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Heterosis for Improvement of Various Agronomic Traits in Bread Wheat

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ABSTRACT

Heterosis studies in 12 crosses of bread wheat involving nine varieties (Uqab-2000, Punjab-96, Inqilab-91, Shafaq-06-, Seher-06, Lasani-08, Achyuta, Oasis and AS-2002) and an advanced line (V-03094) were carried out at the Wheat Research Institute, Faisalabad. Highly significant genetic variability was present in the experimental material for the traits under study. Most of the crosses showed significant heterosis over mid- and better-parents for various characters. The Oasis/Punjab-96 cross depicted highly significant and the maximum heterosis and heterobeltiosis for grain yield/plant, spike length, number of spikelets/spike and flag leaf area. However, maximum 1000-grain weight and number of tillers/plant were produced from the cross V-03094/Uqab-2000. These crosses will be considered for finding transgressive segregants in advanced segregating generations for the evolution of wheat varieties with high yield potential.

Keywords: Heterosis, heterobeltiosis, quantitative traits and bread wheat

INTRODUCTION

Wheat demand is increasing due to fast growing world population. Global demand for wheat was increasing a decade ago at a rate of 2%/year, twice the current rate of gain in genetic yield potential (Skovmand and Reynolds 2000). Pakistan is one of the leading wheat-producing countries and the area under wheat cultivation is 9,046,000 ha with an average yield of 2657 kg/ha during 2008-2009 (Anonymous 2009) which is insufficient to feed Pakistan's population of 170 million. Therefore, there is a dire need to develop varieties producing high grain yield per unit area. Hassan *et al*. (2005) reported that a heterosis study could be used to boost various yield-associated traits in a wheat crop. Heterosis is a genetic expression of the beneficial effects of hybridization (Akhter *et al*. 2003). Heterosis studies also provide useful information about the combining ability of parents. Hybrids with high heterotic effects may offer better chances for identification of desirable pure lines in the following advanced generations as compared to hybrids with low heterosis (Sharif *et al.* 2001). This phenomenon could be commercially exploited in wheat to increase yield (Abdullah 2002). Therefore, the present study was conducted to determine the effect of heterosis in 12 crosses of 10 parent wheat genotypes to generate information which would be helpful in designing a meaningful breeding programme for releasing high yielding wheat varieties.

MATERIALS AND METHODS

The experiment was conducted in the research field of the Wheat Research Institute, AARI, Faisalabad, Pakistan during 2008-09. The experimental material consisted of F_1 crosses and their parents, which were planted in triplicate in a completely randomized block design (CRBD) in November, 2008 by maintaining an inter-row and inter-plant distance of 30 and 15 cm, respectively. The agronomic data recorded from five plants per entry in each repeat (plant height, days to 50% heading, days to maturity, number of productive tillers/plant, spike length, number of spikelets/spike, flag leaf area and grain yield/plant) were subjected to statistical analysis of variance (Steel and Torrie 1980). The heterosis (H%) and heterobeltiosis (HB%) values were estimated as the deviation of the F_1 value from the mid-parent and the better-parent values as suggested by Matzinger *et al*. (1962) and Fonseca and Patterson (1968), respectively, using the following formula.

$H\% = F_1 - MP/MP$

$HB\% = F_1 - BP/BP$

where F_1, MP and BP denote the performance of hybrid, average performance of parents and performance of better-parent, respectively. The *t*-test was used to determine the significance of heterosis and heterobeltiosis for all characters.

t calculation for heterosis: $t = F_1 - Mp / \sqrt{3/8EMS}$

t calculation for heterobeltiosis: $t = F_1 - Bp / \sqrt{½\ EMS}$

where F_1 = value of each cross, Mp = the mid-parent value, Bp = the better-parent value, *t* at 5% = 2.02 and *t* at 1% = 2.70 for 42 degrees of freedom.

RESULTS

Analysis of variance revealed that all traits under study showed highly significant differences among the genotypes (**Table 1**).

