JOURNAL OF AGRICULTURE & SOCIAL SCIENCES
1813–2235/2005/01–4–304–308
http://www.ijabjass.org

Estimation of Heterosis for Yield and Yield Components in Bread Wheat

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ABSTRACT

Heterosis studies of twenty crosses of bread wheat involving five varieties/lines viz., 8763, 8779, 8784, Inqlab-91 and Iqbal-2000 were carried out. Highly significant genetic variability was present in the experimental material for the traits under study. Grain yield per plant revealed maximum significant heterosis over mid parent (44.19%), (29.65%) followed by flag leaf area (28.72%), tillers per plant (18.83%) and spike length (18.79%). The maximum significant heterobeltiosis was recorded for grain yield per plant (33.4`5%), flag leaf area (28.75%) tillers per plant (12.91%) and spike length (15.77%). The crosses 8779 × Iqbal-2000, 8779 × 8763 and 8784 × Inqlab-91 may be considered for selection as hybrid or pure line wheat varieties after achieving desired homozygosity.

Key Words: Estimation of heterosis; Yield; Components; Bread; Wheat

INTRODUCTION

Wheat is a source of staple food of the people of Pakistan for mankind and is grown on an area of about 8.4 million hectares annually. The attainment of maximum crop yield is an important objective in most breeding programmes and the major emphasis in wheat breeding is on the development of improved varieties. Sharp increase in population is a sign of caution towards our wheat breeding programs to increase per acre yield, which can be achieved by accelerating the pace of research on developing new wheat genotypes with high yielding potential and resistance against stresses.

Exploitation of heterosis for more yield was largely attributed to cross pollinated crops. Available evidence confirms presence of heterotic effects in self-pollinated crops like wheat (Freeman, 1919). The increase or decrease in the productivity and vigor of hybrids compared to those of their parents is generally attributed to heterotic effects expressed in F1 and following generations. The 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 this crop to increase per acre yield. Briggle (1963) and Sajnani (1968) suggested the possibility of heterotic effects in wheat. Krishnaand Ahmed (1992) reported that maximum mean heterosis was obtained for 1000-grain weight (14.60%) and grain yield (12.52%). Yagdi and Karan (2000) observed significant heterosis and heterobeltiosis in spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield per plant. The present studies were, therefore, conducted to ascertain the extent of heterosis in a diallele cross of five wheat varieties to generate information which would be helpful in designing a meaningful breeding programme for the development of better quality and high yielding wheat varieties.

MATERIALS AND METHODS

The research work was carried out in the experimental area of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The diallel-cross involving five wheat varieties/lines namely 8763, 8779, 8784, Inqlab-91 and Iqbal-2000, was made. The seeds of F1 hybrids along with their parents were planted in a triplicated randomized complete block design on Nov. 8, 2002. The sowing was done with the help of a dibble keeping plant-to-plant and row-to-row distance of 15 and 30 cm, respectively. At maturity data were collected for plant height (cm), flag leaf area (cm^2), peduncle length (cm), tillers per plant, spike length (cm), number of spikelets per spike, spike density, number of grains per spike, 1000-grain weight (g) and grain yield per plant (g), from ten guarded plants and subjected to variance analysis (Steel & Torrie, 1980). Significant differences were subjected to Duncan's New Multiple Range (DMR) Test.

The percent increase or decrease of F1 hybrids over mid as well as better parent was calculated to estimate possible heterotic effects for above mentioned traits by using the formula of Fonseca and Patterson, 1968 as under.

$$Ht\ (\%) = \frac{F1 - MP}{MP} \times 100$$

$$Hbt\ (\%) = \frac{F1 - BP}{BP} \times 100$$

Where,

Ht = Heterosis

Hbt = Heterobeltiosis

MP = Mid parent value

BP = Better parent value

The 't' test was done to determine whether F1 hybrid means were statistically significant from mid parent and better parent means as follow (Wynne *et al*., 1970).

$$\text{Heterosis: } tij = \frac{F1ij - MP}{3/8\ EMS}$$

$$\text{Heterobeltiosis: } tij = \frac{F1ij - BP}{1/2\ EMS}$$

Where

Fij = The mean of the ijth F1 cross

M.Pij = The mid parent value for the ijth F1 cross

B.Pij = The better parent values for ijth cross.

