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PREDICTION OF SELECTION EFFICIENCY BY SPIKE PRODUCTIVITY ELEMENTS OF BREAD SPRING WHEAT

Pirych A. V., Fedorenko M. V., Ivantsova L. V., Blyzniuk R. M.

The V. M. Remeslo Myronivka Institute of Wheat of NAAS, 68 Tsentralna St., Tsentralne village, Myronivka district, Kyiv region, 08853, Ukraine

Topicality. *Crop yield is a complex trait that requires studying directly by its structural elements. Calculating the efficiency of selection in the next generation is a prerequisite for modern breeding.* ***Purpose.*** *To determine the influence of parental forms on the manifestation of valuable economic traits in F_1 hybrids and to calculate the efficiency of selection in the next generation.* ***Materials and Methods.*** *Field trials were conducted at the V. M. Remeslo Myronivka Institute of Wheat of NAAS (MIW). The research material included 14 F_1 hybrid combinations developed by crossing lines with stem rust resistance genes (33H_1-12, 37H_1-11, 35H_2-18, DHG 146-54, 35H_2-3, 41H_2-4-2, 37H_1-9) submitted by the Institute of Food Biotechnology and Genomics NAS of Ukraine and commercial varieties Dubravka (originator MIW) and Trizo (originator DSV). Analysis of F_1 hybrids and source material of spring wheat was carried out to determine the level of manifestation of spike productivity elements. The influence of parental forms on the manifestation of quantitative traits in F_1 hybrids and coefficients in the broad-sense (H^2) and narrow-sense (h^2) heritability were determined. The variety Elehiia Myronivska was used as the standard.* ***Results.*** *The AVOVA of combining ability revealed a significant advantage in varying the effects of general combining ability (GCA). The mean square for the specific combining ability (SCA) was inferior to the general combining ability, but it was reliable. It was found that the interaction of parental forms had an influence on such traits as number of kernels per spike and kernel weight per spike (influence ratio was 0.46 and 0.56, respectively). The spike length in F_1 hybrids was influenced by the maternal form at 36 %, the influence of the interaction of maternal and paternal genotypes was at 44 % of the total variation. The interaction of the parent components of the crossing had the highest influence on the manifestation of the number of spikelets per spike, it was 69 %. In hybrid combinations, a high coefficient of the broad-sense heritability was of 0.80–0.95, the coefficient of the narrow-sense heritability was of 0.15 to 0.45.* ***Conclusions.*** *Taking into account the significant difference between the two coefficients, it can be concluded that the genotypic variability of the investigated traits is caused in most cases by non-additive (dominant) effects of genes. In subsequent generations, selection based on spike length and kernel number per spike will be effective.*

Key words: *spring wheat, hybrids, combining ability, heritability coefficient, prediction, selection*

Introduction. Harvest formation is a complex multi-stage phenomenon involving many interdependent genetically determined photophysical, photochemical and physiological-biochemical processes at all stages of organogenesis, which are in close interaction with a complex of environmental factors [1].

In breeding research, the heritability of yield in general needs to be studied, and its individual traits, which it consists of, and an important aspect is the knowledge of the heritability mechanism of these traits under certain environmental conditions [2, 3]. The main yield attributes of the grain crops include spike length, number of spikelets and kernels per spike, spike density, spike weight and kernel weight per spike, and 1000 grain weight [4]. It is noted that the most important elements of the yield structure that are of interest to each breeder for individual selections are the spike length, the number of kernels per spike and the grain weight per spike [5, 6]. The effectiveness of selection depends on the pedigree of hybrids, and the greatest prospects are in the involvement of parental forms with contrasting traits and distant origins.

However, the selection of genotypes based

Author information:

Alina V. Pirych, *Candidate of Agricultural Sciences, Head of the Spring Wheat Breeding Laboratory*, e-mail:alina22pirych@gmail.com, https://orcid.org/0000-0003-2312-9774.

Maryna V. Fedorenko, *Candidate of Agricultural Sciences, Senior Researcher of the Spring Wheat Breeding Laboratory*, e-mail:ira_mip@ukr.net, https://orcid.org/0000-0002-3021-3643.