Grain yield

The range of heterosis and heterobeltiosis for grain yield was positive and highly significant for these crosses: Lasani-08/Seher-06 (0.192, 0.147), Lasani-08/Shafaq-06 (0.437, 0.302), Oasis/Punjab-96 (1.135, 0.738), Oasis/Seher-06 (0.737, 0.341), Achyuta/Inqilab-91 (0.539, 0.505) and Achyuta/Seher-06 (0.334, 0.305). Other crosses gave negative results for heterosis and heterobeltiosis, which have no significance in a breeding programme for grain yield improvement. The Oasis/Punjab-96 cross showed maximum positive heterosis for yield/plant, significantly more than the mid-parent (1.135) and better-parent (0.738).

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Table 1 Analysis of variance for yield and other traits in wheat.

S.O.V	DF	Grain yield/plant	1000-grain weight	Spike length	No. of spikelets/spike	Plant height	Days to 50% heading	Days to maturity	Flag leaf area	No of tillers/plant
Replications	2	4.95	1.38	7.26	7.58	0.81	1.04	3.45	8.87	2.39
Genotypes	21	172.87**	134.52**	26.05**	31.91**	96.75**	45.60**	20.10**	102.59**	20.29**
Error	42	1.10	0.05	1.48	9.27	0.04	1.71	4.24	0.04	5.82

**= Highly significant

Table 2 Mean performance and statistical significance for different traits in wheat.

Varieties/crosses	Grain yield/plant (g)	1000-grain weight (g)	Spike length (cm)	Spikelets/spike	Plant height (cm)	Days to 50% heading	Days to maturity	Flag leaf area (cm^2)	No of tillers/plant
V-03094	30.60 c	35.23 j	13.00 a	20.21 efgh	88.68 g	90.67 efg	132.30 gh	34.07 de	7.40 f
V-03094/Seher-06-	25.45 fg	37.33 hi	13.03 a	20.90 bcd	86.00 h	92.33 cd	133.00 fg	31.94 hij	8.33 ef
V-03094/Uqab-2000	25.52 ef	43.00 de	12.13 bc	21.17 bc	91.33 ef	90.33 efgh	133.30 fg	31.98 hij	9.57 cde
V-3084/Lasani-08	26.73 de	44.33 c	11.97 bc	20.57 cdefg	100.00 a	90.67 efg	132.30 gh	33.91 def	13.20 a
AS-2002	27.43 d	41.33 f	10.87 efg	20.10 ghi	95.00 de	93.67 bc	132.70 fg	31.37 ij	10.60 bc
Lasani-08/Uqab-2000	24.90 fgh	46.40 b	12.17 b	20.97 bcde	93.33 gf	93.00 bc	136.70 b	34.43 d	13.87 a
Lasani-08/Seher-06	31.49 c	36.37 ij	11.10 def	19.67 ij	96.67 cd	94.00 b	138.70 a	29.89 kl	9.57 cde
Lasani-08/Shafaq-06	35.74 a	46.27 b	11.17 def	18.97 k	103.00 a	91.00 def	131.30 hi	29.41 lm	9.27 de
Oasis	13.37 l	31.67 e	10.93 ef	19.77 hij	68.33 j	99.00 a	132.30 gh	31.01 jk	11.17 b
Oasis/Punjab-96	36.96 a	38.50 gh	12.10 bc	20.77 bcdef	88.67 g	99.33 a	130.70 i	39.21 c	11.03 b
Oasis/Seher-06	34.03 b	35.87 j	11.40 de	29.90 bcd	89.33 g	91.33 de	132.10 fg	28.52 m	10.47 bcd
Oasis/Lasani-08	27.41 o	36.40 ij	11.60 cd	20.03 ghi	89.67 g	90.57 efg	135.70 bcd	32.80 fgh	11.23 b
Achyuta	24.25 ghi	36.07 j	12.00 bc	21.23 b	98.67 bc	87.67 jk	133.3 fb	33.22 efg	13.10 a
Achyuta/Inqilab-91	36.51 a	38.67 b	13.07 a	21.93 b	100.00 b	91.33 de	135.00 d	32.67 gh	10.93 b
Achyuta/Seher-06	33.10 b	41.07 f	11.23 def	20.17 fghi	93.00 ef	89.67 fghi	135.30 bc	42.43 b	13.40 a
Achyuta/Shafaq-06	24.15 hi	32.07 e	9.87 ij	20.30 defgh	94.67 de	89.33 ghi	134.70 de	41.67 b	9.13 e
Seher-06	25.36 fgh	48.23 a	10.73 fgh	19.33 jk	100.20 b	87.67 jk	133.00 fg	32.94 efgh	8.55 ef
Lasani-08	24.61 fgh	47.37 ab	10.23 hij	18.73 k	97.30 c	88.33 ij	135.00 d	31.37 ij	13.07 a
Shafaq-06	22.27 jk	46.90 b	12.20 b	18.83 k	103.8 a	89.00 hij	133.30 fg	73.87 a	9.11 e
Punjab-96	21.27 k	42.13 ef	9.73 j	17.63 l	98.00 g	87.67 jk	133.30 fg	31.90 hij	7.33 f
Inqilab-91	23.20 ij	44 cd	10.37 ghi	17.73 l	93.67 i	89.33 ghi	135.30 cd	33.20 efg	8.33 ef
Uqab-2000	23.17 ij	39.33 g	10.83 fg	17.57 l	92.33 f	86.67 i	133.30 ef	32.43 ghi	8.47 ef
LSD values	1.24	1.23	0.54	0.61	2.25	1.39	1.20	1.18	1.28

