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HETEROSIS OF SOME MORPHOLOGICAL AND GRAIN QUALITY TRAITS IN WINTER DURUM WHEAT

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The aim of the presented study was to establish mid parent heterosis and better parent heterosis of five quantitative traits related to the productivity and quality of durum wheat. A diallel cross was performed for three consecutive years. Thus, F_1 generations are provided for three years. The experiments were conducted in randomized block design in three replications for three consecutive years - 2014, 2015 and 2016. The trials were carried out in the breeding field of the Field Crops Institute, Chirpan according to the accepted technology for growing durum wheat. Mid parent and better parent heterosis of ten durum wheat crosses were determined. The better parent heterosis reached up to -7.4 (-7.61%) for plant height, up to 4.66 (56.30%) for number of productive tillers, up to 1.63 (21.01%) for spike length, up to 2.25 (13.84%) for grain protein content and up to 4.66 (13.92%) for grain wet gluten content. Two valuable combinations showed heterosis on several traits. Progres X Predel indicated better parent heterosis for three of the five traits included in the study. Deni X Progres indicated better parent heterosis for three of the five traits studied. The Progres variety is recommended for use as a mother and as a pollinator, and the Deni variety as a mother in winter durum wheat crossing programs. These varieties and their crosses are suitable for improving the productivity and quality of durum wheat. The obtained results may be applied in the hybrid and combining breeding programs to improve durum wheat.

Keywords durum wheat, grain quality traits, heterosis, morphological traits

INTRODUCTION

Durum wheat is a naturally self-pollinating crop, but heterosis is observed for different traits. Heterosis can be positive or negative depending on the required results, and both positive and negative heterosis can be useful to improve the corresponding quantitative trait in a particular crop. Heterosis is often presented and assessed as a percentage increase or decrease in the mean value of the trait in F_1 compared to the mean of both parents. The term heterosis is defined as a better expression of the hybrid plants compared to their parents in terms of hybrid

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vigor, growth and productivity (BEGNA, 2021). Hybrids in F_1 are evaluated by increase or decrease in the value of the trait relative to the mean value of parents (heterosis (mid parent heterosis)) and relative to the better parent (heterobeltiosis (better parent heterosis)) (MAHPARA *et al.*, 2015). From the point of view of breeding, heterobeltiosis (true heterosis) is more effective than heterosis compared to the average, especially in self-pollinating crops, where the aim is to identify the most valuable hybrid combinations. Heterobeltiosis provides a greater chance for reaching transgressive genotypes in later segregated generations.

The commercial use of heterosis is considered one of the greatest achievements of genetics implemented in agriculture. Hybrid seed production of durum wheat is not used yet in crop production. Nevertheless, knowledge of the degree of heterosis is essential to determine the direction of the future breeding programs. The heterosis makes it possible to select promising crosses to obtain better segregants to further improve the new varieties. Heterosis over the better parent may be the result of one or more causes. The accumulation of dominant genes scattered between both parents, ie. dominance. Complementary interaction of additive-dominance on recessive genes, ie. non-allelic interractions or epistasis. Favourable interaction between two alleles in the same locus, ie. intralocus or allelic interactions. In self-pollinating crops, heterosis is best explained by dominance. In addition, the heterosis hybrid can successfully create transgressive forms in offspring generations (LABROO *et al.*, 2021).

In recent years, research into hybrid wheat has made significant progress in overcoming infertility (WHITFORD *et al.*, 2013), cloning of sterility genes (SONG *et al.*, 2015) and research on seed production technologies (VISHNOI *et al.*, 2022). However, this still does not allow their implementation and use. The main limitation is to select elite parents to create a superb hybrid combination (DRAGOV, 2022). The basic task for hybrid varieties is to identify parents with high genetic diversity between them (HUSSAIN *et al.*, 2022). The next important reason is that the level of heterosis depends on environmental factors too (WU *et al.*, 2021). Hybrid wheat is likely to be advantageous to the economic, agronomic, technological and environmental aspects of wheat cultivation and production (WHITFORD *et al.*, 2013).

