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Vecherska L .A., Relina L. I., Bohuslavskyi R. L., Golik O. V.
Plant Production Institute named after V. Ya. Yuriev
142 Moskovskyi Ave., Kharkiv, 61060, Ukraine
E-mail:lyudmila_vecherska@ukr.net

MORPHOGENESIS IN EARLY GENERATIONS OF WINTER EMMER / DURUM WINTER WHEAT HYBRIDS

Morphogenesis profiles in early generations of winter emmer *Triticum dicoccum var. atratum* (Host) Koern. / modern durum winter wheat varieties hybrids were established. High level and frequency of positive transgressions for the grain weight per spike (53.7% and 85.7%, respectively) and kernel number per spike (53.4% and 57.4%, respectively) in all three combinations were observed. Emmer plants with amber grain and high levels of positive transgressions for all performance traits and plant height of ≤ 80cm. (spike length, spikelet and kernel numbers per spike, grain weight per spike, and 1000-kernel weight) were selected in F_2 hybrids between winter emmer / durum winter wheat. The inheritance coefficients varied, depending on the trait and cross combination.
Keywords: *winter emmer, heritability, transgression, durum wheat, performance*.

INTRODUCTION

Emmer (*Triticum dicoccum* (Schrank) Schuebl) is valued for its higher nutritional and dietary properties compared to common wheat, lower requirements on soil and water and higher resistance to biotic factors [1-3]. At the same time, emmer has some undesirable features, namely: very coriaceous flowering and spikelet glumes that are snug against kernels and cause poor threshing, spike brittleness during grain filling, poor resistance to lodging due to tall plants (120-150 cm).

To solve these problems via emmer breeding, it is necessary to develop appropriate starting material adapted to specific soil and climatic conditions. Such material can be obtained when interspecies hybrids are segregated, due to high variability of features, expression of which differs from that in the parents. Modern varieties of durum wheat are sources of traits for the breeding improvement of emmer. Emmer breeding was aimed primarily at improving the pasta properties in combination with high yield capacity.

It is known that in Ukraine winter wheat is usually much more productive than spring wheat. At the same time, all the emmer varieties included in the State Register of Plant Varieties of Ukraine are spring. Creation of winter varieties would increase yields of this valuable crop and to cheapen emmer-based products. However, in Ukraine winter emmer is little known and rarely used in practical breeding. At the same time, durum winter wheat is bred at the Plant Breeding and Genetics Institute – National Center of Seed and Cultivar Investigation and the Plant Production Institute named after V. Ya. Yuriev, and their high-yielding and top-quality varieties are included in the Register. This determines the expediency of involving these species in breeding as parents and establishing the inheritance profiles of breeding-valuable traits in their hybrids. In particular, for practical breeding, positive transgressions for different valuable economic traits obtained in recombinats are important. Such transgressions occur most frequently when geographically and, therefore, genetically distant forms within one species or a group of close species are hybridized [4].

Purpose. To establish the morphogenesis profiles in the early generations of hybrids between winter emmer and modern varieties of durum winter wheat to obtain breeding-valuable emmer accessions.

MATERIALS, METHODS AND CONDITIONS

The study was conducted in the experimental field of the Plant Production Institute named after V. Ya. Yuriev of NAAS (eastern forest-steppe of Ukraine) in 2014–2019. Three varieties of durum winter wheat (Shulyndinka, Kontynent and Agat Donskoy) and 2 winter emmer accessions (*T. dicoccum var. atratum* 0300081 POL, *T. dicoccum var. atratum* 0300214 USA) were investigated. They were provided by the National Center for Plant Genetic resources of Ukraine (NCPGRU). It is quite difficult to obtain such hybrids, as *T. dicoccum var. atratum* develops very slowly, and durum wheat plants, on the opposite, develop quickly. Accordingly, the anthesis dates of the male and female forms do not coincide. To overcome this, we sowed durum winter wheat very. In addition, the weather in 2016 favored hybrid caryopsis setting.

Seeds of hybrids and parents were sown in a hybrid nursery according to the scheme "female form – F_1, F_2 - male form", 40 kernels per row, with an interrow spacing of 15 cm.

The performance of parent and hybrid plants were analyzed by the following traits: plant height, spike length, spikelet and kernel numbers per spike, spike weight, grain weight per spike, and 1000-kernel weight (W1000).

The broad-sense heritability coefficients (H^2) were calculated from parents' and hybrids' variances [5]. The narrow-sense heritability coefficients (h^2) were calculated from the regression coefficients between the parents' and offspring's values of the traits [6]. The level (T_l) and frequency (T_f) of positive transgression were calculated by Voskresenskaya and Shpota's method [7].

RESULTS AND DISCUSSION

Both species used in crosses (*T. dicoccum* and *T. durum*) belong to the same genomic group (A^uB), so they are genetically compatible: they are easily crossed (when their anthesis is concurrent) and give fertile hybrids. J. McKey [8] regards them as subspecies of one species – *T. turgidum* L. Therefore, genetically, their hybrids can be regarded as intraspecies. In our experiments, the rate of hybrid caryopsis setting was 80-92%.

Emmer completely dominated in F_1; no features of durum wheat were seen: tall plants (160 cm), large flat black awny spikes (grain weight per spike = 1.59 g), large emmer-like kernels with 1000-kernel weight of 60 g. F_2 populations, several traits segregated. We distinguished emmer- and durum wheat-like types as well as compactoids (forms with very dense spikes [38 spikelets per 10cm] and light threshing. Within each of these types, the spike color (black, white, grayish-yellow) and kernel color (red, white) were differently combined.

