

PECULIARITIES OF MANIFESTATION OF THE DEGREE OF TRANSGRESSION IN POPULATIONS OF WINTER BREAD WHEAT FOR INHERITANCE OF BREEDING VALUE ELEMENTS

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Summary. The objective of this research was to identify the characteristics of transgressions degree in terms of main spike productivity in populations of the second and third generation of winter soft wheat. The material for the research comprised 30 hybrid combinations created through the use of a full diallel crossing scheme of six winter soft wheat varieties carrying wheat-rye translocations (WRT). There were: 1AL.1RS (Zolotokolosa, Columbia, Eksprompt), 1BL.1RS (Svitanok Myronivskiyi, Legenda Myronivska, Kalynova). The involvement of the local gene pool of winter bread wheat-rye translocations represents a highly effective measure that can serve as the next stage of significant improvement of varieties in terms of yield.

Keywords: *Triticum aestivum* L., wheat-rye translocations, populations, main spike productivity, main spike length, number of kernels, kernel weight.

Introduction

The primary challenge in developing winter wheat varieties for diverse applications is the potential for high yield and product quality. The objective of every wheat breeder is to develop wheat varieties with the highest possible productivity. Increasing yields is one of the most significant challenges, given the considerable difficulties and complexity involved in achieving this goal. However, in parallel with the significant increase in productivity, there has been a loss of genetic diversity (Braun et al., 1998). The high level of genetic potential of modern varieties presents a challenge to further improving the crop, necessitating the search for new opportunities. One such opportunity is provided by the introduction of new genetic material into the local gene pool. The involvement of winter-rye translocations in breeding programmes to create new varieties is an example of the successful use of a foreign resource to improve a crop.

The 1R chromosome, particularly its short arm 1RS, has been extensively employed in bread wheat improvement programmes worldwide (Ko et al., 2002). The entire chromosome arm 1RS.1BL translocation represents the most frequently utilised source of foreign rye chromatin in wheat breeding (Baum et al., 2015). In general, the presence of this translocation in wheat varieties is associated with a significant increase in yield, including an increase in the number of spikelets and grains per spikelet, as well as an increase in the weight of 1000 grains (Zhao et al., 2012; Xynias et al., 2018; 2020; Moskal et al., 2021). Recent studies have shown that the presence of this translocation causes grain elongation (Johansson et al., 2020). A significant contribution to increased yield is made by the postponement of leaf senescence following flowering, which extends the supply of assimilated carbon to the grain. Furthermore, the 1RS.1BL translocation carries the powdery mildew resistance gene Pm8 (*Blumeria graminis* (DC) EO Speer f. sp. tritici Em. Marchal) (Schelegel & Korzun, 1997). Fragment 1RS contains genes Lr26, Sr31 and Yr9, for which confer resistance to brown rust (*Puccinia recondite* Roberge ex Desm. f. sp. tritici), stem rust (*Puccinia*

graminis f. sp. *tritici* Ericsson & Henning) and yellow rust (*Puccinia striiformis* Westend. f. sp. *tritici* Eriks.), respectively. Nevertheless, the resistance conferred by these genes has already been overcome by new virulent biotypes of the respective pathogens (Johansson et al., 2020; Purnhauser et al., 2011; Qi et al., 2016).

The 1RS.1AL translocation has also been used in wheat breeding programs, although on a much smaller scale than 1RS.1BL (Graybosch et al., 1993). In addition to the presence of genes that provide resistance to fungal pathogens, the 1RS.1AL transposition is also useful for providing resistance to pests such as common cereal aphid (*Schizaphis graminum* Rondani), determined by the genes Gb2 and Gb6, wheat mite (*Aceria tosichella* Keifer), determined by the Cmc3 gene, large cereal aphid (*Sitobion avenae* Fabricius) and bird cherry-cereal aphid (*Rhopalosiphum padi* Linnaeus), for which genes have not yet been identified (Lu et al., 2010; Crespo-Herrera et al., 2013; Spetsov & Daskalova, 2023).

