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MANIFESTATION OF THE MAIN QUANTITATIVE TRAITS OF PRODUCTIVITY IN F_1 HYBRIDS OF BREAD AND DURUM SPRING WHEAT IN THE CONDITIONS OF THE FOREST-STEPPE OF UKRAINE

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Topicality. *Studying the nature of the inheritance of productivity traits, the heterosis degree in hybrids of the first generation of bread and durum spring wheat is an urgent task for developing high-yielding varieties, as well as for predicting the selection and genetic effect of crosses.* ***Purpose****. To establish the degree of phenotypic dominance and the heterosis degree in terms of productivity in F_1 hybrids of spring wheat.* ***Materials and methods****. The research was conducted at the V. M. Remeslo Myronivka Institute of Wheat of NAAS of Ukraine in 2023–2024. There were studied 20 hybrid combinations obtained by crossing spring wheat samples of different ecological and geographical origin. Laboratory-field and mathematical-statistical methods were used.* ***Results****. It was found that overdominance and partial positive dominance were the most common types of inheritance of the trait "spike length" in F_1 hybrids of spring wheat during the years of the research. For the trait "number of spikelets per spike", different degrees of phenotypic dominance, which indicates their significant differentiation, were observed. Based on the traits "number of grains per spike" and "grain weight per spike", we identified combinations in which inheritance occurred by the type of overdominance and partial positive dominance, and as a result, high productivity of the spike was formed during the years of study.* ***Conclusions****. Characteristics of productivity elements of ears in F1 hybrids obtained from crossing samples of different ecological and geographical origin of spring wheat had different types of inheritance (from depression to overdominance), depending on the selection of pairs for hybridisation and on the conditions of the year. The most unsuccessful combinations of parental forms were found in combinations of durum spring wheat MIP Kseniia × 211 Tianes, MIP Mahdalena × AR 84/Bintepe 85-OY and bread spring wheat Hingchun 26 × MIP Svitlana, MIP Vesnianka × Line 15-36, resulting in depression and partial negative inheritance, and the degree of true and hypothetical heterosis had negative values. By the level of manifestation of positive heterosis, the combinations of bread spring wheat Xunzhe 9 × MIP Oleksandra, Yaouyaan 448 × Dubravka, Moyin 2 × MIP Zlata and durum spring wheat MIP Kseniia × MIP Mahdalena, MIP Mahdalena × Musk Duke, etc. were identified, which demonstrates the significant genetic potential of the above hybrids.*

Key words*: spring wheat, hybrid combinations, productivity components*

Introduction. One of the main methods of developing source material for wheat breeding is hybridisation, which produces new samples that combine traits and characteristics in their genotype that are intended for the breeding programme. Hybridisation is an important method of crop breeding, and the key to successful hybridisation is the selection of parental forms. Given that the productivity of parental forms varies from that of hybrid offspring, the value of a hybrid combination can only be identified in later generations. In the early stages of wheat breeding, it is important to select traits for analysing hybridisation results, based on which the selection of elite plants will allow certain genetic progress to be achieved and will lead to an increase in yield potential. Based on the analysis of various factorial characteristics, the quantitative parameters of the productivity elements of plants, the nature of their inheritance, and heterosis are determined in first-generation hybrids [1–5].

The development of spring wheat varieties by hybridisation method begins with the selection of parental components based on a set of valuable economic traits.

The selection of parental components (*Triticum aestivum* L. and *Triticum durum* Desf.) for crossing should be carried out according to ecological and geographical principles, conside-

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ring the adaptive capacity of the variety, trait parameters, and the valuable genetic components [6]. The selection is based on the idea that more distant parental forms have greater genetic differences. Thus, a broad formative process in hybrid populations and the selection of transgressive forms are ensured, and the desired traits and properties of different ecotypes are combined in a new genotype [7]. For breeding purposes, genetic material from the Ukrainian plant gene bank collections is widespread, this allows the hybridisation of genetically and ecologically distant forms with different levels of trait manifestation and the production of qualitatively new breeding material. [8]. Therefore, the involvement of biotypes from different ecological and geographical groups in crossbreeding contributes to the development of a greater number of new forms in hybrid populations, which enhances the effectiveness of breeding work.

The research was aimed at establishing the degree of phenotypic dominance and the level of heterosis in terms of productivity traits in first-generation (F_1) hybrids of bread and durum spring wheat.

Materials and Methods. The research was conducted at the V. M. Remeslo Myronivka Wheat Institute of NAAS of Ukraine in 2023 and 2024. The research material included 20 hybrid combinations obtained by crossing samples of bread and durum wheat of different ecological and geographical origins. The seeds of hybrids and parental forms were sown manually in a hybrid nursery according to the scheme 'maternal form – F_1 – parental form' with a 15 cm row spacing. The predecessor was soybeans. Phenological observations were carried out in accordance with the Methodology for State Variety Testing of Agricultural Crops [9]. To characterize the quality of environmental conditions and wheat productivity, the hydrothermal coefficient was calculated [10].

The degree of phenotypic dominance of traits (hp) was determined using the formula B. Griffing [11]: $hp = (F_1 – Mp) / (P_{max} – Mp)$, where hp – degree of phenotypic dominance; F_1 – value of a trait in a hybrid; Mp – average value of both parents; P_{max} – greatest value of one of the parents.