1000-grain weight

The 1000-grain weight values were the highest for the cross Lasani-8/Shafaq-06 (46.27 g) (**Table 2**). For the 1000-grain weight, 7 out of 12 crosses displayed negative values of heterosis and heterobeltiosis. Maximum highly significant positive heterosis was revealed by the cross V-03094/Lasani (0.157) followed by V-03094/Uqab-2000 (0.154) and Lasani-08/Uqab-2000 (0.151) whereas maximum positive highly significant heterosis over better-parent was observed for the cross Lasani-08/Uqab-2000 (0.123) followed by V-03094/Uqab-2000 (0.102) and Oasis/Punjab-96 (0.086).

Spike length

An individual comparison of average spike length (**Table 2**) showed that among the crosses, the cross Achyuta/Inqilab-91 showed the highest with an average spike length of 13.07 cm. Positive heterosis ranged from 0.002 (V-03094/Lasani) to 0.171 (Oasis/Punjab-96) whereas the magnitude of heterosis over better parents ranged from 0.002 (V-03094/Seher-06) to 0.119 (Lasani-08/Uqab-2000) (**Table 3**). Maximum positive significant mid-parent and better-parent heterosis values were 0.171 and 0.107 for the crosses Oasis/Punjab-96 and Lasani-08/Uqab-2000, respectively.

Number of spikelets per spike

For this parameter, 9 out of 12 crosses showed a positive heterosis value and 7 crosses displayed positive heterobeltiosis. Among the crosses, Oasis/Punjab-96 contributed the highest highly significant value for mid-parent heterosis (0.1105) as well as for heterobeltiosis (0.0509) followed by V-3094/Uqab-2000 (0.118, 0.044).

Plant height

Taller plants are more likely to lodge quite often. Short stature wheat is therefore preferred and so, negative heterosis is desirable. The comparison of mean values (**Table 2**) indicated that among parents Shafaq-06 was the tallest (103.8 cm) while Oasis was the shortest (68.33 cm); among F_1 hybrids Lasani-08/Shafaq-06 was the tallest (103.00 cm) while V-03094/Seher-06 was shortest (86.0 cm). Heterosis and heterobeltiosis (**Table 3**) indicated that 3/12 hybrids were taller than their respective parents. Crosses showing positive heterobeltiosis values ranged from 0.010 (V-03094/Uqab-2000) to 0.052 (V-03094/Lasani-08). Negative values ranged from -0.003 (Oasis/Punjab-96) to -0.141 (V-03094/Seher-06).

Days to 50% heading

The highest value (99.33) for days to 50% heading was observed in cross Oasis/Punjab-96 and the minimum value (86.00) for cross V-03094/Seher-06 (**Table 2**). Only two crosses showed negative values for heterobeltiosis ranging from -0.003 in cross V-03094/Uqab-2000 and -0.007 in cross Oasis/Seher-06 (**Table 3**). Cross Lasani-08/Seher-06 had a highly significant positive value (0.036, 0.064) for mid parental heterosis and for heterobeltiosis (-0.003) (**Table 3**) and hence, this cross would be further used in a breeding program.