The heterosis is a very good way to overcome obstacles to increasing yields (WOLKO *et al.*, 2019). This approach is widely used in the cross-pollinated crops, but can also be used in self-pollinated crops (REHMAN *et al.*, 2021). ADHIKARI *et al.* (2020) have previously noted the exploitation of heterosis in wheat. Previous results reveal a wide range of heterosis manifestations for all studied traits. DEVI *et al.* (2013) and CHAWAN *et al.* (2022) reported reliable levels of mid and better parent heterosis for plant height and spike length. Positive mid and better parent heterosis for the plant height was reported by the other authors (AKEL *et al.*, 2019; BASNET *et al.*, 2019), but KALHORO *et al.* (2015) reveal negative mid and better parent heterosis. For number of productive tillers has been established preponderance of positive mid and better parent heterosis (KALHORO *et al.*, 2015; KAJLA *et al.*, 2020; CHAWAN *et al.*, 2022). In some cases of study, a positive mid and better parent heterosis was observed for the spike length (KHOMENKO *et al.*, 2021; CHAWAN *et al.*, 2022). KALHORO *et al.* (2015) reveal negative mid and better parent heterosis for spike lenght. For the grain protein content a number of authors reported mid and better parent heterosis (KAUR and MONDAL, 2018; PATEL *et al.*, 2018; AKEL *et al.*, 2019). Many authors reveal positive mid and better parent heterosis for grain wet gluten (AHMAD *et al.*, 2016; PATEL, 2018; KAUR and MONDAL, 2018).

The aim of the study is to trace and establish the heterosis levels of five quantitative traits related to productivity and grain quality in winter durum wheat. To determine the breeding value of hybrid combinations and parents for their proper use in hybrid and combining breeding programs in this crop.

MATERIAL AND METHODS

The study included five modern durum wheat varieties as the parent varieties needed for the half diallel cross: Victoria, Deni, Superdur, Progres and Predel. The varieties were selected from the set of new Bulgarian durum wheats, including the old and the new checks and the Austrian variety Superdur, which has recently become widespread in our country. The choice of varieties is based on their previous observations. A diallel cross was performed in which all the described varieties were crossed with each other without reciprocal combinations. Crossbreeding was carried out at the beginning of heading under field conditions, emasculation and pollination were done handmade. From each combination, 30 spikes were emasculated and pollinated.

The diallel cross was performed in three consecutive years. In this way, F_1 generation was provided for three years. The harvest years of the experiments were from 2014 to 2016. The experiments were carried out on the breeding nursery of the Field Crops Institute - Chirpan using the accepted technology for growing durum wheat. The precrop was spring peas. The average temperature values during the three years of research are characterized by higher than the multi-year average temperatures. The first two years were characterized higher amount of precipitation than the multi-year value of precipitation. The third harvest year was the hottest and at the same time driest with 20% less precipitation compared to the multi-year values.

Parents and F_1 hybrids were sown in a randomized block design with three replications under field conditions. Each parent and F_1 was sown by hand in two rows, each row was 2 m long, spaces between rows were 20 cm and 5 cm between plants. At full maturity stage plants from each replication were selected and collected for further morphological examination. From the parents and F_1 generation, 20 plants were randomly selected.

The following traits were studied: Plant height (cm) - Measured from the surface of the ground to the end of the spike without the awns on the main stem in centimetres, number of productive tillers (pcs.) - the fertile spikes of one plant were counted, spike length (cm) - main spike length was measured from the base of the spike to the top spikelet (excluding awns), Grain protein content (%) - Kjeldahl method BDS ISO 20483:2014, grain wet gluten content (%) – BDS EN ISO 21415-2:2008.

The obtained data were used for statistical analysis for the calculation of mid parent and better parent heterosis, using the software of Mark D. Burow and James G. Coors 1994 (BUROW and COORS, 1994). The percentage of the two types of heterosis for each cross was calculated according to the respective formulas of FONSECA and PATTERSON (1968): $BP\%=(F_1-BP)/BP*100$, $MP\%=F_1-MP/MP*100$. MP is mid parent heterosis i.e. value of hybrid over the mean of both parents and BP is better parent heterosis i.e. value of hybrid over better parent.