V. F. Dorofeev [9] categorized varieties by height into five classes: dwarfs (< 60cm), semi-dwarfs (60-85cm), short-stemmed (85-105cm), mid-tall (105-120), and tall (> 120cm). Similar, however with minor differences (semi-dwarfs of <80cm, low plants of 80-105cm), classification of varieties is given by S. P. Lyfenko [10].

We distinguished the following classes of plant height in all the types: < 80cm, 81-105cm (as the most valuable to develop intensive varieties), 106-120cm, and > 120cm (*Fig. 1*). The greatest number (22%) of semi-dwarfs (< 80cm) was seen in the 'UA0300214 / Kontynent' combination. The total percentage of the most valuable forms for development of intensive emmer varieties, semi-dwarfs and low forms was also highest in the 'UA0300214 / Kontynent' combination (41%). In the 'UA0300214 / Shulyndinka' combination there were no semi-dwarfs among plants with black spikes, whereas plants > 120 cm were the most numerous (71%).

The frequency of positive transgressions for the spike length was 18.9-55.7%, depending on the combination (Table 1).

Table 1. **Variation, level and frequency of transgression for the spike length in F_2 hybrids between winter emmer and durum winter wheat, 2018–2019**

Combination	Max, cm	Mean ± SD	CV, %	T_f, %	T_l, %
UA0300214 / Kontynent	9.0	6.5±1.0	15.3	18.9	12.1-14.3
UA0300214 / Shulyndinka	11.0	6.7±1.0	15.4	55.7	5.3-57.6
Agat Donskoy / UA0300081	8.0	6.4±0.9	14.9	48	6.4-15.9

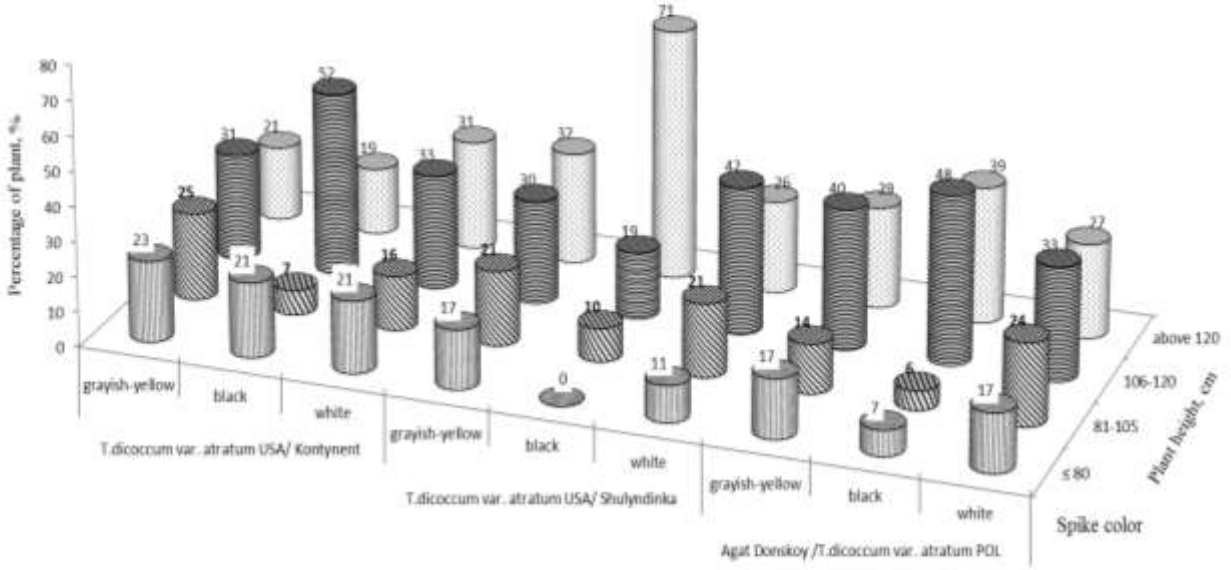

Fig. 1. **Grouping of F_2 hybrids between winter emmer and durum winter wheat by plant height, 2018–2019.**

The highest frequency (55.7%) and level (up to 57.6%) of transgressions for this trait was observed in the ‘UA0300214 / Shulindinka’ combination. The variation coefficient for this trait was medium (14.9-15.4%).

The total frequency of positive transgressions for the spikelet number per spike ranged 13.6 to 60.2% (Table 2). The highest frequency (60.2%) and level (up to 69%) of transgressions for this trait were observed in the ‘UA0300214 / Kontynent’ and ‘Agat Donskoy / UA0300081’ combinations – 58.9% and up to 65.1%, respectively.

Table 2. **Variation, level and frequency of transgression for the spike number per spike in F_2 between winter emmer and durum winter wheat, 2018–2019**

Combination	Max	Mean ± SD	CV, %	T_f, %	T_l, %
UA0300214 / Kontynent	24	16.3±3.0	18.2	60.2	7.1-69
UA0300214 / Shulyndinka	27	16.0±2.9	18.1	13.6	5.5-32.9
Agat Donskoy / UA0300081	26	16.9±2.7	16.1	58.9	6.6-65.1

The highest frequency of positive transgressions for the kernel number per spike was recorded in the ‘UA0300214 / Kontynent’ combination – 53.4% (Table 3). The total frequency of transgressions for this trait varied from 22.2 to 53.4%. The highest level of transgressions for the kernel number per spike was observed in the ‘UA0300214 / Shulyndinka’ combination – up to 57.4%. The coefficient of variation was within 20-22.2%.

