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Genetic analysis and heterosis for some quantitative characters in bread wheat

Nassar H. S. A.*, Abd-El-Haleem S. H. M., Haridy M. H., Ahmed B. H.

Department of Agronomy, Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt

Abstract

This investigation was carried out to study the combining ability and heterosis in a half diallel mating among seven bread wheat varieties. Some traits i.e. days to heading, plant height, no. of spikes/plant, spike length, no. of grains/spike, 1000-grain weight and grain yield/plant were studied. The results showed that there were highly significant estimates of both GCA and SCA combining ability effects, indicating the relative importance of additive and non-additive genetic variances for all studied characters. The ratios of GCA/SCA were more than unity in all studied traits, indicating that additive gene effects were more important than dominance in the expression of these traits. Shandaweel-1 (P_2) had positive significant for plant height and negative significant for days to heading, while it gave non-significant values for spikes number plant^{-1}, grains number spike^{-1}, 1000-grain weight and grain yield/ plant^{-1}. Gemmeiza-11 (P_3) gave positive and highly significant GCA effects for days to heading, no. of grains/spike and grain yield/plant^{-1} and negative highly significant for no. of grains/spike and GW, while it had non-significant for PH. The parent Giza-171 (P_4) was good combiner for PH and GW, while Sakha 93(P_7) was the best combiner for DH, PH, GW and grain yield plant^{-1}. $P_3 \times P_7$ showed the maximum positive SCA effects, while $P_1 \times P_2$ displayed the highest negative SCA effects. Concerning grain yield/plant^{-1}, the crosses P3×P_6 and $P_3 \times P_7$ gave the highest positive significant values for the heterosis over mid parent and better parent.

Keywords: wheat, combining ability, heterosis.

*Corresponding author: Nassar H. S. A.,
E-mail address: seaward1994@gmail.com

1. Introduction

Wheat (*Triticum aestivum* L.) is the major cereal crop in Egypt as well as several other countries. World average cultivated area of wheat reached 220.88 million hectares in 2020/2021, the total production was 775.9 million metric tons, with an average productivity of 3.51 metric tons per hectare (WAP, 2022). It is a food staple for millions of people because it provides 50% of the calorie and protein requirements of a large number of the world's population. The grain yield can be improved through indirect selection on the basis of yield components. The breeder is focusing on improving wheat yield potential by developing now divergent genotypes with a trait that may have a positive and negative effect on traits of other components. Diallel cross technique is a good tool for identification of hybrid combinations that have the potentiality of producing maximum improvement and identifying superior lines among the progeny in early segregation generations. Combining ability analysis of Griffing (1956) is most widely used as a biometrical tool for identifying parental lines in terms of their ability to combine in hybrid combinations. With this method, the resulting total genetic variations is partitioned into the variance of general combining ability, as a measure of additive gene action and specific combining ability, as a measure of non-additive gene action Afiah (2002) and Afiah and Darwish (2002). Dagustu (2008) studied genetic of grain number, grain yield, 1000-grain weight and harvest index by using diallel crosses analysis. The value of heterosis relative to mid and better parent in wheat and its components were many investigators, such as Khan *et al*. (1995), Chowdhry *et al.* (2001), Abd Allah and EL-Gammaal (2009) and Beche *et al.* (2013). The main objectives of the present investigation were to study performance heterosis, general and specific combining abilities for studied characters in 21 hybrids and seven parents of bread wheat.

2. Materials and methods

2.1 Experimental site and treatments description

The present study was carried out during three successive seasons of 2018/2019, 2019/2020 and 2020/2021 in the Agricultural Experimental Farm of Al-Azhar University, Assiut, Egypt. Seven genetically diverse genotypes of bread wheat (*Triticum aestivum* L.) widely different in their agronomic traits were used as parental genotypes in this study. The code no., pedigree and origin of these seven genotypes are shown in Table (1). In the 1st season (2018/2019), the seven parental genotypes were sown in a field on 25 November 2018 to obtain enough flowers for crossing. Parents were crossed in all possible combinations except reciprocals to produce 21 F_1 hybrids. These parents were crossed again in the 2nd season (2019/2020) to obtain more hybrids grains (F_1) for all combinations.

