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HEREDITY OF MAIN EAR GRAIN WEIGHT IN F_1 OF SOFT WINTER WHEAT ACCORDING TO GENOTYPE OF INITIAL FORMS AND HYDROTHERMAL CONDITIONS OF THE YEAR

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Abstract

In 2020-2022, the types of inheritance of grain weight of the main ear in F_1 were studied during the hybridisation of short, medium, and tall varieties of soft winter wheat. The obtained hybrids formed a grain weight of the main ear ranging from 1.48 g to 3.01 g, while the parental forms ranged from 1.24 g to 2.05 g. The determined indices of the degree of phenotypic dominance (hp = -23.0 to 273.0) indicate significant differentiation. In most cases, the grain weight of the main spike was inherited with positive superdominance (hp = 1.3 to 273.0), accounting for 86.5% of hybrids. Negative dominance was observed in six hybrids (5.8%), partial positive dominance in four (3.8%), intermediate inheritance in three (2.9%), and partial negative inheritance in one hybrid. Over the three years, heredity by the type of positive superdominance was observed in 21 out of 36 crossing combinations, predominantly when the maternal form was one of the local varieties, Bilotserkivska semi-dwarf and Lisova Pisnya. The conducted studies indicate a significant influence of the parental components of hybridisation and the hydrothermal conditions of the year on the formation of grain weight of the main ear in F_1, as well as on the determined indices of the degree of phenotypic dominance.

Key words*: hybrids, varieties, grain weight of the main ear, degree of phenotypic dominance.*

INTRODUCTION

Wheat, as one of the oldest and most valuable food crops, remains a key component of food security for a significant part of humanity under modern conditions and plays an important role in Ukraine's export potential (Lotysh, 2018). To meet the growing demand driven by the increasing global population, it is essential to find ways to enhance the production of winter soft wheat grain in the coming decades (Röder et al., 2014). As the productivity of modern varieties has increased, the problem of genetically enhancing their resistance to biotic and abiotic stress factors that can significantly reduce yields has become more actuality (Sarto et al., 2017).

The breeding of new high-yielding adapted winter wheat varieties is of primary importance for achieving food security in Ukraine, as it is at great risk due to the exhaustion of natural resources and climate change (Yurchenko & Voloshchuk, 2014). Wheat is affected by climatic conditions characterised by an increase in the frequency of extreme factors in recent years, which determine plant phenology, sowing dates, the duration of ontogenetic stages and, finally, grain yields (Raza et al., 2015; Wang Bin et al., 2019; Shiferaw et al., 2013; Yujie et al., 2021; Lozinskiy et al., 2023; Ustinova et al., 2024).

High temperatures affect crop productivity by accelerating phenological development. The most pronounced effect of high temperatures on wheat growth is a significantly shorter grain filling time (Tashiro & Wardlaw, 1989). It is therefore very important to closely monitor those climate changes that have the greatest impact on winter wheat yields in order to make timely adjustments to the technology of its cultivation (e.g. variety selection, sowing and harvesting dates). This close monitoring and rapid response will help to mitigate the potentially adverse effects of climate change on wheat production (Tao et al., 2008).

In recent years, meteorological conditions in Ukraine have become more diverse, with significant extremes that cause the actual climatic component to deviate from the optimum for wheat plant growth and development (Yarosh &

Ryabchun, 2021; Ustinova et al, 2024). Accordingly, the genetic potential of soft winter wheat varieties is realised only by 50-60% (Tao & Zhang, 2013). In order to realise the genetic potential of new varieties in production, it is necessary that their biological characteristics are best adapted to both climatic conditions and the technological capabilities of farms. Information on the dynamics of climate change allows breeders to adapt the model of the future variety and use it in the development of environmentally friendly varieties (Starichenko et al., 2014). However, recently, not only climate change, but also inappropriate use of available varietal resources has created obstacles to the realisation of the genetic potential of new winter wheat varieties (Ovezmyradova et al., 2020). One of the most common methods of creating breeding material and varieties of soft winter wheat is intraspecific hybridization with subsequent selection of breeding valuable recombinants (Burdeniuk-Tarasevych & Lozinsky, 2015; Vlasenko et al., 2015; Kolomiets et al., 2018). The crossing is not just a combination of traits of the parental components, but the basis of formation, which allows concentrating the desired economically valuable traits in one genotype. At the same time, the formation process is determined by both inheritance factors and environmental conditions (Pirych et al., 2021; Ustinova et al, 2024).

Knowledge of the patterns of variability of valuable economic traits and their inheritance by descendants during hybridisation makes it possible to select pairs for crossing more efficiently and obtain preliminary information about the possible end result from early hybrid generations (Khomenko, 2021; Luchna, 2013). Studies conducted to determine the degree of phenotypic dominance in hybrids confirm the importance of its use in the selection of parental forms of crossing and at the same time rapid evaluation of hybrid generations (Ustinova et al., 2022). However, the highest effect of heterosis is observed in the hybridisation of ecologically and geographically distant forms (Labroo et al., 2021).

In wheat breeding, the grain weight of the main spike has always been one of the most important indicators, because this trait, together with productive bushiness, determines the productivity of the plant (Lozinskyi & Filitska, 2023; Ustinova et al., 2024). Grain weight of the main ear of soft winter wheat is a genetically determined trait that is influenced by environmental conditions and is realised in the interaction 'genotype - year conditions' (Havryliuk & Kovalyshyna, 2024). The most common type of heredity of grain weight of the main ear in F_1 winter wheat is positive superdominance, which is found in 82.5% of hybrids (Lozinsky & Ustinova, 2021).

The study of the norms of response of different varieties of soft winter wheat to biotic and abiotic environmental factors, the nature of manifestation and interrelationships of quantitative traits is the basis for the targeted use of certain new varieties in adaptive breeding programmes (Litvinenko, 2010).