EMS = Error mean square

RESULTS AND DISCUSSION

Plant height. The comparison of genotypic means (Table II) indicated that among parents 8763 had maximum plant height (111.6 cm). The 8779 had minimum plant height (92.99 cm) whereas among F1 hybrids, cross combination 8763 × Inqlab-91 had maximum plant height (110.0 cm). Inqlab-91 × Iqbal-2000, had minimum plant height (94.81 cm). Heterosis and heterobeltiosis estimates (Table III) indicated that heterotic effects of 16 crosses out of 20 were positive and highly significant. Positive heterosis ranged from 0.11 (Inqlab-91 × 8763) to 9.82% (8779 × Iqbal-2000). As far as heterobeltiosis is concerned, seven out of 20 hybrids were positive and highly significant and one cross was significant, crosses showing positive heterobeltiosis values ranged from 0.24 (8779 × 8784) to 9.73% (8779 × Iqbal-2000). Negative values ranged from -0.93 (Inqlab-91 × Iqbal-2000) to -7.39% (Iqbal-2000 × 8763). Seven crosses out of were highly significant and one was significant. The negative estimates of heterosis and heterobeltiosis for plant height are preferred in wheat breeding because dwarfness is a desirable character (Budak & Yildirim, 1996). In those crosses where heterobeltiosis was observed, over dominance might be involved and it may be concluded that effective selection of desirable recombinants from this material is possible.

Flag leaf area. Individual comparison of average flag leaf area (Table II) showed among parents Inqlab-91 and 8779 had maximum (37.29cm2) and minimum (29.86cm2) values, respectively whereas among hybrids, cross combination Inqlab-91 × 8784 was at the top with an average of 47.94 cm2 flag leaf area. Positive heterosis ranged from 1.69 (Iqbal-2000 × Inqlab-91) to 28.72% (Inqlab-91 × 8784) whereas the magnitude of heterosis over better parents ranged from 0.42 (Iqbal-2000 × Inqlab-91) to 28.58% (Inqlab-91 × 8784). Ninety percent of these crosses had highly significant heterotic values over mid parents. Cross combinations like Inqlab-91 x 8784, 8763 x 8779 and 8779 x Iqbal-2000 showing good heterotic values of 28.72%, 22.70% and 18.92% respectively, can be used in future breeding programs for the improvement of this trait. Similar findings had also been reported by Youchun *et al.* (1997).

Peduncle length. A marked variation was evident for average peduncle length among parents and hybrids (Table II) The individual comparison of means of all genotypes showed that among parents, 8784 and 8763 had maximum value (41.13cm) and minimum value (35.64cm) for peduncle length, respectively. Whereas among crosses, hybrids 8784 x 8779 and 8784 x Iqbal-2000 showed maximum (44.82 cm) and minimum (36.27cm) value for this trait, respectively. It was observed from estimation of percent heterosis (Table II) that out of 20 crosses 15 displayed increase over their mid parents for this trait. Six were highly significant and one was significant ranging from 0.33 (8784 x 8763) to 11.53% (8784 x 8779). So 75% crosses showed positive estimates for percent heterosis over their mid parents. About 40% crosses showed positive estimates for percent heterobeltiosis, ranging from 0.48 (Iqbal-2000 x 8779) to 8.96 (8784 x 8779). Two crosses 8784 x 8779 and 8779 x Iqbal-2000 were highly significant, one cross 8779 x 8763 significant and others were non-significant. Chowdhry *et al* (*2001*) and Subhani *et al* (2000) also reported similar results.