The obtained data were grouped according to the classification of G. M. Beil, R. E. Atkins [12].

The manifestation of heterosis was determined according to Matzinger et al. [13] and S. Fonseca, F. Patterson [14]:

$$Ht\ (\%) = (F_1 – MP)/MP \times 100,$$

$$Hbt\ (\%) = (F_1 – BP)/BP \times 100,$$

where F_1 – arithmetic mean value of a trait in a hybrid;

BP – the highest manifestation of a trait from one of the parents;

MP – arithmetic mean of the indicator for both parental forms.

Class of dominance	Numeric value of hp
Гетерозис (наддомінування)	$hp > +1$
Часткове позитивне наддомінування	$+0.5 < hp \leq +1$
Проміжне успадкування	$-0.5 \leq hp \leq +0.5$
Часткове від'ємне успадкування	$-1 \leq hp < -0.5$
Депресія	$hp < -1$

Results and Discussion. Weather conditions were favourable for the growth and development of spring wheat plants, but were accompanied by uneven distribution of precipitation and varying temperature regimes in certain periods (Table 1). During the period from sowing to seedling emergence in 2023, the average daily air temperature was +8.3 °C (1.2 °C above the long-term average), and this period was characterised by excessive precipitation of 54.6 mm (higher than the long-term average of 37.0 mm). During the period from seedling emergence to stem elongation, the average daily air temperature was within the long-term average of +12.5 °C. During the period from stem elongation stage to heading stage, the air temperature was +18.2 °C, which is 1.8 °C higher than the long-term average, while precipitation was only 19.9 mm, which is 2.4 times lower than the long-term average.

During the period from heading stage to full ripeness, the air temperature was +20.6 °C (1.0 °C above the long-term average), and precipitation was 199.2 mm (1.5 times higher than the long-term average of 128.0 mm). For a comprehensive characterisation of moisture and temperature conditions, the hydrothermal coefficient (HTC) was used, which was 1.34, corres-

ponding to the optimal moisture level. In separate periods, the following conditions were observed: the interstage periods ‘sowing – seedling emergence’ and ‘heading – full ripeness’ were characterised by excessive moisture (HTC = 3.47 and 1.97, respectively), dry conditions prevailed during the periods ‘seedling emergence – stem elongation’ and ‘stem elongation – heading’, where the HTC was 0.86 and 0.73, respectively.

Table 1. Hydrothermal conditions for spring wheat vegetation, 2023–2024

Indicator	Sowing – seedlings	Seedlings – stem elongation	Stem elongation– heading	Heading – full ripeness
Air temperature (°C) during interstage periods of spring wheat vegetation				
2023	8.3	12.5	18.2	20.6
2024	10.2	13.4	19.8	22.7
$\bar{x}$	9.25	12.9	19.0	21.7
min	8.3	12.5	18.2	20.6
max	10.2	13.4	19.8	22.7
R	1.9	0.9	1.6	2.1
Long-term average	7.1	12.5	16.4	19.6
Precipitation (mm) in interstage periods of spring wheat vegetation				
2023	54.6	57.4	19.9	199.2
2024	44.3	71.5	26.1	102.4
$\bar{x}$	49.5	64.5	23.0	150.8
min	44.3	57.4	19.9	102.4
max	54.6	71.5	26.1	199.2
R	10.3	14.1	6.2	96.8
Long-term average	37.0	58.0	48.0	128.0
HTC 2023/2024	3.47/2.82	0.86/1.21	0.73/0.94	1.97/1.05

Notes. *$\bar{x}$, min, max – average, minimum and maximum values, respectively, R – range of variation (max–min).*

During the period from sowing to seedling emergence in 2024, the average daily air temperature was +10.2 °C, which is 3.1 °C higher than the long-term average and was accompanied by excessive moisture levels (HTC = 2.82). During the interstage period of plant development (seedling emergence – stem elongation), the average daily air temperature was within the long-term average (+13.4 °C). Precipitation was 71.5 mm, which was close to the long-term average of 58.0 mm. During the period from stem elongation to heading stage, the air temperature was +19.8 °C, which is 3.4 °C higher than the long-term average. Precipitation during the interstage period was only 26.1 mm, and the hydrothermal coefficient was 0.94. During the period from heading to full ripeness, the air temperature was +22.7 °C, which is 3.1 °C higher than the long-term average. Precipitation was 102.4 mm, which is below the long-term average with optimal moisture conditions, as confirmed by the HTC of 1.05. During the growing season of 2024, the hydrothermal coefficient was 1.22, which corresponds to the optimal moisture level.

It was found that the spike length is characterised by a clear phenotypic manifestation, is relatively stable, genetically determined, well inherited trait, and it is determined by many genes located in almost all wheat chromosomes. At the same time, this trait is a convenient morphological marker for identifying valuable genotypes.

Absolute values may vary under the influence of environmental factors and agricultural technologies, but the relative difference in this trait remains the same under identical agroecological conditions. Therefore, it can be used to identify genotypes [15–17]. In 2023 and 2024, it was found that the F_1 hybrids had different inheritance patterns for trait 'spike length' – from depression to overdominance (Table 2).

