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Heterosis and combining ability analysis for earliness and grain yield in bread wheat (*Triticum aestivum* L.)

C. S. DESALE[1], D. R. MEHTA[2] AND A. P. SINGH[3]

Department of Genetics and Plant Breeding, College of Agriculture,
Junagadh Agricultural University, Junagadh-362 001 (Gujarat)

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ABSTRACT

Heterosis and combining ability analysis were studied in a 10 × 10 diallel set of bread wheat. Significant heterosis over better parent was observed in HW-5018 x HI-1544 for dwarfness and grain yield per plant. The analysis of variance for combining ability revealed that the mean squares due to both general combining ability (gca) and specific combining ability (sca) were highly significant for all the characterss indicated that both additive and non-additive genetic variances played a vital role in the inheritance of all these four traits. The GCA and SCA ratio (σ^2GCA/σ^2SCA) was less than unity for all the traits indicated that non-additive component play relatively greater role in the inheritance of all the four traits. On the basis of GCA, SCA effects and *per se* performance, parents HI-1544 for three traits and UAS-281 for two traits were found good general combiners and crosses HW-5018 x HI-1544 and GW-322 × GW-173 for two traits each were found good specific combiners in bread wheat.

Key words: Heterosis, general and specific combining ability, bread wheat

Wheat (*Triticum spp.)* is usually accorded a premier place among the cereals because of the vast acreage devoted to its cultivation, its high nutritive value and its association with some of the earliest and most important civilizations of the world. Wheat is the second most important staple food crop next to rice, consumed by nearly 35% of the world population and providing 20% of the total food calories. This crop occupies about 32% of total acreage in the world. The choice of suitable parents for evolving better varieties/hybrids is a matter of concern to the plant breeders. In systemic breeding programme, selection of parent with desirable characteristics having good general combining ability effects for grain yield and its components, high heterosis and high estimates of specific combining ability effects are essential. These estimates will help in formulating efficient and effective breeding procedure to bring about rapid and suitable improvement in this crop. The present investigation was, therefore, attempt to study the extent of heterosis and combining ability for traits related to earliness and grain yield in bread wheat.

MATERIALS AND METHODS

The initial experimental material consisted of ten genotypes /varieties viz., GW-496, GW-322, LOK-1, GW-173, KYZ-300, RAJ-4136, HW-5018, K-604, UAS-281, HI-1544, GW-366 of bread wheat (*Triticum aestivum* L. Em. Thell). These genotypes were crossed in all possible combinations using diallel mating design excluding reciprocal during Rabi 2010-11 at Wheat Research Station, Junagadh Agricultural University, Junagadh. A set of 56 entries, including 10 parents, their 45 crosses and one standard check (GW-366) were sown in randomized block design with three replications during Rabi 2011-12. Each entry was sown in a single row plot of

[1] & [3] PG student, [2] Associate Professor

2.5 m long keeping row to row and plant to plant distance of 22.5 cm, and 10 cm, respectively. Five plants of each parents and hybrids were selected randomly for recording observations for four traits namely days to 50 % flowering, days to maturity, plant height (cm) and grain yield per plant (g). The plant material was evaluated by analysis of the data on heterosis and combining ability. Heterobeltiosis and standard heterosis were calculated by using formula of Fonseca and Patterson (1968). The analysis of variance for general (GCA) and specific (SCA) combining abilities were carried out according to Model I, Method 2 (half-diallel set) of Griffing (1956).

RESULTS AND DISCUSSION

Mean square due to genotypes was highly significant for all the four characters, indicating that experimental materials had sufficient genetic variability for all the characters studied. Mean square due to parents *Vs* hybrids comparison was significant for all the characters indicated the performance of hybrids as a group was different than that of parents for all the characters. This revealed the presence of substantial amount of heterosis in various cross combinations due to effect of directional dominance.

