26
	max	105.3±0.83	5.4±0.15	11.6±0.15	20.9±0.25	56.5±1.58	2.6±0.05	6.4±0.33	53.2±0.62
	min	82.5±0.91	3.4±0.13	7.9±0.09	15.8±0.29	32.5±0.84	1.2±0.06	2.4±0.15	37.0±0.90
	Cv	4.72	22.68	6.58	6.53	13.09	18.06	29.36	13.21
ER 55023	$\bar{X}$	85.1±0.82	3.5±0.13	8.6±0.11	16.2±0.24	38.3±1.24	1.6±0.06	3.7±0.22	39.7±1.21
	max	95.8±0.62	4.7±0.17	9.5±0.12	17.3±0.26	44.0±1.88	2.0±0.09	5.3±0.30	46.7±1.59
	min	74.1±1.69	3.0±0.18	7.4±0.10	15.1±0.18	30.1±0.56	1.1±0.04	1.8±0.19	31.8±0.77
	Cv	5.55	17.58	6.17	6.71	13.81	17.41	28.61	12.28

*Notes: * – statistical indicators:* $\bar{X}^1$ *– average; max*^{2}*, min*^{2} *– minimum and maximum values; Cv*^{3} *– coefficient of variation, %.*

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date) and ER 55023 (30.9±0.68 pcs; I sowing date and 30.1±0.56 pcs; II sowing date). The varieties and breeding lines of winter wheat, which were sown on 5 October, formed a larger number of grains in the main spike regardless of the weather conditions of the year. According to the average indicator, the standard (41.4 ± 1.07 pcs) and adaptive norm (42.5 pcs) were exceeded by the varieties MIP Dniprianka (44.5±1.34), MIP Lada (43.9±1.07), MIP Assol (43.1±1.00) and breeding line LUT 55198 (44.8±1.48) that characterises them as high productivity genotypes. An average level of variability (Cv = 10.7–17.6 %) was observed for the trait (see Tables 1, 2). It was found that the indicator of spike grain content was significantly influenced by environmental conditions (73.0 %) and varietal characteristics (5.3 %).

The grain weight of the main spike depends on the grain content and on the moisture and nutrients supply, especially carbohydrates, of winter wheat plants. The minimum values at both sowing dates were observed in dry conditions (HTC = 0.88) in the grain filling and ripening stages in 2020. According to the research results, the average value of the trait at both sowing dates was almost at the same level: in 2019 – 2.3 and 2.2 g, in 2020 – 1.3 and 1.3 g, in 2021 – 2.0 and 1.9 g, respectively. The highest grain weight from the main spike was formed by the variety MIP Assol and the breeding line LUT 55198: in 2018/19 – 2.2 g and 2.3 g (I sowing date); 2.3 and 2.5 (II sowing date), respectively; in 2019/20 – 1.5 g and 1.4 g; 1.2 g and 1.5 g, respectively. It should be noted that these genotypes, as well as the standard, under the influence of limiting environmental factors had the lowest variability in the trait. The MIP Assol variety provided high spike productivity by increased grain content and grain size, and the LUT 55198 breeding line had the highest level of these traits on average in the experiment (Table 3). In unfavourable 2019/20, higher grain weight was formed by the standard (1.5±0.03; 1.6±0.03 g) and varieties: MIP Dniprianka (1.6±0.03 g; 1.4±0.04 g), MIP Assol (1.5±0.03 g; 1.5±0.03 g), MIP Yuvileina (1.4±0.04 g; 1.5±0.05 g), confirming their increased drought tolerance. The level of trait variability (Cv=13.1–20.5 %) was average (Tables 1, 2). It was found that sowing dates did not have a significant effect on the formation of grain weight from the main spike, which significantly depended on the weather conditions (66.2 %) and varietal characteristics (7.0 %).

