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Heterosis manifestations for spike productivity traits in durum wheat

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Abstract. *The aim of the study is to investigate the heterosis manifestations in durum wheat for quantitative traits related to spike productivity. Diallel cross includes five modern varieties of durum wheat: Victoria (BG), Deni (BG), Superdur, Progress (BG), Predel (BG). The heterosis manifestations of the ten crosses are traced for the traits: spikelet number per spike, number of kernel per spike, grain weight per spike and thousand kernel weight. The experiment is conducted in the 2014-2016 period in the experimental field of FCI-Chirpan. Standard technology for the cultivation of durum wheat is applied. The trials are organized in a randomized block design with three replications. Of each replication 30 plants are randomly picked and harvested for biometric analysis. The mean values by years from the F_1 spike biometric measurements are included in the statistical analysis to determine the mid parent and better parent heterosis. For spikelet number per spike, seven crosses show high parent heterosis in the first year, four in the second and six in the third year. In all years, hybrids with a variety of Victoria have more spikelet number per spike and show better parent heterosis. For the trait kernel number per spike it is observed that combinations with Deni variety in most cases have better parent heterosis. In all years, the cross Superdur x Predel indicates high parent heterosis for this trait. For grain weight per spike most of the combinations exhibit high levels of better parent heterosis. When the Deni variety is used as female parent, all hybrid combinations show high levels of heterosis for the trait grain weight per spike. In regard to the thousand kernel weight different heterosis levels are observed, with only negative values in the first year. In the other two years in hybrid combinations there is positive heterosis in one year and negative in another year. The participation of the Deni variety in hybrid combinations leads to better parent heterosis for this trait. The data allow the use of these crosses directly in the breeding of durum wheat to increase individual traits and/or increase productivity.*

Keywords: durum wheat (*Triticum durum* L.), mid parent heterosis, better parent heterosis, productivity traits

Introduction

Plant breeders attribute significance to the heterosis manifestation and its levels regarding the selection of the best hybrid combinations to serve as the bases of a well-developed breeding program (Abdel-Moneam, 2009; Subhashchandra et al., 2009). Heterosis and combining ability are two very important aspects of the breeding program. A great number of authors find proven heterosis levels in the self-pollinating crops (Fonseca and Patterson, 1968; Gyawali, 1968; Bitzer et al., 1982; Ozgen, 1989; Topal et al., 2004; Akinci, 2009).

The knowledge of the genetic structure and the method of inheritance of the quantitative traits help breeders choose an appropriate strategy for selecting the desired genotypes under the respective growing conditions. Parent selection is an important and essential step in starting breeding programs and creating new genotypes with the desired traits. According to Ilker et al. (2010) one of the methods for this is evaluation of heterosis or the hybrid vigor of the combination. Diallel crossing schemes are widely used to analyze the combining ability in wheat (common and durum) and to obtain information on the genetic mechanism controlling grain yield and its components (Khan et al., 2007).

Nowadays it is clear that self-pollinating crops such as wheat can exhibit a similar degree of heterosis as in the cross-pollinating ones (Larik et al., 1988, 1992, 1995). F_1 hybrids are assessed by the percentage increase or decrease of the value of the trait compared to the average value of both parents (heterosis) and compared to the better parent (heterobeltiosis) (Inamullah et al., 2006a; Hochholdinger and Hoecker, 2007). From the point of view of selection, heterobeltiosis (true heterosis) is more efficient than heterosis compared to the average, especially in self-pollinating crops where the aim is to identify the most valuable hybrid combinations (Lamkey and Edwards, 1999).

Recently, heterosis breeding has been used in self-pollinating crops as well, such as wheat (Peterson, 1992; Krystkowiak et al., 2009). The development of hybrid durum wheat varieties is based on the heterosis observed in that crop (Elfadl et al., 2006). Heterosis is related to the genetic differences in the parent components and corresponds to the theory of dominance and over-dominance. Heterosis is the result of allelic and non-allelic gene interactions arising during hybridization (Fonseca and Patterson, 1968; Martin and Talbert, 1995; Elfadl et al., 2006).