For development of character in positive direction *viz.* days to 50 % flowering, plant height and days to maturity, negative heterosis is desirable. The heterosis was estimated over better parent and standard variety (GW 366) and results are presented in Table1. For days to 50 % flowering, only one cross (GW-496 x GW-173) had significant heterosis over better parent, while three crosses *viz*; GW-496 x GW-322, GW-496 x RAJ-4136 and HW-5018 x HI-1544 showed significant and negative heterobeltiosis for dwarfness. For days to maturity, eleven crosses showed significant and negative heterobeltiosis. Five most early maturing crosses over better parent were GW-322 x Lok-1, Lok-1 x K-604, GW-322 x GW-173, GW-173 x K-604 and KYZ-300 x K-604. These crosses also exhibited negative values in desirable direction over standard check. Seven and three crosses showed heterobeltiosis and standard heterosis estimates in desirable direction for grain yield. The crosses which exhibited significant heterobeltiosis for grain yield per plant were RAJ-4136 x UAS-281, HW-5018 x K-604, KYZ-300 x HW-5018, HW-5018 × UAS-281, KYZ-300 × RAJ-4136, GW-173 × RAJ-4136, and HW-5018 x HI-1544 and the crosses which exhibited significant standard heterosis for grain yield per plant were HW-5018 x K-604, RAJ-4136 x UAS-281, and HW-5018 x HI-1544. It indicated that high yielding varieties involved in the crosses were predominantly responsible for enhancing the yield. Similar finding were reported by Chakraborty and Tewari (1995); Sharma and Menon (1996); Nehvi *et al.*, (2000); Vanpariya *et al.*, (2006a) and Singh *et al.*, (2007).

The analysis of variance for combining ability revealed that the variances due to gca and sca were significant for all the four characters (Table 2) that indicated existence of genetic variability in the parental lines included in the present study and involvement of both additive and non-additive gene effects in the inheritance of these traits. The magnitude of gca and sca variances revealed that the sca variances were higher than their respective gca variances for all the characters. The gca and sca variance ratio was less than unity for all the traits indicated that non-additive component play relatively greater role in the inheritance of these traits.

The GCA effects of the parents (Table 3) indicated that there was close relationship between parental mean performance and GCA effects for all the characters except grain yield per plant. Thus, the perfect relationship could be established between *per se* performance and GCA effects of the parents. The GCA values indicated that four parents *viz.*, GW-496, HI-1544, GW-322 and UAS-281 exhibited significant and negative GCA effects and were registered as good general combiners for earliness in days to 50 % flowering. Two parents *viz.*, Lok-1 and GW-173 showed significant and negative GCA effects for plant height which is desirable in wheat and registered as good general combiners for dwarfness. Likewise, four parental lines *viz.*, HI-1544, UAS-281, GW-173 and RAJ-4136 were good

Table 1 Estimates of heterobeltiosis (H) and standard heterosis (SH) for days to 50% flowering, plant height, days to maturity and grain yield per plant in bread wheat