RESULTS AND DISCUSION

Research on the inheritance of quantitative traits related to grain yield and grain quality is of great importance for the success of the breeding process. Improving the phenotypic

morphological traits in durum wheat is associated with increased productivity in newly created varieties. Improving the quality and in particular the grain protein content and the grain wet gluten content will provide a higher nutritional value to the newly created genotypes. The consideration of the heterosis manifestations is presented below and is divided according to the traits of the ten crosses.

Valuable breeding hybrid combinations for the plant height trait are hybrids that demonstrate lower values compared to the lower parent and the average of both parents. Better parent heterosis is calculated relative to the lower parent which is better from a breeding point of view. This is related to the resistance to lodging. Dwarf durum wheat plants are resistant to lodging, and this would allow higher rates of nitrogen fertilization. The results for the real mid parent and better parent heterosis are presented in Table 1. The mean value in the first year for mid parent heterosis was -2.64, and for better parent heterosis was 3.62. Seven combinations had negative mid parent heterosis and three better parent heterosis. The lowest value for mid parent heterosis and better parent heterosis was observed in Progres X Predel combination. In the second year of testing, the mean value for mid parent heterosis was 3.17 and for better parent heterosis was 8.43. Negative mid parent heterosis was demonstrated in three crosses, and for better parent heterosis only one. The Progres X Predel combination got the lowest value for mid parent heterosis and the lowest value for better parent heterosis was calculated for the combination Deni X Predel. The mean values in the third year of testing for mid parent heterosis was 3.17, and for better parent heterosis was 9.3. Two crosses demonstrate negative mid parent heterosis and all had positive better parent heterosis. The lowest value for mid parent heterosis was the combination Superdur X Progres, and for better parent heterosis was Victoria X Progres. Generally, for the three years of testing, Progres X Predel always had negative mid parent heterosis, and the cross Deni X Predel had negative mid and better parent heterosis for two years. The Deni X Predel combination stands out with negative values for better parent heterosis for two years. Table 1 presents the values for mid and better parent heterosis in percentage. Deni X Predel in two years had negative values for better parent heterosis, but in the third the value is positive. The results show that the cross Deni X Predel is extremely valuable for obtaining dwarf durum wheat genotypes. Dwarf transgressive forms can be expectedly obtained from this combination. This can reduce the durum wheat plant height in breeding programs where this cross is present. In wheat breeding, negative mid and better parent heterosis for plant height is preferred because dwarfs were more attractive (KALHORO *et al.,* 2015). AHMED *et al.* (2023) and CHAWAN *et al.* (2023) reported negative better parent heterosis for plant height such as in our case.

Combinations with higher values for mid and better parent heterosis are more valuable in breeding for the traits like number of productive tillers, spike length, grain protein content and grain wet gluten content. These requirements will increase the productivity and grain quality of durum wheat in the newly created varieties. Table 2. presents the real heterosis manifestations for a number of productive tillers. The mean value in the first year for mid parent heterosis was 0.69, and for better parent heterosis was 0.52. Positive values for mid and better parent heterosis had eight crosses. The highest value for mid and better parent heterosis had the cross Superdur X Predel. It was followed by the cross Deni X Progres which also had high values. In the second year of testing, the mean value for mid parent heterosis was 1.71 and for better parent heterosis

1.35. Nine crosses were positive for mid parent heterosis and eight for better parent heterosis. Combination Superdur X Predel had the highest value for mid parent heterosis and better parent heterosis. It was followed by the cross Deni X Progres. The mean values in the third year for mid parent and better parent heterosis were negative. Only the cross Progres X Predel had a positive value for mid parent and better parent heterosis. All other crosses had negative values. The combination Progres X Predel in all three years had positive values for mid parent and better parent heterosis. Crosses with positive and high values for two years were Superdur X Progres and Deni X Progres. Table 2. presents the percentage of mid and better parent heterosis for number of productive tillers. A high percentage for mid parent and better parent heterosis had the Progres X Predel cross for the three years of the study. The hybrid combinations Superdur X Predel and Deni X Progres had very high values, but only for two of the three years of testing. In the third year, both of them demonstrated negative values. The crosses Superdur X Predel, Deni X Progres and Progres X Predel are characterized as valuable breeding combinations in terms of number of productive tillers. They can successfully increase the number of productive tillers of durum wheat. A number of authors report high levels of better parent heterosis for number of productive tillers (KALHORO *et al.,* 2015; AHMAD *et al.,* 2016; KAJLA *et al.,* 2020; CHAWAN *et al.,* 2022).