Tillers per plant. It is obvious from the comparison of means (Table II) that the parent 8779 had maximum number of tillers per plant (10.70) were closely followed by Inqlab-91 (10.27) whereas the parent Iqbal-2000 had minimum number of tillers (8.13). Among F1 hybrids, cross combination 8763 × 8779 gave maximum number of tillers per plant (11.60) closely followed by cross combination 8779 x Iqbal-2000 (11.23) and Iqbal-2000 x 8763 gave minimum (8.57) number of tillers per plant. The estimates of heterosis showed that hybrid 8779 × Iqbal-2000 manifested maximum highly significant heterosis (19.29%) followed by 8784 x Iqbal-2000 (18.83%) and Inqlab-91xIqbal–2000 (10.87%). Estimates of positive heterosis ranged from 0.87 to 19.29%. Among these positive estimates, 7 crosses were highly significant, 2 were significant and, 4 were non-significant. The heterotic effects over better parents showed that 14 crosses had negative values ranging from –16.51 (8779 x Inqlab-91) to –0.65% (Inqlab-91 x Iqbal-2000). Hybrid 8784 × Iqbal-2000 showed maximum positive heterobeltiosis (12.91%) followed by cross combinations 8763 x 8779 (8.41%), 8779 x Iqbal-2000 (4.98%) and 8784 x Inqlab-91 (4.55%). The negative estimates of heterosis and heterobeltiosis are undesirable because less tillers per plant means low grain yield. So it is concluded that F1 hybrids, 8779 x Iqbal-2000 (19.29) and 8784 x Iqbal-2000 (18.83%) can contribute for the improvement of tillers per plant in further wheat breeding programme. Similar findings had been reported by

Table I. Analysis of variance (mean square values) for different traits in wheat

SOV	DF	Plant height	Flag leaf area	Peduncle length	Tillers per plant	Spike length	Spieklets per spike	Spike density	No. of grains per spike	1000-grain weight	Grain yield per plant
Replication	2	3.88**	0.23N.S.	0.72 N.S.	0.08 N.S.	0.52 N.S.	1.83*	0.007 N.S.	0.82 N.S.	6.04*	1.36 N.S.
Genotype	24	80.81	32.63**	11.55**	2.14**	1.04**	1.65**	0.010**	45.01**	24.95**	22.30**
Error	48	1.84	1.52	1.13	0.04	0.38	0.41	0.004	2.06	1.21	1.38