Days to maturity

Maximum negative mid-parent heterosis was recorded for the cross Lasani-08/Seher-06 (-0.012) followed by V-03094/Lasani (-0.001), whereas maximum negative better-parent heterobeltiosis was shown by the same cross, V-04094/Lasani-08 (-0.019).

Table 3 Expression of heterosis (mid parent) and heterobeltiosis (better parent) in bread wheat for various traits under study.

Sr No	Grain yield/plant (g)		1000-grain weight (g)		Spike length (cm)		Spikelets/spike		Plant height (cm)	
	Het	Hb	Het	Hb	Het	Hb	Het	Hb	Het	Hb
V-03094/Seher-06	-0.09**	-0.168**	-0.106**	-0.22**	0.098**	0.002 N.S	0.056**	0.0315*	-0.089**	-0.141**
V-03094/Uqab-2000	-0.05**	-0.166**	0.154**	0.102**	0.018 N.S	-0.066**	0.118**	0.044**	0.042**	0.010 N.S
V-03094/Lasani	-0.078**	-0.126**	0.157**	0.072**	0.002 N.S	-0.082**	0.019 N.S	0.014 N.S	0.100**	0.052**
Lasani-08/Uqab-2000	-0.011N.S	-0.092**	0.151**	0.123**	0.121**	0.119**	0.107 N.S	0.038**	-0.003 N.S	-0.017 N.S
Lasani-08/Seher-06	0.192**	0.147**	-0.187**	-0.246**	0.028 N.S	0.022 N.S	-0.002 N.S	-0.022 N.S	-0.009 N.S	-0.035**
Lasani-08/Shafaq-06	0.437**	0.302**	0.048**	-0.013 N.S	-0.032 N.S	0.027 N.S	-0.025*	-0.056**	0.0364**	-0.007 N.S
Oasis/Punjab-96	1.135**	0.738**	0.043**	0.086**	0.171**	0.107**	0.1105**	0.0509**	0.127**	-0.003 N.S
Oasis/Seher-06	0.737**	0.341**	-0.102**	-0.256**	0.052**	0.043*	0.0691**	0.057**	0.0601**	-0.108**
Oasis/Lasani-08	0.343**	-0.001 N.S	-0.002 N.S	-0.118**	0.065**	0.061**	0.005 N.S	-0.003 N.S	0.097**	-0.056**
Achyuta/Inqilab-91	0.539**	0.505**	-0.034**	-0.121**	0.168**	0.088**	0.125**	0.0328*	0.096**	0.0135 N.S
Achyuta/Seher-06	0.334**	0.305**	-0.025*	-0.148**	-0.011 N.S	-0.064**	-0.005 N.S	-0.050**	-0.064*	-0.071**
Achyuta/Shafaq-06	0.038N.S	-0.004 N.S	-0.227**	-0.316**	-0.185**	-0.191**	0.013**	-0.043**	-0.064**	-0.087**