Ludmyla V. Ivantsova, *Junior Researcher of the Spring Wheat Breeding Laboratory*, e-mail: ivancovaluda75@gmail.com, https://orcid.org/0000-0001-7319-9653

Ruslan M. Blyzniuk, *Candidate of Agricultural Sciences, Senior Researcher of the Spring Wheat Breeding Laboratory*, e-mail:bliznyuk359@gmail.com, https://orcid.org/000-0002-8645-2539

on a set of adaptive traits is facilitated by the choice of growing conditions, which increases the yield of valuable recombinants [7, 8]. The study of quantitative traits controlled by polymeric genes is extremely difficult due to their significant variability caused by environmental conditions [9, 10]. Therefore, determining the influence of parental forms on the manifestation of valuable economic traits in F_1 hybrids and calculating the efficiency of selection in the next generation is a necessary stage of modern breeding [11].

Materials and Methods. Field trials were conducted in a breeding crop rotation of the V. M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine (MIW). Mustard was the previous crop. Agronomic practices to prepare the soil for sowing were in line with the recommendations for spring wheat cultivation. The material for the research was fourteen F1 hybrid combinations developed by crossing lines with known stem rust resistance genes ($33H_1$-12, $37H_1$-11, $35H_2$-18, DHG 146-54, $35H_2$-3, $41H_2$-4-2, $37H_1$-9), which were provided by the Institute of Food Biotechnology and Genomics of the National Academy of Sciences of Ukraine, serving as the maternal form, and commercial spring wheat varieties Dubravka (originator MIW) and Trizo (originator DSV) as the parental form. To determine the manifestation degree of the spike productivity elements, the structural analysis of F1 hybrids and the source material was carried out. The influence of parental forms on the manifestation of quantitative traits in F1 hybrids was determined according to the method of B. O. Dospiekhov [12]. The coefficients of the broad-sense (H^2) and narrow-sense (h^2) heritability were determined according to G. K. Dremliuk and V. P. Gerasimenko [13]. According to the spike productivity elements, the standard was the Elehiia Myronivska variety.

Research is aimed at determining the influence of parental forms on the manifestation of valuable economic traits in F_1 hybrids and calculating the effectiveness of selection in the next generation.

Results and Discussion. According to analysis of weather conditions in 2022, they were generally favourable for normal growth and development of spring wheat, but were accompanied by uneven distribution of precipitation and temperature regime in some periods. The average daily air temperature for the period from sowing to seedlings was +7.8 °C, which is +0.7 °C higher than the long-term average. Sufficient precipitation during this period (42.8 mm) contributed to the emergence of friendly seedlings. In the period from seedlings to the stem elongation, the average daily temperature corresponded to the long-term average and was +12.5 °C; the moisture supply during this period was 84.7 mm, which is 26.7 mm higher than the long-term average. In the period from stem elongation to heading, the air temperature was at +19.8 °C, which is +3.4 °C higher than the long-term average, while the precipitation during this period was practically zero (0.7 mm). In the period from heading to full ripeness, the air temperature was 20.9 °C, which is +1.3 °C higher than the long-term average, although the precipitation was 92.8 mm that was 35.2 mm less than the long-term average. It was noted that the minimum air temperature in the morning and at night decreased to +10.6 °C (16 June), and during the day it increased to +32.1 °C (29 June). The average daily air temperature in the stage of milk ripeness was +21.6 °C, which is 2.1 °C higher than the long-term average (+19.5 °C).

The analysis of the spike productivity confirmed the variation of the traits studied among F1 hybrids and parental components. In the growing season of 2022, the average spike length of the parental forms was 6.5–8.8 cm, in the studied hybrid combinations – 8.4–12.1 cm. The maximum manifestation of this trait (12.1 cm) was in the hybrid combination $35H_2$-3/Trizo (Table 1). The number of spikelets in the spike of parental components varied at the level of 13.9–17.3 pcs, in hybrids developed based on them, this indicator was 15.3–20.1 pcs. The highest number of spikelets per spikelet was also obtained in the combination $35H_2$-3/Trizo.

Variation in the number of kernels per spike in F_1 hybrids ranged from 33.75 to 66.75 pcs (Table 2).

The average value of the parental forms ranged from 30.10 to 46.0 pcs.