Table (1): The name, Pedigree and origin of the seven bread wheat parental varieties.

Genotypes	Pedigree	Origin
P_1 (Misr 10)	OASIS/SKAUZ//4×BCN/3/2×PASTOR CMSS00Y01881T-050M-030Y	Egypt
P_2 (Shandaweel 1)	SITE//MO/4/NAC/THAC//3×PVN/3/MIRLO/BUC	Egypt
P_3 (Gemmeiza 11)	BOW"S"/KVZ"S"//7C/SER182/3/GIZA 168/SAKHA61. GM7892-2GM-1GM-2GM-1GM-0GM	Egypt
P_4 (Giza 171)	SAKHA 93/GEMMEIZA 9S.6-1GZ-4GZ-1GZ-2GZ-0S	Egypt
P_5 (Sids 12)	BUC//7C/ALD/5MAYA74/0N//1160/47/BB/GLL/4/CHAT"S"/6MAYA/VUL//CMH74A.63014*SX.SD7096-4SD-1SD-1SD-0SD	Egypt
P_6 (Sids 14)	BOWS S/EE S//BOWS S/TSI//BANI SEWEF 1	Egypt
P_7 (Sakha 93)	SAKHA 92/TR 810328 S8871-1S-2S-1S-0S	Egypt

In the 2^{nd} season of 2020/2021, the forty-nine genotypes (seven parents and twenty one for F_1) were sown in a Randomized Complete Block Design (R.C.B.D) with three replications. Planting was carried out on 25 November 2020. Plants were sown on rows with 3 m long and 60 cm apart, in hills, one seed/ hill and spaced at 20 cm. There were two rows/plot for each parent. In addition, all other agricultural practices as irrigation, fertilization were as recommended for the growth and production of the bread wheat. Data were recorded on the means of ten guarded plants/plot, selected randomly for the parents and the F1's., The studied traits were as follows: days to 50% heading (DH), plant height (PH) (cm), number of spikes/plant (NSP), number of grains/spike (NKS), weight of 1000-grains (GW) (g) and (GYP) grain yield/plant (g).

2.2 Statistical and genetic analysis

The statistical analysis was made on an entry mean basis. The data was forwarded to analysis of variance (ANOVA) technique as outlined by Gomes and Gomes (1984) to test the null hypothesis of no differences between various F1 hybrids and their parental genotypes Table (2). Least Significant Difference (LSD) test was also applied for means separate on and comparison after significance of the ANOVA.

2.3 Combining ability in relation to diallel cross

Variation among parents, F_1 crosses was partitioned into general and specific combining abilities according to Griffing (1956) Model I, Method 2.

2.4 Heterosis

Estimate of heterosis (%) were calculated as the percent deviation of F_1 mean performance from the mid-parent or better parent as follows:

Heterosis from the mid-parent % (M.P) = (F_1-MP) / MP) × 100

Heterosis from the better-parent % (BP) = (F_1 – BP) / BP) × 100

Table (2): The form of the analysis of variance and the expectation of mean squares.

Source of variation	D.F.	M.S.	Expectation Model 1
Replications	k-1	M_b	$\sigma^2_e + g\,\sigma^2 b$
Genotypes	g-1	Mg	$\sigma^2_e + k\,\sigma^2 v$
Parents	(p-1)		
Crosses	(c-1)		
Parents *vs* crosses	1		
Error	(k-1)(g-1)	MS_e	$\sigma^2 e$

3. Results and discussion

3. 1 Analysis of variance

Data in Table 3 found that mean square of the studied traits for the genotypes, parents, crosses and parents vs crosses were significant (0.01 or 0.05 probability) except for spike length. These results indicated that there was genetic variability among 28 genotypes (seven parents and 21 F_1 hybrids). Similarly, the results reported that there were highly significant estimates for both GCA and SCA combining ability effects, indicating the relative importance of additive and non-additive genetic variances for all studied characters. Similar results Zaazaa (2010), and El-Gammaal and Yahya (2018). The ratios of GCA /SCA were more than unity in all studied traits, indicating that additive gene effects were more important than dominance in the expression of these traits. These results are in agreement with those reported by Zaazaa (2010). On the other hand, the non-additive genetic variance was previously reported to be most prevalent for spike length, N.K/S, 1000 grain weight and G.Y/P by Hammam *et al*. (2020).