MATERIALS AND METHODS

In the experimental field of the Research and Production Centre of Bila Tserkva National Agrarian University (Ukraine), 36 crossing combinations obtained by hybridizing winter wheat varieties of different heights were studied in 2019-2022. The varieties were classified into height groups as follows:

- Short (Group II, 66-80 cm): Bilotserkivska semi-dwarf, Sonechko, Smuglyanka;
- Medium (Group I, 81-95 cm): Donska semi-dwarf, Lisova Pisnya;
- Medium (Group II, 96-110 cm): Stolichna, Pisanka, Vidrada, Albatros Odeskyi;
- Tall (Group I, 111-125 cm): Odeska 267, Lastivka Odeska, Pylypivka.

The F_1 seeds were sown using a manual seeder according to the following scheme: maternal form (♀), hybrid, and paternal form (♂), with three rows of each component, each one metre long and with an inter-row spacing of 15 cm. For all cross combinations and their parental forms, identical plot sizes were maintained throughout the years of research. The wheat hybrids studied in 2020, 2021, and 2022 were created in 2019, 2020, and 2021, respectively.

The hybrid generation was studied using the pedigree method. Throughout the growing season, phenological observations were conducted, and after full ripeness was reached, a biometric analysis was performed on an average sample of 25 plants in triplicate, following the methodology of Tkachyk et al. (2016).

Winter soft wheat was sown in the last days of the third decade of September to early October. The preceding crop was mustard for grain. The soil of the experimental field is classified as typical deep low-humus chernozem.

The degree of phenotypic dominance ($\mathbf{h_p}$) for the length of the main ear in F_1 was determined according to B. Griffing (1950).

$$hp = \frac{(F1 - MP)}{(BP - MP)}$$

where: hp - degree of domination; F_1 - average arithmetic value of the hybrid; BP - arithmetic mean of the parental component with the stronger manifestation of the trait; MP - the average arithmetic value of the indicator of both parental forms.

The data obtained were grouped by classification G. M. Beil, R. E. Atkins (1965): positive dominance (heterosis) hp > +1; partial positive dominance +0.5 < hp ≤ + 1; intermediate inheritance –0.5 ≤ hp ≤ +0.5; partial negative inheritance –1 ≤ hp < –0.5; negative dominance (depression) hp < –1.

To characterize the weather conditions of the years of soft winter wheat cultivation, the average monthly hydrothermal coefficient was calculated (HTC) (Pol'ovij et al., 2004). The following differentiation of the HTC indicators was adopted: < 0.4 - very strong drought; 0.4-0.5 - severe drought; 0.5-0.6 - medium drought; 0.7-0.9 - weak drought; 1.0-1.5 - sufficiently humid; > 1.5 - extremely humid.

The results of the experimental data were statistically processed using the Statistica 12.0 programme.

In September 2019-2021, the actual amount of precipitation was 19.2 mm, 26.7 mm, and 16.8 mm, which was 15.8 mm, 8.3 mm, and 18.2 mm less than the long-term average, respectively. Due to insufficient precipitation in these years, the wheat seedling stage was observed on 8 October in 2019 and 2020, and on 10 October in 2021.

The duration of the autumn vegetation period of winter wheat was 44 days in 2019, 38 days in 2020, and 49 days in 2021, with dormancy beginning on 21 November, 14 November, and 29 November**,** respectively. In general, autumn vegetation occurred at higher average air temperatures: 9.6°C (2019), 8.5°C (2020), and 5.7°C (2021), compared to the long-term average for this period of 4.7°C, 5.0°C, and 3.9°C, respectively (Table 1).

Table 1. Meteorological conditions in 2019-2022 (according to the Bila Tserkva meteorological station)

Month	Decade	Precipitation, mm					Air temperature, °C				
		Year				long-term average	Year				long-term average
		2019	2020	2021	2022		2019	2020	2021	2022	
September		19.2	26.7	16.8		35.0	15.3	17.3	12.7		13.8
October	I	5.7	27.3	0.0		11	10.3	16.0	7.3		10.1
	II	0.0	62.7	0.6		10	13.3	11.6	6.7		8.1
	III	0.4	6.8	0.6		12	8.2	10.4	7.6		5.4
November	I	6.7	12.5	7.2		13	9.5	7.0	6.7		3.4
	II	10.1	11.4	5.6		15	7.3	1.5	2.7		1.9
	III	6.6	3.3	7.3		13	-1.9	2.0	4.6		0.7
December		35.1	33.0	49.8		44.0	2.5	-0.5	-1.4		0.4
January			22.6	40.0	30.5	35.0		0.4	-2.6	-1.4	-5.9
February			38.4	47.7	10.2	33.0		2.2	-4.6	1.7	-4.4
March			17.2	21.2	16.0	30.0		5.9	1.8	1.7	0.3
April	I		0.0	8.6	14.0	14.0		7.9	5.9	7.0	7.0
	II		5.5	13.5	7.2	17.0		8.0	8.1	6.5	7.8
	III		7.7	6.8	18.6	16.0		11.7	8.3	10.8	10.4
May	I		30.8	24.9	0.0	16.0		12.8	12.0	12.8	13.5
	II		17.6	26.5	2.7	12.0		13.2	14.5	14.9	15.3
	III		53.9	47.9	32.4	18.0		11.5	15.4	15.6	15.8
June	I		7.1	6.3	2.8	23.0		18.5	16.1	20.4	17.3
	II		50.4	28.3	1.2	27.0		23.2	20.0	20.6	17.4
	III		3.2	0.7	14.6	23.0		22.0	23.6	21.3	18.7
July	I		36.6	11.3	0.8	35.0		21.3	22.6	21.8	18.5
	II		6.3	30.0	24.1	24.0		19.8	24.6	17.6	19.4

The amount of precipitation during the autumn growing season of wheat, with the exception of 2020 (115.3 mm), was significantly lower than the long-term average. Specifically, during the autumn growing season, the actual amount of precipitation was 22.9 mm in 2019 and 21.3 mm in 2021, compared to the long-term averages of 61.0 mm and 74.0 mm, respectively.

During the winter dormancy period, which lasted 99 days in 2019/2020, 135 days in 2020/2021, and 113 days in 2021/2022, the actual amount of precipitation was 102.7 mm, 150.6 mm, and 109.0 mm**,** respectively, which was 13.3 mm, 18.4 mm, and 12.0 mm less than the long-term average for the corresponding periods. The average air temperatures during the winter dormancy period were +1.4°C (2019/2020), -2.3°C (2020/2021), and -0.5°C (2021/2022), exceeding the long-term average by 1.5°C, 0.9°C, and 2.3°C, respectively. These conditions contributed to the successful overwintering of soft winter wheat.