In 2023, the spike length in F_1 bread spring wheat ranged from 8.1 cm (MIP Vesnianka × Line 15-36, hp = -0.6) to 10.4 cm (Yaouyaan 448 × Dubravka, hp = 6.5), and in durum spring wheat from 6.5 cm (MIP Kseniia × 211 Tianes, hp = -1.4) to 7.6 cm (MIP Kseniia × MIP Mahdalena, hp = 3.5). Only two of the 10

Table 2. Inheritance and degree of heterosis for the trait 'spike length' in F_1 hybrids of bread and durum spring wheat, 2023–2024

Hybrid combination	2023				2024			
	hp	*	Ht, %	Hbt, %	hp	*	Ht, %	Hbt, %
Bread spring wheat								
A2 × Elehiia Myronivska	1.1	OD	3.1	1.0	0.9	PPD	1.6	0.4
Hunhux × Oksamyt Myronivskyi	0.3	II	1.0	-2.0	0.6	PPD	1.0	-0.1
MIP Vesnianka × Line 15-36	-0.6	PNI	-1.2	-2.9	-0.3	II	0.6	-1.2
Xunzhe 9 × MIP Oleksandra	2.1	OD	5.2	3.0	1.9	OD	4.9	2.7
Trizo × MIP Vesnianka	0.5	II	0.8	-0.8	0.6	PPD	1.7	0.5
Yaouyaan 448 × Dubravka	6.5	OD	7.9	7.1	7.0	OD	5.9	3.9
Moyin 2 × MIP Zlata	1.4	OD	5.5	1.1	1.3	OD	2.6	1.2
Line 15-36 × Trizo	0.4	II	1.2	-1.4	0.7	PPD	1.2	0.1
Gingchun 533 × Struna Myronivska	0.9	PPD	1.0	-0.4	0.8	PPD	0.5	-0.9
Hingchun 26 × MIP Svitlana	-0.4	II	-0.7	-1.8	-0.2	II	-0.9	-2.8
Durum spring wheat								
MIP Kseniia × 211 Tianes	-1.4	D	-9.3	-11.7	-1.1	D	-2.5	-3.5
MIP Kseniia × Neodur	0.3	II	1.0	-2.8	0.4	II	0.5	-1.0
MIP Kseniia × MIP Mahdalena	3.5	OD	18.4	12.5	5.0	OD	4.7	4.0
MIP Mahdalena × AR 84/Bintepe 85-OY	-0.8	PNI	-4.4	-5.4	-2.5	D	-2.7	-3.7
MIP Mahdalena × Musk Duken	1.5	OD	1.8	0.6	3.0	OD	3.8	2.5
Leukurum 21-04 × Yaryna	0.9	PPD	1.1	-1.8	1.1	OD	0.9	0.1
MIP Raiduzhna × Neodur	1.5	OD	10.4	6.5	2.0	OD	2.7	1.3
MIP Raiduzhna × Yazi 13	-0.7	PNI	-4.0	-3.3	-0.6	PNI	-2.9	-3.8
MIP Kseniia × 121 Yavaros 79	0.7	PPD	1.3	0.4	0.9	PPD	2.0	0.6
MIP Mahdalena × 030M-1X-OM	1.2	OD	1.5	0.2	1.7	OD	1.8	0.5

***Notes**. hp – degree of dominance;* – type of inheritance; Ht, % – hypothetical heterosis; Hbt, % – true heterosis; OD – overdominance; PPD – partial positive dominance; II – intermediate inheritance; PNI – partial negative inheritance; D – depression.*

bread spring wheat hybrids had long spike (10.0–10.4 cm), while other hybrids formed spike at the level of 8.1–9.8 cm. Among durum spring wheat hybrids, medium-length spike (6.5–7.6 cm) was observed in all studied hybrids. It should be noted that parental forms with medium-length spikes predominantly transmitted the trait to F_1 by partial positive dominance and intermediate inheritance. The degree of phenotypic dominance for the 'spike length' trait in F_1 bread spring wheat ranged from -0.6 to 6.5, which corresponds to the type from partial negative inheritance to overdominance, and in durum spring wheat from -1.4 to 3.5 – from depression to overdominance. It was established that F_1 bread spring wheat inherited the trait mainly by the type of overdominance and intermediate inheritance. Overdominance (hp = 1.1–6.5) was observed in four hybrid combinations, in which positive values of hypothetical (Ht = 3.1–7.9 %) and true (Hbt = 1.0–7.1 %) heterosis were found, allowing us to predict the appearance of transgressive forms in subsequent generations. Negative values of both hypothetical and true heterosis were found in hybrids of bread wheat and durum wheat, where the degree of phenotypic dominance was characterised by an intermediate type of inheritance (Hingchun 26 × MIP Svitlana, hp = -0.4), partial negative inheritance (MIP Vesnianka × Line 15-36, hp = -0.6; MIP Raiduzhna × Yazi 13, hp = -0.7; MIP Mahdalena × AR 84/Bintepe 85-OY, hp = -0.8) and depression (MIP Kseniia × 211 Tianes, hp = -1.4). In 2024, the nature of trait inheritance did not differ significantly from that in 2023. Overdominance was observed in three combinations of bread spring wheat and five combinations of durum spring wheat, with positive values of hypothetical (Ht = 2.6–5.9 %; 0.9–4.7 %, respectively) and true (Hbt = 1.2–3.9 %; 0.1–4.0 %, respectively) heterosis. The highest values of overdominance were observed in hybrid