Sr. No.	Hybrids	Days to 50% flowering		Plant height		Days to maturity		Grain yield per plant	
		H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)
1	GW-496 X GW-322	5.66**	9.80 **	-6.78**	0.00	4.95**	1.92**	-2.71	-2.41
2	GW-496 X Lok-1	1.96	1.96	14.90**	9.24**	-1.98**	-4.81**	-7.55	0.98
3	GW-496 X GW-173	-3.77*	0.00	26.13**	8.44**	-3.96**	-6.73**	-8.90	-8.62
4	GW-496 X KYZ-300	0.63	4.58**	3.56	13.36**	3.96**	0.96	-15.08*	-14.82*
5	GW-496 X RAJ-4136	5.66**	9.80**	-6.26**	2.51	1.98**	-0.96	-12.54	-12.27
6	GW-496 X HW-5018	7.55**	11.76**	6.43**	16.13**	8.25**	5.13**	-9.93	-9.65
7	GW-496 X K-604	5.66**	9.80**	5.67*	9.04**	3.96**	0.96	-0.40	-0.10
8	GW-496 X UAS-281	7.55**	11.76**	-0.58	7.41**	3.82**	-4.17**	-6.96	-6.67
9	GW-496 X HI-1544	2.00	0.00	4.52*	7.81**	3.16**	-5.77**	2.76	3.08
10	GW-322 X Lok-1	3.92*	3.92*	12.92**	7.35**	-8.49**	-6.73**	-20.82**	-13.51
11	GW-322 X GW-173	-1.17	10.46**	19.89**	3.08	-5.88**	-7.69**	-0.53	-0.22
12	GW-322X KYZ-300	3.51*	15.69**	-2.22	5.36*	6.15**	5.13**	-11.74	-11.47
13	GW-322X RAJ-4136	-3.03	4.58**	6.88**	15.17**	0.00	-1.92**	-19.38**	-19.13**
14	GW-322 x HW-5018	5.26**	17.65**	1.38	9.24**	5.94**	2.88**	-10.22	-9.95
15	GW-322 x K-604	7.02**	19.61**	7.65**	11.08**	6.60**	8.65**	-12.44	-12.18
16	GW-322 x UAS-281	0.00	5.88**	-2.63	4.91*	3.47**	-4.49**	-7.56	-7.27
17	GW-322 x HI-1544	10.00**	7.84**	8.35**	11.77**	8.42**	-0.96	-7.83	-7.55
18	Lok-1x GW-173	0.65	0.65	33.47**	14.75**	6.86**	4.81**	-29.99**	-23.92**
19	Lok-1x KYZ-300	28.76**	28.76**	3.27	-1.08	1.94**	0.96	-29.77**	-23.68**
20	Lok-1x RAJ-4136	28.76**	28.76**	2.98	-1.37	0.00	-1.92**	-10.06	-2.27
21	Lok-1x HW-5018	23.53**	23.53**	3.17	-1.18	10.89**	7.69**	-9.79	-1.98
22	Lok-1x K-604	21.57**	21.57**	10.06**	5.42*	-8.49**	-6.73**	-9.32	-1.46
23	Lok-1x UAS-281	15.69**	15.69**	10.11**	5.46*	7.29**	-0.96	-1.91	6.59
24	Lok-1x HI-1544	34.67**	32.03**	6.02*	1.55	4.21**	-4.81**	-3.79	4.54
25	GW-173 x KYZ-300	9.20**	24.18**	19.27**	2.00	-3.92**	-5.77**	3.40	-3.06
26	GW-173 x RAJ-4136	14.55**	23.53**	22.01*	4.34	-3.92**	-5.77**	16.42*	7.05
27	GW-173 x HW-5018	10.53**	23.53**	24.46**	6.44**	-1.98**	-4.81**	6.20	-2.35
28	GW-173 x K-604	11.11**	30.72**	17.23**	0.26	-5.88**	-7.69**	12.08	3.05
29	GW-173 x UAS-281	20.99**	28.10**	32.41**	13.24**	-1.04	-8.65**	7.95	-0.74
30	GW-173 x HI-1544	19.33**	16.99**	27.32**	8.88*	5.26**	-3.85**	-9.54	-10.62
31	KYZ-300 x RAJ-4136	1.82	9.80**	3.50	13.18**	-2.94**	-4.81**	19.53*	9.91
32	KYZ-300 x HW-5018	0.00	11.76**	-3.51	5.29*	2.97**	0.00	22.32**	12.47
33	KYZ-300 x K-604	5.17**	19.61**	8.55**	12.02**	-4.85**	-5.77**	11.00	2.06
34	KYZ-300 x UAS-281	0.00	5.88**	-3.83	3.90	2.08**	-5.77**	10.73	1.81
35	KYZ-300 x HI-1544	6.00**	3.92*	5.43*	8.75**	1.05	-7.69**	6.09	4.83
36	RAJ-4136 x HW-5018	7.27**	15.69**	2.51	11.86**	-0.99	-3.85**	7.62	-1.63
37	RAJ-4136 x K-604	14.55**	23.53**	-0.47	2.71	4.90**	2.88**	9.80	-4.96
38	RAJ-4136 x UAS-281	3.70	9.80**	5.44*	13.91**	1.04	-6.73**	39.60**	16.69*
39	RAJ-4136 x HI-1544	6.00*	3.92*	5.68*	9.01**	1.05	-7.69**	13.70	12.36
40	HW-5018 x K-604	10.53**	23.53**	13.38**	17.00**	1.98**	-0.96	30.56**	20.05**
41	HW-5018 x UAS-281	7.41**	13.73**	-3.80	3.93	0.00	-7.69**	19.76**	10.11
42	HW-5018 x HI-1544	12.00**	9.80**	-5.55*	-2.57	1.05	-7.69**	16.18*	14.81*
43	K 604 x UAS-281	5.56**	11.76**	7.02**	9.83**	3.13**	-4.81**	5.03	-7.82
44	K-604 x HI-1544	12.00**	9.80**	7.61**	10.43**	1.05	-7.69**	-6.19	-7.30
45	UAS-281 x HI-1544	12.00**	9.80**	0.54	3.71	0.00	-8.65**	4.36	3.12
	Mean heterosis (%)	**8.93**	**13.90**	**7.87**	**7.19**	**1.40**	**-2.96**	**0.0031**	**-2.09**
	SE±	0.86	0.86	1.32	1.32	0.75	0.75	1.66	1.66