Each improvement in the main spike through selection and breeding work could enhance the plant productivity (Iqbal and Khan, 2006a). Hybrid breeding is still considered to be a possible method for increasing the productivity of the wheat plant. Heterosis manifestations regarding quantitative traits related to wheat plant productivity have also been observed by Joshi

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et al. (2002); Kindred and Gooding (2005); Zuo et al. (2007). The use of heterosis is considered to be one of the greatest achievements in the breeding of cross-pollinating plants (Jaisaw et al., 2010).

The aim of the present study is to trace the manifestations of heterosis in 10 hybrid combinations of five modern durum wheat varieties under the conditions of Central South Bulgaria. Obtaining information about heterosis manifestation in durum wheat of spike productivity is of particular importance for the combined breeding and development of new higher-yielding durum wheat varieties.

Material and methods

The experiment was carried out under field conditions in the experimental field of the Field Crops Institure - Chirpan, Bulgaria. A standard technology of growing durum wheat has been applied. The experiment includes five modern durum wheat cultivars: Victoria (BG), Deni (BG), Superdur (BG), Progress (BG) and Predel (BG), which are crossed at a diallel design. The experiment has been conducted in a randomized block method in three replications in three consecutive years 2014, 2015 and 2016. In each replication there are representatives of the five parents and the ten crosses. The width of the bed is 2m, the interrow distance 20cm, and the intrarow at 10cm. From each replication 30 plants have been picked randomly. The biometric parameters of the following traits have been recorded: spikelet number per spike (by counting), kernel number per class (by counting), grain weight per spike (by weighing the grain of the main spike) and thousand kernel weight calculated by the formula (weight of grain per spike/kernel number per spike)*1000. On the data obtained, statistical processing was used to calculate the mid parent and better parent heterosis using the software by Mark Burow and James G. Coors (1993). The percentage of the two types of heterosis for each cross has been calculated by using the relevant formulas by Fonseca and Patterson (1968):

HP=(F1-BP)/BP*100; MP=F1-MP/MP*100.

Statistica 10 software was used to calculate the latter analysis.

Results and discussion

Research on the inheritance of the main yield components is of great importance for the creation of a new variety of durum wheat and is crucial to the structure of the breeding program. The increase of the studied traits will enhance the productivity, respectively yield, per unit area. This is associated with the positive values of heterosis in the hybrids. The results and discussion have been done separately for each of the studied traits.

For the trait spikelet number per spike, seven crosses show high parent heterosis in the first year, four in the second and six in the third year (Table 1). In most years, hybrids of the Victoria variety have more spikelets per spike than their parents showing mid parent heterosis and better parent heterosis. The crosses Victoria x Deni, Victoria x Superdur, Victoria x Progress manifest in all three years better parent heterosis. These crosses are extremely valuable in terms of obtaining transgressions forms by this trait. In most crosses positive values of mid parent heterosis have been observed. Manifestations of mid parent and better parent heterosis are also reported in wheat by the authors Rasul et al. (2002).

Table 1. Mid parent (MPH) and better parent (BPH) heterosis in F1 for spikelet number per spike trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH	BPH	MPH	BPH	MPH	BPH
Victoria X Deni	12	2.3	1.26	1.25	0.56	1.083	0.40
Victoria X Superdur	13	1.68	1.13	0.91	0.70	0.33	0.16
Victoria X Progress	14	1.96	1.36	1.58	1.5	0.56	0.30
Victoria X Predel	15	1.61	0.83	0.50	-0.16	0.45	0.30
Deni X Superdur	23	0.61	0.13	1.1	0.63	0.18	-0.66
Deni X Progress	24	-0.03	-0.46	0.76	0	-0.35	-1.3
Deni X Predel	25	0.88	0.63	-0.28	-0.3	0.36	-0.46
Superdur X Progress	34	0.08	0.03	-1.26	-1.56	-1.5	-1.6
Superdur X Predel	35	-1.66	-1.9	-0.48	-0.93	0.65	0.63
Progress X Predel	45	-1.15	-0.11	-0.38	-1.13	0.38	0.26
Mean heterosis ± m		0.62±0.41	0.29±0.31	0.37±0.29	-0.06±0.29	0.21±0.22	-0.19±0.24

Table 2 shows the percentages for mid parent and better parent heterosis. For spikelet number per spike, better parent heterosis ranged from -8.78% to 6.91%. In most hybrid combinations with the participation of the Victoria variety the obtained hybrids have more spikelets per spike calculated in percentage. This was observed throughout all the study years. Only the hybrid combination Victoria x Predel has a negative value for better parent heterosis in F_1 - 2015. The other crosses in some cases exhibit mid parent heterosis, but not better parent heterosis. Of interest are the crosses that show better parent heterosis. During the three years of studying the diallel crossing, there are always 5 or 6 combinations that show better parent heterosis for this trait. However, they change their ranking by value in different environments. In this trait the percentage levels of heterosis over the better parent are not high enough. Nevertheless, F_1 hybrids may be involved in additional hybridization as donors to enhance the trait or as a source for greater frequency of transgression forms.