combinations of bread spring wheat Yaouyaan 448 × Dubravka (hp = 7.0) and durum spring wheat MIP Kseniia × MIP Mahdalena (hp = 5.0). Partial positive dominance was found only in one combination of durum spring wheat – MIP Kseniia × 121 Yavaros 79, hp = 0.9, where positive values of both hypothetical and true heterosis (Ht = 2.0%; Hbt = 0.6%) were determined. Depression was characteristic of two-hybrid combinations: MIP Kseniia × 211 Tianes, hp = -1.1 and MIP Mahdalena × AR 84/Bintepe 85-OY, hp = -2.5, while in F_1 bread spring wheat, the type of inheritance that prevailed was partial positive dominance.

Thus, the most common type of inheritance of spike length was overdominance and partial positive dominance during the years of research. During 2023–2024, the effect of heterosis was consistently observed in three combinations of F_1 bread spring wheat: Xunzhe 9 × MIP Oleksandra, Yaouyaan 448 × Dubravka, Moyin 2 × MIP Zlata, and in four combinations of durum spring wheat: MIP Kseniia × MIP Mahdalena, MIP Mahdalena × Musk Duken, MIP Raiduzhna × Neodur, MIP Mahdalena × 030M-1X-OM, which had positive values of hypothetical and true heterosis. This indicates the significant genetic potential of the above hybrids.

The study of the degree of phenotypic dominance for the trait 'number of spikelets in spike' in first-generation hybrids of bread and durum spring wheat obtained from intraspecific crosses of samples of different ecological and geographical origins showed that the degree of inheritance in different years of research varied from depression to overdominance (Table 3).

It is known that the trait 'number of spikelets in a spike' has high heritability, therefore this trait is quite important as an indicator for selection for productivity. The more spikelets in the ear, the higher the productivity and the

Table 3. Inheritance and degree of heterosis for the trait 'number of spikelets per spike' in F_1 hybrids of bread and durum spring wheat, 2023–2024

Hybrid combination	2023				2024			
	hp	*	Ht, %	Hbt, %	hp	*	Ht, %	Hbt, %
Bread spring wheat								
A2 × Elehiia Myronivska	0.9	PPD	1.1	0.3	0.8	PPD	1.0	0.1
Hunhux × Oksamyt Myronivskyi	0.2	II	0.3	-2.0	0.6	PPD	0.8	0.1
MIP Vesnianka × Line 15-36	-0.8	PNI	-1.4	-3.2	-0.9	PNI	-2.6	-4.2
Xunzhe 9 × MIP Oleksandra	2.1	OD	3.2	2.4	2.3	OD	5.1	2.1
Trizo × MIP Vesnianka	-0.3	II	-0.7	-2.8	0.1	II	0.7	-0.5
Yaouyaan 448 × Dubravka	2.4	OD	3.9	2.1	1.9	OD	3.9	1.9
Moyin 2 × MIP Zlata	0.8	PPD	1.0	0.1	1.1	OD	2.0	0.7
Line 15-36 × Trizo	-0.4	II	-1.0	-2.4	0.5	II	0.3	0.1
Gingchun 533 × Struna Myronivska	0.3	II	0.2	-0.9	0.1	II	0.3	-0.7
Hingchun 26 × MIP Svitlana	-1.7	D	-2.7	-9.8	-1.2	D	-1.9	-8.8
Durum spring wheat								
MIP Kseniia × 211 Tianes	-1.7	D	-10.3	-14.7	-1.5	D	-5.5	-9.5
MIP Kseniia × Neodur	0.6	PPD	1.8	1.0	0.5	II	0.4	-1.1
MIP Kseniia × MIP Mahdalena	2.3	OD	12.4	7.5	4.2	OD	3.7	2.1
MIP Mahdalena × AR 84/Bintepe 85-OY	-1.3	D	-5.4	-9.4	-2.8	D	-4.7	-7.7
MIP Mahdalena × Musk Duken	1.9	OD	2.8	1.6	2.1	OD	2.8	1.5
Leukurum 21-04 × Yaryna	0.8	PPD	1.0	0.7	1.1	OD	0.6	0.1
MIP Raiduzhna × Neodur	1.7	OD	11.4	5.5	2.2	OD	3.7	1.8
MIP Raiduzhna × Yazi 13	-0.9	PNI	-4.5	-3.9	-0.8	PNI	-3.1	-2.8
MIP Kseniia × 121 Yavaros 79	0.3	II	0.3	-0.4	0.4	II	0.4	-0.3
MIP Mahdalena × 030M-1X-OM	0.7	PPD	1.0	0.2	0.8	PPD	1.1	0.3