The resumption of spring vegetation in 2020 occurred on February 28, with a gradual increase in the average monthly temperature regime in March and April. At the same time, the average monthly temperature in May was 2.4°C lower than the long-term average, while in June and the first two decades of July, it exceeded the long-term average by 3.4°C and 1.6°C, respectively. From the beginning of spring vegetation renewal to the first decade of May, 30.4 mm of precipitation fell, which accounted for only 39.5% of the long-term average. In May, 102.3 mm of precipitation was recorded, compared to the long-term average of 46.0 mm, significantly improving the moisture supply for wheat plants. The vegetation of winter wheat in June 2020 occurred under mild drought conditions (HTC = 0.92), while grain ripening in the second decade of July (HTC = 0.32) took place under extremely severe drought conditions.

The growth and development of winter wheat in 2021, from the resumption of spring vegetation (March 28), occurred under a gradual increase in temperature during April, May, and the first decade of June. However, in the second and third decades of June, as well as the first and second decades of July, the actual air temperature significantly exceeded the long-term average by 2.6°C, 4.9°C, 4.1°C, and 3.2°C, respectively. The amount of precipitation was lower than the long-term average in April, June, and the first two decades of July by 18.1 mm, 37.7 mm, and 17.7 mm, respectively, while in May, it was higher by 53.0 mm. The calculated hydrothermal coefficient for June and the first decade of July (HTC = 0.55) indicates moderate drought and unfavourable conditions during the grain formation and filling period of wheat.

During the resumption of spring vegetation in 2022 (March 22), a gradual increase in temperature was observed until the end of May. At the same time, the average monthly temperature in June (20.8°C) exceeded the long-term average by 3.0°C, while in the first decade of July, it was higher by 3.3°C. The actual amount of precipitation in April (39.8 mm), May (35.1 mm), June (18.6 mm), and the first two decades of July (24.9 mm) was lower than the long-term averages by 7.2 mm, 10.9 mm, 54.4 mm, and 34.1 mm, respectively.

Our research established that after the resumption of spring vegetation in each of the studied years, the growth and development of soft winter wheat plants lasted from 30 days (2022) to 40 days (2020) under insufficient precipitation. The most critical conditions for grain formation were observed in 2022 when wheat vegetation, from early June to the second decade of July, lasted 40 days under extreme drought conditions (HTC = 0.31), which significantly affected the grain weight per ear.

RESULTS AND DISCUSSIONS

When using the short-statured variety Bilotserkivska semi-dwarf as the maternal form in hybridisation during 2020-2022, F_1 hybrids formed a grain weight of the main ear ranging from 1.58 g to 2.54 g, exceeding the parental forms in 20 out of 24 hybrids. In 2021 (2.01 g) and 2020 (1.97 g), the obtained hybrids of winter wheat exhibited significantly higher average grain weight of the main ear compared to 2022, where the average was 1.76 g (Table 2). The grain weight in F_1 hybrids in 2020 exceeded the average for F_1 in the following combinations: Bilotserkivska semi-dwarf/ Albatross Odeskyi (2.19 g), Bilotserkivska semi-dwarf/Pylypivka (2.23 g), Bilotserkivska semi-dwarf / Vidrada (2.36 g).

Table 2. Grain weight of the main ear (g) and the degree of phenotypic dominance in F_1 hybrids obtained using the short variety Bilotserkivska semi-dwarf as the maternal form.

Variety, hybrid	2020		2021		2022	
	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p
♀ Short (Group II) / ♂ Short (Group II)						
Bilotserkivska semi-dwarf	1.52±0.04	-	1.55±0.03	-	1.47±0.05	-
Bilotserkivska semi-dwarf / Sonechko	1.93±0.14	14.7	1.98±0.11	4.3	1.39±0.09	-7.0
Sonechko	1.46±0.05	-	1.72±0.04	-	1.44±0.04	-
♀ Short (Group II) / ♂ Medium (Group I)						
Bilotserkivska semi-dwarf / Donska semi-dwarf	1.75±0.11	4.3	1.60±0.07	-0.6	1.69±0.08	0.8
Donska semi-dwarf	1.38±0.05	-	1.83±0.04	-	1.72±0.04	-
Bilotserkivska semi-dwarf / Lisova Pisnya	1.58±0.10	5.0	1.95±0.11	1.4	1.73±0.12	3.3
Lisova Pisnya	1.54±0.06	-	1.88±0.07	-	1.59±0.06	-
♀ Short (Group II) / ♂ Medium (Group II)						
Bilotserkivska semi-dwarf / Albatros Odeskyi	2.19±0.16	68.0	2.07±0.10	6.4	1.78±0.10	29.0
Albatros Odeskyi	1.49±0.04	-	1.69±0.06	-	1.50±0.05	-
Bilotserkivska semi-dwarf / Stolichna	1.92±0.15	4.3	1.83±0.12	0.1	1.71±0.13	5.0
Stolichna	1.28±0.05	-	2.04±0.07	-	1.55±0.06	-
Bilotserkivska semi-dwarf / Vidrada	2.36±0.14	19.8	2.34±0.11	3.2	2.54±0.25	7.9
Vidrada	1.61±0.05	-	1.93±0.05	-	1.71±0.05	-
♀ Short (Group II) / ♂ Tall (Group I)						
Bilotserkivska semi-dwarf / Odeska 267	1.81±0.14	3.1	2.17±0.15	5.6	1.62±0.14	2.0
Odeska 267	1.24±0.04	-	1.83±0.06	-	1.57±0.04	-
Bilotserkivska semi-dwarf / Pylypivka	2.23±0.22	143.0	2.16±0.11	3.0	1.62±0.09	2.5
Pylypivka	1.51±0.04	-	1.86±0.05	-	1.56±0.05	-
The average for F_1	1.97	-	2.01	-	1.76	-

In 2021, the following combinations exceeded the F_1 average: Bilotserkivska semi-dwarf / Albatros Odeskyi (2.07 g), Bilotserkivska semi-dwarf/Pylypivka (2.16 g), Bilotserkivska semi-dwarf/Odeska 267 (2.17 g), Bilotserkivska semi-dwarf / Vidrada (2.34 g). In 2022, the F_1 average grain weight was exceeded by two hybrids: Bilotserkivska semi-dwarf/Albatross Odeskyi (1.78 g) and Bilotserkivska semi-dwarf / Vidrada (2.54 g). The average grain weight of the main ear for 2020-2022 (1.91 g) was exceeded by 12 hybrids, six of which resulted from crosses with tall and medium-height varieties of group II.