Table 3. **Variation, level and frequency of transgression for the kernel number per spike in F_2 between winter emmer and durum winter wheat, 2018–2019**

Combination	Max	Mean ± SD	CV, %	T_f, %	T_l, %
UA0300214 / Kontynent	49	31.0±6.9	22.2	53.4	6.0-53.0
UA0300214 / Shulyndinka	54	30.8±6.7	21.6	22.2	7.0-57.4
Agat Donskoy / UA0300081	48	32.0±6.5	20.2	26.7	12.1-55.8

The frequency of positive transgressions for the grain weight per spike was 18.6-53.7% (Table 4). The ‘Agat Donskoy / UA0300081’ combination should be distinguished, since it showed the highest frequency (53.7%) and level (up to 85.7%) of transgressions. The coefficient of variation for the grain weight per spike was within 29.1-32.5%.

Table 4. **Variation, level and frequency of transgression for the grain weight per spike in F_2 between winter emmer and durum winter wheat, 2018–2019**

Combination	Max, g	Mean ± SD	CV, %	T_f, %	T_l, %
UA0300214 / Kontynent	2.6	1.4±0.5	32.5	40.3	5.7-84.4
UA0300214 / Shulyndinka	3.0	1.5±0.4	29.7	18.6	5.6-74.7
Agat Donskoy / UA0300081	2.61	1.5±0.4	29.1	53.7	8.9-85.7

The highest frequency (22.0% and 22.3%) and level (5.3-21.1% and 2.6-19.8%) of transgressions for the 1000-kernel weight were noted were recorded for the ‘UA0300214 / Shulyndinka’ and ‘Agat Donskoy / UA0300081’ combinations, respectively (Table 5). The lowest frequency (6.3%) and level (5.0-11.1%) of positive transgressions for the 1000-kernel weight were noted in the ‘UA0300214 / Kontynent’ combination.

Table 5. **Variation, level and frequency of transgression for the 1000-kernel weight in F_2 between winter emmer and durum winter wheat, 2018–2019**

Combination	Max, g	Mean ± SD	CV, %	T_f, %	T_l, %
UA0300214 / Kontynent	61.5	44.2±7.8	17.7	6.3	5.0-11.1
UA0300214 / Shulyndinka	62.4	46.4±6.5	14.1	22.0	5.3-21.1
Agat Donskoy / UA0300081	58.1	44.9±6.9	15.4	22.3	7.6-19.8

In general, the lowest coefficients of variation were recorded for the 1000-kernel weight (14.1-17.7%) and spike length (14.9-15.4%). The segregation range for the grain weight per spike was highest in the three combinations −29.1-32.5%. Thus, the hybrid combinations obtained differ significantly by presence - absence of transgressions on the whole and in their frequency, in particular.

The results of analysis of F_2 hybrid plants singled out semi-dwarfs and low forms. The percentage of low plants (≤ 80cm) in the ‘UA0300214 / Kontynent’ combination was 21-23% (*Fig. 1*). Among the plants with grayish-yellow spikes, the proportion of low (≤ 80cm) plants was 23%; among the plants with black and white spikes – 21%. Emmer-like plants with vitreous red and amber grain were selected: kernels are triangular in cross section, sharpened at germs and tails. The proportions of amber-grained plants with black and white spikes were 5%, and 1% of plants with grayish-yellow spikes had amber grain. In addition, we selected amber-grained forms with a high level of positive transgression for all the performance traits and with a plant height of ≤ 80cm.

In the ‘UA0300214 / Shulyndinka’ combination, the proportion of semi-dwarfs (≤ 80cm) was 17% among the plants with grayish-yellow spikes; among the forms with white spikes, the percentage of such plants was 11%; and there were no such plants among the forms with black spikes. Emmer-like plants with vitreous red and amber grain were distinguished. The percentage of such plants in the ‘UA0300214 / Shulyndinka’ combination was 4-5%, depending on the spike color (*Fig. 2*). The proportion of white-grained plants was highest (10%) among the forms with grayish-yellow spikes.

In the ‘Agat Donskoy / UA0300081’ F_2 hybrid population, the proportion of semi-dwarfs (≤ 80cm) was within 7-17%. The highest proportions of low plants (17%) and white-grained forms (8%) were observed in the ‘grayish-yellow spike’ class. Amber-grained plants had low levels of transgression for the spike performance, or their performance was similar to the parents’ performance. It should be noted that these patterns were observed in all the combinations.