Table 1. Real mid parent and better parent and percentage of heterosis in F_1 for plant height trait

Hybrid combinations	F_1-2014 year				F_1-2015 year				F_1-2016 year			
	MPH	MPH %	BPH	BPH %	MPH	MPH %	BPH	BPH %	MPH	MPH %	BPH	BPH %
Victoria X Deni	-6.3	-6.17	0.5	0.52	6.48	7.03	13.24	15.49	6.8	7.01	13.4	14.82
Victoria X Superdur	8.1	8.60	22.8	28.71	8.66	9.81	19.3	24.83	2.35	2.56	13.3	16.31
Victoria X Progres	-4.1	-4.08	1.9	1.96	5.81	5.95	7.44	7.77	2.6	2.56	2.8	2.71
Victoria X Predel	-4.4	-4.42	3.7	4.0	5.61	6.04	12.04	13.99	1.5	1.62	10.77	12.65
Deni X Superdur	5.4	6.18	13.3	16.75	9.31	11.42	13.2	16.98	10.15	11.79	14.5	17.74
Deni X Progres	-6.9	-7.19	-6.2	-6.51	1.06	1.14	6.14	7.18	0.83	0.87	7.3	8.07
Deni X Predel	-4.6	-4.92	-3.27	-3.53	-0.53	-0.65	-0.26	-0.30	5.63	6.42	8.27	9.71
Superdur X Progres	0.6	0.68	9.2	11.58	-1.01	-1.17	7.96	10.24	-3.68	-3.96	7.13	8.72
Superdur X Predel	-5.1	-5.99	1.4	1.76	0.21	0.26	4.4	5.66	8.21	9.84	9.93	12.15
Progres X Predel	-9.1	-9.61	-7.04	-7.61	-3.9	-4.35	0.84	0.97	-2.66	-2.81	6.43	7.55
Min	-9.1		-7.04		-3.9		-0.26		-3.68		2.8	
Max	8.1		22.8		9.31		19.3		10.15		19.3	
Mean ± m	-2.64 ± 1.76		3.62 ± 2.92		3.17 ± 1.43		8.43 ± 1.92		3.17 ± 1.42		9.3 ± 1.16	

Table 2. Real mid parent and better parent and percentage of heterosis in F_1 for number of productive tillers trait

Hybrid combinations	F_1-2014 year				F_1-2015 year				F_1-2016 year			
	MPH	MPH%	BPH	BPH%	MPH	MPH%	BPH	BPH%	MPH	MPH%	BPH	BPH%
Victoria X Deni	-0.84	-11.47	-1.25	-16.08	-0.26	-2.95	-0.93	-10.74	-1.76	-19.77	-2.10	-22.82
Victoria X Superdur	0.74	10.5	0.61	8.43	1.05	14.69	0.50	6.70	-0.15	-1.43	-0.30	-3.17
Victoria X Progres	-0.31	-4.5	-0.46	-6.47	0.15	2.19	-0.3	-4.35	-0.93	-10.84	-1.13	-12.94
Victoria X Predel	0.38	5.42	0.25	3.45	0.45	6.57	-0.36	-3.57	-0.55	-7.40	-0.96	-11.76
Deni X Superdur	0.38	5.06	0.11	1.41	1.48	18.75	1.36	17.28	-0.88	-10.34	-1.36	-15.2
Deni X Progres	1.94	25.88	1.69	21.75	4.28	54.21	4.10	51.35	-1.03	-12.13	-1.56	-17.39
Deni X Predel	0.86	11.6	0.59	7.72	2.21	27.63	2.06	25.35	-0.28	-2.95	-1.03	-10.87
Superdur X Progres	0.38	5.17	0.36	4.95	1.43	18.47	1.36	17.72	-0.88	-10.42	-0.93	-10.97
Superdur X Predel	2.38	32.91	2.39	32.91	4.93	61.10	4.66	56.30	-0.50	-6.91	-0.76	-9.75
Progres X Predel	1.00	13.87	0.99	13.63	1.46	18.51	1.13	14.28	0.41	5.06	0.20	2.46
Min	-0.84		-1.25		-0.26		-0.93		-1.76		-2.1	
Max	2.38		2.39		4.93		4.66		0.41		0.20	
Mean ± m	0.69 ± 0.30		0.52 ± 0.32		1.71 ± 0.53		1.35 ± 0.58		-0.65 ± 0.18		-0.99 ± 0.20	