The variation in the experiment ranged from 0.15 g to 0.61 g**,** with the least variability in grain weight of the main ear (from 0.15 g to 0.21 g) observed in the contrasting meteorological conditions of 2020-2022 for the following crossing combinations: Bilotserkivska semi-dwarf/Donska semi-dwarf**,** Bilotserkivska semi-dwarf/Vidrada**,** Bilotserkivska semi-dwarf/Stolichna. The average range of the trait **(**0.37 g to 0.41 g**)** was observed in the combinations Bilotserkivska semi-dwarf/Lisova Pisnya and Bilotserkivska semi-dwarf/Albatross Odeskyi**.** All other combinations showed significant variability, ranging from 0.55 g to 0.61 g**.**

In 2020–2022, positive superdominance was identified in 20 out of 24 hybrids**.** Partial positive dominance, intermediate inheritance, partial negative inheritance, and negative superdominance were observed in one hybrid for each type of grain weight inheritance of the main ear (Figure 1).

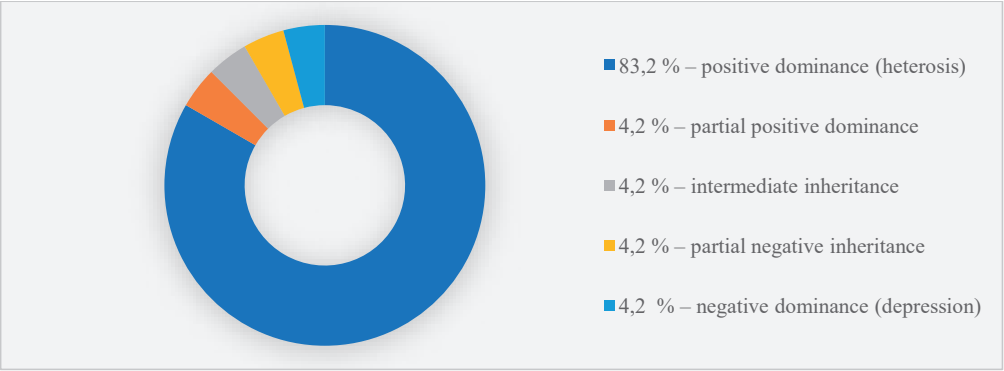

Figure 1. Types of heredity of grain weight per main ear in F_1 when using a stunted variety as a mother form Bilotserkivska semi-dwarf (2020-2022)

The degree of phenotypic dominance is a valuable genetic indicator that reflects the extent of inheritance of a particular quantitative trait in F1 and provides insights into its genetic control, as well as the potential to predict the effectiveness of selection in subsequent hybrid generations (Dubovyk et al., 2019). In hybrids exhibiting positive overdominance for productivity elements, the selection of transgressive forms in the second-generation population is possible, leading to individuals that surpass the parental forms (Samoylyk et al., 2023; Ustynova et al., 2024a; Ustynova et al., 2024b).

When using medium-height varieties of group I as the maternal form, the grain weight of the main ear in F_1 ranged from 1.58 g to 3.01 g, and in most cases exceeded the values observed in hybrids where the maternal component was the short-statured variety Bilotserkivska semi-dwarf. The parental forms for grain weight of the main ear exceeded the values of 19 out of 21 hybrids (Table 3).

Table 3. Grain weight per main ear (g) and the degree of phenotypic dominance of F_1 obtained by using the as a mother form varieties Medium Group I

Variety, hybrid	2020		2021		2022	
	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p
♀ Medium (Group I)/ ♂ Short (Group II)						
Donska semi-dwarf / Sonechko	1.97±0.14	18.3	2.18±0.11	7.8	1.72±0.08	1.0
Lisova Pisnya / Smuglyanka	2.17±0.22	11.4	2.32±0.19	4.4	1.90±0.14	6.8
Smuglyanka	1.65±0.05	-	2.05±0.06	-	1.67±0.04	-
♀ Medium (Group I) / ♂ Medium (Group I)						
Donska semi-dwarf / Lisova Pisnya	2.11±0.25	8.1	2.35±0.12	24.5	1.72±0.09	1.0
♀ Medium (Group I)/ ♂ Medium (Group II)						
Donska semi-dwarf / Albatros Odeskyi	2.54±0.30	22.0	2.40±0.12	9.0	1.58±0.09	-0.3
Donska semi-dwarf / Stolichna	2.11±0.21	15.6	2.18±0.20	2.4	1.81±0.12	2.1
Donska semi-dwarf / Vidrada	2.45±0.27	8.6	2.53±0.13	16.0	1.60±0.12	-23.0
Lisova Pisnya / Albatros Odeskyi	2.13±0.14	30.5	2.51±0.15	8.0	1.67±0.09	3.0
Lisova Pisnya / Stolichna	2.50±0.19	8.4	2.87±0.22	11.4	1.86±0.22	14.5
Lisova Pisnya / Vidrada	1.86±0.14	9.3	2.04±0.08	6.5	1.82±0.12	2.8
♀ Medium (Group I)/ ♂ Tall (Group I)						
Donska semi-dwarf / Odeska 267	2.47±0.19	16.6	2.67±0.11	84.0	1.63±0.10	-0.3
Donska semi-dwarf / Pylypivka	2.53±0.33	18.0	2.46±0.09	61.0	2.08±0.17	5.5
Lisova Pisnya / Odeska 267	2.20±0.52	5.4	2.61±0.22	25.3	2.10±0.18	52.0
Lisova Pisnya / Pylypivka	3.01±0.66	148.0	2.55±0.18	68.0	1.84±0.09	26.0
The average for F_1	2.31	-	2.44	-	1.79	-