In the context of breeding programmes for the development of high-yielding winter soft wheat varieties resistant to abiotic and biotic factors, it is of paramount importance to have information on the nature of variability and inheritance of quantitative traits at the initial stages of the breeding process. Transgressive breeding, based on the selection of the best forms in a hybrid population, represents one of the principal methods of improving self-pollinated crops. For practical breeding for productivity elements, positive transgressions resulting from the emergence of recombinants with certain valuable economic traits and properties are of great importance (Sönmez et al., 2022; Tahmasebi et al., 2015). The productivity traits of the main ear are under the genetic control of numerous genes from different linkage groups. In the genotype system, the functional action and interaction of these genes result in a wide range of types of inheritance of productivity traits that can vary under different conditions of winter wheat plant cultivation (Ko et al., 2002; Ren et al., 2012).

The investigation of the manifestation of transgressions in the productivity elements of soft winter wheat varieties carrying WRT represents a pivotal aspect of the development of novel wheat breeding material. In order to identify transgressive forms and ascertain the viability of their selection, the variability of the main spikelet productivity elements was analysed. In populations of the second and third generation, the frequency of positive transgressions was contingent upon the degree of heterosis or trait's depression.

Materials and methods

The research conducted during the 2022/23 vegetation year. Research location – field of selection crop rotation at the V. M. Remeslo Myronivka Institute of Wheat, National Academy of Agrarian Sciences of Ukraine. The research material comprised 30 hybrid combinations created through the use of a full diallel crossing scheme ($\leftrightarrow$) of winter bread wheat varieties, carriers of WRT: Kalynova, Legenda Myronivska, Svitanok Myronivskyi (1BL.1RS) and Eksprompt, Columbia, Zolotokolosa (1AL.1RS). The hybrid combinations were divided into four groups based on the crosses ($\times$) of WRT carrier varieties. The first group consisted of 1BL.1RS $\times$ 1BL.1RS S crosses, which accounted for 20% of the total. The second group included 1AL.1RS $\times$ 1AL.1R crosses, which constituted 20% of the total. The third group comprised 1BL.1RS $\times$ 1AL.1RS crosses, which represented 30% of the total. The fourth group consisted of 1AL.1RS $\times$ 1BL.1RS crosses, which accounted for 30% of the total. The experiments and phenological observations were conducted in accordance with the prevailing methodological standards. Seeds of hybrids were manually sown on 2-meter-long plots in three replicates. To optimize the realization of productivity elements, a sparse sowing method was employed, with a distance of 10 cm between plants in a row, and 30 cm between rows. Phenological observations were conducted throughout the growing season. At the onset of full ripeness, a structural analysis of the productivity elements of the main spike of parental components and hybrids was conducted. This analysis was performed on 25 plants of each category.

In order to achieve this objective, we employed the use of accepted breeding and genetic methods for the analysis of experimental material, in addition to statistical processing methods in order to confirm the reliability of the results.

The characteristics of moisture availability in winter wheat plant growth conditions were calculated using the average monthly hydrothermal coefficient (HTC). The differentiation of HTC indicators was employed, with values ranging from 0.5 to 1.0 indicating a dry or dry period, from 1.0 to 1.5 representing a normal condition, and values exceeding 1.5 indicating a wet or excessively wet period. The optimal value of HTC for wheat is 1.2.

Results and discussions

The weather conditions of the study were very different in terms of temperature and precipitation, so that reliable data could be obtained on the level of potential of valuable economic characteristics and properties in hybrid combinations in the conditions of the central part of Ukraine's forest-steppe.

In the autumn period of 2022, the air temperature was not significantly different from the long-term average, but it was characterised by excessive precipitation (August - 84.4 mm, September - 117.5 mm), which led to waterlogging of the top layer of the soil and later sowing of winter wheat.

