RESEARCH OF THE PARENTAL ROLE IN VARIABILITY AND HERITABILITY OF CHARACTERS ASSOCIATED WITH COMMON WHEAT PRODUCTIVITY

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Abstract. The morphometric analysis of the spike productivity elements in common winter wheat (*Triticum aestivum* L.) (7 parental genotypes, 5 pairs of the F_1 reciprocal hybrids F_1 and 5 – F_2) and the application of the correlation analysis method highlighted different level dependencies between them. The integral index – the seed productivity of the spike depended most on the number of grains per spike and the length of the spike: 0.51 and 0.72, respectively. The parental factor influenced the degree of dominance in the F_1 hybrids for all the characters under study. The calculation of the reciprocity effect demonstrated that the number of grains per spike is more associated with the paternal parent, and the mass of the grain – with the maternal one. The maternal parent as a hybridization component influenced the degree, the frequency of transgressions, the coefficient of heritability of the productivity elements of the spike, the spectrum of the phenotypic classes in the F_2 generation, which reveals the involvement of parental factors in the formation of the phenotype of the characters associated with the productivity of the common wheat spike. The *Amor* x *Moldova 16, Cuialnic* x *Miranda, Moldova11* x *Centurion* F_2 combinations were identified, which differed from the others by higher values of the degree (8.7 ... 14.6%) and frequency (2.5 ... 5.8%) of positive transgressions for the mass of grains per spike, which denotes the opportunities to involve these combinations in the breeding programs.

Keywords: wheat, productivity, spike, parental effect, variability, heritability.

Rezumat. Cercetări ale rolului parental în variabilitatea și heritabilitatea caracterelor asociate cu productivitatea grâului comun. Analiza morfometrică a elementelor de productivitate ale spicului la grâul comun de toamnă (*Triticum aestivum* L.) (7 genotipuri parentale, 5 perechi de hibrizi reciproci F_1 și 5 – F_2) și aplicarea metodei de analiză corelațională a pus în evidență dependențe de diferit nivel între acestea. Indicele integral – productivitatea seminceră a spicului a depins cel mai mult de numărul de boabe per spic și lungimea spicului: 0.51 și 0.72, respectiv. Factorul parental a influențat gradul de dominare la hibrizii F_1 pentru toate caracterele aflate în studiu. Calculul efectului reciprocității a demonstrat că numărul boabelor per spic se asociază mai mult cu genitorul patern, iar masa bobului – cu cel matern. Genitorul matern în calitate de component de hibridare a influențat gradul, frecvența transgresiilor, coeficientul de heritabilitate a elementelor de productvitate ale spicului, spectrul claselor fenotipice în generația F_2 ceea ce relevă implicarea factorilor parentali în formarea fenotipului caractelor asociate cu productivitatea spicului de grâu comun. Au fost identificate combinațiile combinațiile F_2 *Amor x Moldova 16, Cuialnic x Miranda, Moldova 11 x Centurion* care s-au deosebit de celelalte prin valori mai înalte ale gradului (8.7 … 14.6%) și frecvenței (2.5 … 5.8%) transgresiilor pozitive pentru masa boabelor per spic, ceea ce denotă oportunitățile de implicare a acestor combinații în programele de ameliorare.

Cuvinte cheie: efect parental, grâu, heritabilitate, productivitate, spic, variabilitate.

INTRODUCTION

In the global agriculture, wheat holds a unique and crucial position. As a major staple crop, wheat provides essential food and energy sources for people around the world. However, the growth and development of wheat is highly dependent on the stability of climatic conditions (MIYUKI, 2024).

The association of high values of heritability and genetic advance for the mass of grains per spike and the mass of 1000 grains reveals the involvement of additive actions in the formation of characters and the opportunities for their genetic improvement through selection (CHAVAN et al., 2013). As with other plants, in common wheat the quantitative characters, which include the productivity ones, show a wide variability, and at the same time – different. Among the basic characters of productivity are the height of the plant, the number of productive stems, the mass of grains per spike, the length of the spike, the number of spikelets per spike, the number of grains in the spike, the mass of 1000 grains (KADAM et al., 2022), between which there are the most diverse correlations (SAINI et al., 2024). The high values of phenotypic and genotypic coefficients of variation of productivity characters, including wheat spike in parents and F_1 hybrids, reveal sufficient variability to provide opportunities for genetic improvement through selection (KUMAR et al., 2020). Wheat spike architecture is a key determinant of multiple components of grain yield, and detailed examination of spike morphometric traits is beneficial for explaining wheat grain yield, agronomic management effects, and genetic research (ZHOU et al., 2021).