The real mid and better parent heterosis for the spike length is presented in Table 3. The mean value for mid parent heterosis in the first year of testing was 1.13, and for better parent heterosis was 0.58. All combinations were positive for mid parent heterosis, while nine were positive for better parent heterosis. The highest value for mid and better parent heterosis was the cross Deni X Predel. It was followed by the crosses Victoria X Progres and Victoria X Predel for mid parent heterosis. In relation to the better parent heterosis cross Deni X Predel is followed by the crosses Deni X Superdur and Deni X Progres. In the second year of testing, the mean value for mid parent heterosis was 0.37 and for better parent heterosis was -0.04. The positive values for mid parent heterosis were calculated in nine crosses, and for better parent heterosis - in six. The highest value was the cross Deni X Progres which was followed by Deni X Superdur. The Deni X Predel cross also had positive values. Crosses Superdur X Predel and Progres X Predel also have positive values for mid and better parent heterosis. In the third year, the mean value for mid parent heterosis was 0.07, and for better parent heterosis was -0.46. Five crosses showed positive mid parent heterosis and only one showed better parent heterosis. Crosses with Deni variety as a mother parent in two years show high values. The Progres X Predel cross had positive but not very high values in all three years of testing. Table 3. presents the results for the percentage of heterosis manifestations. The combinations Deni X Superdur, Deni X Progres and Deni X Predel had relatively high percentages. The results show that the variety Deni used as a mother parent increases the spike length in durum wheat. Its use in the breeding programs will allow the production of genotypes with longer spikes. KHOMENKO *et al.* (2021) determined the inheritance of the spike length attribute. They reported that the inheritance had a range from

negative better parent heterosis to negative better parent heterosis. According to KUMAR *et al.* (2018) in inheriting spike length, better parent heterosis is observed to the longer spike. On other hand, KALHORO *et al.* (2015) reported negative mid and better parent heterosis for this trait. Spike length is a major yield component and is directly proportional to grains/spike. The longer the spike length, the higher will be the grain yield (KUMAR *et al.*, 2018). Greater spike length is essential for enhanced yield (AHMED *et al.*, 2023).

Table 3. Real mid parent and better parent and percentage of heterosis in F_1 for spike length trait

Hybrid combinations	F_1-2014 year				F_1-2015 year				F_1-2016 year			
	MPH	MPH %	BPH	BPH %	MPH	MPH %	BPH	BPH %	MPH	MPH %	BPH	BPH%
Victoria X Deni	1.16	16.78	0.13	1.26	0.48	6.41	-0.63	-7.44	-0.15	-1.85	-1.30	-14.08
Victoria X Superdur	1.08	15.49	-0.16	-2.04	0.31	4.37	-0.63	-7.62	0.25	3.25	-0.66	-7.53
Victoria X Progres	1.55	21.97	0.26	3.09	0.35	4.66	-0.80	-9.23	0.008	0.06	-0.96	-10.83
Victoria X Predel	1.41	21.16	0.36	5.06	0.35	7.43	-0.70	-4.41	0.40	5.31	-0.20	-2.46
Deni X Superdur	1.18	14.60	0.96	11.64	0.73	8.65	0.56	6.51	-0.03	-0.38	-0.26	2.92
Deni X Progres	1.21	14.84	0.96	11.42	0.86	10.08	0.83	9.69	-0.05	-0.49	-0.23	-2.49
Deni X Predel	1.65	21.01	1.63	21.01	0.35	6.20	0.30	3.48	0.31	3.68	-0.23	-2.49
Superdur X Progres	0.73	8.78	0.70	8.33	-0.13	-1.53	0.33	-3.81	-0.48	-5.44	-0.53	-5.98
Superdur X Predel	0.56	7.2	0.36	4.44	0.28	5.48	0.16	4.84	-0.08	-1.00	-0.40	-4.56
Progres X Predel	0.86	10.79	0.63	7.5	0.18	4.16	0.10	1.15	0.53	6.29	0.13	1.91
Min	0.56		-0.16		-0.13		-0.80		-0.48		-1.30	
Max	1.65		1.63		0.86		0.83		0.53		0.13	
Mean ± m	1.13 ± 0.11		0.58 ± 0.16		0.37 ± 0.08		-0.04 ± 0.18		0.07 ± 0.09		-0.46 ± 0.13	