***Notes**. hp – degree of dominance;* – type of inheritance; Ht, % – hypothetical heterosis; Hbt, % – true heterosis; OD – overdominance; PPD – partial positive dominance; II – intermediate inheritance; PNI – partial negative inheritance; D – depression.*

greater the consistency, with less variability compared to other traits, making it more important in plant breeding. This trait is genetically determined but is influenced by growing conditions and therefore depends on meteorological factors [18]. Over the years of research, the number of spikelets per spike in parent forms in the bread spring wheat varied from 14.0 pcs (Hingchun 26) to 18.2 pcs (Dubravka), and in durum spring wheat from 12.6 pcs (211 TIANES) to 15.8 pcs (MIP Mahdalena). In F_1, depending on the year of research, the value of the trait ranged from 14.3 pcs (Hingchun 26 × MIP Svitlana) to 19.1 pcs (Yaouyaan 448 × Dubravka) for bread wheat, and for durum wheat – from 13.0 pcs. (MIP Kseniia × 211 Tianes) to 16.3 pcs. (MIP Mahdalena × Musk Duken) in 2023; and in 2024 – from 14.8 pcs. (MIP Vesnianka × Line 15-36) to 19.2 pcs. (Xunzhe 9 × MIP Oleksandra) – for bread wheat, and for durum spring wheat – from 13.3 pcs (MIP Mahdalena × AR 84/Bintepe 85-OY) to 16.6 pcs (MIP Kseniia × MIP Mahdalena). In 2023, the maximum number of spikelets per spike (17.9–19.1 pcs.) was formed by bread spring wheat hybrids: Yaouyaan 448 × Dubravka (hp = 2.4); Xunzhe 9 × MIP Oleksandra (hp = 2.1, and durum spring wheat hybrids: MIP Kseniia × MIP Mahdalena (hp = 2.3), MIP Mahdalena × Musk Duken (hp = 1.9), and MIP Raiduzhna × Neodur (hp = 1.7). Positive values for both hypothetical and true heterosis were found in 40.0 % of hybrid combinations of bread spring wheat and 60.0 % of durum spring wheat with inheritance patterns ranging from partial positive dominance to overdominance. Hybrid combinations characterised by intermediate, partial negative inheritance and depression had negative heterosis values.

In 2024, the following types of phenotypic dominance were found in first-generation hybrids of bread spring wheat: overdominance was observed in three combinations, partial positive dominance in two, intermediate inheritance in three, partial negative inheritance in one, depression in one combination, and in durum spring wheat, four combinations showed overdominance, one showed partial positive dominance, two showed intermediate inheritance, one showed partial negative inheritance, and two showed depression. Combinations of spring wheat that showed partial positive dominance and overdominance had positive values of hypothetical and true heterosis, while combinations with intermediate (except for the combination of bread spring wheat Line 15-36 × Trizo), partial negative inheritance and depression had negative values. Thus, in F_1 spring wheat, different degrees of phenotypic dominance were observed for the trait ‘number of spikelets per spike’, indicating their significant differentiation. In 2023–2024, inheritance by overdominance was found in hybrid combinations of bread spring wheat: Xunzhe 9 × MIP Oleksandra, Yaouyaan 448 × Dubravka, and durum spring wheat: MIP Kseniia × MIP Mahdalena, MIP Mahdalena × Musk Duken, MIP Raiduzhna × Neodur, which represents particular value for breeding work.

Research by many scientists has shown that the trait ‘number of grains per spike’ is the most stable, and therefore selection should be based on this trait. The inheritance of the trait ‘number of grains per spike’ is more reliable, but depends on environmental factors, especially meteorological conditions. This trait is determined by heredity and can be improved through selection, and is recommended as a criterion for selecting source material [19, 20].

Different types of inheritance and degrees of heterosis were identified based on the ‘number of grains per spike’ trait in bread and durum spring wheat hybrids (Table 4).

In 2023, the inheritance pattern of the trait ‘number of grains per spike' in spring wheat hybrids varied from depression to overdominance. Overdominance was observed in two combinations of bread spring wheat: Yaouyaan 448 × Dubravka (hp = 2.0); Xunzhe 9 × MIP Oleksandra (hp = 1.7) and in three combinations of durum spring wheat - MIP Kseniia × MIP Mahdalena, (hp = 2.0); MIP Raiduzhna × Neodur (hp = 1.8); MIP Mahdalena × Musk Duken (hp = 1.1), which showed positive values of hypothetical and true heterosis. Their highest indicators were in the combination of durum spring wheat MIP Raiduzhna × Neodur (Ht = 12.4%; Hbt = 6.5%). Partial positive dominance was observed in one combination of bread spring wheat and in two combinations of durum spring wheat, where positive values of both hypothetical and true heterosis were found. Depression was observed in hybrid combinations Hingchun 26 × MIP Svitlana (hp = -1.9); MIP Vesnianka × Line 15-36 (hp = -1.8) of bread

Table 4. Inheritance and degree of heterosis for the trait 'number of grains per spike' in F_1 hybrids of bread and durum spring wheat, 2023–2024