*,** Significant at 5% and 1% levels, respectively

Table 2 Analysis of variance for combining ability for various characters in bread wheat

Source	Df	Days to 50% flowering	Plant height	Days to maturity	Grain yield per plant(g)
gca	9	40.94**	15.36**	55.52**	4.46**
sca	45	15.61**	10.88**	14.84**	5.69**
Error	108	0.37	0.87	0.28	1.37
σ^2gca		3.38	1.21	4.60	0.26
σ^2sca		15.24	10.00	14.55	4.31
σ^2gca/σ^2sca		0.22	0.12	0.32	0.06

*,** Significant at 5% and 1% levels, respectively

gca and sca denote general and specific combining ability, respectively

Table 3 Estimates of general combining ability effects for different characters in bread wheat

Parents	Days to 50% flowering		Plant height		Days to maturity		Grain yield per plant	
	Mean	GCA effect	Mea	GCA effect	Mean	GCA effect	Mean	GCA effect
GW-496	53.00	-3.20**	63.67	0.89**	101.00	1.00**	23.66	-0.42
GW-322	57.00	-1.01**	62.72	0.44*	106.33	2.78**	23.61	-1.10**
LOK-1	51.00	0.61**	55.59	-2.11**	106.00	1.92**	26.13	-0.10
GW-173	59.67	2.11**	50.27	-1.96**	102.00	-1.67**	22.30	-0.43
KYZ-300	58.00	0.38*	66.80	0.86**	103.00	0.53**	22.43	-0.06
RAJ-4136	55.00	0.11	63.93	0.80**	102.00	-0.33*	20.36	0.15
HW-5018	57.00	1.36**	63.80	0.53*	101.00	1.36**	21.87	0.92**
K-604	60.00	2.66**	60.33	0.52*	106.00	1.17**	20.71	-0.08
UAS-281	54.00	-0.78**	63.17	0.43	96.00	-3.17**	19.47	0.20
HI-1544	50.00	-2.23**	60.31	-0.39	95.00	-3.58**	23.64	0.92**
SE(gi) ±		0.17		0.26		0.15		0.32
SE(gi-gj) ±		0.25		0.38		0.22		0.47
Correlation between Per se performance and GCA effects	0.711*		0.919**		0.877**		0.214	

*,** Significant at 5% and 1% levels, respectively

Table 4 Estimates of specific combining ability effects for days to 50% flowering, plant height, days to maturity, grain yield per plant in bread wheat