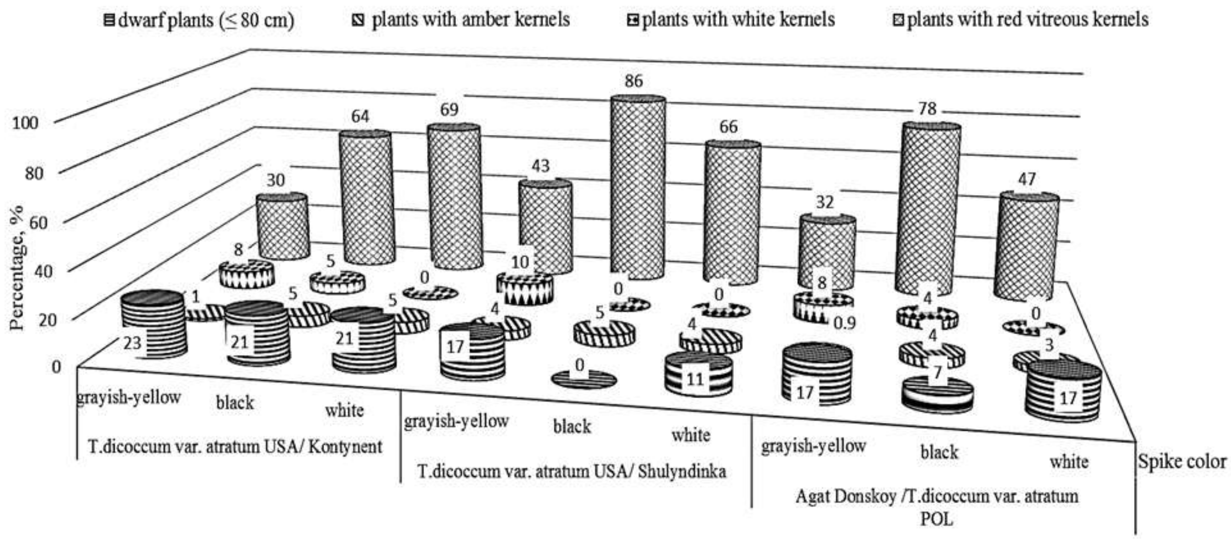

Fig. 2. **Grouping of F_2 hybrids between winter emmer and durum winter wheat by spike and grain color, 2018–2019**

A considerable number of transgressive plants and rather high levels of expression of the performance traits as well as combination of the performance characteristics with organoleptic qualities of grain justify good perspectives of these hybrid combinations.

To solve breeding challenges, it is necessary to understand how valuable economic traits are inherited. Broad- and narrow-sense heritability coefficients of quantitative traits, as numerous studies demonstrated, vary considerably [11, 12], which is due to genetically distant forms involved in crossing.

The spike performance elements in the F_2 hybrids between winter emmer and durum wheat had various heritability coefficients (Table 6). Selection allowed us to single out long-spiked forms with large kernels. Spike length is determined by many additive genes localized in almost all wheat chromosomes, which in some cases dominate in various degrees, over-dominate or show non-allelic interactions [13, 14].

Table 6. **Heritability of the spike performance elements in the F_2 winter emmer / durum winter wheat hybrids, 2018–2019**

Combination	Spike length	Spikelet number per spike	Kernel number per spike	Grain weight per spike	W1000
UA0300214/ Kontynent	0.61/0.36*	0.15/0.13	0.51/0.49	0.51/0.50	0.34/0.31
UA0300214/ Shulyndinka	0.73/0.63	0.13/0.12	0.18/0.14	0.19/0.16	0.56/0.54
Agat Donskoy / UA0300081	0.46/0.31	0.10/0.10	0.58/0.30	0.15/0.14	0.55/0.52

* broad-sense heritability coefficient (H^2)/ narrow-sense heritability coefficient (h^2)

The broad-sense heritability index for the spike length varied within 0.46-0.73, and the narrow-sense index – within 0.31-0.63 (Table 6). In breeding experiments, both of the coefficients are important. Their comparison allows determining the variability portion attributed to additive and non-additive effects, and, on this basis, choosing a method of evaluation and selection of breeding material. In the ‘UA0300214 / Shulyndinka’ and ‘Agat Donskoy / UA0300081’ combinations, the broad- / narrow-sense heritability coefficient ratios were 0.73/0.63 and 0.46/0.31 respectively. Since the difference between the two coefficients is insignificant, we can conclude that the genotypic variability in these combinations is due to the additive effects of genes, and phenotype-driven selection will be close to genotype-driven selection. In the

‘UA0300214 / Kontynent’ combination, the difference between H^2 and h^2 is significant (0.61/0.36); therefore, selection by phenotype will not give forms with genetically-determined expression of the traits.

The spike performance is significantly affected by the spikelet number per spike. In our study, the heritability indices for the spikelet number per spike were quite low (0.10-0.15), indicating a wide phenotypic diversity with narrow genotypic diversity, and, therefore, the probability of selection of desirable genotypes by phenotype will low.

Recent studies demonstrated that wheat grain yield is influenced rather by the kernel number per spike than by the kernel size [15, 16].

In our experiments, the heritability index for the kernel number per spike in the ‘UA0300214 / Kontynent’ and ‘Agat Donskoy / UA0300081’ combinations was 0.51 and 0.58, respectively (Table 6). In the ‘UA0300214 / Shulyndinka’ combination, this index was 0.18. Comparison of the broad- and narrow-sense heritability coefficients leads to the conclusion that selection by the kernel number per spike will give the best result in the ‘UA0300214 / Kontynent’ combination (0.51/0.49), and selection by this trait in the ‘UA0300214 / Shulyndinka’ combination will be unproductive.

Our data are consistent with the results of other researchers [17], who recorded rather high heritability of the kernel number per spike. S. Wegrzyn and L. Pochaba [18] noted epistasis when they investigated the heritability of the kernel number per spike in spiked cereals.

The grain weight per spike is one of the main elements of the spike performance. The inheritance of this trait is polygenic [19]. In our experiments, the highest broad-sense heritability coefficient was observed in the ‘UA0300214 / Kontynent’ combination −0.51.

Given the narrow-sense heritability coefficient of 0.50 for the grain weight per spike, we can assume that the genotypic variability is due largely to the additive effects of genes, and selection by this trait in a population will be effective.

1000-kernel weight is an important element of grain yields in cereals and an important characteristics of grain. Numerous studies have demonstrated a complex genetic control of this important trait [20]. Environmental conditions, such as water deficit and high temperatures during the growing period, nutrition, etc., affect the plant performance.

In our study, sufficiently high broad- and narrow-sense heritability coefficients for the 1000-kernel weight were found in the ‘UA0300214 / Shulyndinka’ (0.56/0.54) and ‘Agat Donskoy / UA0300081’ combinations (0.55/0.52), whereas in the ‘UA0300214 / Kontynent’ combination this indices were 0.34/0.31 (Table 6).

Analysis of starting forms and hybrid offspring leads to the conclusion that in order to create starting material of winter emmer with strong expression of performance traits and organoleptic qualities of grain one should involve durum winter wheat varieties with a 1000-kernel weight of ≥46 g.