The most favourable conditions for the formation of grain weight in most F_1 hybrids (ranging from 2.18 g to 2.87 g) were observed in 2021, with the average value (2.44 g) being exceeded in seven out of 13 hybrids obtained by crossing medium-height varieties from group I with medium-height varieties from group II and tall varieties. In 2020, the average grain weight of the main ear in F_1 was slightly lower at 2.31 g, with significantly greater variability, ranging from 1.86 g to 3.01 g. A higher-than-average grain weight was observed in the following combinations: Donska semi-dwarf/Vidrada (2.45 g), Donska semi-dwarf/Odeska 267 (2.47 g), Lisova Pisnya/Stolichna (2.50 g), Donska semi-dwarf /Pylypivka (2.53 g), and Lisova Pisnya/ Pylypivka (3.01 g). The lowest grain weight in F_1 was recorded in 2022, with the average value (1.79 g) being exceeded in seven hybrids, and higher than the parental forms in eight out of 13 combinations.

With variability in grain weight of the main ear ranging from 0.22 g to 1.17 g in F_1, the least variability was observed in the following crossing combinations: Lisova Pisnya/ Vidrada, Donska semi-dwarf/Stolichna, Lisova Pisnya/ Smuglyanka, Donska semi-dwarf/Pylypivka, Donska semi-dwarf/ Sonechko, and Lisova Pisnya/Odeska 267. Average variability was recorded in the combinations Donska semi-dwarf/Lisova Pisnya (0.63 g) and Lisova Pisnya/Albatross Odeskyi (0.84 g), while significant variability was observed in other crossing combinations, ranging from 0.93 g to 1.17 g.

In all hybrids in 2020 and 2021, the determination of grain weight followed positive superdominance (hp = 4.4 to 148.0). In 2022, positive superdominance (hp = 2.1 to 52.0) was identified in eight hybrids, while two F_1 hybrids inherited the trait through partial positive dominance (hp = 1.0) and intermediate inheritance (hp = -0.3). The combination Donska semi-dwarf/Vidrada exhibited negative superdominance (hp = -23.0) (Figure 2).

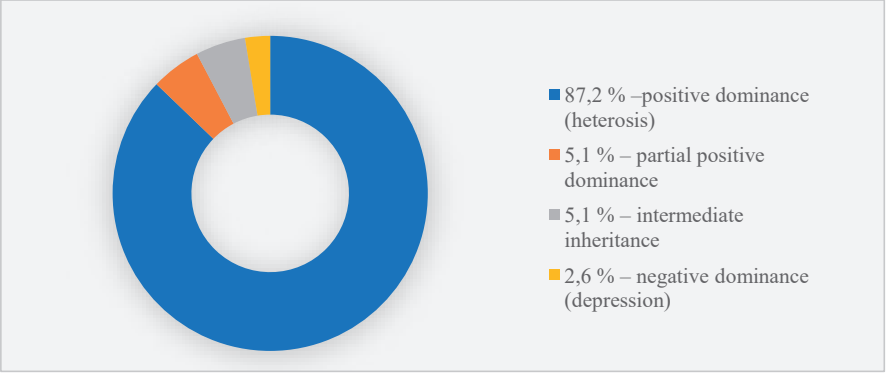

Figure 2. Types of heredity of grain weight from the main ear in F1 using the mother form of varieties of Medium Group I (2020-2022)

Hybrids obtained using medium-height varieties from group II as the maternal form formed grain weight of the main ear ranging from 1.48 g (Vidrada/Pylypivka) to 2.98 g (Pisanka/Vidrada) in the years of the study. Higher values, compared to the original components of the hybridisation, were observed in 29 out of 32 hybrids (Table 4).

Table 4. Grain weight per main spike (g) and the degree of phenotypic dominance in F1 obtained by using as a mother form varieties of medium group II

Variety, hybrid	2020 p.		2021 p.		2022 p.	
	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p
♀ Medium (Group II)/ ♂ Short (Group II)						
Albatros Odeskyi / Smuglyanka	2.02±0.29	5.6	2.26±0.13	2.2	1.69±0.11	1.3
♀ Medium (Group II)/ ♂ Medium (Group II)						
Albatros Odeskyi / Stolichna	2.49±0.23	11.0	2.24±0.10	2.2	2.09±0.21	28.0
Albatros Odeskyi / Vidrada	2.21±0.19	11.0	2.58±0.32	6.2	2.16±0.32	5.5
Stolichna / Pisanka	2.87±0.54	8.4	2.13±0.48	2.1	2.11±0.44	57.0
Pisanka	1.62±0.05	-	1.88±0.06	-	1.53±0.04	-
Stolichna / Vidrada	2.47±0.26	6.4	2.86±0.33	17.4	2.35±0.27	9.0
Pisanka / Vidrada	2.98±0.34	273.0	2.34±0.20	21.5	-	-
♀ Medium (Group II)/ ♂ Tall (Group I)						
Albatros Odeskyi / Odeska 267	2.19±0.19	6.4	2.53±0.23	12.8	1.60±0.18	2.0
Albatros Odeskyi / Pylypivka	2.38±0.27	44.0	2.40±0.43	7.8	2.13±0.18	20.0
Stolichna / Odeska 267	1.90±0.36	32.0	2.00±0.48	0.6	2.07±0.22	52.0
Stolichna / Pylypivka	2.74±0.39	12.2	2.34±0.25	4.3	-	-
Vidrada / Odeska 267	2.15±0.13	3.8	2.12±0.12	4.8	-	-
Vidrada / Pylypivka	1.48±0.20	-1.6	1.72±0.12	-6.0	-	-
The average for F_1	2.32	-	2.29	-	2.02	-

Consistent grain weight of the main ear was formed in the years of the study in the combinations Stolichna/Odeska 267, Albatross Odeskyi/Pylypivka, Albatross Odeskyi/Stolichna, Albatross Odeskyi/ Vidrada, with variability ranging from 0.17 g to 0.42 g. Average variability was observed in Stolichna/Vidrada (0.51 g) and Albatross Odeskyi/Smuglyanka (0.57 g). In the crossing combinations Stolichna/Pisanka and Albatross Odeskyi/Odeska 267, the variability of the trait was found to be 0.76 g and 0.93 g, respectively. In F_1, where medium-height varieties of group II were used as the maternal form, positive superdominance was observed in 29 out of 32 hybrids (90.6%) during the years of the study. At the same time, negative superdominance was identified in two hybrids (6.3%), and partial positive dominance in one hybrid (3.1%) (Figure 3).