3.2 Mean performance

The mean performance of the seven parents and F_1 hybrids are presented in Tables (4) and (5). The parental variety P4 was the earliest in days to heading. The parental variety P7 gave the highest value for plant height and N.S/P. However, the parent P3 for spike length, N.k/p and G.Y/ P. While, the P1 and P5 and P5 gave the highest value for 1000 grains weight and N.K/S. For G.Y/P, the parental P7 gave the highest value, while the P6 gave the lowest value. For hybrids, P1*P2 and P4*P5 was the earliest for days to heading, while P5*P7 was the longest for plant height. The crosses P1*P7, P3*P6, P3*P7 P5*P6 and P6*P7 gave the highest values for N.S/P. Also, the main performance for the spike length ranged from 11.8 for the cross P5*P7 to 13.67 for the cross P1*P2.

Table (3): Analysis of variance for all studied traits of 7-parents half diallel cross in F_1 generation.

S.O.V	Df	MS						
		Days to heading	Plant height	N.S/P	Spike length	N.K/P	1000-Kernels weight	G.Y/P
Rep.	2	13.6071	1.2262	0.5671	1.5394	5.2262	5.580	8.1730
Genotype	27	13.4039**	79.2747**	7.6035**	0.6199	46.9290**	26.00**	34.8846**
Parents	6	23.8254**	115.4127**	14.2838**	0.2278	28.8162*	54.196**	16.9952**
Crosses	20	10.4111**	69.9524**	5.0968**	0.6570	43.6159**	12.271**	25.2700**
P vs c	1	10.7302	48.8929*	17.6543**	2.2289	230.4802**	131.458**	334.5132**
G.C.A	6	46.1199**	300.0741**	26.8863**	0.9263	59.1605**	82.936**	46.5860**
S.C.A	21	4.0564**	16.1892*	2.0941	0.5323	43.4343**	9.735**	31.5414**
Error	54	4.3973	7.2879	1.4369	1.4129	15.1274	4.100	6.9428**
GCA/SCA		11.36		12.86	1.74	1.36	8.51	1.47
Rep.	2	-	-	-	-	-	-	-
Genotype	27	-	-	-	-	-	-	-
Parents	6	-	-	-	-	-	-	-
Crosses	20	-	-	-	-	-	-	-
P vs c	1	-	-	-	-	-	-	-
G.C.A	6	-	-	-	-	-	-	-
S.C.A	21	-	-	-	-	-	-	-
Error	54	-	-	-	-	-	-	-
GCA/SCA		-	-	-	-	-	-	-

Also, the main performance for the N.K/S ranged from 64 for the cross P2*P7 to 75 for the cross P1*P2. The crosses P1*P5 gave the highest values for 1000-grain weight. The crosses P3*P6 and, P3*P7 gave the highest values for G.Y/P. Similar results were obtained by Zaazaa *et al*., (2012).

Table (4): Mean performance of parental mean and their F1 hybrids for days to heading, plant height, spike number and spike length of wheat.