There were significant differences between the heritability coefficients, depending on parents. Relatively high narrow-sense heritability coefficients were observed for the spike length in the ‘UA0300214 / Shulyndinka’ combination (0.63); the narrow-sense heritability coefficients were high for the kernel number per spike (0.49) and grain weight per spike (0.50) in the ‘UA0300214 / Kontynent’ combination. Assessment of the heritabilility of specific components of the yield revealed that the 1000-kernel weight had the highest coefficint across the combinations (0.31-0.54). Therefore, these are the most reliable traits that should be used to perform individual selections in early generations (F_2) with a high probability of developing lines with desired traits.

Our results are consistent with the literature data, which indicate a high heritabilility of the 1000-kernel weight [21, 22].

It is known that the minimum value of the heritabilility coefficient, by which successful selection in early generations can be made, should be around 0.50 [6]. Table 6 shows that such coefficients are intrinsic to the spike length and 1000-kernel weight grains in the ‘UA0300214 / Shulyndinka’ combination, to the grain weight per spike in the ‘UA0300214 / Kontynent’ combination and to the 1000-kernel weight in the ‘Agat Donskoy / UA0300081’ combination.

The broad-sense heritability coefficient for the spikelet number per spike ranged 0.10 to 0.15; the narrow-sense heritability coefficient −0.10 to 0.13, therefore, selection by the spikelet number per spike is not effective. Selection by traits with low heritability coefficients is recommended to start in later generations to eliminate waste of valuable forms.

CONCLUSIONS

The breeding value of hybrids between winter emmer *T. dicoccum var. atratum* and intensive varieties of durum winter wheat was determined. Generally, the highest frequencies and levels of transgression in F_2 hybrids between winter emmer and durum winter wheat were observed for the grain weight per spike (T_f = 53.7%; T_l = 85.7%) and kernel number per spike (T_f = 53.4%; T_l = 57.4%).

The highest frequency of transgressions for the 1000-kernel weight was recorded in the ‘UA0300214 / Shulyndinka’ (22%) and ‘Agat Donskoy / UA0300081’ (22.3%) combinations.

The ‘UA0300214 / Kontynent’ combination comprised forms with emmer-like vitreous amber grain, with a high level of positive transgressions for performance and short-stemed forms (≤ 80cm).

We demonstrated that, in order to develop starting material of winter emmer with strong expression of the performance traits and organoleptic qualities of grain, it is necessary to involve durum winter wheat varieties with a 1000-kernel weight of ≥ 46 g.

When winter emmer is crossed with durum winter wheat, the most reliable traits for individual selection in the early generation (F_2) are the kernel number per spike and 1000-kernel weight.

REFERENCES

1. Vecherska LA, Relina LI, Golik OV. 2018. Emmer: advantages, disadvantages and prospects. Visnyk Umanskoho Natsionalnoho Universytetu Sadivnytstva. 2: 10-16. doi: 10.31395/2310-0478-2018-21-10-16. [in Ukrainian]
2. Čurná V, Lacko-Bartošová M. 2015. Nutritional characteristics of emmer wheats varieties. Journal of microbiology, biotechnology and food sciences. 4 (Special issue 3): 95-98. doi: 10.15414/jmbfs.2015.4.special3.95-98.
3. Čurná V and Lacko-Bartošová M. 2017. Chemical Composition and Nutritional Value of Emmer Wheat (Triticum dicoccon Schrank): a Review. Journal of Central European Agriculture. 18(1): 117-134. doi: 10.5513/JCEA01/18.1.1871.
4. Orlyuk AP, Bazaliy VV. 1998. Principles of the transgressive breeding of wheat. Kherson: Naddniprianska Pravda. 274 p. [in Russian]
5. Mahmud I, Kramer H.1951. Segregation for yield, height and maturity following a soybean cross. Agron. S. 43 (12): 605-609.
6. Fedin MA, Silis DYa, Smiryaev AV. 1980. Statistical methods of genetic analysis. Moscow: Kolos. 207 p. [in Russian]
7. Voskresenskaya GS, Shpota VI. 1967. Transgression of traits in Brassica hybrids, a method for measurement of this phenomenon. Doklady VASKhNIL. 7: 18-19. [in Russian]
8. Mackey JM. 2005. Wheat: its concept, evolution and taxonomy In: Royo C, Nachit MM, Di Fonzo N, Araus JL, Pfeiffer WH, Slafer GA, editors. Durum wheat breeding: current approaches and future strategies. New York. Food Products Press. p. 3-61.
9. Dorofeyev VF. 1987. Wheat of the world. Leningrad: VO "Agropromizdat". 560 p. [in Russian]
10. Lifenko SF. 1987. Semi-dwarf varieties of winter wheat. Kiev: Urozhay: 192 p. [in Russian]
11. Orliuk AP, Usyk LO, Kolesnykova ND. 2011. Genotypic correlations between yield and component traits in winter bread wheat. Zroshuvane Zemlerobstvo. Interdepartmental thematic scientific collection. 55: 236-245. [in Ukrainian]
12. Chekalin NM, Tishchenko VN, Zyukov ME. 2004. Simple partial coefficients of genetic correlation between yield and spike performance traits in winter wheat lines and varieties. Zb. Nauk. Prats SGI – NUSN. 6 (46): 103-110. [in Russian]