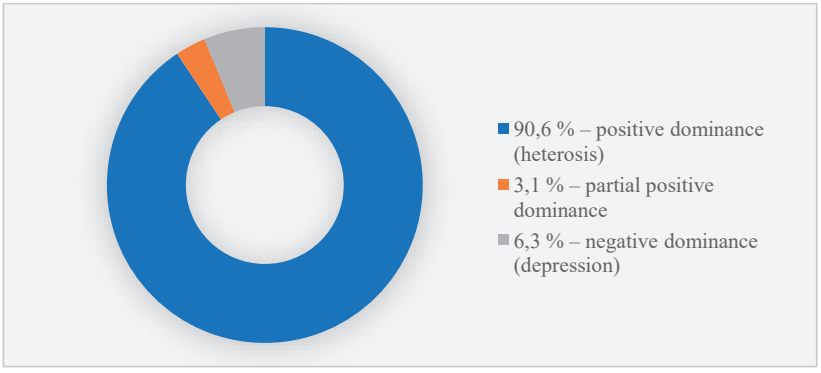

Figure 3. Types of inheritance of grain weight from the main ear in F_1 using medium-sized varieties of Medium Group II as a mother form (2020–2022)

In the hybridisation of tall varieties of group I, the grain weight of the main ear in F_1 ranged from 1.50 g to 2.81 g, with an increase over the parental forms in seven out of nine hybrids. The maximum average grain weight (2.31 g) was observed in 2020, with the highest value in the combination Odeska 267 / Lastivka Odeska – 2.81 g. Exceeding the average hybrid grain weight in 2021 was observed in Pylypivka/ Lastivka Odeska, and in 2022, in Odeska 267/Pylypivka and Pylypivka/Lastivka Odeska (Table 5).

Table 5. Grain weight per main ear (g) and the degree of phenotypic dominance in F1 obtained by hybridisation of tall varieties

Variety, hybrid	2020		2021		2022	
	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p	$\bar{x}\pm S\bar{x}$	h_p
Odeska 267 / Pylypivka	2.17±0.33	5.7	1.79±0.10	-2.5	1.83±0.21	53.0
Odeska 267 / Lastivka Odeska	2.81±0.50	77.5	1.96±0.10	3.2	1.50±0.13	-15.0
Lastivka Odeska	1.28±0.04	-	1.78±0.04	-	1.58±0.04	-
Pylypivka / Lastivka Odeska	1.96±0.14	5.1	2.35±0.17	13.3	1.82±0.43	25.0
The average for F_1	2.31	-	2.03	-	1.72	-

The variability in the grain weight of the main ear ranged from minimal in the crossing combinations Odeska 267 / Pylypivka (0.38 g) and Pylypivka / Lastivka Odeska (0.53 g) to high in Odeska 267 / Lastivka Odeska (1.31 g).

In seven out of nine hybrids, the inheritance of grain weight of the main ear occurred through positive superdominance, with the degree of phenotypic dominance ranging from 3.2 in 2021 to 77.5 (in 2020) in the combination Odeska 267/Lastivka Odeska (Figure 4).

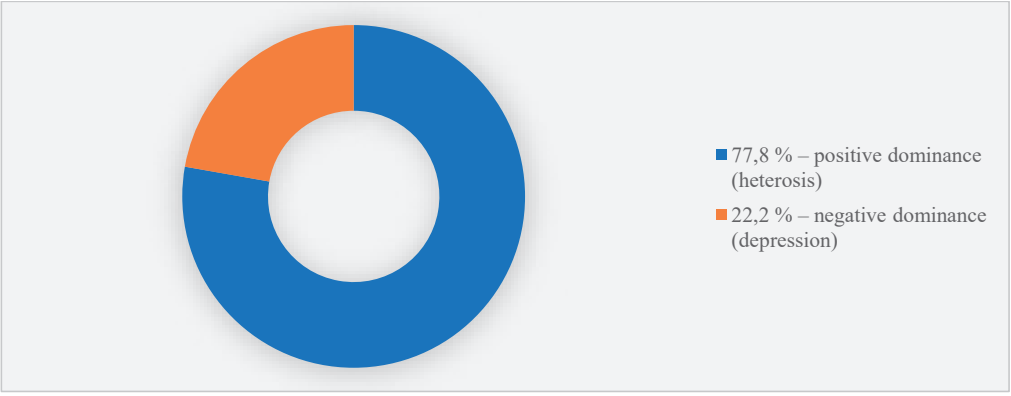

Figure 4. Types of inheritance of grain weight from the main spike in F1 at hybridisation of tall varieties (2020-2022)

Over the course of three years, the trait was inherited through positive superdominance only in the hybridisation of Pylypivka / Lastivka Odeska. Two hybrids determined the trait through negative superdominance.

The inheritance of grain weight from the main spike of winter wheat in reciprocal crosses of the forest-steppe, steppe, and Western European ecotypes (2022) followed a pattern of positive overdominance in 26 out of 27 hybrids. Depending on the parental pairs selected for hybridisation, the degree of phenotypic dominance varied within the range of hp = 2.1-83.0. In 18 F2 populations (2023), a positive degree of transgression was observed (Ts = 0.3-40.0%; Tch = 50-100%) (Samoylyk et al., 2023).

The methodology used in our study to determine the degree of phenotypic dominance for assessing first-generation hybrids has been widely applied in the early stages of winter wheat breeding (Yakymchuk, 2018; Bazaliy et al., 2020; Lozinskyi et al., 2021), as well as in the selection of winter rye (Huba, 2021), winter triticale (Tromsyuk & Bugayov, 2021), spring barley (Nyska & Petrynkova, 2018), and spring rapeseed (Kumanska, 2018).