The study of correlations between characters is of great importance in the process of creating valuable plant genotypes. Grain yield per wheat plant demonstrated a positive correlation with a number of characters including those of the spike – plant height, number of productive stems, spike length, number of spikelets per spike, number of grains in the spike, mass of 1000 grains, mass of grains per spike. At the same time, these characters recorded a positive correlation between them. These phenomena suggest that direct selection based on the mentioned traits facilitates the selection of genotypes with high yield (KADAM et al., 2022; SAINI et al., 2024).

Maternal effects are ubiquitous in nature, being found in many taxa for several characters (AYCAN et al., 2021), being defined as the causal influence of the maternal genotype or phenotype on the offspring phenotype (WOLF & WADE, 2009). Wheat plants descended from salinity-tolerant mother plants were found to have a higher salinity

tolerance than those from sensitive mothers (AYCAN et al., 2021). In rye, it was found that the direction of crossing plays an important role in the inheritance of plant height: certain genotypes show a particular effect in obtaining short F_1 hybrids only when used as a maternal form (IZDEBSCKI, 1995).

Transgressive segregation, along with heterosis, is an important phenomenon, successfully used in plant breeding (MACKAY et al., 2021).

The study of transgressive variability in F_2 segregating populations of common wheat in terms of the spike productivity elements has demonstrated that the parental genotypes exhibit different capacity to induce transgressive variability. The participation of some varieties as a component of hybridization (Gobustan) exhibits high capacity to induce transgressive forms regardless of the direction of crossing, while others (Onur, Mirbasir-128) exhibit high efficiency for all spike productivity elements only when used as a maternal form (YUSIFOVA, 2024).

In relation to the mentioned, the aim of the research was to establish the parental effects on the variability and heritability of the characters associated with the productivity of the spike of common autumn wheat at the level of the F_1, F_2 generations.

MATERIAL AND METHODS

A number of 7 varieties of common winter wheat (*Triticum aestivum* L.) served as study material – *Moldova 11* (*M11*), *Moldova 16* (*M16*), *Moldova 66* (*M66*), *Cuialnic*, *Amor*, *Miranda*, *Centurion*, 5 pairs of reciprocal hybrids F_1, 5 pairs of F_2 hybrid populations obtained from reciprocal F_1 hybrids.

Spike length (cm), number of spikelets and number of grains per spike, mass of one grain (mg), mass of grains per spike (g) were analyzed for 20 spikes in parental forms and F_1 hybrids, and 120 spikes – F_2 populations.

The degree of dominance (h_p) according to BRUBAKER (1966), the heritability coefficient in the broad sense (h^2) (SCHMIDT et al., 2019) were calculated.

The influence of parental genotypes on the phenotype of productivity characters of the ear was established by calculating the effect of reciprocity (r_e) according to the author REYNHOLD (2002). The degree (T_d) and the frequency of transgressions (T_f) were calculated based on the formulas proposed by RADCENKO (2008).

Means, correlations, histograms of plant distribution were calculated and analyzed in STATISTICA 7 software package.

RESULTS AND DISCUSSION

The morphometric analysis of the productivity elements of the wheat spike established that the length of the spike varied within the limits of 10.3 ... 12.1 cm, 10.2 ... 11.8 cm, 9.3 ... 10.6 cm; number of spikelets – 19.1 ... 21.4, 20.4 ... 22.7, 18.3 ... 20.4; the number of grains per spike – 51.4 ... 70.7, 63.4 ... 73.0, 47.0 ... 61.3; grain mass – 33.5 ... 46.8 mg, 36.5 ... 43.9 mg, 35.6 … 43.4 mg; mass of grains per spike – 2.16 ... 3.46 g, 2.31 ... 2.93 g, 1.95 ... 2.48 g, respectively, for parents, F_1 and F_2 hybrids.