Parent	Days to heading	Plant height	Spike number/plant	Spike length
1	87.33	98.67	11.67	12.33
2	84.00	102.00	10.17	12.33
3	85.67	99.33	9.37	12.67
4	80.67	100.67	8.50	12.33
5	82.00	97.67	11.00	12.03
6	88.00	87.33	12.67	12.37
7	87.00	108.00	15.00	11.80
Crosses				
1×2	82.33	103.33	12.00	13.67
1×3	86.00	100.00	13.00	13.37
1×4	84.00	102.33	11.33	12.87
1×5	85.67	99.00	13.00	11.93
1×6	88.33	93.00	13.00	12.30
1×7	86.33	105.33	14.00	12.33
2×3	87.00	102.00	11.00	12.67
2×4	83.67	103.67	10.00	13.00
2×5	84.67	103.00	11.33	12.67
2×6	87.67	90.67	12.00	12.67
2×7	86.67	106.00	13.00	12.67
3×4	83.00	101.00	11.00	13.00
3×5	87.00	101.00	11.00	12.80
3×6	87.67	94.00	14.00	12.23
3×7	87.67	104.00	14.00	13.10
4×5	82.67	99.00	11.00	12.33
4×6	86.33	101.00	11.00	12.33
4×7	84.00	108.33	11.00	12.73
5×6	87.00	95.33	12.67	13.00
5×7	85.67	109.00	14.00	11.90
6×7	88.00	97.00	14.00	11.93
Mean	85.78	100.86	12.25	12.64
LSD				
0.05%	2.47	3.08	1.83	1.57
0.01%	3.56	4.43	2.63	2.26

3.3 General combining ability

The values of GCA effects of parents for the studied characters is shown in Table (6). The results claimed that the seven parents were elicited highly significant for studied traits showed that P1 (Misr 1) had positive and highly significant GCA effects for N.S/P and 1000 grains weight and negative highly significant for G.Y/P. While, it had non-significant for days to heading, plant height and N.K/P. P2 (Shandaweel 1) had positive significant for plant height and negative significant for days to heading, while it gave non-significant values for S/P, N.K/S, 1000 grains weight and G.Y/P. P3 (Misr 1) gave positive and highly significant GCA effects for days to heading, N.K/P and G.Y/P and negative highly significant for Spike /plant and 1000 grains weight.

Table (5): Mean performance of parental mean and their F1 hybrids for number of kernels/spike and 1000-kernels weight grain and yield/plant.

Parent	Number of grains/spike	1000-grains weight	Grain yield/plant
1	66.00	56.00	17.57
2	64.00	50.95	20.40
3	71.00	48.01	19.03
4	68.00	53.27	18.23
5	64.00	54.27	16.53
6	67.33	43.44	15.17
7	62.00	52.32	22.27
Crosses			
1x2	75.00	54.70	18.67
1x3	72.00	54.93	20.17
1x4	69.00	56.47	19.50
1x5	65.00	57.14	18.70
1x6	78.00	51.10	23.03
1x7	66.00	56.91	24.23
2x3	72.00	51.77	25.23
2x4	70.00	55.10	21.95
2x5	73.00	55.51	21.40
2x6	67.00	51.70	27.07
2x7	64.00	53.17	24.50
3x4	70.33	54.48	22.43
3x5	68.00	55.13	25.03
3x6	75.00	50.07	28.27
3x7	67.00	54.04	29.67
4x5	66.00	56.25	22.43
4x6	69.00	51.35	22.47
4x7	69.00	55.03	22.53
5x6	75.00	52.23	21.67
5x7	71.00	54.20	23.87
6x7	66.00	54.17	21.57
Mean	69.87	54.07	23.07
LSD			
0.05%	5.70	2.27	3.96
0.01%	8.21	3.26	5.71

While it had non-significant plant height The parent P4 was good combiner for plant height and 1000 grains weight. While P7 (Sakha 93) the best combiner for days to heading, plant height, 1000 grains weight and grain yield/plant. The genetic variance was previously reported to be mostly due to additive effects by Kumar *et al*. (2011) and El Saadoown *et al*. (2017).

3.4 Specific combining ability

Specific combining ability effects of the seven parents in their hybrids are showed in Table (6 and 7). Concerning days to heading , the crosses which had negative and highly significant S.C.A. effects for P1 × P2, P1 × P3, P3 × P4, P4 × P7 and P5 × P7. While the crosses which had positive and significant SCA effects were P1 × P5, P1 × P6, P2 × P3, P2 × P4, P2 × P5, P2 ×P6, P3 × P5, P3 × P7, P4 × P6, P5 × P6 and P6 × P7. For plant height, five crosses, P1 × P2, P2 ×P5, P4 × P6, P4 × P7 and P5 × P7 has positive and highly significant SCA effects and the hybrids P4 × P6, P4 × P7 and P5 × P7 were the best crosses for plant height, and they had the highest positive significant.