In a study of the heterosis, CHAWAN *et al.* (2022) found manifestations of mid parent and better parent heterosis for the traits: plant height, number of productive tillers and spike length. BAJANIYA *et al.* (2019) report that in durum wheat the range of heterosis is highest in terms of spike length and number of productive tillers. For plant height this range was average. The authors LAL *et al.* (2013) and DEVI *et al.* (2013) published negative better parent heterosis for the tested traits. DEVI *et al.* (2013) and GUL *et al.* (2015) reported manifestation of better parent heterosis for those traits. From a trial with 45 combinations THOMAS *et al.* (2017) reported that, better parent heterosis for plant height reached up to -20.70%, and for spike length up to 12.99%. AHMAD (2015) revealed that the trait number of productive tillers was dominated by better parent heterosis. PATEL *et al.* (2018) reported that both mid and better parent heterosis were observed for the traits plant height and spike length.

The real heterosis manifestations for the grain protein content trait is presented in Table 4. The mean value in the first year of testing for mid parent heterosis was 0.98, and for better parent heterosis was -0.006. Eight of the ten combinations had a positive value for mid parent heterosis, and five - for better parent heterosis. Victoria X Deni cross had the highest value for mid and better parent heterosis. It was followed by the combination Deni X Progres. In the second year of testing, the mean value for mid parent heterosis was -0.22, and for better parent heterosis was -

0.58. Four combination had positive values for mid parent heterosis and two for better parent heterosis. The cross Superdur X Progres had the highest value for mid and better parent and was followed by Deni X Progres. In the third year of testing, the mean value for mid parent heterosis was -0.12 and for better parent heterosis was -0.62. The number of crosses with a positive value for mid parent heterosis was four, while for better parent heterosis it was two. Victoria X Superdur and Victoria X Progres were characterized with positive mid parent and better parent heterosis. The Victoria X Progres and Deni X Progres crosses in two of the years had positive values for mid and better parent heterosis. In the third year, these crosses had negative values. Table 4 presents the heterosis manifestations in as a percentage. The table reveals two crosses: Victoria X Progres and Deni X Progres had a good percentage of mid and better parent heterosis in two of the years. The presence of these two crosses in breeding programs can successfully improve the protein content of durum wheat. It gives the impression, that the variety Progres used as a father increases the values of the trait. Regarding the grain protein content other authors observed manifestations of mid and better parent heterosis in the segregated generations (KUMAR *et al.*, 2018; PATEL *et al.*, 2018; AKEL *et al.*, 2019).

Table 4. Real mid parent and better parent and percentage of heterosis in F_1 for grain protein content trait

Hybrid combinations	F_1-2014 year				F_1-2015 year				F_1-2016 year			
	MPH	MPH %	BPH	BPH%	MPH	MPH %	BPH	BPH %	MPH	MPH %	BPH	BPH%
Victoria X Deni	3.00	19.39	2.25	13.84	-0.32	-2.25	-0.77	-5.31	-0.81	-5.33	-1.71	-10.57
Victoria X Superdur	-0.06	-0.39	-1.96	-10.57	-0.41	-2.89	-0.83	-5.68	1.32	8.60	0.34	2.13
Victoria X Progres	1.04	6.94	0.73	4.82	-0.26	-1.84	-0.91	-6.05	0.61	4.12	0.30	1.98
Victoria X Predel	1.21	7.45	-0.26	-1.52	-0.56	-3.85	-1.34	-8.75	0.68	4.49	-0.18	-1.11
Deni X Superdur	0.17	0.97	-0.97	-5.23	-0.87	-5.94	-0.91	-6.20	-0.83	-5.07	-0.91	-5.53
Deni X Progres	1.48	9.36	1.03	6.33	0.27	1.85	0.08	0.59	-0.80	-5.16	-1.39	-8.60
Deni X Predel	1.15	6.80	0.43	2.42	0.13	0.93	-0.18	-1.17	-1.07	-6.58	-1.09	-6.76
Superdur X Progres	0.87	5.13	-0.72	-3.88	0.36	2.46	0.13	0.93	-0.08	-0.50	-0.75	-4.56
Superdur X Predel	-0.42	-2.34	-0.84	-4.53	0.01	0.06	-0.34	-2.25	-0.61	-3.73	-0.72	-4.38
Progres X Predel	1.42	8.62	0.25	1.41	-0.61	-4.05	-0.74	-4.89	0.37	2.42	-0.18	-1.11
Min	-0.42		-1.96		-0.87		-1.34		-1.07		-1.71	
Max	3.00		2.25		0.36		0.16		1.32		0.34	
Mean ± m	0.98 ± 0.30		-0.006 ± 0.37		-0.22 ± 0.12		-0.58 ± 0.15		-0.12 ± 0.25		-0.62 ± 0.21	