The environmental factor also influenced the grain weight per plant, which varied by years and sowing dates. The highest (6.0 and 5.8 g; I and II sowing dates, respectively) level of the trait was observed in 2018/19, when June (the period of grain formation, filling and ripening) was favourable in terms of precipitation and temperature, and the lowest (2.6 and 2.5 g; I and II sowing dates, respectively) was in the dry 2019/20. The first sowing date prevailed in the number of cases with a high grain weight per plant: in 2018/19 – four, 2019/20 – three, 2020/2021 – seven. In favourable weather conditions, the productivity of the MIP Dniprianka variety did not depend on the sowing dates, and due to the biological peculiarity of the formation of a large (3.4±0.15 pcs) number of productive stems and high (36.3±0.94 pcs) grain content of the spike, it formed the maximum (4.1±0.23 g) grain weight per plant. The varieties MIP Assol (4.5±0.26 g), MIP Dniprianka (4.5±0.27 g), MIP Lada (4.4±0.22 g), MIP Yuvileina (4.2±0.21 g) and breeding lines LUT 55198 (4.6±0.31 g), LUT 37519 (4.2±0.23 g), which exceeded the standard (4.1±0.25 g) by the average trait indicator, were identified. It should be noted that the varieties MIP Assol and MIP Dniprianka prevailed over the standard in favourable years despite the sowing date, and in 2019/2020 – at the first sowing date. A significant (Cv=20.5–36.3 %) level of variability in grain weight per plant was observed in all varieties and breeding lines of winter wheat with a range of variation from 0.3 g to 2.0 g (see Tables 1, 2). We found that the formation of plant productivity is significantly determined by the conditions of the cultivation year (80.6 %) and varietal characteristics (4.2 %).

The highest 1000 grain weight was formed under favourable conditions in 2018/19 at both sowing dates (49.9 and 47.6 g, respectively). It is known that an extremely important period in the winter wheat development is the grain filling stage, when the grain weight and other quality indicators are formed. Air drought during this period reduces grain size.

Therefore, in 2019/20, the minimum (38.1±0.94 g; I sowing term; 38.8±0.84 g; II term) indicator was due to moisture deficit. It should be noted that the largest grain size was in varieties MIP Assol (41.8±0.80; I sowing date; 42.0±0.72 g; II sowing date), MIP Dniprianka (41.4± 0.72 and 41.2±0.91 g, respectively), MIP Yuvileina (39.0±0.87 and 41.5±0.77 g, respectively) at both sowing dates, which indicates their high adaptability in drought conditions. During the years of research, the 1000 grain weight varied from 31.8±0.77 g (breeding line ER 55023; 2019/20; II sowing date) to 53.2±0.62 g (LUT 55198; 2018/19; II sowing date), and in the standard – from 39.1±0.82 g (2020/21; II sowing date) to 50.2 g (2018/2019; I sowing date). Plants formed a higher indicator in favourable conditions at sowing on 5 October, and in dry conditions – on 15 October. There was a significant difference in the 1000 grain weight by sowing dates in the varieties MIP Lada and Podolianka (2018/19), MIP Yuvileina and breeding lines ER 55023, LUT 37519 (2019/20), Hratsiia MIR and ER 55023 (2020/21). The high average 1000grain weight was observed in the varieties MIP Dniprianka (44.9±1.17g), MIP Assol (44.4±0.78g), MIP Lada (43.4±1.32g), Hratsiia MIR (43.0±1.26 g), MIP Yuvileina (42.9±0.90g) and the breeding line LUT 55198 (45.2±1.23g). According to the response rate, the highest (10.3 g) range of variation was observed at the second sowing date (15 October) in 2018/19, and the lowest (3.1 g) – at the first sowing date (5 October) in 2020/21. The level of trait variability was average (Cv=8.8–16.9 %). It was found that the 1000 grain weight varied mostly depending on the conditions of the cultivation year and varietal characteristics, the effect of these factors was 66.6 % and 9.0 %, respectively.

Conclusions. According to our research, it was found that the maximum realisation of the winter wheat potential in terms of productivity structure elements occurred under optimal growing conditions, i.e. in years with higher moisture supply and sowing on 5 October. It was proved that weather conditions of the year, genotype and unaccounted factors significantly influenced the formation of yield structure elements. Sowing dates significantly affected only the plant height. A higher level of variability in productivity traits (except for the number of spikelets in the main spike) was observed in winter wheat breeding lines.

1. Insignificant variation in plant height was found in all varieties and breeding lines of winter wheat. The coefficient of variation ranged from 3.4 % to 6.6 %, which corresponds to a low level of variability.

2. The study proved that the formation of productive tillering was more conditioned by the weather conditions of the year (52.3 %) and varietal characteristics (23.6 %) than by the sowing date. Accordingly, the variability of the number of productive stems was different: from Cv=16.4 % (II sowing date in the dry 2019/20) to Cv=27.6 % (I sowing date in the favourable 2020/21).