It was found that the length of the spike most correlated (r) with the mass of grains per spike, followed by the number of grains per spike, the number of spikelets in the spike, the mass of a grain: 0.72, 0.49, 0.43, 0.38, respectively. Between the mass of grains per spike and its direct components – the number of grains per spike, the mass of a grain, the correlation coefficient recorded 0.51 and 0.37 ($p<0.05$), which indicates that the seed productivity of the wheat spike in the parents and hybrids under study depended more on the number of grains than on the weight of the grain. It should be noted that there were practically no dependencies between the number of grains per spike and the weight of the grain (-0.05), which reveals their independent genetic control (Fig.1).

The degree of dominance (h_p) of productivity characters in F_1 hybrids (Table 1) recorded weak dominance/dominance/overdominance and different orientations (+/-) in the direction of the parent with high or low values. It should be noted that this phenomenon was observed not only in different combinations, but also within reciprocal combinations. For example, in the case of the integral character – mass of grains per spike, in the combinations *Amor* x *M16*, *M16* x *Amor*, h_p parameter constituted: -3.09, -0.82, *Cuialnic x Miranda*, *Miranda x Cuialnic:* +1.05, -0.57, *Centurion x M11*, *M11 x Centurion*: +1.05, +0.16, respectively.

The data obtained reveal that the productivity elements of the wheat spike are inherited according to a dominant or recessive model, the manifestation of which depends on the combination, but also on the choice of the maternal / paternal parent as a hybridization component.

By calculating the reciprocal effect (r_e) in F_1 hybrids, it was found that for the productivity elements, the ratio of maternal / paternal effects was 3/2, 2/3, 1/4, 3/2, 3/2, respectively, the length of the spike, the number of spikelets, the number of grains per spike, the mass of the grain, the mass of grains per spike (Table 2).

Studies of paternal and maternal effects on grain weight and protein content in hexaploid and tetraploid wheat demonstrated that at any ploidy level, F_1 grains resembled selfed grains on the mother plant in both grain weight and grain protein percentage, indicating a major maternal effect on both traits (MILLET, ZACCAI, FELDMA, 1992).