Table 2. Percentages of mid parent (MPH) and better parent (BPH) heterosis in F1 for spikelet number per spike trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH, %	BPH, %	MPH, %	BPH, %	MPH, %	BPH, %
Victoria X Deni	12	10.9	5.73	5.58	2.47	4.74	1.69
Victoria X Superdur	13	8.19	5.38	4.17	3.16	1.38	0.63
Victoria X Progress	14	9.3	6.3	7.33	6.91	2.58	1.35
Victoria X Predel	15	7.9	4.02	2.21	-0.7	2.04	1.35
Deni X Superdur	23	2.84	0.58	4.89	2.77	0.79	-2.84
Deni X Progress	24	-0.16	-2.12	3.61	0.17	-1.55	-5.52
Deni X Predel	25	4.02	2.84	-1.23	-1.30	1.60	-1.99
Superdur X Progress	34	0.42	0.18	-5.81	-7.09	-6.90	-7.32
Superdur X Predel	35	-7.78	-8.78	-2.12	-4.03	2.99	2.92
Progress X Predel	45	-5.33	-6.14	-1.70	-4.90	1.77	1.23

For the trait kernel number per spike, the results show that most of the hybrid combinations exhibit better parent heterosis (Table 3). In the first year F_1 nine out of ten crosses are with better parent heterosis. In the second year 6 crosses show better parent heterosis. In the third year, 8 crosses show better parent heterosis. In terms of mid parent heterosis, only one cross has a negative value. Of interest are the crosses that show better parent heterosis in most of the years. Crosses Deni x Superdur, Deni x Progress, Deni x Predel and Superdur x Predel have better parent heterosis over the three years. It is evident that hybrid combinations with Deni variety in most cases have better parent heterosis. In all years, the cross Superdur x Predel shows better parent heterosis. Farahani and Arzani (2007) and Ahmat (2015) reported manifestations of mid parent and better parent heterosis in their hybrid combinations for the trait kernel number per spike. The noted crosses are extremely important for the durum wheat productivity breeding program.

Table 3. Mid parent (MPH) and better parent (BPH) heterosis in F1 for number of grains per spike trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH	BPH	MPH	BPH	MPH	BPH
Victoria X Deni	12	13.81	13.80	1.95	-1.63	4.68	1.70
Victoria X Superdur	13	16.61	12.43	2.05	-0.40	8.18	6.30
Victoria X Progress	14	12.26	10.56	1.33	-1.96	4.65	1.76
Victoria X Predel	15	14.20	8.46	0.78	-2.66	3.51	3.03
Deni X Superdur	23	13.76	9.56	8.2	7.06	8.36	3.50
Deni X Progress	24	4.45	2.73	11.11	10.83	1.70	1.60
Deni X Predel	25	9.35	3.60	9.66	2.63	3.86	1.36
Superdur X Progress	34	16.38	13.90	11.01	10.16	1.96	-2.8
Superdur X Predel	35	3.25	1.70	10.80	4.90	5.06	2.70
Progress X Predel	45	2.70	-1.33	6.58	-0.16	-0.1	-2.5
Mean heterosis ± m		10.67±1.7	7.54±1.72	6.34±1.38	2.87±1.60	4.18±0.84	1.66±0.85

Table 4 shows the mid parent and better parent heterosis in percentages. The range of better parent heterosis for the studied trait ranges from -4.89 to 30.74% in the Superdur x Progress cross. The results thus looked at show that this cross has the highest and the lowest value for this trait. A careful reading of the results shows that better parent heterosis is typical for the combinations Deni x Superdur, Deni x Progress, Deni x Predel and Superdur x Predel by this trait. These combinations show one-way results over the three years of testing and can be considered a promising type for perceptible improvement of the productivity in these environments. In most cases crosses having values over the better parent in this trait show elevated values about the productivity of one plant as well. In this way, heterobeltiosis (true heterosis or BPH) may, for a given trait, contributes to increased yields.