Hybrid combination	2023				2024			
	hp	*	Ht, %	Hbt, %	hp	*	Ht, %	Hbt, %
Bread spring wheat								
A2 × Elehiia Myronivska	0.4	II	0.2	-0.3	0.6	PPD	0.9	0.1
Hunhux × Oksamyt Myronivskyi	-0.2	II	-0.4	-2.6	0.1	II	0.4	-0.5
MIP Vesnianka × Line 15-36	-1.8	D	-4.4	-7.2	-0.8	PNI	-2.4	-4.0
Xunzhe 9 × MIP Oleksandra	1.7	OD	3.0	2.1	2.1	OD	4.9	2.0
Trizo × MIP Vesnianka	-0.4	II	-0.9	-3.1	0.2	II	0.9	-0.2
Yaouyaan 448 × Dubravka	2.0	OD	3.4	1.5	1.8	OD	3.6	1.6
Moyin 2 × MIP Zlata	0.9	PPD	1.1	0.3	1.4	OD	2.2	1.1
Line 15-36 × Trizo	-0.6	PNI	-1.3	-2.9	0.5	II	0.5	0.1
Gingchun 533 × Struna Myronivska	0.5	II	0.3	-0.4	0.7	PPD	0.9	0.3
Hingchun 26 × MIP Svitlana	-1.9	D	-2.9	-11.8	-1.4	D	-2.2	-7.8
Durum spring wheat								
MIP Kseniia × 211 Tianes	-1.9	D	-11.3	-16.7	-1.7	D	-5.9	-10.5
MIP Kseniia × Neodur	0.8	PPD	2.8	1.2	0.5	II	0.3	-1.0
MIP Kseniia × MIP Mahdalena	2.0	OD	10.4	6.5	3.1	OD	3.0	1.5
MIP Mahdalena × AR 84/Bintepe 85-OY	-1.5	D	-6.4	-11.2	-1.8	D	-2.7	-8.3
MIP Mahdalena × Musk Duken	1.1	OD	1.8	1.0	1.4	OD	2.0	1.2
Leukurum 21-04 × Yaryna	0.9	PPD	1.1	0.7	1.2	OD	0.8	0.2
MIP Raiduzhna × Neodur	1.8	OD	12.4	6.5	1.7	OD	3.0	1.1
MIP Raiduzhna × Yazi 13	-0.7	PNI	-4.1	-3.3	-0.6	PNI	-3.1	-2.4
MIP Kseniia × 121 Yavaros 79	0.4	II	0.6	-0.1	0.5	II	0.7	-0.1
MIP Mahdalena × 030M-1X-OM	0.5	II	0.2	-0.3	0.7	PPD	1.0	0.3

Notes. *hp – degree of dominance;* * *– type of inheritance; Ht, % – hypothetical heterosis; Hbt, % – true heterosis; OD – overdominance; PPD – partial positive dominance; II – intermediate inheritance; PNI – partial negative inheritance; D – depression.*

spring wheat and in combinations of durum spring wheat – MIP Kseniia × 211 Tianes (hp = -1.9) and MIP Mahdalena × AR 84/Bintepe 85-OY (hp = -1.5) with negative values of hypothetical and true heterosis. In 2024, F_1 bread and durum spring wheat formed a greater number of grains per spike compared to 2023. It was found that the degree of phenotypic dominance differed slightly over the years of research. Overdominance was found in three hybrid combinations (hp = 1.4–2.1) of bread spring wheat and in four (hp = 1.2–3.1) of durum spring wheat, which showed positive values of hypothetical (Ht = 0.8–4.9 %) and true (Hbt = 0.2–2.0 %) heterosis. Partial positive dominance was observed in two combinations A2 × Elehiia Myronivska (hp = 0.6); Gingchun 533 × Struna Myronivska (hp = 0.7) of bread spring wheat and in one durum spring wheat MIP Mahdalena × 030M-1X-OM (hp = 0.7), which were characterised by positive values of hypothetical and true heterosis. Negative values of both hypothetical and true heterosis were found in combinations that showed partial negative inheritance and depression. Hybrid combinations (Xunzhe 9 × MIP Oleksandra, Yaouyaan 448 × Dubravka) of bread spring wheat and durum spring wheat (MIP Kseniia × MIP Mahdalena, MIP Mahdalena × Musk Duken, MIP Raiduzhna × Neodur), in which overdominance with positive values of hypothetical and true heterosis observed over the years of study, are of particular value.

The grain weight per spike is an important yield attribute, having a relatively high heritability and transgressive variability, which makes this trait one of the most important for research and selection as a productivity marker in breeding nurseries [21]. According to the results of structural analysis in 2023–2024, it was established that the degree of phenotypic dominance in F_1 varied from depression to overdominance (Table 5). Over the period of research, the ave-

Table 5. Inheritance and degree of heterosis for the trait 'grain weight per spike' in F_1 hybrids of bread and durum spring wheat, 2023–2024