* = Significant
** = Highly significant
N.S. = Non-significant

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

Genotypes	Plant height(cm)	Flag leaf area	Peduncle length	Tillers per plant	Spike length	Spiklets per spike	Spike density	No. of grains per spike	1000-grain weight	Grain yield per plant
8763	111.6 a	34.62 hi	35.64 h	10.13 d	13.40 bcd	19.70abcdef	1.47 abc	57.77 ghi	46.83 a	23.32 def
8779	92.99 k	29.86 i	39.24 cdefg	10.70 c	12.72 d	18.37 g	1.44 abcd	61.43 de	38.43 i	20.04 gh
8784	98.68 I	37.20 fg	41.13 bcd	9.03 gh	13.29 bcd	18.17 g	1.37 cd	57.17 ghi	39.10 hi	20.22 g
Inqlab-91	95.70 j	37.29 fg	40.93 bcd	10.27 d	13.61 bcd	18.47 fg	1.36 cd	58.27 fgh	39.20 hi	21.14 fg
Iqbal-2000	93.14 k	36.35 ghi	37.21 gh	8.13 j	12.92 cd	19.80 abcde	1.54 ab	63.23 cd	40.27 efghi	17.05 i
8763 × 8779	106.40 de	39.56 cdef	38.27 efg	11.60 a	15.51 a	20.60 a	1.33 d	65.23 bc	47.20 a	26.55 ab
8763 × 8784	109.10 bc	34.14 i	38.52 efg	9.17 gh	13.09 bcd	19.23bcdefg	1.47 abc	55.27 i	48.17 a	21.56 efg
8763 × Inqlab-91	110.00 ab	38.20 efg	39.13 defg	9.17 gh	14.06 bc	20.33 ab	1.45 abcd	64.90 bc	46.93 a	22.26 defg
8763 × Iqbal-2000	105.60 def	37.88 efg	38.40 efg	9.27 gh	13.79 bcd	20.20 abc	1.47 abc	60.53 def	44.83 b	21.13 fg
8779 × 8763	106.80 cde	37.28 fg	40.85 bcd	10.97 bc	14.02 bc	20.23 abc	1.44 abcd	65.90 ab	43.67 bc	27.91 a
8779 × 8784	98.92 I	36.11 ghi	39.36 cdef	10.10 d	13.20 bcd	19.13bcdefg	1.45 abcd	61.20 de	41.47 defg	24.23 cd
8779 × Inqlab-91	98.03 I	36.11 ghi	38.55 efg	8.93 h	13.55 bcd	19.40abcdefg	1.43 bcd	56.20 hi	40.13 fghi	18.13 hi
8779 × Iqbal-2000	102.20 gh	39.37 cdef	41.15 bcd	11.23 b	14.21 b	20.33 ab	1.43 bcd	68.30 a	41.30 defg	26.74 ab
8784 × 8763	107.40 cd	41.02 bc	38.51 efg	9.67 ef	12.70 d	19.83 abcde	1.57 a	56.47 hi	42.83 bcd	20.86 g
8784 × 8779	99.30 I	37.68 fg	44.82 a	10.07 d	13.14 bcd	19.07 cdefg	1.45 abcd	61.63 de	42.43 cd	21.46 efg
8784 × Inqlab-91	104.90 ef	40.14 bcde	41.97 b	10.73 c	14.02 bc	20.53 a	1.47 abc	67.10 ab	42.27 cde	26.58 ab
8784 × Iqbal-2000	102.00 gh	41.58 bc	36.27 h	10.20 d	13.20 bcd	20.07 abcd	1.52 ab	59.60 efg	39.10 hi	20.14 g
Inqlab-91 × 8763	103.80 fg	40.55 bcd	40.74 bcd	10.07 d	14.23 b	20.23 abc	1.42 bcd	65.33 bc	41.87 cdef	25.55 bc
Inqlab-91 × 8779	100.00 hi	39.96 g	41.30 bc	9.33 fg	13.73 bcd	19.10bcdefg	1.39 cd	61.77 de	42.97 bcd	21.21 cde
Inqlab-91 × 8784	102.10 gh	47.94 a	40.04 bcde	9.97 de	13.54 bcd	18.83 defg	1.39 cd	62.10 de	39.73 ghi	23.52 cde
Inqlab-91 × Iqbal-2000	94.81 jk	36.55 gh	40.05 bcde	10.20 d	13.97 bc	19.27bcdefg	1.38 cd	67.00 ab	39.17 hi	21.12 fg
Iqbal-2000 × 8763	103.40 fg	37.88 efg	38.40 efg	8.57 i	13.63 bcd	20.00abcde	1.47 abc	60.43 ef	44.67 b	21.77 efg
Iqbal-2000 × 8779	95.52 j	38.46 def	39.43 cdef	10.03 d	13.64 bcd	18.80 efg	1.38 cd	65.90 ab	41.03 defgh	24.04 cd
Iqbal-2000 × 8784	102.10 gh	42.12 b	40.78 bcd	9.33 fg	14.01 bc	20.60 a	1.47 abc	61.23 de	41.77 cdefg	22.06 defg
Iqbal-2000 × Inqlab-91	100.20 hi	37.44 fg	37.50 fgh	8.97 gh	13.85 bcd	18.90 defg	1.36 cd	67.53 ab	39.00 hi	20.23 g

Chowdry *et al.* (2001) but Knobel *et al.* (1997) reported negative heterosis for this trait.

Spike length. It is apparent from Table II that among parents Inqlab-91 and 8779 had maximum (13.61cm) and minimum value (12.72 cm) for spike length, respectively. Maximum spike length was observed from cross combination 8763 × 8779 (15.51cm) and minimum from 8784 x 8763 (12.70cm) among hybrids. Positive heterosis over mid parent was observed for18 crosses from which two were highly significant, three were significant and remaining were non-significant. While positive heterobeltiosis over better parent was observed from 13 out of 20 crosses, among them two were highly significant and others were non-significant. Hybrid 8763 × 8779 exhibited highest value for heterosis i.e., 18.79% as well as for heterobeltiosis (15.77%). It was noted that 90 and 65% hybrids showed increase for spike length over their respective mid and better parental values and 10 and 35% cross combination indicated decrease for this character. Similar results were reported by Wang *et al.* (1997), Subhani *et al.* (2000) and Rasul *et al.* (2002).