13. Walton P D. 1969. Inheritance of morphological characters associated with yield in spring wheat. Canad. J. Plant Sci. 49 (5): 587-596.
14. Marza F, Bai G-H, Carver BF, Zhou W-C. 2006. Quantitative trait loci for yield and related traits in the wheat population Ning7840 & Clark. Theor. Appl. Genet. 112: 688-698.
15. Lynch JP, Doyle D, McAuley Sh, McHardy F, Danneels Q, Black LC, White EM, Spink J. 2017. The impact of variation in grain number and individual grain weight on winter wheat yield in the high yield potential environment of Ireland. Eur J. Agron. 87: 40-49. doi: 10.1016/j.eja.2017.05.001.
16. Feng F, Han Y, Wang S, Yin S, Peng Z, Zhou M, Gao W, Wen X, Qin X, Siddique KHM. 2018. The Effect of Grain Position on Genetic Improvement of Grain Number and Thousand Grain Weight in Winter Wheat in North China. Front Plant Sci. 9:129. doi: 10.3389/fpls.2018.00129..
17. Reyter BG, Leontyev SI. 1972. Inheritance of some quantitative traits and the genetic effect of selection in hybrid populations of spring wheat. Sibirskiy Vestnik S.-Kh. Nauki. 2: 44-49. [in Russian]
18. Wegrzyn S, Pochaba L. 1980. Wartosc kombinacyjna i sposoby dzialania genow dla kilku cech odmian i mieszancow pszenicy ozimej. Hod. Rosl. Aklim. 24 (3): 211-224.
19. Boichuk IV, Bazalii VV. 2015. Expression of the spike performance elements and their impact on the yield in winter bread wheat. Tavriiskyi Nauk. Visnyk. 94: 3-8. [in Ukrainian]
20. Maphosa L, Taylor H, Langridge P, Parent B. 2014. Genetic control of grain yield and grain physical characteristics in a bread wheat population grown under a range of environmental conditions. Theoretical and Applied Genetics. 127 (7): 1607-1624. doi: 10.1007/s00122-014-2322-y.
21. Vasilis C Gegas, Nazari A, Griffiths S, Simmonds J, Fish L, Orford S, Sayers L, Doonan JH, Snape JW. 2010. A Genetic Framework for Grain Size and Shape Variation in Wheat. Plant Cell. 22(4): 1046-1056. doi: 10.1105/tpc.110.074153.
22. Bozhanova V, Taneva K, Bozhanova V, Hadzhiivanova B. 2015. Study of emmer (Triticum dicoccum (Schrank) Shuebl.) accessions for traits related to spike productivity and grain quality in connection to durum wheat improvement. Agricultural Science and Technology. 7 (2): 199-203. doi: 10.13140/RG.2.1.2545.5844.

СПИСОК ЛІТЕРАТУРИ

1. Вечерська Л. А., Реліна Л. І., Голік О. В. Пшениця полба: преваги, недоліки і перспективи. Вісник Уманського національного університету садівництва». 2018. № 2. С. 10–16. doi: 10.31395/2310-0478-2018-21-10-16.
2. Čurná V., Lacko-Bartošová M. Nutritional characteristics of emmer wheats var.ieties. Journal of microbiology, biotechnology and food sciences. 2015. V. 4 (Special issue 3). P. 95–98. doi: 10.15414/jmbfs.2015.4.special3.95-98.
3. Čurná V. and Lacko-Bartošová M. Chemical Composition and Nutritional Value of Emmer Wheat (*Triticum dicoccon* Schrank): a Review. Journal of Central European Agriculture. 2017. V. 18. № 1. P.117–134. doi: 10.5513/JCEA01/18.1.1871.
4. Орлюк А. П. Базалий В. В. Принципы трансгрессивной селекции пшеницы. Херсон: Наддніпрянська правда, 1998. 274 с.
5. Mahmud I., Kramer H. Segregation for yield, height and maturity following a soybean cross. Agron. S. 1951. Vol. 43. № 12. P. 605–609.
6. Федин М. А., Силис Д. Я., Смиряев А. В. Статистические методы генетического анализа. Москва: Колос, 1980. 207 с.
7. Воскресенская Г. С., Шпота В. И. Трансгрессия признаков у гибридов Brassica, методика количественного учета этого явления. Доклады ВАСХНИЛ. 1967. № 7. С. 18–19.
8. Mackey J. M. Wheat: its concept, evolution and taxonomy In: Royo C., Nachit M. M, Di Fonzo N., Araus J. L., Pfeiffer W. H., Slafer G. A., editors. Durum wheat breeding: current approaches and future strategies. New York. Food Products Press. 2005. P. 3–61.