Kernel number per spike is the main component of productivity that determines yield per unit area. Manipulations directly on it can make it easier to obtain forms with a greater kernel number per spike and increase the yield of durum wheat. On the other hand, the high percentages of better parent heterosis indicate that it is possible to use these crosses both in hybrid and in combined breeding. This is an interesting statement since hybrid breeding is not primarily found in wheat. At this point, the issue is being tackled, but the problem of castration and pollination is not entirely solved, which poses great difficulties. Longin et al. (2013) present in their paper different prerequisites for designing a hybrid wheat breeding program. The data presented show that the participation of the Deni variety in the crosses increases kernel number per spike in durum wheat. This is evidenced by the high percentages of better parent heterosis exhibited by the crosses it is involved in. In addition, Superdur x Predel cross also exhibits better parent heterosis and is suitable for obtaining transgression forms by this trait.

Table 4. Percent mid parent (MPH) and better parent (BPH) heterosis in F1 for number of grains per spike trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH, %	BPH, %	MPH, %	BPH, %	MPH, %	BPH, %
Victoria X Deni	12	37.59	37.50	3.91	-3.06	9.27	3.17
Victoria X Superdur	13	40.54	27.48	4.04	-0.75	14.7	11.00
Victoria X Progress	14	31.90	26.3	2.68	-3.68	9.17	3.28
Victoria X Predel	15	33.34	17.43	1.39	-4.42	6.60	5.66
Deni X Superdur	23	33.61	21.15	17.37	14.64	15.96	6.11
Deni X Progress	24	11.58	6.80	24.00	23.28	3.56	3.35
Deni X Predel	25	21.93	7.35	18.21	4.39	7.70	2.60
Superdur X Progress	34	38.38	30.74	23.2	21.07	3.74	-4.89
Superdur X Predel	35	6.88	3.41	19.9	8.15	9.22	4.71
Progress X Predel	45	6.06	-2.85	12.3	-0.26	-0.19	-4.75

For the trait kernel weight per spike in the first year nine crosses show better parent heterosis (Table 5). For the second year, all crosses show better parent heterosis. In the third year, 6 crosses showed better parent heterosis. This reveals that most of the combinations exhibit high levels of better parent heterosis. The highest value for mid parent heterosis has the Superdur x Progress cross of 0.99. Better parent heterosis values reach 0.72 in the Deni x Superdur cross.

Table 5. Mid parent (MPH) and better parent (BPH) heterosis in F1 for kernel weight per spike trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH	BPH	MPH	BPH	MPH	BPH
Victoria X Deni	12	0.42	0.41	0.28	0.14	0.14	-0.14
Victoria X Superdur	13	0.61	0.57	0.32	0.16	0.48	0.28
Victoria X Progress	14	0.34	0.32	0.31	0.20	-0.02	-0.14
Victoria X Predel	15	0.65	0.64	0.51	0.35	0.12	-0.17
Deni X Superdur	23	0.77	0.72	0.30	0.28	0.76	0.69
Deni X Progress	24	0.13	0.12	0.97	0.71	0.26	0.12
Deni X Predel	25	0.36	0.36	0.78	0.48	0.41	0.39
Superdur X Progress	34	0.13	0.07	0.99	0.71	0.38	0.33
Superdur X Predel	35	0.02	-0.03	0.92	0.60	0.60	0.50
Progress X Predel	45	0.15	0.14	0.55	0.51	0.08	-0.06
Mean heterosis ± m		0.35±0.08	0.33±0.08	0.59±0.09	0.41±0.06	0.32±0.07	0.18±0.09

It is notable that all crosses without one have a positive mid parent heterosis. On the other hand, the majority of crosses show better parent heterosis. The combinations Victoria x Superdur, Deni x Superdur, Deni x Progress, Deni x Predel, and Superdur x Progress in all years of study show positive better parent heterosis. This makes them very important by this trait in the productivity breeding program. Obtaining transgression forms from them can be expected. The results achieved show that when the Deni variety is used as a female parent, all hybrid combinations with it show high heterosis levels in the trait kernel weight per spike. Solomon et al. (2007), Ciftci and Yagdy (2007) and Patel et al. (2016) report manifestations of better parent heterosis in the expression of this trait, too.