Spikelets per spike. Iqbal-2000 indicated maximum mean value (19.80) for number of spikelets per spike and 8784 exhibited minimum mean value (18.17). While among crosses 8763 × 8779 showed maximum mean value (20.60) and Iqbal-2000 x 8779 gave minimum mean value (18.80) for this trait (Table II). It is apparent from estimation of percent heterosis that out of 20 crosses, 18 displayed increase over their mid parents and16 over better parents for this trait (Table III). Among positive heterotic values, 8 were highly significant, 4 were significant and 6 were non significant. Hybrid 8784 × Inqlab-91 contributed highest value for mid parent (12.10%) as well as for better parent heterosis (11.19%). These results are in agreement with the findings of Mujahid *et al.* (2000) and Rasul *et al.* (2002).

Spike density. Individual comparison of average spike density (Table II) indicated that among parents highest and lowest mean estimates recorded were 1.54 (Iqbal-2000) and

Table III. Estimation of percent Heterosis (Ht%) and heterobltosis for different parameters

Crosses	Plant height		Flag leaf area		Peduncle length		Tillers per plant		Spike length	
	ht %	hbt %	ht %	hbt %	ht %	hbt %	ht %	hbt %	ht %	hbt %
8763×8779	3.98**	-4.69**	22.70**	14.26**	2.06ns	-2.63ns	11.36**	8.41**	18-79**	15.77**
8763×8784	3.71**	-2.31*	-4.94**	-8.24**	0.36ns	-6.34**	-4.35**	-9.54**	-1.87ns	-2.29ns
8763×Inqlab-91	6.10**	-1.47ns	6.24**	2.44*	2.21ns	-4.41**	-10.13**	-10.71**	4.07ns	3.26ns
8763×Iqbal-2000	3.10**	-5.43**	6.74**	4.20**	5.43**	3.20ns	1.46ns	-8.55**	4.78ns	2.89ns
8779×8763	4.43**	-4.29**	15.65**	7.93**	9.11**	4.11*	5.28*	2.49*	7.33*	4.60ns
8779×8784	3.23**	0.24ns	7.70**	-2.93**	-2.06ns	-4.31**	2.36ns	-5.61**	1.54ns	-0.63ns
8779×Inqlab-91	3.90**	2.43*	7.56**	-3.16**	-3.84*	-5.83**	-14.78**	-16.51**	2.94ns	-0.44ns
8779×Iqbal-2000	9.82**	9.73**	18.92**	8.30**	7.65**	4.88**	19.29**	4.98**	10.88**	10.04**
8784×8763	2.12**	-3.79**	14.22**	10.25**	0.33ns	-6.37**	0.87ns	-4.61**	-4.85ns	-5.25ns
8784×8779	3.61**	0.62ns	12.39**	1.29ns	11.53**	8.96**	2.03ns	-5.92**	1.08ns	-1.08ns
8784×Inqlab-91	7.93**	6.30**	7.78**	7.66**	2.29ns	2.05ns	11.23**	4.55**	4.24ns	2.99ns
8784×Iqbal-2000	6.37**	3.38**	13.07**	11.77**	-7.41**	-11.82**	18.83**	12.91**	0.76ns	-0.63ns
Inqlab-91×8763	0.11ns	-7.03**	12.79**	8.76**	6.42**	-0.46ns	-1.31ns	-1.95ns	5.36ns	4.53ns
Inqlab-91×8779	6.04**	4.54**	10.10**	-0.87ns	3.03ns	0.90ns	-10.97**	-12.77**	4.28ns	0.86ns
Inqlab.91×8784	5.05**	3.46**	28.72**	28.58**	-2.41ns	-2.64ns	3.28*	-2.92*	0.69ns	-0.51ns
Inqlab-91×Iqbal-2000	0.41ns	-0.93ns	-0.74ns	-1.98ns	2.50ns	-2.16ns	10.87**	-0.65ns	5.29ns	2.60ns
Iqbal-2000×8763	0.97ns	-7.39**	6.74**	4.20**	5.42**	3.19ns	-6.20**	-15.46**	3.56ns	1.69ns
Iqbal-2000×8779	2.64*	2.56*	16.17**	5.80**	3.14ns	0.48ns	6.55**	-6.23**	6.41*	5.60ns
Iqbal-2000×8784	6.46**	3.47**	14.52**	13.21**	4.11*	-0.84ns	8.74**	3.32*	6.93*	5.44ns