9. Пшеницы мира / Под ред. В. Ф. Дорофеева. Ленинград: ВО «Агропромиздат», 1987. 560 с.
10. Лифенко С. Ф. Полукарликовые сорта озимой пшеницы. Киев: Урожай, 1987. 192 с.
11. Орлюк А. П., Усик Л. О., Колесникова Н. Д. Генотипові кореляції між урожайністю та компонентними ознаками пшениці м'якої озимої. Зрошуване землеробство. Між. темат. наук. збірник. 2011. Вип. 55. С. 236–245.
12. Чекалин Н. М., Тищенко В. Н., Зюков М. Е. Простые частные коэффициенты генетической корреляции между урожаем и признаками продуктивности колоса у линий и сортов озимой пшеницы. Зб. наук. праць СГІ-НУСН. 2004. Вип. 6. № 46. С. 103–110.
13. Walton P. D. Inheritance of morphological characters associated with yield in spring wheat. Canad. J. Plant Sci. 1969. V. 49. № 5. P. 587–596.
14. Marza F., Bai G.-H., Carver B. F., Zhou W.-C. Quantitative trait loci for yield and related traits in the wheat population Ning7840 & Clark. Theor. Appl. Genet. 2006. 112. P. 688–698.
15. Lynch J. P, Doyle D., McAuley Sh., McHardy F., Danneels Q., Black L. C., White E. M., Spink J. The impact of variation in grain number and individual grain weight on winter wheat yield in the high yield potential environment of Ireland. Eur J. Agron. 2017. V. 87. P. 40–49. doi: 10.1016/j.eja.2017.05.001.
16. Feng F., Han Y., Wang S, Yin S, Peng Z, Zhou M, Gao W, Wen X, Qin X, Siddique KHM. The Effect of Grain Position on Genetic Improvement of Grain Number and Thousand Grain Weight in Winter Wheat in North China. Front Plant Sci. 2018. V. 9. P. 129. doi: 10.3389/fpls.2018.00129.
17. Рейтер Б. Г., Леонтьев С. И. Наследуемость некоторых количественных признаков и генетический эффект отбора в гибридных популяциях яровой пшеницы. Сибирский вестник с.-х. науки. 1972. № 2. С. 44–49.
18. Wegrzyn S., Pochaba L. Wartosc kombinacyjna i sposoby dzialania genow dla kilku cech odmian i mieszancow pszenicy ozimej. Hod. Rosl. Aklim. 1980. V. 24. № 3. P. 211–224.
19. Бойчук І. В., Базалій В. В. Характер прояву елементів продуктивності колоса і їх вплив на формування врожайності пшениці м'якої озимої. Таврій. наук. вісник. 2015. Вип. 94. С. 3–8.
20. Maphosa L., Taylor H., Langridge P., Parent B. Genetic control of grain yield and grain physical characteristics in a bread wheat population grown under a range of environmental conditions. Theoretical and Applied Genetics. 2014. V. 127. № 7. P. 1607–1624. doi: 10.1007/s00122-014-2322-y.
21. Vasilis C. Gegas, Nazari A., Griffiths S., Simmonds J., Fish L., Orford S., Sayers L., Doonan J. H., Snape J. W. A Genetic Framework for Grain Size and Shape Var.iation in Wheat. Plant Cell. 2010. V. 22. № 4. P. 1046–1056. doi: 10.1105/tpc.110.074153.
22. Bozhanova V., Taneva K., Bozhanova V., Hadzhiivanova B. Study of emmer (Triticum dicoccum (Schrank) Shuebl.) accessions for traits related to spike productivity and grain quality in connection to durum wheat improvement. Agricultural science and technology. 2015. V. 7. № 2, P. 199–203. doi: 10.13140/RG.2.1.2545.5844.

Вечерська Л. А., Реліна Л. І., Богуславський Р. Л., Голік О. В.
Інститут рослинництва ім. В. Я. Юр'єва НААН
Московський просп., 142, Харків, 61060, Україна
E-mail: lyudmila_vecherska@ukr.net

ФОРМОУТВОРЕННЯ В РАННІХ ПОКОЛІННЯХ ГІБРИДІВ МІЖ ОЗИМИМИ ПОЛБОЮ ТА ПШЕНИЦЕЮ ТВЕРДОЮ

Мета: встановити характер формотворчого процесу в ранніх поколіннях гібридів між полбою озимою і сучасними сортами пшениці твердої озимої, спрямованого на отримання селекційно цінних форм полби.

Результати та обговорення. Вивчали три комбінації гібридів між зразками полби озимої *T. dicoccum* (Schrank) Schuebl.) var. *atratum* і сортами пшениці твердої озимої Шулиндінка, Континент і Агат донской. У F_1 повністю домінувала полба. В F_2 виділені морфотипи полби, пшениці твердої і форми з дуже щільними колоссям (38 колосків на 10 см) і легким вимолотом. У межах кожного з цих морфотипів по-різному поєднувалися колір колоса (чорний, білий, палевий) і колір зерна (червоний, білий). Найбільшою кількістю (22 %) напівкарликів (до 80 см), цінних для створення сортів полби інтенсивного типу, характеризувалася комбінація полба UA0300214 / Континент. Високими частотою і ступенем трансгресії по масі зерна з колосу (відповідно 53,7 %; до 85,7 %) і масі 1000 зерен (22,3 %; до 19,8 %) виділилася комбінація Агат донской / полба UA0300081. У комбінації UA0300214 / Континент виділені короткостебельні (≤ 80 см) форми зі склоподібним бурштиновим зерном полб'яного типу та високим ступенем позитивних трансгресій за продуктивністю. У цій же комбінації відзначено вищий, ніж в двох інших, коефіцієнт успадковуваності у широкому розумінні маси зерна з колоса: 0,51 при коефіцієнті успадковуваності у вузькому розумінні 0,50. Високими коефіцієнтами успадковаості маси 1000 зерен в широкому і вузькому розумінні характеризувалися комбінації UA0300214 / Шулиндінка (0,56 / 0,54) і Агат донской / UA0300081 (0,55 / 0,52). Невисока різниця між коефіцієнтами успадкованості у широкому і вузькому розумінні свідчить про адитивний ефект генів і високу ефективність відбору за цими ознаками в ранніх поколіннях гібридів. Коефіцієнт успадкованості кількості колосків у колосі в широкому і вузькому розумінні становив від 0,10 до 0,15, відбір за цією ознакою слід починати в більш пізніх поколіннях.

Висновки. Встановлено селекційну цінність гібридів полби звичайної озимої *T.dicoccum* var. *atratum* з інтенсивними сортами пшениці твердої озимої. Для створення вихідного матеріалу полби озимої з високими продуктивністю і органолептичними якостями зерна слід залучати сорти пшениці твердої озимої з масою 1000 зерен не нижче 46 г.