Table (6): General combining ability (GCA), specific combining ability (SCA) effects for all studied traits of parents and their F_1 wheat crosses.

Genotypes	Days to heading	Plant height	Spikes number/plant	Genotypes	Number of kernels/spike	1000-kernels weight	Grain Yield per plant
P1	0.92	-1	1.25**	GCA			
P2	-1.52*	3.11**	-2.08	P1	1.89	5.49**	-5.29**
P3	1.70*	-0.89	-1.06**	P2	-0.78	-0.98	1.43
P4	-6.52**	4.44**	-4.53**	P3	5.00**	-3.44**	4.52**
P5	-2.63**	-0.56	-0.3	P4	-0.67	2.81**	-2.51**
P6	5.48**	-19.22**	2.029**	P5	-1.78	4.08**	-3.05**
P7	2.59**	14.11**	4.70**	P6	4.44**	-9.75**	-3.05**
LSD for gi (0.05)	1.31	1.68	0.75	P7	-8.11**	1.79**	5.20**
LSD for gi (0.01)	1.75	2.25	1	LSD (0.05)	2.42	1.26	1.64
1x2	-9.11**	6.64**	0.86	LSD (0.01)	3.24	1.69	2.20
1x3	-1.33*	0.64	2.84*	SCA			
1x4	0.89	2.31	1.31	1×2	17.14**	-0.45	-5.88*
1x5	2.00*	-2.69	2.09	1×3	2.36	2.71	-4.47
1x6	1.88*	-2.03	-0.25	1x4	-0.97	1.05	0.56
1x7	-1.22	1.64	0.09	1x5	-11.86**	1.80	-1.30
2×3	4.11**	2.53	0.17	1x6	20.92**	-2.48	8.95**
2×4	2.33*	2.19	0.64	1x7	-2.53	3.41	7.05**
2×5	1.44*	5.19*	0.42	2×3	5.03	-0.32	4.01
2×6	2.33*	-13.14**	0.09	2×4	4.69	3.42	1.17
2×7	-0.22	3.64	-2.91**	2×5	14.81**	3.40	0.07
3×4	-2.89*	-1.81	2.62*	2×6	-9.42*	5.79**	14.33**
3×5	5.22**	3.19	-1.6	2×7	-8.53*	-7.83**	7.85**
2×6	-0.89	0.86	5.06**	3×4	-0.08	4.03*	-0.45
2×7	2.77*	-2.36	0.09	3×5	-5.97	4.72*	7.89**
4×5	0.44	-8.14**	1.86	2×6	8.81*	3.37	14.84**
4×6	3.33**	16.53**	-0.47	2×7	0.47	-5.21**	23.35**
4×7	-8.22**	10.64**	-8.91**	4×5	-6.31	1.82	7.12**
5×6	1.44*	4.53	0.31	4×6	-3.53	0.96	4.47
5×7	-3.22**	12.64**	0.09	4×7	6.47	-2.23	1.95
6×7	3.77**	-23.36**	0.09	5×6	15.58**	2.33	2.61
LSD for sij (0.05)	1.32	4.89	2.17	5×7	12.47**	-4.73*	5.95*
LSD for sij (0.01)	3.08	6.54	2.9	6×7	-2.53	-4.83*	-0.95
				LSD for sij (0.05)	7.05	3.67	4.78
				LSD for sij (0.01)	9.43	4.91	6.39

*and ** indicate significance at 0.05 and 0.01 levels of probability respectively.