3. It was found that the level of variability of the grain content of the main spike and the 1000 grain weight was average (Cv=10.7–17.6 % and Cv = 8.8–16.9 %, respectively).

4. The length of the main spike had insignificant phenotypic variability (Cv=5.6–8.8 %) with a variation range of 0.2–2.0 cm, regardless of varietal characteristics.

5. The level of variability of traits was determined: the number of spikelets was maximum (8.27; 8.48 %) in the standard and breeding line LUT 55198, respectively, and minimum (6.53 %) in the variety Hratsiia MIR; the grain weight per spike was Cv=13.1–20.5 %; the grain weight per plant was Cv=20.5–36.3 % with a variation range from 0.3 g to 2.0 g.

6. We have identified varieties MIP Assol, Hratsiia MIR, MIP Dniprianka, MIP Yuvileina and breeding lines LUT 55198, LUT 37519, having high adaptability, they formed productivity elements with a high stability regardless of sowing dates and growing year conditions. To create new high-yielding winter wheat varieties, it is recommended to include the above varieties and breeding lines in crossbreeding programmes as valuable parental components.

7. Characteristics of formation of plant productivity elements are reliable criteria for solving the basic task in winter wheat breeding – to increase the grain yield potential with consideration of regional climate changes.

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Актуальність. Основною задачею селекції пшениці озимої є підвищення продуктивності, тому актуальним напрямом досліджень є створення та впровадження в сільськогосподарське виробництво нових сортів пшениці озимої з високим потенціалом продуктивності, які добре адаптовані до мінливих умов вирощування. Зусилля селекціонерів спрямовані на створення сортів із вдалим поєднанням в одному генотипі високих параметрів усіх основних елементів продуктивності, що уможливить максимально підвищити врожайність зерна. Селекційна робота визначається багатьма факторами, серед яких першочерговим завданням є пошук і створення нових генетичних джерел з високими показниками продуктивності. Тому особливості реалізації потенціалу врожайності та дослідження механізмів формування елементів продуктивності за мінливих метеорологічних умов мають важливе значення для встановлення норми реакції та добору найбільш стійких продуктивних генотипів і подальшого включення їх у селекційні програми. **Мета.** Виділити в умовах Лісостепу України кращі за елементами продуктивності сорти та селекційні лінії пшениці озимої для їх залучення в програми схрещувань. **Методи**. Візуальний – фенологічні спостереження; лабораторно-польовий – визначення біометричних показників; математично-статистичні – встановлення достовірності одержаних даних. **Результати.** Установлено, що максимальна реалізація потенціалу рослин пшениці озимої за елементами структури врожайності відбувалася за оптимальних умов вирощування – в роки з вищою вологозабезпеченістю та за сівби 5 жовтня. Суттєвий вплив на формування врожайності мали погодні умови року, генотип і невраховані фактори. Строки сівби істотно впливали тільки на прояв ознаки «висота рослин». Відмічено незначне (3,8 %÷5,5 %) варіювання за висотою рослин у всіх сортів і селекційних ліній. Виявлено різний рівень мінливості за ознаками: «кількість продуктивних стебел» від Cv=16,4 % (ІІ строк сівби в посушливому 2019/20 р.) до Cv=27,6 % (І строк сівби у сприятливому 2020/21 р.); «озерненість головного колоса» і «маса 1000 зерен» – Cv = 10,7÷17,6 % і Cv=8,8÷16,9 % відповідно. Незалежно від сортових особливостей довжина головного колоса мала незначну (Cv=5,6÷8,8 %) фенотипову мінливість з розмахом варіації 0,2–2,0 см. Визначено рівень мінливості ознак за кількістю колосків (Cv=5,7 %÷8,6%), масою зерна з колоса (Cv=13,1÷20,5 %) та з рослини (Cv=20,5÷36,3 %). **Висновки.** Сорти МІП Ассоль, Грація МИР, МІП Дніпрянка, МІП Ювілейна та селекційні лінії ЛЮТ 55198, ЛЮТ 37519 стабільно формувалививисокий рівень елементів продуктивності незалежно від строків сівби та умов року вирощування, що свідчить про їх високу адаптивну здатність. Рекомендовано включати їх у програми схрещувань як цінні батьківські компоненти.

Ключові слова: *параметри продуктивності, ознака, варіювання, строк сівби, умови року*