Grain weight per spike in F_1 hybrids was 1.62–2.78 g. The highest grain weight per spike was 2.78 g in hybrid combination 37H1-9 / Dubravka. The analysis of variance of combining

Table 1. Variation in spike length and number of spikelets per spike in cross components and F_1 hybrid combinations, 2022

Hybrid combination	Main spike length, cm		Number of spikelets per spike, pcs.	
	P	F_1	P	F_1
$33H_1$-12 / Dubravka	6.7±0.71	8.5±2.12	14.8±3.32	16.0±4.24
$33H_1$-12 / Trizo	7.0±1.06	8.5±1.54	14.1±2.40	15.3±1.33
$37H_1$-11 / Dubravka	6.9±0.49	9.7±1.23	14.5±3.68	16.0±1.62
$37H_1$-11 / Trizo	7.1±0.85	9.7±2.00	13.9±2.76	17.1±2.61
$35H_2$-18 / Dubravka	7.5±0.42	10.4±1.04	15.4±2.47	17.4±1.39
$35H_2$-18 / Trizo	7.8±0.007	9.4±1.10	14.7±1.56	17.1±1.47
$35H_2$-3 / Dubravka	7.5±0.42	9.4±1.09	15.7±2.05	16.7±3.61
$35H_2$-3 / Trizo	7.8±0.07	12.1±1.65	15.0±1.13	20.1±0.83
$41H_2$-4-2 / Dubravka	8.5±1.84	10.7±0.49	17.3±0.28	17.7±0.47
$41H_2$-4-2 / Trizo	8.8±1.48	11.0±1.41	16.7±1.20	19.5±0.71
$37H_1$-9 / Dubravka	6.5±1.06	8.4±3.75	15.1±2.83	18.0±1.10
$37H_1$-9 / Trizo	6.7±1.41	9.7±2.75	14.5±1.91	16.1±2.57
DHG 146-54 / Dubravka	7.3±0.14	10.2±0.77	15.5±2.26	17.8±1.99
DHG 146-54 / Trizo	7.6±0.21	11.4±0.99	14.9±1.34	18.1±2.70
Min	*6.5±1.06*	*8.4±3.75*	*13.9±2.76*	*15.3±1.33*
Max	*8.8±1.48*	*12.1±1.65*	*17.3±0.28*	*20.1±1.62*

Notes: P - parental forms; F_1 - hybrid combination;
min - minimum value of the trait; max - maximum value of the trait

Table 2. Variation of number of kernels per spike and grain weight per spike in cross components and F_1 hybrid combinations, 2022

Hybrid combination	Number of kernels per spike, pcs.		Grain weight per spike, g	
	P	F_1	P	F_1
33H1-12 / Dubravka	31.0±14.50	34.00±5.66	1.15±0.57	1.62±0.27
33H1-12 / Trizo	30.1±13.30	42.75±8.32	1.10±0.49	2.03±0.33
37H1-11 / Dubravka	33.4±11.20	45.40±14.55	1.13±0.45	2.26±0.81
37H1-11 / Trizo	32.5±9.90	52.05±12.45	1.20±0.49	2.07±0.59
35H2-18 / Dubravka	31.8±13.40	48.20±13.45	1.15±0.42	2.24±0.61
35H2-18 / Trizo	30.9±12.20	49.50±12.75	1.33±0.17	2.24±0.67
35H2-3 / Dubravka	32.7±8.20	41.05±15.91	1.18±0.52	1.81±0.73
35H2-3 / Trizo	34.6±6.90	51.45±10.00	1.32±0.18	2.35±0.51
41H2-4-2 / Dubravka	46.0±6.58	33.75±9.94	1.51±0.06	1.65±0.43
41H2-4-2 / Trizo	45.1±7.85	60.00±16.97	1.46±0.01	2.63±1.24
37H1-9 / Dubravka	31.8±13.51	55.85±11.58	1.20±0.49	2.78±0.96
37H1-9 / Trizo	30.9±12.23	50.20±9.37	1.15±0.42	2.35±0.72
DHG 146-54 / Dubravka	35.8±7.78	51.80±8.47	1.38±0.28	2.45±0.41
DHG 146-54 / Trizo	34.9±6.50	66.75±10.11	1.37±0.25	1.81±0.51
Min	*30.10±13.30*	*33.75±9.94*	*1.10±0.49*	*1.62±0.27*
Max	*46.00±6.58*	*66.75±10.11*	*1.51±0.06*	*2.78±0.96*

Notes: P - parental forms; F_1 - hybrid combination;
min - minimum value of the trait; max - maximum value of the trait

ability revealed a significant advantage in the variation of the effects of general combining ability (GCA) (Table 3). The mean square for specific combining ability (SCA) was inferior to the general combining ability, but was significant.