Otherwise, P2 × P6, P4 ×P5 and P6 × P7 crosses had negative and significant specific combining ability (Table 6). Similar results were obtained by (Kumar *et al.* 2011 and EL Saadoown *et al*. 2017). With regard to N.S/P, significantly positive SCA effects were shown by three out of twenty-one crosses, suggesting that these specific crosses have good genes for number of spikes/plant. P3 × P6 showed the maximum positive SCA effects, while P4 × P7 displayed the highest negative SCA effects for N.K/S, significantly desirable positive SCA effects were shown by six out of twenty-one crosses, suggesting that these specific crosses have good genes for numerous kernels/spike. P1 × P6 and P1 × P2 showed the maximum positive SCA effects, while P1 × P5 displayed the highest negative SCA effects. For 1000 grains weight, once cross, P2 × P6 has positive and highly significant SCA effects and the hybrid P2 × P7 had negative and highly significant specific combining ability (Table 6). Concerning G.Y/P, the estimates of specific combining ability effects were significantly positive SCA effects were shown by nine out of twenty-one crosses, suggesting that these specific crosses have good genes for grain yield. P3 × P7 showed the maximum positive SCA effects, while P1 × P2 displayed the highest negative SCA effects. Similar results were obtained by Kumar *et al*. (2011) and EL Saadoown *et al*. (2017).

3.5 Heterosis

Table (7) show that, for days to heading, the cross P1 × P2 (Misr 1×Shandaweel 1) gave the highest negative significant values of the heterosis over mid parent and better parent, while the crossP3×P5 (Gemmeiza 11 × Sids 12) gave the highest positive significant values of the heterosis over mid parent. For the plant height of mid parent heterosis showed highly positive significant to mid parent, which recorded 7.45% (P4*P6) and 6.00% (P5*P7). On the other hand , the crosses (P1 *P6), (P2 *P6), (P3 *P6) and (P6 *P7) exhibited highly significant and negative heterosis effect relative to better parents, which ranged from -5.74, -11.11,-5.37 and -10.19% respectively. For the number of spike /plant the crosses (P1*P2), (P1*P3), (P1*P5), P1*P6), (P2*P3), (P2*P5), (P3*P4) and (P3*P6) gave the highest positive significant values for heterosis over mid parent and better parent, the results suggested that heterosis played an important role in the inheritance of N.S/P for the spike length, P1*P2, P1*P3, P1*P5, P1*P6, P1*P7, P2*P6, P3*P6, P4*P6, P4*P7 and P6*P7 showed highly positive significant values for the heterosis over mid parent and the cross P1*P3 over better parent, while the crosses P1*P4, P2*P4, P3*P4, P4*P6 and P5*P6 gave the highest negative significant values for the heterosis over better parent.

Table (7): Heterosis relative to both mid and better parents for all studied traits of F_1 bread wheat crosses.