CONCLUSIONS

The formation of grain weight of the main ear and the degree of phenotypic dominance in F_1 hybrids is determined by the selection of parental forms for crossing and is significantly modified by the meteorological conditions of the year. In most hybrids, the inheritance of grain weight followed positive superdominance, ranging from 77.8% in the hybridisation of tall varieties from group I to 90.6% with the use of medium-height varieties from group II as the maternal form. The most promising crossing combinations were identified as Albatros

Odeskyi/ Stolichna, Lisova Pisnya/Odeska 267, Albatros Odeskyi/Pylypivka, Albatros Odeskyi/Vidrada, Donska semi-dwarf/ Pylypivka, Stolichna/Pysanka, Bilotserkivska semi-dwarf/Vidrada, Lisova Pisnya/ Stolichna, Lisova Pisnya/Pylypivka, and Stolichna/Vidrada, which consistently produced high grain weight values for the main ear (2.27-2.56 g) over the three years, exceeding the average F_1 value. Further research will focus on the evaluation of hybrid populations of soft winter wheat for valuable selection traits and the selection of promising lines to create a new high-yielding parent material adapted to the conditions of the Forest-Steppe zone of Ukraine.

REFERENCES

Bazaliy, V., Domaratskyi, E., Boichuk, I., Teteruk, O., Kozlova, O., & Bazaliy, H. (2020). Genetic control and recombination of lodging resistance traits in winter wheat hybrids under different growing conditions. *Agrarian Innovations, 4*, 87–93 [in Ukrainian].

Beil, G.M. & Atkins, R.E. (1965). Inheritance of quantitative characters in grain sorghum. *Iowa State Journal, 39*, 3.

Burdeniuk-Tarasevych, L.A. & Lozinsky, M.V. (2015). Principles of selection of pairs for hybridisation in the selection of winter wheat T. aestivum L. for adaptability to environmental conditions. *Factors of experimental evolution of organisms*, *16*, 92-96 [in Ukrainian].

Dubovyk, N. S., Kyrylenko, V. V., Humeniuk, O. V., & Vologdina, H. B. (2019). The nature of plant height inheritance in F_1 *Triticum aestivum* L. using wheat-rye translocations under the conditions of the Central Forest-Steppe of Ukraine. *Myronivskyi Visnyk, 9*, 27–34 [in Ukrainian].

Griffing, B. (1950). Analysis of quantitative gene-action by constant parent regression and related techniques. *Genetics, 35*, 303–321.

Havryliuk, I., & Kovalyshyna, H. (2024). Characteristics of soft winter wheat varieties by crop structure and grain quality indicators. *Ukrainian Black Sea region agrarian science*, *4*, 68-84 [in Ukrainian].

Huba, I. I. (2021). Expression and variability of multi-flowered spikelets in first-generation hybrids of winter rye. *Colloquium-Journal, 5*, 92 [in Ukrainian].

Khomenko, L. (2021). Creation of winter wheat source material with increased adaptive potential to adverse environmental conditions. *EUREKA: Life Sciences,* (6), 25-33.

Kolomiets, L.A., Humeniuk, O.V., Yurchenko, T.V., Zamlila, N.P. & Pirich, A.V. (2018). Manifestation of adaptive traits in winter bread wheat genotypes under different hydrothermal conditions. *Myronivskyi visnik,* 6, 6-29 [in Ukrainian].

Kumanska, Y. O. (2018). Inheritance of quantitative traits in intervarietal F1 hybrids of spring rapeseed. *Collection of Scientific Papers of the National Scientific Centre Institute of Agriculture of NAAS, 4*, 152–159. [in Ukrainian].

Labroo, M. R., Studer, A. J., & Rutkoski, J. E. (2021). Heterosis and hybrid crop breeding: a multidisciplinary review. *Frontiers in Genetics*, *12*, 643761.

Litvinenko, M. A. (2010). Realisation of genetic potential. Problems of productivity and grain quality of modern winter wheat varieties. *Seed production,* 6, 1-6 [in Ukrainian].

Lotysh, O. Y. (2018). Strategic analysis of the grain industry of Ukraine: state and prospects of development. *Intellect. XXI,* 3, 74–79 [in Ukrainian].

Lozinskiy, M., Burdenyuk-Tarasevych, L., Grabovskyi, M., Grabovska, T., Roubík, H. (2023). Winter wheat (T. aestivum L.) yield depending on the duration of autumn vegetation and the terms of spring vegetation recovery: 50-years study in Ukraine. *Scientific Papers. Series A. Agronomy*, *LXVI* (1), 406-416.

Lozinsky, M.V., Ustinova, G.L. (2021). Peculiarities of inheritance of main spikelet grain weight in hybridisation of winter bread wheat varieties with different early maturity. *Agrarian innovations, 9*, 61–68 [in Ukrainian].

Lozinskyi, M., Ustynova, H., Grabovska, T., Kumanska, Y., & Horodetskyi, O. (2021). Manifestation of heterosis and degree of phenotypic dominance by the number of grains from the main ear in the hybridisation of different early-maturing varieties of soft winter wheat. *Scientific Horizons, 24*(11), 28–37.

Lozinskyi, M.V. & Filitska, O.O. (2023). Formation of grain weight of the main ear in different height varieties of winter wheat (T. aestivum L.) in the forest-steppe of Ukraine. *Agrarian innovations, 19*, 168–174 [in Ukrainian].

Luchna, I.S. (2013). Inheritance of the main elements of productivity in F1 winter wheat hybrids in the process of creating disease-resistant source material. *Breeding and seed production,* 103, 154–160 [in Ukrainian].

Nyska, I. M., & Petrynkova, V. P. (2018). Inheritance of resistance to biotic factors and certain productivity elements in F1 hybrids of spring barley. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine, 1*(71). [in Ukrainian].