The values of variance and the proportion of influence of the paternal form revealed that

Table 3. Analysis of variance for combining ability of spring wheat in terms of spike productivity elements, 2022

Factor	Main spike length		Number of spikelets per spike		Number of kernels per spike		Grain weight per spike	
	MS	F	MS	F	MS	F	MS	F
GCA of maternal forms (A)	6.83	11.87*	8.90	7.93*	328.46	15.83*	0.77	8.51*
GCA of paternal forms (B)	6.31	10.97*	3.60	3.21	1123.23	54.14*	1.04	11.44*
SCA (AB)	2.93	5.10*	6.01	5.36*	204.60	9.86*	0.49	5.40*
Deviation	0.58	-	1.12	-	20.75	-	0.09	-

*Notes: MS - mean square; F - Fisher exact test (actual value); * results are statistically significant at 0.05 % significance level.*

the influence of the maternal form on the spike length in hybrids was 0.36 or 36 %, the paternal form – 0.10 or 10 %, the influence of the interaction of maternal and paternal genotypes – 0.44 or 44 %, random factors – 0.1 or 10 % of the total variation in spike length (Table 4). The manifestation of the number of spikelets per spikelet was most influenced by the interaction of parental crossing components; the proportion of influence was 0.69 or 69 %.

Table 4. Variances of general and specific combining ability, 2022

Factor	Main spike length		Number of spikelets per spike		Number of kernels per spike		Grain weight per spike	
	variance	Proportion of influence	variance	Proportion of influence	variance	Proportion of influence	variance	Proportion of influence
Maternal form (A)	1.95	0.36	1.45	0.20	61.93	0.16	0.14	0.20
Paternal form (B)	0.48	0.10	-0.34	-0.05	131.23	0.33	0.08	0.11
Interaction	2.36	0.44	4.89	0.69	183.86	0.46	0.40	0.56

The data obtained indicate that the interaction of parental forms had a significant influence on the manifestation of such traits as number of kernels per spike and grain weight per spike in the studied spring wheat hybrids (the proportion of influence was 0.46 and 0.56, respectively).

The main tool of crop breeding is selection. In the process of breeding varieties, the breeder evaluates and selects spikes for the main elements of productivity, resistance to abiotic and biotic factors. Therefore, for high-quality breeding work, it is necessary to identify the traits that will be effective in the next generation.

The broad-sense heritability (H^2) is the proportion of total phenotypic variation that results from the influence of any heritable factors.

The narrow-sense heritability (h^2) is only that part of the total variability that is caused by the additive action of genes (polymery). In breeding, narrow-sense heritability is commonly used because it allows predicting the results of breeding work. The heritability degree of a trait is conventionally divided into high (h^2>0.4), medium (h^2=0.2–0.4) and low (h^2<0.2).

In our study, the coefficient of broad-sense heritability *(H^2)* ranged from 0.80 to 0.95, which indicates a significant influence of genetic factors on the variability of the trait [14]. The coefficient of narrow sense heritability *(h^2)* for the spike length was 0.45, for the number of spikelets in the spike – 0.15, for the number of kernels per spike – 0.49 and for the grain weight per spike – 0.31. The lowest difference between the two heritability coefficients was observed for the spike length (0.42) and the number of spikelets per spike (0.46). For the number of spikelets per spike and grain weight per spike, the difference was 0.65 and 0.55, respectively (Table 5).

A significant difference between broad-sense heritability *(H^2)* and narrow-sense herita-

Table 5. Average heritability coefficients for traits of spring wheat productivity, 2022

Trait	Main spike length	Number of spike-lets per spike	Number of kernels per spike	Grain weight per spike
h^2	0.45	0.15	0.49	0.31
H^2	0.87	0.80	0.95	0.86
$H^2 – h^2$	0.42	0.65	0.46	0.55

bility *(h^2)* indicates that genotypic variation is often caused by non-additive gene effects. As practice shows, selection to increase the parameters of traits with dominant heritability will not always provide the desired results in the selection of the required biotypes. Therefore, the selection of a significant amount of morphobiotypes in the populations of split hybrids is required. In addition, selection for increasing the parameters of quantitative traits should be carried out in the latest generations, where, as a rule, there will be more constant morphobiotypes [15].