Mid parent and better parent heterosis presented in percentage are within the range from -7.28 to 42.68 (Table 6). By this trait, better parent heterosis is very well expressed. The values of better parent heterosis in percentages are very high and show that hybrids have heterosis manifestations on a large scale. Most crosses show mid parent heterosis. For this trait, the values for positive better parent heterosis also prevail. With the highest better parent heterosis, the cross Deni x Superdur ranks first in all study years. Other crosses with positive and high better parent heterosis in all years of study are: Victoria x Superdur, Deni x Predel and Superdur x Progress. The mentioned crosses by this important trait are extremely valuable and of great interest. They have very high values, which allow their wide application for both hybrid breeding and for obtaining transgression segregants.

The results for heterosis manifestations by the trait thousand kernel weight are shown in Table 7. In the first year all crosses showed negative better parent heterosis. Regarding mid parent heterosis, some crosses have positive values. In the second and third year seven crosses exhibited better parent heterosis. In these two years all hybrid combinations exhibit mid parent heterosis. Crosses Victoria x Deni, Deni x Superdur, Deni x Progress, Deni x Predel and Superdur x Predel have positive values in two of the years. Higher values for better parent heterosis have the crosses Deni x Superdur, Deni x Predel and Superdur x Predel and they show one-way results over two of the study years. The combinations including Deni as a parent in both years retain their levels of better parent heterosis. The cross Superdur x Predel displays better parent heterosis for two of the years. Akinci (2009) also reported manifestations of better parent heterosis for this trait.

Table 6. Percent mid parent (MPH) and better parent (BPH) heterosis in F1 for kernel weight per spike trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH, %	BPH, %	MPH, %	BPH, %	MPH, %	BPH, %
Victoria X Deni	12	25.29	24.56	11.02	5.22	6,63	-5.66
Victoria X Superdur	13	36.96	33.72	12.92	5.97	21.41	11.33
Victoria X Progress	14	20.34	18.28	11.27	6.87	-0.86	-6.88
Victoria X Predel	15	38.41	37.2	17.81	11.7	5.52	-7.28
Deni X Superdur	23	46.9	42.69	12.84	11.66	38.8	33.49
Deni X Progress	24	8.09	6.85	36.34	24.39	13.02	5.99
Deni X Predel	25	21.28	20.9	29.12	16.38	22.01	21.05
Superdur X Progress	34	8.33	4.00	37.64	24.39	18.2	15.20
Superdur X Predel	35	1.5	-1.74	34.45	20.06	30.78	24.75
Progress X Predel	45	8.93	8.00	18.98	17.39	3.96	-3.22

Table 7. Mid parent (MPH) and better parent (BPH) heterosis in F1 for 1000-kernel weight trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH	BPH	MPH	BPH	MPH	BPH
Victoria X Deni	12	-4.49	-4.82	3.56	2.56	3.12	0.26
Victoria X Superdur	13	5.71	-0.40	4.66	3.60	1.67	-3.43
Victoria X Progress	14	-3.86	-5.32	4.15	-1.90	1.62	1.59
Victoria X Predel	15	0.87	-4.40	8.06	7.91	0.25	-4.90
Deni X Superdur	23	4.31	-2.13	3.90	1.84	7.12	4.87
Deni X Progress	24	-1.79	-3.59	5.83	0.78	3.44	0.61
Deni X Predel	25	-0.92	-6.54	4.22	3.06	4.55	2.16
Superdur X Progress	34	-4.76	-9.41	3.32	-3.79	4.76	-0.32
Superdur X Predel	35	-0.99	-1.83	5.99	5.08	7.24	7.10
Progress X Predel	45	1.45	-2.35	2.45	-3.75	1.29	-3.92
Mean heterosis ± m		-0.44±1.12	-4.07±0.83	4.61±0.51	1.53 ±1.19	3.5±0.76	0.40±1.20

Results for mid parent and better parent heterosis as percentage are presented in Table 8. In the first year, all values had a negative percentage for better parent heterosis. Most crosses had positive percentages for this trait over the other two years. The extent of heterosis over the years of study ranges between -21.7 and 20.23. The presented results show that the combinations Deni x Superdur, Deni x Progress, Deni x Predel, and Superdur x Predel have enough percentages for better parent heterosis. These crosses are extremely valuable for the increase of that trait. Accordingly, they can be used in combined breeding to create transgressional forms. For these hybrid combinations are also found manifestations of better parent heterosis for the traits kernel number per spike and kernel weight per spike. On the basis of above-mentioned results Deni variety appears to be extremely valuable for the durum wheat breeding programs. The mentioned hybrid combinations can be used in the breeding program to create superior segregants or better pure lines.