Hybrid combination	2023				2024			
	hp	*	Ht, %	Hbt, %	hp	*	Ht, %	Hbt, %
Bread spring wheat								
A2 × Elehiia Myronivska	-0.3	II	-0.3	-1.8	0.6	PPD	0.8	0.3
Hunhux × Oksamyt Myronivskyi	-0.6	PNI	-2.4	-7.6	0.2	II	0.5	-0.7
MIP Vesnianka × Line 15-36	-2.2	D	-6.4	-11.2	-0.6	PNI	-1.4	-3.3
Xunzhe 9 × MIP Oleksandra	1.2	OD	2.1	1.6	2.0	OD	4.2	1.8
Trizo × MIP Vesnianka	-0.5	II	-1.1	-4.1	0.1	II	0.4	-0.1
Yaouyaan 448 × Dubravka	2.2	OD	3.7	1.8	2.8	OD	5.6	3.6
Moyin 2 × MIP Zlata	0.7	PPD	1.0	0.3	1.2	OD	2.0	0.8
Line 15-36 × Trizo	-0.8	PNI	-2.3	-4.9	0.6	PPD	0.7	0.2
Gingchun 533 × Struna Myronivska	-0.6	PNI	-4.3	-6.4	0.4	II	0.3	-0.4
Hingchun 26 × MIP Svitlana	-2.5	D	-4.9	-12.8	-1.8	D	-3.2	-8.7
Durum spring wheat								
MIP Kseniia × 211 Tianes	-2.2	D	-13.3	-18.7	-1.8	D	-6.9	-11.5
MIP Kseniia × Neodur	0.9	PPD	2.9	1.5	0.6	PPD	0.7	0.3
MIP Kseniia × MIP Mahdalena	1.3	OD	5.4	3.5	3.0	OD	2.7	1.1
MIP Mahdalena × AR 84/Bintepe 85-OY	-3.5	D	-9.4	-13.2	-2.2	D	-2.9	-9.2
MIP Mahdalena × Musk Duken	1.4	OD	2.9	1.1	1.1	OD	1.3	0.9
Leukurum 21-04 × Yaryna	0.7	PPD	1.0	0.6	1.1	OD	0.9	0.2
MIP Raiduzhna × Neodur	2.8	OD	14.4	6.9	2.7	OD	11.0	5.1
MIP Raiduzhna × Yazi 13	0.3	II	-0.2	-2.3	-0.7	PNI	-3.2	-2.5
MIP Kseniia × 121 Yavaros 79	0.6	PPD	0.9	0.2	0.5	II	0.7	-0.2
MIP Mahdalena × 030M-1X-OM	0.7	PPD	0.9	0.3	0.9	PPD	1.3	0.8

Notes. *hp – degree of dominance;* * *– type of inheritance; Ht, % – hypothetical heterosis; Hbt, % – true heterosis; OD – overdominance; PPD – partial positive dominance; II – intermediate inheritance; PNI – partial negative inheritance; D – depression.*

rage grain weight per spike in the parental forms of bread spring wheat ranged from 1.37 g to 1.75 g, and of durum spring wheat from 1.42 g to 1.88 g, which indicates differentiation both within the genotype and over the years of study. The highest average grain weight per spike of F_1 hybrid combinations was formed in 2024 (1.56 g), while in 2023 the indicator was lower (1.44 g).

In 2023, based on the trait 'grain weight per spike", the hybrid combinations of bread spring wheat Yaouyaan 448 × Dubravka, hp = 2.2; Xunzhe 9 × MIP Oleksandra, hp = 1.2, and of durum spring wheat – MIP Raiduzhna × Neodur, hp = 2.8; MIP Mahdalena × Musk Duken, hp = 1.4; MIP Kseniia × MIP Mahdalena, hp = 1.3, which showed overdominance with positive values of hypothetical and true heterosis, were recognised as highly valuable for breeding. The least valuable were hybrid combinations of durum spring wheat MIP Kseniia × 211 Tianes, MIP Mahdalena × AR 84/Bintepe 85-OY and bread spring wheat – MIP Vesnianka × Line 15-36, Hingchun 26 × MIP Svitlana 1, in which the inheritance of the trait had negative values of hypothetical and true heterosis.

Partial positive dominance with positive values of hypothetical and true heterosis was found in one combination Moyin 2 × MIP Zlata (hp = 0.7) of bread spring wheat and in four combinations MIP Kseniia × Neodur (hp = 0.9); Leukurum 21-04 × Yaryna (hp = 0.7); MIP Mahdalena × 030M-1X-OM (hp = 0.7); MIP Kseniia × 121 Yavaros 79 (hp = 0.6) of durum spring wheat.

An intermediate type of inheritance was found in one combination of bread spring wheat (hp = -0.3) and one combination of durum spring wheat (hp = 0.3) with a negative value of hypothetical (Ht = -0.2 –-0.3 %) and true (Hbt = -1.8– -2.3 %) heterosis. In the conditions of 2024, which was characterised by sufficient moisture levels, different types of inheritance were identified, which ranged from depression

to overdominance. The highest values of hypothetical and true heterosis were observed in hybrid combinations Xunzhe 9 × MIP Oleksandra, Yaouyaan 448 × Dubravka, Moyin 2 × MIP Zlata of bread spring wheat and MIP Kseniia × MIP Mahdalena, MIP Mahdalena × Musk Duken, MIP Raiduzhna × Neodur of durum spring wheat. An intermediate type of inheritance with a degree of phenotypic dominance ranging from 0.1 to 0.4 was determined in 30 % of hybrid combinations Hunhux × Oksamyt Myronivskyi, Trizo × MIP Vesnianka, Gingchun 533 × Struna Myronivska of bread spring wheat, and in 10 % of durum spring wheat – MIP Kseniia × 121 Yavaros 79. The least common type of inheritance of the 'grain weight per spike' trait in bread spring wheat hybrids was partial negative inheritance and depresssion, and in durum spring wheat – intermediate type and partial negative inheritance. However, it should be noted that the hybrid combinations of durum spring wheat MIP Kseniia × 211 Tianes, MIP Mahdalena × AR 84/Bintepe 85-OY and bread spring wheat Hingchun 26 × MIP Svitlana showed depression in 2023, 2024 and had negative values of hypothetical and true heterosis. Hybrid combinations of spring wheat were identified in which the trait was inherited as overdominance and partial positive dominance over the years of study, resulting in high spike productivity – Xunzhe 9 × MIP Oleksandra, Yaouyaan 448 × Dubravka, Moyin 2 × MIP Zlata, MIP Kseniia × MIP Mahdalena, MIP Mahdalena × Musk Duken, MIP Raiduzhna × Neodur, MIP Mahdalena × 030M-1X-OM.