Precipitation in the first ten days of October helped to further replenish soil moisture reserves, creating optimal conditions for winter crop growth in the early stages of development.

In general, the winter of 2022/2023 was moderate and contributed to the overwintering of winter crops (in January and February, the average monthly air temperatures were 3.3°C and 1.7°C above the long-term average, respectively). An increased temperature regime was observed in December 2022 (11.12 - plus 8.6°C) and January 2023 (1.01 - plus 9.5°C; 18.01 - plus 8.7°C) compared to the long-term average of the last 30 years of -1.6°C and -3.4°C respectively. Absolute minimum air temperatures were recorded on 11 January 2023 - minus 10.4°C and on 9 February 2023 - minus 11.7°C, with a temperature at the depth of the tillering node of -5.5°C. The maximum height of the snow cover was between 3 and 5 cm, and the soil freezing during the period of low temperatures was 22.5 cm.

The resumption of winter crop vegetation in 2023 was observed on 21 March (winter wheat was in the second stage of organogenesis) at an average daily air temperature of +9.0°C, with a gradual increase thereafter.

April was characterised by an excessive supply of moisture, with precipitation 40.0 mm above normal. However, the period from May to June was characterised by a rather acute precipitation deficit (HTC - 0.46 and 0.67, respectively), especially in June - only 39.4 mm (the long-term average was 84.8 mm). July was characterised by excessive precipitation - 183.5 mm, exceeding the long-term average by 111.8 mm. Precipitation from the resumption of vegetation until the end of July was 349.6 mm (213.1 mm in 2022) or 81.7% of the long-term average (262.9 mm). The maximum temperature (32.1 °C) was recorded on 6 July. The total rainfall for the year was 768.9 mm, 180 mm more than the long-term average (588.9 mm). The maximum precipitation (183.5 mm) occurred in July 2023, the minimum (10.6 mm) in January 2023. The average monthly precipitation was 64.1 mm. According to the hydrothermal coefficient, the growing season 2022/23 was excessively wet (HTC = 1.52).

Thus, weather conditions during the 2022/2023 winter wheat growing season with a favourable hydrothermal regime significantly influenced the formation of high productivity potential. The ecological effect of early vegetation recovery - a short winter and a long spring, when air temperatures are exceptionally favourable for biomass growth of soft winter wheat plants - worked.

The aim of our research was to determine the peculiarities of the degree of transgression in terms of productivity of the main spike in hybrids of the second and third generations.

In 2023, hybrids of populations F_2 , F_3 of different crossing groups were analysed, using parental components of WRT carriers in hybridisation, in which different degrees of transgression were found according to the elements of the main spike structure.

According to the results of the analysis of plants of hybrids of the second and third generation, a positive transgression was noted for all indicators of the structure of the main spike and in all groups of crosses of varieties of carriers of WRT.

As a result of the analysis, the degree of transgression was conditionally divided into four groups: 0-10% - not significant; 11-30% - low; 31-50% - medium; 51-100% - high.

According to the length of the main spike, 24 F_2 hybrid combinations were included in the first group, representing 80.0% of the total number of crosses. The second group included four (13.3%) second generation hybrid populations.

By the number of kernels from the main spike in hybrid combinations F_2 , 10 hybrid combinations belonged to the first group, that is 33.3%; 17 (56.7%) to the second group; three (10.0%) of the total number of combinations F_2 to the third group.

According to the weight of the grains of the main spike of the hybrid combinations F_2 , 11 combinations (36.7%) were assigned to the first group, 13 (43.3%) to the second group, four (13.3%) to the third group and two (6.7%) to the fourth group.

In the hybrid populations of the third generation, according to the length of the main spike, the hybrid combinations were mainly assigned to the first (13 combinations, i.e. 43.3%) and second (16 combinations, i.e. 53.3%) groups, and only one combination (Columbia $\times$ Zolotokolosa) - to the third group.