Sr. No.	Hybrids	Days to 50 % flowering	Plant height	Days to maturity	Grain yield per plant
1	GW-496 X GW-322	2.59**	-5.23**	1.13*	1.63
2	GW-496 X Lok-1	-3.02**	2.71**	-5.01**	1.44
3	GW-496 X GW-173	-5.52**	2.10*	-3.42**	-0.53
4	GW-496 X KYZ-300	-1.46**	2.16*	2.38**	-2.38*
5	GW-496 X RAJ-4136	1.48**	-4.13**	1.24*	-1.98
6	GW-496 X HW-5018	1.23**	4.11**	5.88**	-2.12*
7	GW-496 X K-604	-1.07	-0.03	1.74**	1.17
8	GW-496 X UAS-281	3.37**	-0.89	0.74	-0.69
9	GW-496 X HI-1544	-1.18*	0.16	-0.51	0.92
10	GW-322 X Lok-1	-4.21**	2.06*	-8.79**	-1.36
11	GW-322 X GW-173	-4.38**	-0.59	-6.20**	2.16*
12	GW-322 X KYZ-300	2.01**	-2.08*	4.94**	-0.90
13	GW-322 X RAJ-4136	-3.38**	3.72**	-1.54**	-2.95**
14	GW-322 x HW-5018	2.04**	0.53	1.77**	-1.52
15	GW-322 x K-604	1.73**	1.62	7.97**	-1.05
16	GW-322 x UAS-281	-1.82**	-1.90*	-1.37**	-0.16
17	GW-322 x HI-1544	0.62	2.92**	2.72**	-0.95
18	Lok-1x GW-173	-8.99**	8.78**	7.66**	-4.51**
19	Lok-1x KYZ-300	7.07**	-3.30**	1.47**	-4.83**
20	Lok-1x RAJ-4136	7.34**	-3.40**	-0.67	0.09
21	Lok-1x HW-5018	3.43**	-3.09**	7.63**	-0.61
22	Lok-1 x K-604	1.12*	0.85	-7.17**	0.51
23	Lok-1x UAS-281	1.57**	0.96	3.16**	2.16*
24	Lok-1x HI-1544	11.34**	-0.51	-0.42	0.94
25	GW-173 x KYZ-300	3.23**	-1.65	-1.95**	0.44
26	GW-173 x RAJ-4136	3.18**	-0.21	-1.09*	2.65**
27	GW-173 x HW-5018	1.93**	1.29	-1.79**	-0.37
28	GW-173 x K-604	4.29**	-2.32**	-4.59**	1.93
29	GW-173 x UAS-281	6.40**	5.36**	-1.26	0.74
30	GW-173 x HI-1544	2.18**	3.63**	4.16**	-2.35*
31	KYZ-300 x RAJ-4136	-2.10**	2.13*	-2.29**	2.97**
32	KYZ-300 x HW-5018	-2.35**	-2.21*	1.02*	2.81**
33	KYZ-300 x K-604	0.34	1.74*	-4.79**	1.32
34	KYZ-300 x UAS-281	-3.21**	-2.92**	-0.45	0.98
35	KYZ-300 x HI-1544	-2.77**	0.73	-2.04**	0.98
36	RAJ-4136 x HW-5018	-0.07	1.70*	-2.12**	-0.77
37	RAJ-4136 x K-604	2.62**	-3.66**	5.08**	-0.57
38	RAJ-4136 x UAS-281	-0.93	2.99**	-0.59	4.33**
39	RAJ-4136 x HI-1544	-2.49**	0.94	-1.17*	2.57*
40	HW-5018 x K-604	1.37*	4.99**	-0.62	4.64**
41	HW-5018 x UAS-281	-0.18	-2.57**	-3.29**	1.99
42	HW-5018 x HI-1544	-0.74	-5.55**	-2.87**	2.38*
43	K-604(8) x UAS-281	-2.49**	0.89	-0.09	-1.30
44	K-604 x HI-1544	-2.05**	2.06*	-2.67**	-1.91
45	UAS-281x HI-1544	1.40*	-1.79*	0.66	0.31
	SE(Sij) ±	0.56	0.86	0.49	1.08
	SE(Sij-Sik) ±	0.83	1.27	0.72	1.59
	SE(Sij-Skl) ±	0.79	1.21	0.69	1.51