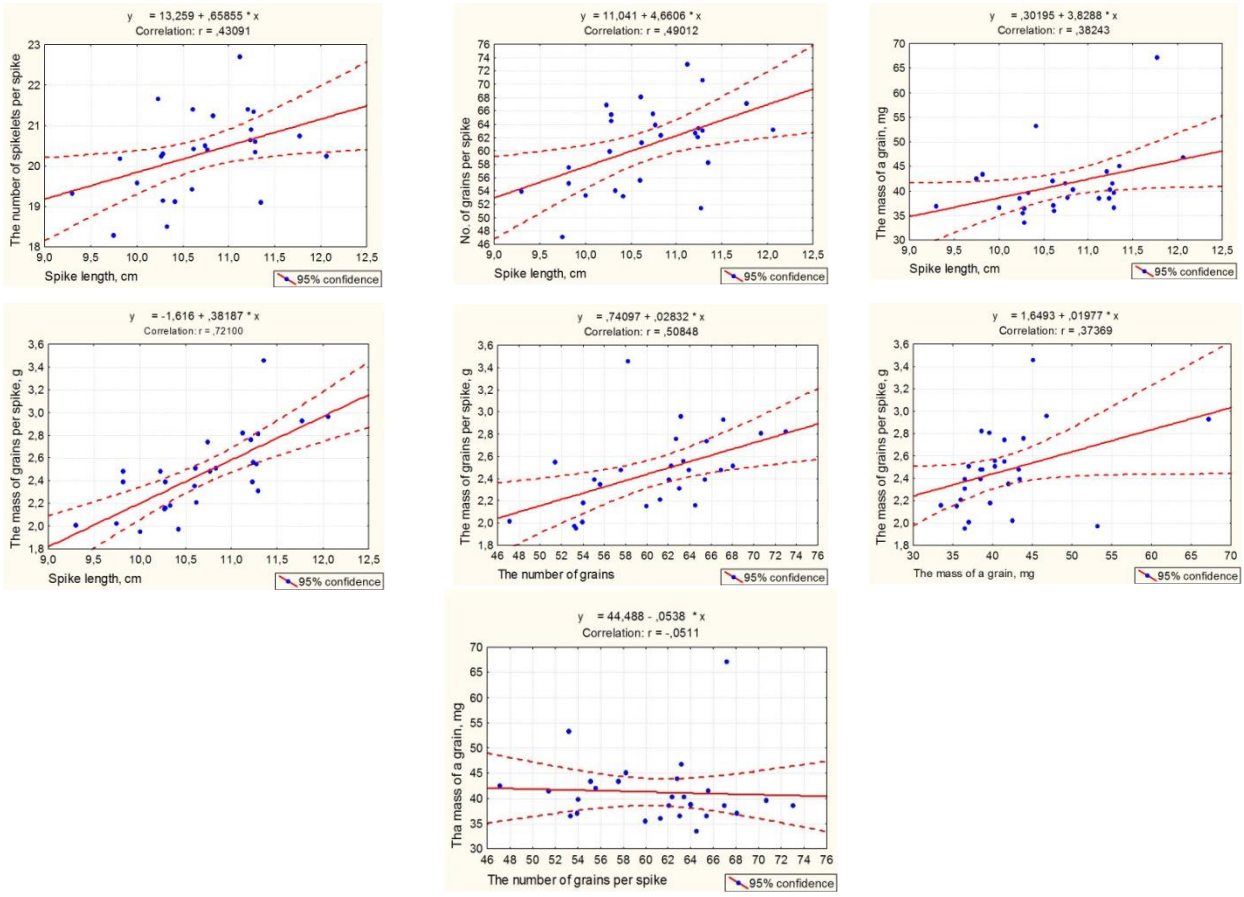

Figure 1. Regression dependence of the characters associated with the productivity of the common wheat spike.

Table 1. Dominance degree (h_p) of productivity elements in F1 reciprocal hybrids of common winter wheat.

Nr.	F_1 hybrid	Length of the spike	Number of the spikelets per spike	Number of the grains per spike	The grain mass	The mass of grains per spike
1	*Amor x M66*	+0.58	+1.21	+0.04	-2.69	-2.06
2	*M66 x Amor*	+2.32	+1.29	+1.44	+0.14	-0.47
3	*Amor x M16*	-0.86	+7.0	-1.70	-1.46	-3.09
4	*M16 x Amor*	-0.29	+8.16	-1.33	-0.08	-0.82
5	*M16 x Cuialnic*	+0.14	+3.0	-1.13	-0.99	-1.29
6	*Cuialnic x M16*	-0.45	+5.0	-0.29	0.56	-0.68
7	*Cuialnic x Miranda*	+0.66	+15.0	+1.90	+0.35	+1.05
8	*Miranda x Cuialnic*	-1.10	+8.07	-0.41	+0.30	-0.57
9	*Centurion x M11*	+0.94	+0.59	+0.83	+0.69	+1.05
10	*M11 x Centurion*	-0.33	+1.05	+1.55	-0.12	+0.16

Table 2. The effect of reciprocity (r_e) on characters associated with wheat spike productivity.

Nr.	F_1 combination	Length of the spike	Number of the spikelets per spike	Number of the grains per spike	The grain mass	The mass of grains per spike
1	*Amor x M66 / M66 x Amor*	-0.89	+0.1	+0.70	-8.03	-0.75
2	*Amor x M16 / M6 x Amor*	-0.20	+0.60	+0.18	-0.70	-1.14
3	*M16 x Cuialnic / Cuialnic x M16*	-0.29	-1,0	-0.42	+0.26	+0.30
4	*Cuialnic x Miranda / Miranda x Cuialnic*	+0.88	+3.47	+1.15	-0.03	+0.81
5	*Centurion x M11 / M11 x Centurion*	+0.64	-0.23	+0.36	+0.41	-0.13
	Maternal / paternal effect ratio	3/2	2/3	1/4	3/2	3/2