Table 5. presents the real heterosis manifestations for the grain wet gluten. The mean value for mid parent heterosis in the first year of testing was 2.82, and for better parent heterosis it was 1.20. All crosses had positive values for mid parent heterosis and seven - for better parent heterosis. Crosses Victoria X Deni, Superdur X Predel, Superdur X Progres and Progres X Predel were with high positive values for mid and better parent heterosis. In the second year of

testing, the mean value for mid parent heterosis was -0.55, and for better parent heterosis -1.59. Three crosses with positive values for mid parent heterosis were identified, while for better parent heterosis it was only one. Of interest is the combination Superdur X Progres, which had positive values for mid and better parent heterosis. The mean values in the third year for mid parent heterosis was -1.10, and for better parent -2.55. There were three positive values for mid and better parent heterosis. Victoria X Superdur combination had the highest value. It was followed by the crosses Progres X Predel and Victoria X Predel. In two of the years, the hybrid combinations Superdur X Progres and Progres X Predel had positive values. In the third year of testing, their value was negative. Table 5 presents the heterosis manifestations as a percentage for the grain wet gluten content. The Superdur X Progres and Progres X Predel combinations had positive and high percentages in two of the three years of testing. In terms of breeding these crosses are valuable for grain wet gluten content. Their use in durum wheat breeding programs can increase the grain wet gluten content. Many researchers reveal positive mid and better parent heterosis (AHMAD *et al.,* 2016; PATEL, 2018; KUMAR *et al.,* 2018). According to PATEL (2018) these differences in trait inheritance may be due to the different genotypes included in the different studies.

Table 5. Real mid parent and better parent and percentage of heterosis in F_1 for wet gluten content trait

Hybrid combinations	F_1-2014 year				F_1-2015 year				F_1-2016 year			
	MPH	MPH %	BPH	BPH%	MPH	MPH %	BPH	BPH%	MPH	MPH %	BPH	BPH%
Victoria X Deni	4.63	15.85	3.73	12.39	-0.40	-1.38	-0.77	-2.60	-3.93	-11.65	-6.33	-17.51
Victoria X Superdur	0.36	1.18	-2.66	-7.74	-1.47	-5.14	-1.98	-6.79	5.73	17.66	4.66	13.92
Victoria X Progres	1.95	6.57	0.60	1.93	-0.06	-0.17	-1.53	-4.76	-0.31	-1.00	-0.50	-1.59
Victoria X Predel	1.95	6.24	-1.00	-2.92	-1.65	-5.42	-2.91	-9.18	1.05	3.39	0.46	1.46
Deni X Superdur	0.86	2.69	-1.26	-3.66	-2.05	-7.11	-2.93	-9.83	-5.60	-16.0	-6.93	-19.17
Deni X Progres	2.48	8.11	2.03	6.54	0.78	2.53	-0.32	-0.99	-3.98	-11.85	-6.56	-18.14
Deni X Predel	3.65	11.35	1.60	4.67	0.06	0.22	-0.82	-2.58	-2.91	-8.70	-5.90	-16.29
Superdur X Progres	4.38	13.4	2.70	7.85	2.4	7.96	0.41	1.30	-0.88	-2.72	-2.13	-6.35
Superdur X Predel	4.21	12.3	4.13	12.04	-0.95	-3.19	-2.72	-8.58	-1.78	-5.58	-3.43	-10.23
Progres X Predel	3.80	11.65	2.20	6.43	-2.19	-6.88	-2.41	-7.50	1.53	4.99	1.13	3.64
Min	0.36		-2.66		-2.19		-2.93		-5.6		-6.93	
Max	4.63		4.13		2.4		0.41		5.73		4.66	
Mean ± m	2.82 ± 0.48		1.20 ± 0.70		-0.55 ± 0.45		-1.59 ± 0.37		-1.10 ± 1.04		-2.55 ± 1.24	