*,** Significant at 5% and 1% levels, respectively

general combiners as they showed significant and negative GCA effects for days to maturity. Two parental lines *viz.*, HW-5018 and HI-1544 were found to be good general combiners for grain yield per plant as they had significant and positive GCA effects for this trait. On the basis of overall performance, parent HI-1544 was found to be good general combiner for early flowering, early maturity and high grain yield. The parent HW-5018 was also good for tall plant, late maturity flowering and with general combiner for higher grain yield per plant. Similar finding was reported by Sharma and Garg (2005), Vanpariya *et al.* (2006b) and Zahid *et al.* (2011).

As regard the specific combining ability effects (Table 4), nine crosses exhibited significant and positive SCA effects for grain yield per plant The cross combination HW-5018 x K-604 (good x poor) recorded the highest SCA effect followed by RAJ-4136 x UAS-281 (average x average), KYZ-300 x RAJ-4136 (average x average), KYZ-300 x HW-5018 (average x good) and GW-173 x RAJ-4136 (average x average) and were rated as good specific cross combinations for grain yield per plant. Similar results were also reported by Singh *et al.* (1990) and Mavi *et al.* (2003). Fifteen crosses exhibited significant and negative SCA effects for days to 50% flowering. The highest, significant and negative SCA effect was observed for days to 50% flowering in cross Lok-1 x GW-173 followed by GW-322 x GW-173, GW-322 x RAJ-4136 and KYZ-300 x UAS-281. Fourteen crosses were showed significant and negative SCA effects for plant height out of which the three best cross combinations were HW-5018 x HI-1544, GW-496 x GW-322 and GW-496 x RAJ-4136. Fourteen hybrids exhibited significant and negative SCA effects for earliness. The hybrid GW-322 x Lok-1 had maximum SCA effect for days to maturity followed by Lok-1 x K-604, GW-322 x GW-173 and GW-496 x Lok-1 in desired direction.

Considering the desired SCA effects, the best cross combinations were KYZ-300 x RAJ-4136 and KYZ-300 x HW-5018 for early flowering, early maturity and higher grain yield per plant. The GCA effects of the parents and SCA effects of their crosses indicated that the crosses between two high general combiners were not always the best specific combiners. The best specific combinations for different characters were either good x poor, average x average, average × good and *vice versa* general combiners.

The correlation coefficient studies (Table 5) revealed that *per se* performance of hybrids with that of heterobeltiosis and SCA effects as well as between heterobeltiosis and SCA effects showed significant and positive correlation between all parameters for all the traits indicating good association among all three parameters in this study.

Table 5 Correlation coefficient among *per se* performance of hybrids, heterobeltiosis and SCA effects in bread wheat

Sr. No.	Characters	Per se performance and heterobeltiosis	Per se performance and SCA effects	Heterobeltiosis and SCA effects
1	Days to 50% flowering	0.776**	0.850**	0.823**
2	Plant height	0.317*	0.884**	0.661**
3	Days to maturity	0.719**	0.822**	0.893**
4	Grain yield per plant	0.899**	0.949**	0.856**

*,** Significant at 5% and 1% levels, respectively

CONCLUSION

Overall it is concluded that the cross HW-5018 x HI-1544 possessed high heterobeltiosis and high SCA effect with good general combining ability for grain yield per plant. Both additive and non-additive gene action played an important role in expression of these traits, although non-additive genetic variance was predominant. Therefore, recurrent selection which may allow intermating of the selects in different cycles and utilize both additive and non-additive gene effect could be effective in developing wheat cultivar having high grain yield with early maturity period. Dominance genetic effect shall be valuable in wheat breeding programmes when hybrid seed production is made economically feasible through an efficient cytoplasmic male sterility system.

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