Iqbal-2000×Inqlab-91	6.07**	4.65**	1.69ns	0.42ns	-4.03*	-8.39**	-2.54NS	-12.66**	4.41ns	1.74ns
Crosses	**Spike lets per spike**		**Spike density**		**Grains per spike**		**1000-grain weight**		**Grain yield per plant**	
	ht %	Hbt %	ht %	hbt %	ht %	hbt %	ht %	hbt %	ht %	hbt %
8763×8779	8.23**	4.57*	-8.57**	-9.30**	9.45**	6.19**	10.71**	0.78ns	22.47**	13.85**
8763×8784	1.58ns	-2.37ns	3.52ns	0ns	-3.83*	-4.33**	12.10**	2.85ns	-0.93ns	-7.51*
8763×Inqlab-91	0.55**	3.21ns	2.59ns	-1.36ns	11.86**	11.38**	9.10**	0.21ns	0.15ns	-4.52ns
8763×Iqbal-2000	2.28ns	2.02ns	-2.55ns	-4.76ns	0.06ns	-4.27**	2.95ns	-4.27**	4.68ns	-9.38**
8779×8763	6.30**	2.71ns	-1.26ns	-2.04ns	10.57**	7.27**	2.42ns	-6.76**	28.75**	19.69**
8779×8784	4.74*	4.17 ns	3.20ns	0.46ns	3.20*	-0.37ns	6.96**	6.05**	20.40**	19.86**
8779×Inqlab-91	5.34*	5.05*	2.26ns	-0.92ns	-6.10**	-8.52**	3.39ns	2.38ns	-11.93**	-14.23**
8779×Iqbal-2000	6.55**	2.69ns	-4.24ns	-7.14**	9.57**	8.01**	4.95ns	2.57ns	44.19**	33.45**
8784×8763	4.75*	0.68ns	10.33**	6.58*	-1.74ns	-2.25ns	-0.31ns	-8.54**	-4.15ns	-10.52**
8784×8779	4.38*	3.81ns	3.20ns	0.46ns	3.93*	0.33ns	9.45**	8.52**	6.60ns	6.13ns
8784×Inqlab-91	12.10**	11.19**	7.33*	6.81*	16.26**	15.16**	7.96**	7.82**	28.51**	25.69**
8784×Iqbal-2000	5.71**	1.35ns	4.24ns	-1.52ns	-0.99ns	-5.75**	-1.47ns	-2.89ns	9.54*	0.97ns
Inqlab-91×8763	6.03**	2.71ns	0.47ns	-3.40ns	12.61**	12.13**	-2.67ns	-10.60**	14.94**	9.59**
Inqlab-91×8779	3.71ns	3.43ns	-0.83ns	-3.92ns	3.20*	0.54ns	10.69**	9.60**	2.99ns	0.29ns
Inqlab-91×8784	2.82ns	1.99ns	1.96ns	1.46ns	7.59**	6.58**	1.49ns	1.36ns	13.73**	11.24**
Inqlab-91×Iqbal-2000	0.67ns	-2.69ns	-4.72ns	-10.39**	10.29**	5.96**	-1.42ns	-2.73ns	10.58**	-0.11ns
Iqbal-2000×8763	1.27ns	1.01ns	-2.55ns	-4.76ns	-0.11ns	-4.43**	2.56ns	-4.62**	7.83*	-6.65*
Iqbal-2000×8779	-1.48ns	-5.05*	-7.59**	-10.39**	5.72ns	4.22**	4.28*	1.90ns	29.65**	19.99**
Iqbal-2000×8784	8.52**	4.04*	1.03ns	-4.55ns	1.72ns	-3.16*	5.25**	3.72*	18.36**	9.10*
Iqbal-2000×Inqlab-91	-1.21ns	-4.55*	-5.64*	-11.26**	11.17**	6.80*	-1.85ns	-3.15ns	5.94ns	-4.30ns

1.36 (Inqlab-91). Among F1 hybrids, cross combination 8784 × 8763 was at the top with an average value of 1.57 spike density and hybrid 8763 was at the bottom (1.33). Table III showed that among crosses, fifty five percent i.e., 11 out of 20 crosses, in which one was highly significant, one significant and 9 were non-significant, exhibited increased percent heterosis, ranging from 10.33 (8784 × 8763) to 0.47% (Inqlab-91 × 8763). While 30% (6 out of 20 crosses) showed positive heterobeltosis, in which two manifested significant and three non-significant heterobeltiosis, ranging from 0.46 (8779 × 8784) to 6.81 (8784 × Inqlab-91). Most of the crosses showed negative heterobeltiosis (Table III). The results indicated that the heterosis in F1 is mainly due to additive genetic factors acompanied by over dominance type of gene action in some crosses. Similar findings had been reported by Youchun *et al*. (1997).