Ovezmyradova, O. B., Merzlova, H. V., Nevmerzhitska, O. M., Plotnytska, N. M., Gurmanchuk, O. V., Nasikovskyi, V. A., & Kravets, O. O. (2020). Parameters of adaptability, biological and economical valuable traits of soft wheat promising lines. *Ukrainian Journal of Ecology*, *10*(5), 197-205.

Pirych, A. V., Yurchenko, T. V., Hudzenko, V. M., Demydov, O. A., Kovalyshyna, H. M., Humeniuk, O. V., & Kyrylenko, V. V. (2021). Features of modern winter wheat varieties in terms of winter hardiness components under conditions of Ukrainian Forest-Steppe. *Regulatory Mechanisms in Biosystems*, *12*(1), 153-159.

Pol'ovij, A.M., Bozhko, L.Y. & Volvach, O.V. (2004). Fundamentals of agrometeorology. Odesa [in Ukrainian].

Raza, A., Imtiaz, M. & Mohammad, W. (2015). Wheat Root Selections for Sustainable Production. In: Lichtfouse, E. (eds). *Sustainable Agriculture Reviews,* 18, 295–315.

Röder, M., Thornley, P., Campbell, G., Bows-Larkin, A. (2014). Emissions associated with meeting the future global wheat demand: A case study of UK production under climate change constraints. *Environmental Science & Policy*, 39, 13–24.

Samoylyk, M. O., & Lozinskyi, M. V. (2023). Inheritance patterns in F_1 and transgressive variability in F_2 populations of grain weight from the main spike in hybridisation of soft winter wheat ecotypes. *Agrarian Innovations, 22*, 154–161. [in Ukrainian].

Sarto, M. V. M., Sarto, J. R. W., Rampim, L., Rosset, J. S., Bassegio, D., da Costa, P. F., Inagaki, A. M. (2017). Wheat phenology and yield under drought: a review. Austral. *Journal Crop Science*, *11* (8), 941–946.

Shiferaw, B., Smale, M., Braun, H.-J., Duveiller, E., Reynolds, M. & Muricho, G. (2013). Crops that feed the world. Past successes and future challenges to the role played by wheat in global food security. *Food Security, 5*, 291–317.

Starichenko, V. M., Golik, L. M., Tkacheva, N. A., and Litus, M. V. (2014). Evaluation of adaptive capacity and stability of varieties and lines in winter wheat breeding. *Breeding and seed production*, 105, 77-84 [in Ukrainian].

Tao, F. & Zhang, Z. (2013). Climate change, wheat productivity and water use in the North China Plain: a new super-ensemble-based probabilistic projection. *Agricultural and forest meteorology*, 170, 146–165.

Tao, F., Yokozawa, M., Liu, J., Zhang, Z. (2008). Climate-crop yield relationships at province scale in China and the impacts of recent climate trend. *Climate Research*, 38, 83–94.

Tashiro, T. & Wardlaw, I. F. (1989). A Comparison of the Effect of High Temperature on Grain Development in Wheat and Rice. *Annals of Botany*, 64(1), 59–65.

Tkachyk, S.O., Leshchuk, N.V. & Prysiazhniuk, O.I. (2016). Methodology of qualification examination of plant varieties for their suitability for distribution in Ukraine. Vinnytsia [in Ukrainian].

Tromsyuk, V. D., & Bugayov, V. D. (2021). The level of heterosis and the degree of phenotypic dominance of the main productivity traits in F_1 winter triticale. *Bulletin of Sumy National Agrarian University. Series: Agronomy and Biology, 43(1)*, 49–54.

Ustinova, G.L., Lozinsky, M.V. & Grabovsky, M.B. (2022). Peculiarities of inheritance of the number of spikelets in F1 when used in hybridisation with the mother form of early maturing winter durum wheat varieties *Agrarian Innovations*, *9*, 186–191 [in Ukrainian].

Ustynova, H., Lozinskyi, M., Grabovskyi, M., Pokotylo, I., Fedoruk, Yu., Khakhula, V., Lupitko, O., Panchenko, T., Aldoshyn, A., Karaulna, V., Prysiazhniuk, N., Yezerkovska, L., & Bazilieva, Yu. (2024b). Peculiarities of inheritance and transgressive variability of grain number in intraspecific hybridisation of winter bread wheat. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 24*(3), 953–961 [in Ukrainian].

Ustynova, H., Lozinskyi, M., Grabovskyi, M., Sabadyn, V., Obrazhii, S., Kumanska, Y., & Sydorova, I. (2024a). Inheritance in F_1 and transgressive variability in F_2 populations of main spike length in soft winter wheat. *Scientific Papers Series A. Agronomy, 67*(2), 445–452 [in Ukrainian].

Vlasenko, V., Bakumenko, O., Osmachko, O., Bilokopytov, V., Fanhua, M. E. N. G., & Humeniuk, O. (2019). The usage perspectives of the Chinese current wheat germplasm in the breeding of a new Ukrainian variety generation. *AgroLife Scientific Journal*, *8*(2).

Wang, B., Feng, P., Chen, Ch., Waters, C. & Yu Qiang. (2019). Designing wheat ideotypes to cope with future changing climate in South-Eastern Australia. *Agricultural Systems, 170*, 9–18.

Yakymchuk, R. A. (2018). The nature of stem length inheritance in dwarf mutants of soft winter wheat obtained in the Chornobyl NPP zone. *Physiology of Plants and Genetics, 50(1)*, 46–58. [in Ukrainian].

Yarosh, A. V. & Ryabchun, V. K. (2021). Adaptability of winter soft wheat in terms of homeostatic parameters and breeding value. *Plant Genetic Resources*, 28, 36-47 [in Ukrainian].

Yujie, L., Qiaomin, Ch., Jie Ch. et al. (2021). Plausible changes in wheat-growing periods and grain yield in China triggered by future climate change under multiple scenarios and periods. *Quarterly J. of the Royal Meteorological Society*, *147*(741), 4371–4387.

Yurchenko, T.V. & Voloshchuk, S.I. (2014). Influence of mutagenic factors on the grain weight of the main spike of hybrid populations of winter bread wheat. *Collection of scientific works of Uman National University of Horticulture, 86*(1), 159-167 [in Ukrainian].