The hybrid combination Progres X Predel demonstrates positive values for the number of productive tillers, spike length and grain wet gluten content. The cross Deni X Progres demonstrates positive values for the number of productive tillers, spike length and grain protein content. These two crosses are suitable for obtaining transgressive forms for three traits, respectively. It is impressive that these three varieties are involved in increasing the values of different traits in other crosses. They appear to be extremely valuable in the durum wheat breeding programs. The other varieties were also valuable for the improvement of some of the studied traits. Variety Progres is recommended to be used as both mother and pollinator parent to improve the traits traced in this publication. The Deni variety used as the mother parent is valuable for increasing the spike length in durum wheat. The combinations Progres X Predel and Deni X Progres also had positive effects on the grain weight per spike and number of grains per spike that was directly related to grain yield (DRAGOV, 2019). These crosses can be used in

breeding for high yielding durum wheat genotypes due to their high combining ability values for significant yield associated traits. They can be used equally in hybrid and combining breeding programs.

CONCLUSIONS

The studied durum wheat combinations showed mid and better parent heterosis for all studied traits. The better parent heterosis reaches up to -7.4 (-7.61%) for plant height, up to 4.66 (56.30%) for number of productive tillers, up to 1.63 (21.01%) for spike length, up to 2.25 (13.84%) for grain protein content and up to 4.66 (13.92%) for grain wet gluten content. Two valuable combinations show heterosis on several traits. Progres X Predel indicated better parent heterosis for three of the five traits included in the study. Deni X Progres indicated better parent heterosis for three of the five traits studied. The Progres variety is recommended for use as a mother and as a pollinator, and the Deni variety as a mother in winter durum wheat crossing programs. These varieties and their crosses are suitable for improving the productivity and quality of durum wheat. The obtained results may be applied in the hybrid and combining breeding programs to improvement durum wheat.

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HETEROZIS NEKIH MORFOLOŠKIH I SVOJSTAVA ZRNA ZIMSKE DURUM PŠENICE

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IZVOD

Cilj prikazane studije bio je utvrđivanje heterozisa u odnosu na srednjeg roditelje i boljeg roditelja pet kvantitativnih svojstava povezanih sa produktivnošću i kvalitetom durumpšenice. Dialelno ukrštanje izvedeno je tri uzastopne godine. Tako su F1 generacije obezbeđene tokom tri godine. Eksperimenti su sprovedeni u randomizovanom blok dizajnu u tri ponavljanja tokom tri uzastopne godine 2014, 2015 i 2016. Ogledi su izvedeni na oplemenjivačkom polju Instituta za poljske useve, Chirpan, prema prihvaćenoj tehnologiji gajenja durum pšenice. određen je heterozis u odnosu na srednjeg i boljeg roditelja kod deset ukrštanja durum pšenice. Heterozis u odnosu na bolejg roditelja dostiže do -7,4 (-7,61%) za visinu biljke, do 4,66 (56,30%) za produktivnost, do 1,63 (21,01%) za dužinu klasova, do 2,25 (13,84%) sadržaj proteina i do 4,66 (13,92%) za vlažni sadržaj glutena u zrnu. Utvrđeno je da su dve vredne hibridne kombinacije pokazale heterozis za nekoliko osobina. Progres Ks Predel pokazuje heterozis u odnosu na boljeg roditelja za tri od pet osobina, kao i Deni Ks Progres. Sorta Progres preporučuje se da se koristi kao otac i kao majka, a sorta Deni kao majka u hibridizaciji. Ove sorte i njihova ukrštanja pogodni su za poboljšanje produktivnosti i kvaliteta durum pšenice.

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