Number of grains per spike. A marked variation was evident (Table II) for average number of grains per spike among parents and hybrids, which varied from 55.27 (8763 × 8784) to 68.30 (8779 × Iqbal-2000). Impressive positive heterosis (Table III) was noted in most of the crosses which surpassed mid parental values ranging from 0.06 (8763 × Iqbal-2000) to 16.26% (8784 × Inqlab-91). It is observed that almost all of the crosses contributed increase in number of grains per spike over their respective mid parent values. As regards heterobeltiosis 9 crosses were highly significant, one significant and one was non-significant. The hybrid 8784 × Inqlab-91 had maximum heterobeltiosis (15.16%) it was minimum (0.33%) in hybrid 8784 × 8779. Larik *et al*.

(1995) and Abdullah *et al*. (2002) also reported similar results for this trait.

1000-grain weight. The maximum 1000-grain weight was recorded from the parent 8763 (46.83g) whereas the minimum 1000-grain weight was shown by the parent 8779 (38.43g). Among hybrids 8763 × 8784 showed maximum 1000-grain weight (48.17g) and hybrid Iqbal-2000 x Inqlab-91 gave minimum 1000-grain weight (39.00g). It is also observed from Table III that 15 out of 20 crosses revealed percent increase for 1000-grain weight over their respective mid parents. The range observed was 1.49 (Inqlab-91 x 8784) to12.10% (8763 x 8784) with 8 highly significant, one significant and 6 non-significant crosses. While 25% crosses showed decrease for this trait over their respective mid parents. The estimates of heterobeltiosis showed that 12 out of 20 crosses exhibited increase for the trait concerned over their respective better parents, ranging from 0.21% (8763 x Inqlab-91) to 9.60% (Inqlab-91 x 8779). These crosses included 4 positive and highly significant, one significant and 7 non-significant crosses. It is concluded that effective selection of hybrids like 8763x8784 and Inqlab-91x8779 with maximum percent heterosis and heterobeltiosis will be desirable to continue successful breeding programme. The results are in agreement with findings of Iqbal *et al.* (1990), Khan and Khan (1996) and Rasul *et al*. (2002).

Grains yield per plant. Table II shows that among parents genotype 8763 gave maximum grain yield per plant (23.32 g) and Iqbal-2000 produced minimum grain yield (17.05g). While among crosses, hybrid 8779 × 8763 was the top scorer with average grain yield per plant of 27.91g whereas cross combination 8779 x Inqlab-91 attained the lowest value (18.13g) for this trait. The estimates of heterotic effects revealed that 17 out of 20 crosses contributed increase in yield over mid parental values. Among these, 10 crosses were highly significant, two significant and remaining 8 non-significant. The positive estimates of heterosis ranged from 0.15 (8763 x Inqlab-91) to 44.19% (8779 x Iqbal-2000). The results about percent increase or decrease of F1 over better parents showed that the 60% crosses exhibited increase over their respective better parents. These crosses included 8 highly significant, one significant and 3 non-significant cross combinations. The range recorded was 0.29 (Inqlab-91 x 8779) to 33.45% (8779 x Iqbal-2000). Hybrid vigour expressed for this character had also been reported earlier by many researchers such as Krishna and Ahmad (1992), Munir *et al.* (1999), Subhani *et al.* (2000), Yagdi and Karan (2000) and Rasul *et al.* (2002).

CONCLUSION

Cross combination 8779 x Iqbal-2000, was the best for the improvement in plant height, flag leaf area tillers per plant and grain yield per plant, hybrid 8779 x 8763 for peduncle length and grain yield while 8784 x Inqlab-91, grains per spike and grain yield per plant.

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(Received 13 March 2005; Accepted 16 June 2005)