The tendency to associate the maternal effect with the mass of the grain, and the paternal effect with the number of grains per spike, was also found in previous research on other combinations of common wheat (LUPAŞCU & GAVZER, 2019). This denotes the existence of a general phenomenon for wheat: the number of bound grains depends more on the viability of the paternal pollen, determined both by the resilience of the pollen donor plant and the male gametophyte to extreme factors, and the mass of the grain – by the genetic-physiological environment of the mother plant. The peculiarities of interaction of the mother plant with the surrounding environment cannot be

excluded. Grain mass per spike, for which both significant maternal and paternal effects can be recorded, depends on the subcomponent (number of grains/grain mass) that had a more significant contribution to the spike productivity.

It was found that for the set of combinations under study, the average values of the heritability coefficient in the broad sense (h^2) were 0.56, 0.48, 0.44, 0.54, 0.36, respectively, for the spike length, the number of spikelets, the number of grains per spike, the mass of the grain, the mass of grains per spike (Table 3).

Table 3. Heritability (h^2) of the spike productivity elements in reciprocal hybrids of common wheat.

Nr.	F_2 combination	Length of the spike	Number of the spikelets per spike	Number of the grains per spike	The grain mass	The mass of grains per spike
1	*Amor x M66*	0.64	0.90	0.22	0.73	0.55
2	*M66 x Amor*	0.43	0.37	0.36	0.73	0.31
3	*Amor x M16*	0.26	0.11	0.54	0.38	0.33
4	*M16 x Amor*	0.63	0.29	0.45	0.42	0.31
5	*M16 x Cuialnic*	0.75	0.28	0.59	0.34	0.03
6	*Cuialnic x M16*	0.71	0.62	0.44	0.73	0.48
7	*Cuialnic x Miranda*	0.27	0.69	0.33	0.40	0.27
8	*Miranda x Cuialnic*	0.54	0.58	0.28	0.47	0.31
9	*Centurion x M11*	0.67	0.41	0.60	0.62	0.29
10	*M11 x Centurion*	0.69	0.55	0.54	0.62	0.68
	$x \pm m_x$	**0.56±0.18**	**0.48±0.23**	**0.44±0.13**	**0.54±0.16**	**0.36±0.18**

The lower level of the h^2 coefficient for the number of grains (0.44) and the mass of grains per spike (0.36) compared to the other productivity elements, reveals the significant dependence of these characters on climatic conditions. As with the degree of dominance, the h^2 values were different in the reciprocal hybrids. Only in some combinations – *M16 x Cuialnic/Cuialnic x M16, Centurion x M11/M11 x Centurilon* (spike length), *Amor x M66/M66 x Amor, Centurion x M11/M11 x Centurion* (grain mass), *Amor x M16/M16 x Amor* (grain mass per spike) the crossing direction did not have a significant role in the hereditary transmission capacity of the studied characters. In the other cases – combinations/character, different values of the h^2 parameter were recorded.

The study of the transgressive potential of the segregating F_2 populations – descendants of reciprocal F_1 hybrids, demonstrated that for all the studied characters, the degree (T_d) and frequency (T_f) of transgressions (+/-) were different, both between the combinations of different parents, and between the F_2 hybrids, originating in direct and indirect crosses of the same parents (Table 4).

Table 4. Degree (T_g) and frequency (T_f) of transgressions for spike productivity elements in F_2 combinations of common wheat.