	Days to 50% heading		Days to maturity		Flag leaf area (cm^2)		No of tillers/plant	
	Het	Hb	Het	Hb	Het	Hb	Het	Hb
V-03094/Seher-06	0.035**	0.018**	0.002 N.S	0 N.S	-0.046**	-0.062**	0.045 N.S	-0.025 N.S
V-03094/Uqab-2000	0.018**	-0.003 N.S	0.002 N.S	0 N.S	-0.038**	-0.061**	0.080**	0.129*
V-03094/Lasani	-0.016**	0 N.S	-0.001 N.S	-0.019**	-0.036**	-0.004 N.S	0.289**	0.129 N.S
Lasani-08/Uqab-2000	0.0314**	0.053**	0.026**	0.0123**	0.079**	0.061**	0.287**	0.061 N.S
Lasani-08/Seher-06	0.036**	0.064**	-0.012**	0.042**	-0.07**	-0.092**	-0.115*	-0.268**
Lasani-08/Shafaq-06	-0.003 N.S	0.023**	0.00 N.S	-0.015**	-0.449**	-0.602**	-0.164**	-0.291**
Oasis/Punjab-96	0.064**	0.003 N.S	0.023**	-0.019**	0.246**	0.228**	0.192**	-0.013 N.S
Oasis/Seher-06	-0.021**	-0.07**	0.004 N.S	-0.002 N.S	0.107**	-0.134**	0.061 N.S	-0.062
Oasis/Lasani-08	-0.058**	0.085**	0.016**	0.022**	0.051**	0.045**	-0.073 N.S	-0.141**
Achyuta/Inqilab-91	0.032**	0.022**	0.004	-0.002 N.S	-0.016 N.S	-0.016 N.S	0.020 N.S	-0.165**
Achyuta/Seher-06	0.022**	0.023**	0.023**	0.015**	0.282**	0.288**	0.237**	0.0229 N.S
Achyuta/Shafaq-06	0.011 N.S	0.003 N.S	0.009**	0.009*	-0.221**	-0.436**	-0.177 N.S	-0.302**

Het = heterosis and Hb = heterobeltiosis
* = significant at 5 %, ** = highly significant at 1% and N.S = non-significant

Table 4 t-calculated value for heterosis and heterobeltiosis for different traits in bread wheat.

Grain yield/ plant		1000-grain weight		Spike length		Spikelets/plant		Plant height		Days to 50% heading		Days to maturity		Flag leaf area		No of tillers/plant	
t- Het	t -Hb	t- Het	t -Hb	t- Het	t -Hb	t- Het	t -Hb	t- Het	t -Hb	t- Het	t -Hb	t- Het	t -Hb	t- Het	t -Hb	t- Het	t -Hb
-5.45	-9.63	-9.69	-20.74	5.76	0.13	4.87	2.42	-10.10	-14.73	6.14	2.79	0.76	0.00	-3.57	-4.20	0.76	-0.40
-2.94	-9.51	12.56	7.59	1.08	-3.73	9.87	3.41	4.60	0.00	3.24	-0.57	0.76	0.00	-2.88	-4.12	3.45	2.00
-4.94	-7.23	13.20	5.69	0.15	-4.59	1.68	1.16	10.98	2.80	-2.91	-0.02	-0.36	-5.23	2.72	-0.32	6.26	0.24
-0.65	-4.74	13.35	9.68	6.50	5.58	8.93	2.91	-0.40	-1.73	5.50	7.84	7.83	3.10	5.79	3.94	6.53	1.45
11.02	7.58	-18.38	-22.52	1.53	1.03	-0.21	-1.64	-1.11	-3.67	6.47	9.51	13.04	10.85	-5.19	-6.06	-2.62	-6.39
23.55	15.54	4.73	-1.21	-1.82	1.29	-2.19	-4.29	4.35	-0.74	-0.64	3.36	-3.69	-3.88	-54.92	-88.06	-3.85	-6.94
42.53	29.41	3.53	-6.88	8.72	5.02	9.04	3.79	-12.83	-0.35	11.63	0.55	-4.81	-5.23	17.73	14.46	3.76	-0.25
31.75	16.23	-8.93	-23.47	2.81	2.02	5.93	4.29	12.78	-11.28	-3.88	-12.87	0.00	-0.78	-7.89	-8.67	1.28	-1.28
15.17	-0.06	-0.18	-9.30	3.50	2.88	0.45	-0.25	6.48	-5.54	-10.99	-14.14	7.09	5.81	3.71	2.85	-1.87	-3.36
27.68	22.96	-3.00	-10.14	9.26	4.55	10.73	2.64	21.96	1.39	5.50	3.36	1.50	-0.58	-1.26	-1.11	0.46	-3.95
17.97	14.49	-2.36	-13.14	-0.64	-3.30	-0.50	-4.04	2.20	-7.47	3.88	3.36	4.79	3.88	21.40	18.79	5.43	0.55
1.93	-0.19	-20.62	-128.16	-11.03	-10.04	1.17	-3.53	-5.70	-9.44	1.94	0.55	2.98	2.52	-27.19	-63.78	0.00	-7.24

Flag leaf area

Heterotic studies for flag leaf area revealed that 5/12 crosses showed positive heterosis (**Table 3**). Maximum positive highly significant mid-parent heterosis was recorded by Achyuta/Seher-06 (0.282) followed by Oasis/Punjab-96 (0.246) and Oasis/Seher-06 (0.107), whereas maximum positive highly significant better-parent heterosis was also recorded for Achyuta/Seher-06 (0.288) followed by Oasis/Punjab-96 (0.228) and Lasani-08/Uqab-2000 (0.061).