Traits	Days to heading		Plant height		N.S/P		Traits	Spike length		N.K/S		1000 grains weight		G.Y/P	
Crosses	MP (%)	(HP)%	MP (%)	(HP)%	MP (%)	(HP)%	Crosses	MP (%)	(HP)%	MP (%)	(HP) (%)	MP (%)	(HP) (%)	MP (%)	(HP) (%)
1x2	-3.89**	-5.73**	2.99	1.31	9.92**	2.86**	1x2	8.54**	0.20	15.38**	13.64**	2.29	-2.32	-1.67	-8.50**
1x3	-0.58	-1.53	1.01	0.67	23.61**	11.43**	1x3	11.33**	4.61**	5.11**	1.41	5.63**	-1.90	10.20**	5.95**
1x4	0.00	-3.82*	2.68	1.66	12.40**	-2.86**	1x4	1.73	-13.29**	2.99	1.47	3.36*	0.83	8.94**	6.95**
1x5	1.18	-1.91	0.85	0.34	14.71**	11.43**	1x5	10.41**	-3.31	-	-1.52	3.63**	2.03	9.68**	6.45**
1x6	0.76	0.38	0.00	-5.74**	6.85**	2.63**	1x6	12.35**	12.22	17.00**	15.84**	2.77*	-8.75**	40.73**	31.12**
1x7	-0.96	-1.15	1.94	-2.47	5.00**	-6.67**	1x7	15.23**	4.66	3.13	0.00	5.08**	1.63	21.67**	8.83**
2×3	2.55*	1.56	1.32	0.00	12.63**	8.20**	2×3	2.61	0.69	6.67**	1.41	4.62**	1.61	27.98**	23.69**
2×4	1.62	-0.40	2.30	1.63	7.14**	-1.64*	2×4	1.34	-7.14**	6.06*	2.94	5.74**	3.44	13.62**	7.58**
2×5	2.01	0.79	3.17*	0.98	7.09**	3.03**	2×5	2.41	-3.32*	14.06**	14.06**	5.52**	2.28	15.88**	4.90
2×6	1.94	-0.38	-4.23*	-11.11**	5.11**	-5.26**	2×6	5.56**	-2.66	2.03	-0.50	9.55**	1.48	52.20**	32.68**
2×7	1.36	-0.38	0.95	-1.85	3.31**	-13.33**	2×7	3.14*	1.33	1.59	0.00	2.97*	1.62	14.84**	10.03**
3×4	-0.20	-3.11	1.00	0.33	23.13**	17.44**	3×4	3.19*	-7.05**	1.20	-0.94	7.58**	2.28	20.39**	17.86**
3×5	3.78**	1.56	2.54	1.68	8.02**	0.00	3×5	0.75-	-7.96**	0.74	-4.23	7.80**	1.58	40.77**	31.52**
3×6	0.96	-0.38	0.71	-5.37**	27.08**	10.53**	3×6	8.29**	1.64	8.43**	5.63*	9.50**	4.29*	65.30**	48.51**
3×7	1.54	0.77	0.32	-3.70*	14.91**	-6.67**	3×7	2.51	-1.14	0.75	-5.63*	7.72**	3.29*	43.66**	33.23**
4×5	1.64	0.81	-0.17	-1.66	12.82**	0.00	4×5	1.78	-1.39	-	-2.94	4.61**	3.64*	29.05**	23.03**
4×6	2.37	-1.89	7.45**	0.33	3.94**	-13.16**	4×6	4.14**	-11.32**	1.97	1.47	6.20**	-3.59*	34.53**	23.22**
4×7	0.20	-3.45*	3.83*	0.31	-6.38**	-26.67**	4×7	4.10**	-3.04	6.15*	1.47	4.24**	3.32*	11.28**	1.20
5×6	2.35	-1.14	3.06	-2.39	7.04**	0.00	5×6	1.70	-11.02**	14.21**	11.39**	6.91**	-3.76*	36.70**	31.05**
5×7	1.38	-1.53	6.0**	0.93	7.69**	-6.67**	5×7	1.23	-2.80	12.70**	10.94**	1.69	-0.14	23.02**	7.19**
6×7	0.57	0.00	-0.68	-10.19**	1.20	-6.67**	6×7	11.47**	1.14	2.06	-1.98	13.13**	3.53*	15.23**	-3.14
LSD (0.05)	2.49	2.87	3.20	3.70	1.42	1.64	LSD (0.05)	2.73	3.15	4.61	5.33	2.40	2.77	3.13	3.61
LSD (0.01)	3.56	4.12	4.59	5.30	2.04	2.36	LSD (0.01)	3.91	4.52	6.62	7.64	3.45	3.98	4.48	5.18

Concerning N.K/S, the crosses P1*P2, P1*P6, P2* P5, P5*P6 and P5* P7indicated highly significant positive for the heterosis over mid parent and better parent for 1000-grain weight P2*P6, P3*P6 and P6*P7 gave the highest positive and highly significant values for the heterosis over mid parents, while maximum positive better parent heterosis was exhibited by P3*P6 (4.29%) in F1. These results are in harmony with obtained by Raza (2016), EL Saadoown *et al.* (2017). Concerning G.Y/P, the crosses P3*P6 and P3*P7 gave the highest positive significant values for the heterosis over mid parent and better parent. Significant and positive mid- parent and better- parent heterosis for grain yield was reported by Raza (2016), EL Saadoown *et al.* (2017). These results are in harmony with obtained by Kattab *et al* (2010), Zaazaa *et al* (2012), Abd-Alla and Hassan (2012) and Elmassry and El-Nahas (2018). Kumar *et al* (2018) reported that significant and positive mid parents (M.P) and better parents (B.P) heterosis were observed in four hybrids for grain yield per plant.

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