By the number of kernels from the main spike in hybrid combinations F_3 , 14 hybrid combinations were assigned to the first group, i.e. 46.7%; 13 (43.3%) to the second group; three (10.0%) to the third group of the total number of F_3 combinations.

By weight of grains from the main spike in hybrid combinations F_3 in the first group - eight combinations (26.7%); in the second group - 15 (50.0%); in the third - 3 (10.0%); in the fourth - four (13.3%).

It is worth noting that in the second group of crosses 1AL.1RS $\times$ 1AL.1RS among the F_2 hybrids we distinguished by spike length a reciprocal combination of crosses Zolotokolosa $\leftrightarrow$ Columbia. It should be noted that the hybrid Columbia $\times$ Zolotokolosa in this group was distinguished by all three indicators in F_2 and two (spike length and weight of grains from it) - in F_3 . The highest degree of transgression (64.8%) in this combination was noted in the populations of F_2 by the weight of grains from the main spike.

In the first group of crosses 1BL.1RS $\times$ 1BL.1RS the degree of transgression ranged from 0 to 28.6%. The highest percentages of the degree of transgression were found in the combination of crosses Legenda Myronivska $\times$ Kalynova in the second and third generations in terms of number of kernels per spike and their weight (7.9%, 27.9%, 28.6%, respectively).

In the fourth group of crosses 1AL.1RS $\times$ 1BL.1RS among the populations F_2 , according to the degree of transgression of all the studied parameters of structural analysis of the main spikelet, the population Zolotokolosa $\times$ Kalynov was distinguished (17.3%, 52.9%, 60.9%, respectively).

In the third group of crosses 1BL.1RS $\times$ 1AL.1RS the highest percentage of transgression (54.7%) can be observed in the third generation hybrid Legenda Myronivska $\times$ Ekspromt.

The highest percentages of the degree of transgression (64.8% and 60.9%) were observed in the F_2 populations for the trait kernel weight per spike in the second and fourth groups (Columbia $\times$ Zolotokolosa and Zolotokolosa $\times$ Kalynova) of crosses with the participation of varieties carrying introgressive components of rye (1AL.1RS $\times$ 1AL.1RS and 1AL.1RS $\times$ 1BL.1RS).

To identify transgressive forms and determine the possibility of their selection, we analysed the variability of the productivity elements by the length of the main spike. In second and third generation populations, the frequency of positive transgressions depended on the degree of heterosis

or depression of the trait. The degree of positive transgression and its frequency in all combinations were recorded in four groups of crosses.

The degree of transgression ranged from 1.5% to 52.9% in the F_2 populations and from 2.4% to 30.2% in the F_3 populations. The highest degree of transgression frequency (Tf) was observed in hybrids F_3 (76.0% of the total) of the third group of crosses when two translocations 1BL.1RS / 1AL.1RS were used in the hybridisation. In F_2 , the coefficient of variation for main spike length was weak in six hybrid combinations (20.0%), medium in 22 (73.3%) and significant in two combinations (6.7%). For F_3 it was weak in 22 (73.3%) and medium in 8 (26.7%) combinations. There were no combinations with a significant coefficient of variation.

The coefficient of variation was determined by the number of kernels per main spike.

This indicator varied from 3.0% to 31.6% in the F_2 populations and from 3.9% to 27.2% in the F_3 populations.

In F_2 , the coefficient of variation for the number of kernels per main spike was weak in five hybrid combinations (16.7%), medium in 23 (76.7%) and significant in two combinations (6.7%). For F_3 it was weak in 6 (20.0%) and medium in 24 (80.0%) combinations.