Table 8. Percent mid parent (MPH) and better parent (BPH) heterosis in F1 for 1000-kernel weight trait

Hybrid combinations		F1-14		F1-15		F1-16	
		MPH, %	BPH, %	MPH, %	BPH, %	MPH, %	BPH, %
Victoria X Deni	12	-9.65	-10.3	6.96	4.90	7.19	0.56
Victoria X Superdur	13	14.24	-0.88	9.48	7.17	4.06	-7.45
Victoria X Progress	14	-8.62	-11.53	7.38	-3.06	3.50	3.44
Victoria X Predel	15	2.12	-9.54	13.11	15.7	0.62	-10.81
Deni X Superdur	23	10.62	-4.6	7.78	3.52	18.65	12.03
Deni X Progress	24	-3.98	-7.68	10.2	1.25	7.94	1.32
Deni X Predel	25	-2.24	-13.9	8.27	5.88	11.95	5.33
Superdur X Progress	34	-12.3	-21.7	6.02	-6.09	11.61	-0.69
Superdur X Predel	35	-2.80	-5.13	12.25	10.20	20.23	19.78
Progress X Predel	45	3.70	-5.43	4.37	-6.03	3.15	-8.52

Similar results for the traits kernel number per spike, kernel weight per spike and thousand kernel weight have also been found by researchers Akinci (2009); Ali and Shakor (2012); Brahim and Mohamed (2014); Ismail (2015). Çiftçi and Yaðdý (2007) calculate a very high level of better parent heterosis for the trait kernel number per spike reaching up to 48.12%. This is confirmed by other authors as well, Inamullah et al. (2006) and Farahani and Arzani (2007), who also found high levels of better parent heterosis for the trait kernel number per spike.

The commercial use of heterosis is seen as the application of genetics in plant production. The high degree of heterosis can be used in creation of hybrid varieties and production of hybrid seeds. The high heterosis effect of hybrid combinations on yield components shows an opportunity to increase productivity within the existing diversity. The expression of the better parent heterosis for the studied traits in all environments indicates that such hybrid combinations can be used as a source to increase the values of the relevant traits.

Durum wheat is a self-pollinating crop and no suitable manipulation to produce hybrid seed on a commercial scale is available yet. As a result, heterosis in itself cannot currently have economic value for this crop. Nonetheless, knowing the degree of heterosis will serve to determine the direction of the breeding program. Nominating promising crosses and obtaining better segregants in the early generations is applicable in improving productivity. It is suggested that both additive and non-additive gene effects account for heterosis. It is well known that heterosis hybrids can produce desired transgressive segregants with greater certainty (Arunachalam et al., 1984). According to Pancholi et al. (2011) environment is of great importance in the expressions of the traits, and in the different environments a change in their expression is possible. The superiority of hybrids over the better parent (heterobeltiosis) is more important and useful in determining the commercial use of heterosis. The specified parent combinations above the better parent are able to produce transgression forms more easily.

Conclusion

Manifestations of over-dominance and dominance in the inheritance of the traits spikelet number per spike, kernel number per spike, kernel weight per spike and thousand kernel weight in durum wheat have been established. From the studied traits in the F_1 hybrids, high heterosis effects over the better parent (HPH) has been found in kernel numbers per spike and kernel weight per spike, while it was low in spikelet number per spike and thousand kernel weight. Compared to the mean parental level (MPH) high heterosis effect was found for all traits. The observed heterosis levels over the better parent (HPH) for the traits kernel number per spike and kernel grain weight per spike indicates that these two traits are best suited for hybrid and/or transgressive breeding in durum wheat. High breeding value by several productivity parameters have the hybrid combinations Deni x Superdur, Deni x Progress, Deni x Predel by the traits kernel number per spike, kernel weight per spike and 1000 kernel weight. The combination Superdur x Progress have high breeding value for two traits: kernel number per spike and kernel weight per spike. These crosses can be used directly both for the production of transgression forms and for the development of hybrid breeding. The participation of Deni variety as a parent in the crosses increases the values of the traits kernel number per spike, kernel weight per spike and thousand kernel weight. Victoria variety in all combinations increases the values of the trait spikelet number per spike.