Nr	F_2 combination	Length of the spike		Number of the spikelets per spike		Number of the grains per spike		The grain mass		The mass of grains per spike	
		T_d, %	T_f, %	T_d, %	T_f, %	T_d, %	T_f, %	T_d, %	T_f, %	T_d, %	T_f, %
1	*Amor x M66*	0.3	13.3	7.5	4.2	-2.1	0.9	-0.5	19.2	0.01	0.8
2	*M66 x Amor*	0.78	9.2	-1.5	0.1	-10.7	0.1	0.1	19.2	-3.7	0.8
3	*Amor x M16*	-13.4	0.1	3,0	7.5	9.4	2.5	1.1	24.2	8.7	2.5
4	*M16 x Amor*	-10.2	1.7	3,0	13.3	-4.5	0.8	2.0	27.5	6.4	1.7
5	*M16 x Cuialnic*	0.7	88.3	4.4	3.3	-2.6	0.8	0.3	15.8	-12.6	0.1
6	*Cuialnic x M 16*	-7.7	17.5	-1.5	1.7	-0.9	0.8	-1.3	38.3	-2.8	3.7
7	*Cuialnic x Miranda*	-0.5	8.3	4.4	5.8	-1.6	2.5	-2.6	5.8	12.2	5.0
8	*Miranda x Cuialnic*	0.8	18.3	2.9	8.3	-5.9	1.7	-4.5	6.7	9.4	6.7
9	*Centurion x M 11*	-4.3	11.7	-1.4	5.0	-1.3	1.7	1.1	35.0	-1.8	2.5
10	*M 11 x Centurion*	-3.3	5.0	-1.4	4.2	4.9	2.5	2.3	37.5	14.6	5.8

For example, in the case of the mass of grains per spike in the F_2 Amor x M16 population, T_d = 8.7%, T_f = 2.5%, and in the F_2 *M16 x Amor*, T_d = 6.4%, T_f = 1.7%. More pronounced differences were recorded in the case of *Centurion x M11 / M11 x Centurion* hybrids. Thus, in the direct crossing, T_d = -1.8%, T_f = 2.5%, and in the indirect one – T_d = 14.62, T_f = 5.8%. The combinations F_2 *Amor x M16, Cuialnic x Miranda, M11 x Centurion* were distinguished by higher values of the degree (8.7 ... 14.6%) and frequency (2.5 ... 5.8%) of positive transgressions for the mass of grains per spike.

The study of the spectrum of phenotypic classes in F_2 populations of wheat, descendants of reciprocal F_1 hybrids (Fig. 2) demonstrated that it was influenced by the direction of crossing when creating F_1 hybrids (Fig. 2). Thus, the average values of the investigated characters in both F_2 populations did not differ much. Instead, different deviations from the center of the distribution of values were found. The rate of plants from the center of the distribution of values to the right, that is, in the direction of large values, for the number of grains, the weight of a grain, the mass of grains per spike constituted in F_2 *Centurion x M11*: 39%, 25%, 40%, and in F_2 *M11 x Centurion*: 44%, 26%, 47%, respectively. So in the combination F_2 *M11 x Centurion,* the rate of plants with higher than average productivity element values is more significant than in F_2 *Centurion x M11*. In addition, new classes were found in the F_2 *M11 x Centurion* population: for number of grains – class 80-85 (1% of the entire population) and for weight of grains per spike – class 3.5-4.0 g (2%).