Ключові слова: *полба озима, успадковуваність, трансгресія, пшениця тверда, продуктивність.*

Вечерская Л. А., Релина Л. И., Богуславский Р. Л., Голик О. В.
Институт растениеводства им. В. Я. Юрьева НААН
Московский просп., 142, Харьков,61060, Украина
E-mail:lyudmila_vecherska@ukr.net

ФОРМООБРАЗОВАНИЕ В РАННИХ ПОКОЛЕНИЯХ ГИБРИДОВ МЕЖДУ ОЗИМЫМИ ПОЛБОЙ И ПШЕНИЦЕЙ ТВЕРДОЙ

Цель: установить характер формообразовательного процесса в ранних поколениях гибридов между полбой озимой и современными сортами пшеницы твердой озимой, направленного на получение селекционно ценных форм полбы.

Результаты и обсуждение. Изучали три комбинации гибридов между образцами полбы озимой *T. dicoccum* (Schrank) Schuebl.) *var. atratum* и сортами пшеницы твердой озимой Шулындинка, Континент и Агат донской. В F_1 полностью доминировала полба. В F_2 выделены морфотипы полбы, пшеницы твердой и формы с очень плотными колосьями (38 колосков на 10 см) и легким вымолотом. В пределах каждого из этих морфотипов по-разному сочетались цвет колоса (черный, белый, палевый) и цвет зерна (красный, белый). Найбольшим количеством (22 %) полукарликов (до 80 см), ценных для создания сортов полбы интенсивного типа, характеризовалась комбинация полба UA0300214 / Континент. Высокими частотой и степенью трансгрессии по массе зерна с колоса (соответственно 53,7 %; до 85,7 %) и массе 1000 зерен (22,3 %; до 19,8 %) выделилась комбинация Агат донской / полба UA0300081. В комбинации UA0300214 / Континент выделены формы со стекловидным янтарным зерном полбяного типа, высокой степенью положительных трансгрессий по продуктивности и короткостебельные (≤ 80 см). В этой же комбинации отмечен больший, чем в двух других, коэффициент наследуемости в широком смысле массы зерна с колоса: 0,51 при коэффициенте наследуемости в узком смысле 0,50. Высокими коэффициентами наследуемости массы 1000 зерен в широком и узком смысле характеризовались комбинации UA0300214 / Шулындинка (0,56/0,54) и Агат донской / UA0300081 (0,55/0,52). Близость коэффициентов наследуемости в широком и узком смыслах свидетельствует об аддитивном эффекте генов и высокой эффективности отбора по этим признакам в ранних поколениях гибридов. Коэффициент наследуемости количества колосков в колосе в широком и узком смислах составлял от 0,10 до 0,15, отбор по этому признаку следует начинать в более поздних поколениях.

Выводы. Установлена селекционная ценность гибридов полбы обыкновенной озимой *T.dicoccum var. atratum* с интенсивными сортами пшеницы твердой озимой. Для создания исходного материала полбы озимой с высокими продуктивностью и органолептическими качествами зерна следует привлекать сорта пшеницы твердой озимой с массой 1000 зерен не ниже 46 г.

Ключевые слова: *полба озимая, наследуемость, трансгрессия, пшеница твердая, продуктивность.*

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ЯРОШ А. В., РЯБЧУН В. К., ЧЕТВЕРИК О. О., ЧЕРНОБАЙ Ю. О.
Інститут рослинництва ім. В.Я. Юр'єва НААН
Національний центр генетичних ресурсів рослин України
Московський посп., 142, Харків, 61060, Україна
E-mail: ncpgru@gmail.com

СТАБІЛЬНІСТЬ ТА ПЛАСТИЧНІСТЬ МАСИ ЗЕРНА З КОЛОСУ, МАСИ 1000 ЗЕРЕН ТА ВРОЖАЙНОСТІ СЕРЕДНЬОРОСЛИХ ТА НАПІВКАРЛИКОВИХ ГЕНОТИПІВ ПШЕНИЦІ М'ЯКОЇ ОЗИМОЇ

Викладено результати оцінки в 2015–2018 рр. напівкарликових і середньорослих зразків пшениці м'якої озимої колекції НЦГРРУ за стабільністю та пластичністю маси зерна з колосу, маси 1000 зерен та врожайності. За результатами проведеного вивчення та аналізу визначено, що частка зразків з високою гомеостатичністю (bi <1) за врожайністю є більшою для середньорослих генотипів і складає 70,6 %, за масою 1000 зерен — 64,7 % та масою зерна з колосу — 58,8 %. Виділено джерела з високою гомеостатичністю маси зерна з колосу: Зорепад білоцерківський та Анатолія (UKR); маси 1000 зерен: Краса ланів (UKR) та Ilona (SVK); урожайності: Почайна, Краса ланів, Дарунок Поділля (UKR), Адель, Казачка (RUS), OR2070011 (USA), Ilona (SVK). Також виділено зразки з широкою екологічною реакцією, які можуть реалізувати потенціал урожайності за сприятливих умов вирощування (bi >1) за масою зерна з колосу: Зорепад білоцерківський, Анатолія (UKR); масою 1000 зерен: Гармоніка, Принада (UKR), Москвич (RUS), Aran (AZE); урожайністю: Зорепад білоцерківський, Принада (UKR), Морозко, Вид (RUS).
Ключові слова: *зразок, пшениця м'яка озима, стабільність, пластичність, маса 1000 зерен, маса зерна з колосу, урожайність, джерело, еталон.*

ВСТУП

Одним із найважливіших завдань у селекційній роботі є підвищення врожайності у нових сортах. Велике значення при цьому має адаптивний потенціал та стабільність ознак, які сприяють ефективності впровадження результатів селекційного процесу у виробництво.