Tillers/plant

Heterotic studies revealed that 8/12 crosses were positive for the heterotic effect over their respective mid-parents (**Table 3**). Maximum positive highly significant mid-parent heterosis was exhibited by the cross V-03094/Lasani-08 (0.466) followed by Lasani-08/Uqab-2000 (0.289) and Achyuta/Seher-06 (0.287). Maximum highly positive significant heterobeltiosis was shown by V-03094/Uqab-2000 (0.129).

DISCUSSION

For grain yield in wheat, Afiah *et al.* (2000) and Inamullah *et al.* (2006) reported similar results for yield as in our study. Positive heterosis for 1000-grain weight had also been reported by Singh *et al.* (2004). The predominant heterotic interaction with respect to 1000-grain weight in all the hybrids showed the effectiveness of heterosis for increased grain yield (Inamullah *et al.* 2006). Earlier studies (Li *et al*. 1997; Inamullah 2006) also reported positive heterosis and heterobeltiosis for spike length in different wheat genotypes. Positive heterosis and heterobeltiosis for the number of spikelets/spike was also reported by Mujahid *et al*. (2000). Heterosis and heterobeltiosis (**Table 3**) indicated that 3/12 hybrids were taller than their respective parents. The negative estimates of heterobeltiosis for plant height are preferred over their mid- and better-parents in wheat breeding because dwarfness is a desirable character (Budak and Yildirim 1996). Therefore, it is concluded that the cross Oasis/Punjab-96 was best due to its higher negative value (-0.003) of heterobeltiosis selection. Heading in wheat is a desirable character since it provides sufficient time for grain forma-

tion and filling. Negative heterosis for days to heading is therefore useful (Inamullah *et al*. 2006). Two crosses showed negative values for heterobeltiosis for days to 50% heading (**Table 3**). Cross V-03094/Uqab-2000 had a positive value (0.018) for mid parental heterosis but a negative value for heterobeltiosis (-0.003) for days to 50% heading (**Table 3**), so this cross will be further used in a breeding program. Genotypes with early maturing habit are generally wanted; negative heterosis for days to maturity is therefore a useful parameter (Inamullah *et al*. 2006). Further, earliness in heading and days to maturity occur in the control of dominant genes (Akbar *et al.* 2010). Mahajan and Nagarajan (2001) also observed that heterotic studies could be effectively used for incorporating early maturity in wheat. A larger flag leaf helps to synthesize photosynthates in greater quantities, which are translocated to grains and increase their weight (Inamullah *et al*. 2006). 5/12 crosses showed positive heterosis (**Table 3**). Positive heterosis for flag leaf area was also described by Mahmood and Chaudhry (2000). The number of productive tillers directly contributes to plant yield; positive heterosis for tillers/plant is therefore desirable in wheat (Inamullah *et al*. 2006). 8/12 crosses were positive for the heterotic effect over their respective mid-parents (**Table 3**). Yu *et al*. (1997) was also of the opinion that mid-parent and better-parent heterosis for tillers/plant could be obtained in wheat. Hence, the crosses confirming maximum heterosis, i.e. Lasani-08/Uqab-2000 and V-03094/Uqab-2000, could be further employed for improving yield in bread wheat.

CONCLUSION

It is concluded from this study that the cross Oasis/Punjab-96 performed better than other crosses due to positive and high values of heterosis and heterobeltiosis for grain yield/plant, spike length, spikelets/spike, flag leaf area and 1000-grain weight. This cross will give better genetic combination for high yield in F_2 and later filial generations.

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