Conclusions. As a result of determining the coefficients of broad-sense and narrow-sense heritability in hybrid combinations of spring wheat, developed by using lines resistant to stem rust and commercial varieties (Dubravka, Trizo), high coefficient of broad-sense heritability was noted at 0.80–0.95, and coefficient of narrow-sense heritability ranged from 0.15 to 0.49. Given the significant difference between the two coefficients, we can conclude that the genotypic variability of the studied traits is mostly caused by non-additive (dominant) gene effects. In the next generations, attention should be paid to selection for spike length and number of kernels per spike to increase the efficiency of the breeding process.

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Пірич А. В., Федоренко М. В., Іванцова Л. В., Близнюк Р. М. Прогнозування ефективності добору за елементами продуктивності колоса пшениці м'якої ярої. *Зернові культури. 2023. 7 (2). 248–253.*
Миронівський інститут пшениці імені В. М. Ремесла НААН, с. Центральне, Обухівський р-н, Київська обл., 08853, Україна

Актуальність. Урожайність сільськогосподарських культур – це складна ознака, вивчення якої потрібно проводити безпосередньо за елементами її структури. Розрахунок ефективності добору у наступному поколінні є необхідним етапом у сучасній селекції. **Мета.** Визначити вплив батьківських форм на прояв цінних господарських ознак у гібридів F_1 та розрахувати ефективність добору у наступному поколінні. **Матеріали і методи.** Польові дослідження проводили у Миронівському інституті пшениці імені В. М. Ремесла НААН (МІП). Матеріалом для досліджень були 14 гібридних комбінацій F_1, створених від схрещування ліній з відомими генами стійкості до стеблової іржі (33H_1-12, 37H_1-11, 35H2-18, DHG 146-54, 35H_2-3, 41H_2-4-2, 37H_1-9), які надані ДУ «Інститут харчової біотехнології та геноміки НААН України» і комерційних сортів пшениці ярої Дубравка (оригінатор МІП) та Трізо (оригінатор DSV). Для визначення рівня прояву елементів продуктивності колоса проводили структурний аналіз гібридів F_1 та вихідного матеріалу. Визначали вплив батьківських форм на прояв кількісних ознак у гібридів F_1 і коефіцієнти успадковуваності у широкому (H^2) і вузькому розумінні (h^2). За стандарт використовували сорт Елегія миронівська. **Результати.** Дисперсійний аналіз комбінаційної здатності виявив значну перевагу у варіюванні ефектів загальної комбінаційної здатності (ЗКЗ). Середній квадрат для специфічної комбінаційної здатності (СКЗ) поступався загальній комбінаційній здатності, але був достовірним. Встановлено, що вплив на прояв ознак «кількість зерен з колоса» та «маса зерна з колоса» мала взаємодія батьківських форм (частка впливу 0,46 та 0,56 відповідно). На прояв ознаки «довжина колоса» у гібридів F_1 мала вплив материнська форма – 36 %, вплив взаємодії материнських та батьківських генотипів становив 44 % всієї варіації за довжиною колоса. На прояв «кількості колосків у колосі» найвищий вплив мала взаємодія батьківських компонентів схрещування – 69 %. У гібридних комбінаціях відмічено високе значення коефіцієнта успадковуваності у широкому розумінні (0,80–0,95), значення коефіцієнта успадковуваності у вузькому розумінні становило від 0,15 до 0,45. **Висновки.** Враховуючи значну різницю між двома коефіцієнтами можна зробити висновок, що генотипова мінливість досліджуваних ознак зумовлена в більшості випадків неадитивними (домінантними) ефектами генів. У наступних поколіннях ефективним буде добір за довжиною колоса та кількістю зерен з колоса.

Ключові слова: *пшениця яра, гібриди, комбінаційна здатність, коефіцієнт успадковуваності, прогноз, добір*