References

Abdel-Moneam MA, 2009. Heterosis in some crosses of bread wheat under irrigation and drought conditions. Pakistan Journal of Biological Sciences, 12, 486-491.

Ahmad MSH, 2015. Genetical analysis of some agronomic traits in durum wheat. International Journal of Environment, 4, 336-341.

Akinci C, 2009. Heterosis and combining ability estimates in 6 x 6 half-diallel crosses of durum wheat (*Triticum durum* Desf.). Bulgarian Journal of Agricultural Science,15, 214-221.

Ali IH and Shakor EF, 2012. Estimation of combining ability, gene action and heterosis in durum wheat using nested mating design. The 2nd Scientific Conference the Collage of Agriculture 2012, Erbil, Iraq.

Arunachalam V, Bandhyopadhyay A, Nigam SN and Gibbons RW, 1984. Heterosis in relation to genetic divergence and combining ability in groundnut (*Arachis hypogaea* L.). Euphytica, 33, 33-39.

Bitzer MJ, Patterson FL and Nyquist WE, 1982. Hybrid vigor combining ability in a high-low yielding, eight-parent diallel crosses of soft red winter wheat. Crop Science, 22, 1126-1129.

Brahim B and Mohamed B, 2014. Analysis of diallel crosses between six varieties of durum wheat in semi-arid area. African Journal of Biotechnology, 13, 286-293.

Burow MD and Coors JG, 1993. DIALLEL Analysis and simulation. Madison, Wisconsin, USA.

Ciftci EA and Yagdy K, 2007. Ekmeklik Buðdayda (*Triticum aestivum* L.) diallel melez analizi ile bazý agronomic özelliklerin incelenmesi. Tarým Bilimleri Dergisi, 13, 354-364 (Tr).

Elfadl E, Kling C and Melchinger A, 2006. Evaluation of heterosis in durum wheat (*Triticum Durum* Desf.) “Prosperity and Poverty in a Globalised World-Challenges for Agricultural Research” Tropentag, October 11-13, Bonn, Germany, p. 318.

Farahani E and Arzani A, 2007. Assessment of heterosis in durum wheat F1 hybrids under field conditions. Journal of Science and Technology of Agriculture and Natural Resources, 11, 109-121.

Fonseca S and Patterson FL, 1968. Hybrid vigor in a seven parent diallel crosses in common winter wheat. Crop Science, 8, 85-88.

Gyawali KK, Qualset CO and Yamazaki WT, 1968. Estimates of heterosis and combining ability in winter wheat. Crop Science, 8, 322-324.

Hochholdinger F and Hoecker N, 2007. Towards the molecular basis of heterosis. Trends in Plant Science, 12, 427-432.

Ilker E, Tonk FA and Tosun M, 2010. Heterosis for yield and its components in bread wheat crosses among powdery mildew resistant and susceptible genotypes. Pakistan Journal of Botany, 42, 513-522.

Inamullah AH, Mohammad F, Din SU, Hassan G and Gul R, 2006. Diallel analysis of the inheritance pattern of Agronomic traits of bread wheat. Pakistan Journal of Botany, 38, 1169-1175.

Inamullah HA, Mohammad F, Ud-Din S, Hassan G and Gul R, 2006a. Valuation of the heterotic and heterobeltiotic potential of wheat genotypes for improved yield. Pakistan Journal of Botany, 38, 1159-1167.

Iqbal M and Khan AA, 2006a. Analysis of combining ability for spike characteristics in wheat (*Triticum aestivum* L.) International Journal of Agriculture and Biology, 8, 684-687.

Ismail HA, 2015. Genetic properties of drought tolerance indices in durum wheat. Jordan Journal of Agricultural Sciences, I, 1-109.

Jaiswal KK, Pandey P, Marker S and Anurag PJ, 2010. Heterosis studies for improvement in yield potential of wheat (*Triticum aestivum* L.). Advances in Agriculture & Botanics-Bioflux, 2, 273-278.