It should be noted that a low coefficient of variation for the number of kernels per main spike was found in the populations F_2 Kalynova $\times$ Svitanok Myronivskiy, Svitanok Myronivskiy $\times$ Legenda Myronivska, Kalynova $\times$ Svitanok Myronivskiy, Ekspromt $\times$ Legenda Myronivska, Svitanok Myronivskiy $\times$ Columbia, Svitanok Myronivskiy $\times$ Zolotokolosa and in F_3 - Svitanok Myronivskiy $\times$ Legenda Myronivska, Kalynova $\times$ Svitanok Myronivskiy, Zolotokolosa $\times$ Svitanok Myronivskiy, Svitanok Myronivskiy $\times$ Ekspromt, Legenda Myronivska $\times$ Zolotokolosa) and the combinations Svitanok Myronivskiy $\times$ Legenda Myronivska, Kalynova $\times$ Svitanok Myronivskiy showed a weak coefficient of variation in the second and third generations.

The degree of positive transgression for the characteristic number of kernels per main spike was observed in all hybrid populations. It varied from 2.8% to 56.0% in second generation hybrids and from 1.5% to 41.7% in F_3 .

Transgression frequencies varied from 21.5% to 56.0% in F_2 hybrids and from 36.0% to 89.0% in F_3 hybrids. The highest transgression frequency was observed in the second generation hybrids in the combination Svitanok Myronivskiy $\times$ Kalynova (56.0%) and in the third generation hybrids - in the combination Kalynova $\times$ Legenda Myronivska (89.0%).

We also determined the coefficient of variation of the weight of grains from the main ear. This indicator ranged from 2.2% to 39.3% in the F_2 populations and from 5.5% to 39.2% in the F_3 populations.

In F_2 , the number of kernels per main spike was: weak - in five hybrid combinations (16.7% of the total), medium - in 23 (76.7%) and significant - in two combinations (6.7%). In F_3 , a weak coefficient of variation was observed in two combinations.

It should be noted that in populations F_2 (Columbia $\times$ Ekspromt, Kalynova $\times$ Svitanok Myronivskiy, Ekspromt $\times$ Legenda Myronivska, Svitanok Myronivskiy $\times$ Columbia, Svitanok Myronivskiy $\times$ Zolotokolosa), a weak indicator was found for the coefficient of variation of the weight of grains from the main spike, and in F_3 - Svitanok Myronivskiy $\times$ Legenda Myronivska, Svitanok Myronivskiy $\times$ Ekspromt. The highest degree of transgression (59.6%) and its frequency (62.0%) were observed in hybrids F_3 in the first, second and third groups of crosses.

Thus, with the participation of varieties carrying wheat-rye translocations, a new valuable breeding material of winter soft wheat was created with a higher manifestation of both individual and complex traits of main spike productivity compared to the parental forms.

Conclusions

The results obtained suggest that the use of WRT is a promising direction for increasing the genetic potential of the yield of winter bread wheat varieties.

The highest degree of transgression of productivity elements of the main spikelet was found in the hybrid Columbia × Zolotokolosa from the second group of crosses 1AL.1RS × 1AL.1RS. It was distinguished by three indicators (spike length, number of kernels, and weight of grains per spike) in F₂ and two (spike length, and weight of grains per spike) in F₃. In the first group of crosses 1BL.1RS × 1BL.1RS, the third - 1BL.1RS × 1AL.1RS, and the fourth - 1AL.1RS × 1BL.1RS the hybrids Legenda Myronivska × Kalynova, Zolotokolosa × Kalynova, Legenda Myronivska × Eksprompt were distinguished, according to the degree of transgression of productivity elements of the main spike. In the populations of the second and third generations, the frequency of positive transgressions for main ear length depended on the degree of heterosis or depression of the trait.

The coefficient of variation in the number of kernels per main spike varied from 3.0% to 31.6% in populations F₂ and from 3.9% to 27.2% in F₃. A weak indicator for the coefficient of variation of the weight of the main spike was found in the populations F₂ Columbia × Eksprompt, Kalynova × Svitanok Myronivskiyi, Eksprompt × Legenda Myronivska, Svitanok Myronivskiyi × Columbia, Svitanok Myronivskiyi × Zolotokolosa, and in F₃ - Svitanok Myronivskiyi × Legenda Myronivska, Svitanok Myronivskiyi × Eksprompt.

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