Therefore, one of the most effective ways to expand genetic diversity is to involve ecologically and geographically distant forms of wheat in hybridisation. Under such conditions, future varieties can effectively adapt to the environmental conditions of a specific region and ensure a sufficiently high realisation of the genetic productivity potential of the agrophytocenosis. At the same time, the involvement of samples from different ecological groups contributes to the formation of new forms and the selection of valuable recombinants [17].

Conclusions. The inheritance and manifestation of heterosis of productivity traits in first-generation hybrids obtained from crossing samples of bread and durum spring wheat of different ecological and geographical origins were established. It was found that the indicators of spike productivity elements had different types of inheritance, varying from depression to overdominance, depending on both the selection of pairs for hybridisation and the weather conditions of the year. For some cross combinations, overdominance and hybrid depression, as well as true and hypothetical heterosis, were observed.

The positive degree of heterosis in terms of productivity can be explained by the influence of parental components and the correct approach to their selection, considering the characteristics of quantitative trait formation. According to the studied traits, the hybrid combinations of durum spring wheat MIP Kseniia × 211 Tianes, MIP Mahdalena × AR 84/Bintepe 85-OY and bread spring wheat Hingchun 26 × MIP Svitlana, MIP Vesnianka × Line 15-36 were found to be unsuccessful, resulting in depression and partial negative inheritance, and the degree of true and hypothetical heterosis had negative values.

Based on the degree of positive heterosis, the following hybrid combinations of bread spring wheat Xunzhe 9 × MIP Oleksandra, Yaouyaan 448 × Dubravka, Moyin 2 × MIP Zlata and durum spring wheat MIP Kseniia × MIP Mahdalena, MIP Mahdalena × Musk Duken, MIP Raiduzhna × Neodur, MIP Mahdalena × 030M-1X-OM with significant genetic potential were identified.

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Федоренко М. В., Федоренко І. В., Близнюк Р. М. Прояв основних кількісних ознак продуктивності в F_1 пшениці м’якої та твердої ярої в умовах Лісостепу України.

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Актуальність. Дослідження характеру успадкування ознак продуктивності, ступеня гетерозису в гібридів першого покоління пшениці м’якої та твердої ярої є актуальним завданням при створенні високопродуктивних сортів, а також для прогнозування селекційно-генетичного ефекту схрещувань. **Мета.** Встановити ступінь фенотипового домінування та рівень гетерозису за ознаками продуктивності у гібридах першого покоління (F_1) пшениці ярої. **Матеріали та методи.** Дослідження проведено у 2023–2024 рр. в Миронівському інституті пшениці імені В. М. Ремесла НААН України. Матеріалом для досліджень слугували 20 гібридних комбінацій отриманих від схрещування зразків різного еколого-географічного походження пшениці ярої. Використано лабораторно-польові та математично-статистичні методи. **Результати.** Виявлено, що найпоширенішим типом успадкування ознаки «довжини колоса» в F_1 пшениці ярої в роки досліджень було наддомінування та часткове позитивне домінування. За ознакою «кількість колосків у колосі» спостерігали різний ступінь фенотипо-

вого домінування, що свідчить про їх значну диференціацію. За ознаками «кількість зерен у колосі» та «маса зерна з колоса» виділено комбінації, за якими упродовж років досліджень успадкування відбувалося за типом наддомінування та часткового позитивного домінування і як ре-зультат формувалась висока продуктивність колоса. **Висновки.** Встановлено, що показники елементів продуктивності колоса мали різні типи успадкування від депресії до наддомінування у F_1 отриманих від схрещування зразків різного еколого-географічного походження пшениці ярої залежно як від підбору пар для гібридизації, так і від умов року. Найбільш невдалими виявилися поєднання батьківських форм у комбінаціях пшениці твердої ярої МІП Ксенія × 211 TIANES, МІП Магдале-на × AR 84/BINTEPE 85-OY та м'якої ярої Hingchun 26 × МІП Світлана, МІП Веснянка × Лінія 15-36 внаслідок чого спостерігали депресію та часткове від'ємне успадкування, а ступінь істинного та гіпотетичного гетерозису мав від'ємні значення. За рівнем прояву позитивного гетерозису виділено комбінації пшениці м'якої ярої Xunzhe 9 × МІП Олександра, Yaouyaan 448 × Дубравка, Moyin 2 × МІП Злата та твердої ярої МІП Ксенія × МІП Магдалена, МІП Магдалена × MUSK DUKE та ін., що свідчить про значний генетичний потенціал вищевказаних гібридів.

Ключові слова: *пшениця яра, гібридні комбінації, елементи продуктивності*