Joshi S, Sharma S, Singhania D and Sain R, 2002. Genetic analysis of quantitative and quality traits under varying environmental conditions in bread wheat. Wheat Information Service, 95, 5-10.

Khan MA, Ahmad N, Akbar M, Rehman A and Iqbal MM, 2007. Combining ability analysis in wheat. Pakistan Journal of Agricultural Sciences, 44, 1-5.

Kindred DR and Gooding MJ, 2005. Heterosis for yield and its physiological determinants in wheat. Euphytica 142 (1-2), 149-159.

Krystkowiak K, Adamski T, Surma M and Kaczmarek Z, 2009. Relationship between phenotypic and genotypic diversity of parental genotypes and the specific combining ability and heterosis effects in wheat (*Triticum aestivum*). Euphytica, 165, 419-434.

Lamkey KR, and Edwards JW, 1999. The quantitative genetics of heterosis. In: The Genetics and Exploitation of Heterosis in Crops (eds. J.G. Coors and S. Pandey), Crop Sci. Society of America, pp. 31-48.

Larik AS, Hafiz HMI and Khushk AM, 1988. Estimation of heterosis in wheat population derived from intra-cultivaral hybridization. Wheat Information Service, 66, 15-18.

Larik AS, Hafiz HMI and Sethar H, 1992. Hybrid vigour and combining ability in barley (*Hordeum vulgare* L.). Pakphyton, 4, 17.

Larik AS, Mahar AR and Hafiz HMI, 1995. Heterosis and combining ability estimates in diallel crosses of six cultivars of spring wheat. Wheat Information Service, 80, 12-19.

Longin C, Gowda M, Muhleisin J, Ebmeyer E, Kazman E, Schachscheider R, Schacht J, Kirchhoff M, Zhao Y and Reif J, 2013. Hybrid wheat: quantitative genetic parameters and consequences for the design of breeding program. Theoretical and Applied Genetics, 126, 2791-2801.

Martin JM and Talbert LE, 1995. Hybrid performance in wheat related to parental diversity. Crop Science, 35, 104-108.

Ozgen M, 1989. Hybrid vigour in common winter wheat (*Triticum aestivum* L.). Doga Turkish Journal of Agriculture and Forestry, 13, 1190-1202.

Pancholi SR, Sharma SN, Sharma Y and Maloo SR, 2012. Combining ability computation from diallel crosses comprising ten bread wheat cultivars. Crop Research, 43, 131-141.

Patel NA, Bhatt JP, Dave PB and Chauhan SS, 2016. Genetic analysis of grain yield, its components and quality characters in durum wheat (*Triticum Durum* Desf.) over environments. International Journal of Agriculture Sciences, 8 ,1681-1686.

Peterson PA, 1992. Quantitative inheritance in the era of molecular biology. Maydica, Nr 37,7-18.

Rasul I, Khan AS and Zulfiqar A, 2002. Estimation of heterosis for yield and some yield components in bread wheat. International Journal of Agriculture and Biology, 4, 214-216.

Singh RK and Singh M, 1984. Concepts of heterosis and exploitation of hybrid vigour in pulse crops. In: Proceeding of the National Seminar on Pulse Research and Development, 21 May, 1984. Jabalpur.

Solomon KF, Labuschagne MT and Viljoen CD, 2007. Estimates of heterosis and association of genetic distance with heterosis in durum wheat under different moisture regimes. Journal of Agricultural Science,145, 239-248.

Subhashchandra B, Lohithaswa HC, Desai SA, Hanchinal RR, Kalappanavar IK, Math KK and Salimath PM, 2009. Assessment of genetic variability and relationship between genetic diversity and transgressive segregation in tetraploid wheat. Karnataka Journal of Agricultural Sciences, 22, 36-38.

Topal A, Aydin C, Akgun N and Babaoglu M, 2004. Diallel cross analysis in durum wheat (*Triticum durum* Desf.): identification of best parents for some kernel physical features. Field Crops Research, 87, 1-12.

Zuo S, Ma Y and Inanaga S, 2007. Allelopathy variation in dryland winter wheat (*Triticum aestivum* L.) accessions grown on the Loess Plateau of China for abour fifty years. Genetic Resources and Crop Evolution, 54, 1381-1393.