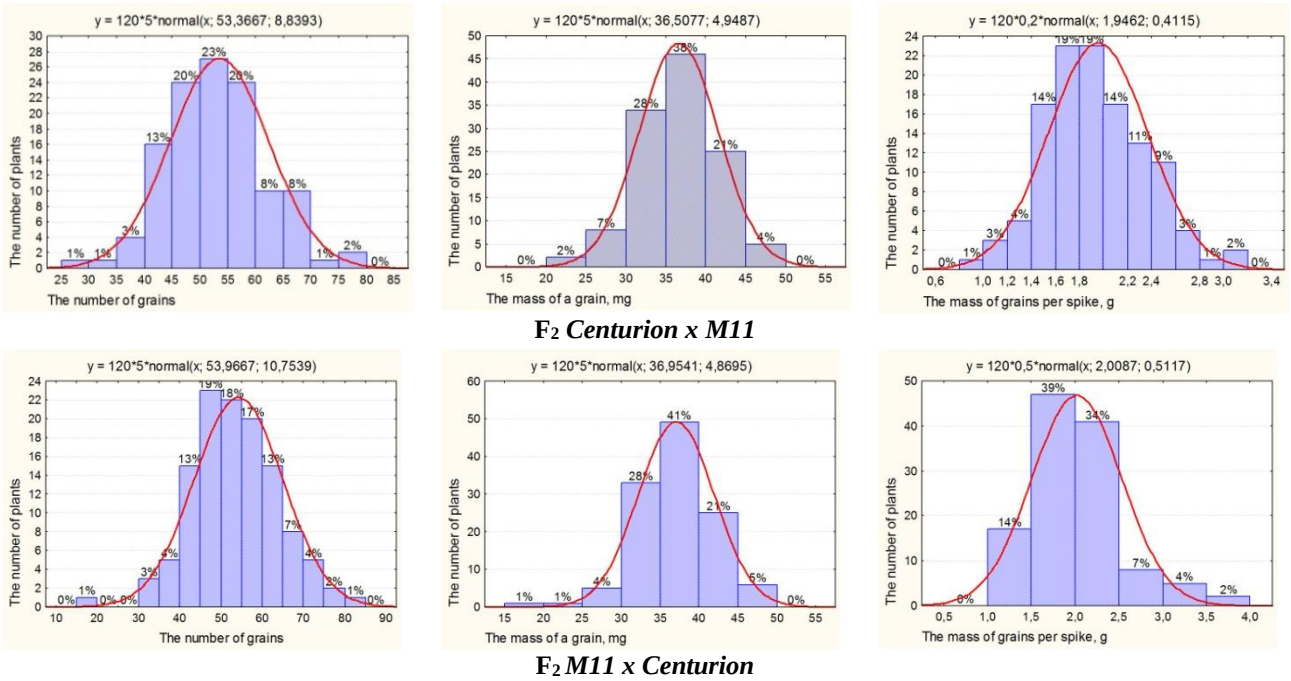

Figure 2. Histogram of distribution of wheat F_2 populations in phenotypic classes based on some productivity characters.

The data obtained in the presented research show the existence of different degrees of dependence between the productivity components of the wheat ear, which requires a holistic approach to the explanation of the phenotypic pattern of the integral index – the spike seed productivity. At the same time, the correct choice of the maternal or paternal genotype in the crosses to obtain F_1 hybrids, determines the hereditary transmission capacity of productivity elements, the degree of variability in the F_2 segregating population, its transgressive potential.

CONCLUSIONS

The analysis of the morphometric data for the spike productivity elements of 7 common winter wheat parents, 5 pairs of reciprocal F_1 hybrids, 5 pairs of F_2 hybrids and the application of the correlation analysis demonstrated that the integral index – grain weight per spike correlated the most with the length of the spike ($r=0.72$, $p<0.05$) and with the number of grains per ear (0.51), but less with the weight of the grain (0.37). Between the number of grains per spike and the mass of a grain, the dependence was insignificant (-0.05), which denotes the independent genetic control of these characters.

The degree of dominance (h_p) of spike productivity elements in F_1 reciprocal hybrids varied between incomplete dominance and overdominance, with positive or negative values, denoting their inheritance according to the dominant or recessive pattern. The expression of the degree and orientation of dominance was highly dependent on the orientation of the cross.

The calculation of the parental effect in F_1 hybrids demonstrated that the number of grains depended more on the paternal genotype, and the mass of the grain – on the maternal one.

The average values of the heritability coefficient in the broad sense (h^2) were 0.56, 0.48, 0.44, 0.54, 0.36, respectively, of the spike length, the number of spikelets, the number of grains per spike, the mass of the grain, the mass of grains per spike. The lower level of the h^2 coefficient for the number of grains (0.44) and the mass of grains per spike (0.36) compared to the other productivity elements, reveals the significant dependence of these characters on climatic conditions. In most of the cases (combination/character) the coefficient h^2 was different in F_2 hybrids (descendants of reciprocal F_1 hybrids), which denotes the influence of the maternal factor on the ability to heritably transmit wheat spike characters.

The study of the degree, frequency of transgressions and the spectrum of phenotypic classes in F_2 populations demonstrated a significant influence of the direction of crossing to create F_1 hybrids on the transgressive potential of wheat combinations and the variability of spike productivity characters in F_2 combinations. The crosses F_2 *Amor x M16, Cuialnic x Miranda, M11 x Centurion* stood out from the others by higher values of the degree (8.7 ... 14.6%) and frequency (2.5 ... 5.8%) of positive transgressions for the mass of grains per spike, which denotes the opportunities to involve these combinations in the breeding programs.

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