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Heterosis for grain yield and its contributing traits in bread wheat (*T. aestivum* L.)

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Abstract
Eight diverse genotypes *viz*., HD 3171, WH 147, K 906, K 307, K 1006, K 7903, DBW 14, and PBW 502 were crossed in diallel mating design excluding reciprocals for studying of heterosis in F_1 generation of wheat. The range of heterosis was observed -30.25 to 14.17for grain yield per plant, -7.92 to 2.43 for days to maturity,-16.01 to 6.12 for plant height, -32.67 to 22.01 for number of tiller per plant, -13.61 to 7.88 for 1000-grain weight, and -18.83 to 20.76 for harvest index. The cross WH147 X DBW14 for grain yield per plant, K7903 X PBW502 for days to maturity, K7903 X PBW502 for plant height, DBW14 X PBW502 for number of tiller per plant, WH147 X K1006 for 1000-grain weight and K1006 X DBW14 for harvest index. was observed best cross with highest heterosis. The cross combinations namely WH147 x DBW14, K7903 x DBW14, WH147 x K1006, K307 x K1006 were found promising for yield, yield components and quality traits. The cross K7903 x DBW14 exhibited desirable heterotic response for four other traits; *viz.*, days to 75% heading, plant height, number of grains per spike and biological yield.

Keywords: heterosis, metric traits, wheat

Introduction
Wheat (*Triticum aestivum* L.) is the most widely cultivated crop among the cereals and is the principal food crop in most areas of the world. The centre of origin of wheat is Asia Minor. Wheat (*Triticum aestivum* L.) is belonging to poaceae family presently. Bread wheat is an allohexaploid (AABBDD).The evolution of bread wheat occurred by combining the tetraploid species *T. turgidum var. dicoccoides* (AABB) and diploid species *Aegilops squarrosa* (DD) followed by natural doubling the chromosome number. The major wheat growing countries in the world are China, India, U.S.A., Russia, France, Canada, Germany, Turkey, Australia and Ukraine. At national level area under wheat is 30.78 million ha with the production of 98.51million tonnes with a productivity of 3.2 metric tonnes per hectare (DACFW 2017).
Nearly 55 per cent of the world population depends on wheat for intake of about 20 per cent of food calories. The consumption of wheat in the form of flour, bread, chapatti, porridge and suji etc. Nutritional value per 100 g of wheat (germ crude) provides (energy 360 Kcal, Protein 23.15g, Thiamine 1.88 mg, Niacin 6.81 mg, Calcium 39 mg, Iron 6.26 mg, Magnesium 239 mg). India has become self sufficient in meeting wheat grain consumption of its population at present but substantial increase in wheat production will be required to provide food security to the ever increasing population of our country. The population of India is likely to reach around 1.3 billion by the year 2020. Thus, the huge target of increasing wheat production by about 35 million tonnes within two decades is a big challenge that can be met only by increasing the area under production and improving the production technology until and unless the genetic potential of newly developed wheat varieties for different areas and environments is enhanced considerably. Attaining higher yield level, the breeder is required to deal the complex situation through rational approaches of breeding for high grain yield in wheat. The use of component approach is very fruitful for a successful breeding programme. The heterosis in addition to workable system to realizing it. Therefore, the present investigation was carried out to know the direction and magnitude of heterosis through diallel analysis. In addition study will also be helpful in evolution of high yielding varieties with better quality.

Material and Methods
The nature and magnitude of heterosis was computed as per cent increase or decrease of the mean values of F_1 better parent (BP) and standard variety (SV).

Significance of heterosis was tested by simple 't' test.
Heterosis over better parent (%)

$$Hbt = \frac{\overline{F_1} - \overline{B.P}}{\overline{B.P}} x\ 100$$

Where,
Ht = Heterosis
Hbt = Heterobeltiosis
B.P= Better parent

Test of significance

The "t" values for heterobeltiosis and standard heterosis were calculated by the formula as reported by Wynne *et al*. (1970).

$$t_{ij} = \frac{\overline{F}_{1\ ij} - \overline{BP}}{\sqrt{\frac{2MSE}{r}}}$$

Where,
F_1ij = The mean of the ij_{th} F_1 cross
B.P = The better parent value
EMS = Error mean square.

The value of critical difference (C.D.) was used for testing the significance of heterosis.
The critical difference (C.D.) was calculated with the help of following formula:

$$C.D. = S.Ed. \times t\ value$$

Where,
S.Ed. is standard error of the difference of the treatment means to be compared, and is equal to:

$$S.Ed. = (2\ Mse/r)^{0.5}$$

Where,
MSe = Error mean square obtained from ANOVA table
r = Number of replications
t = Table value of 't' at 5% and 1% level of significance for error degree of freedom.

The experimental material for present investigation comprised of 28 F'_1s developed by crossing 8 lines *viz*., HD 3171, WH 147, K 906, K 307, K 1006, K 7903, DBW 14, and PBW 502 following half diallel mating design. A total of 36 treatments (28 F_1's and 8 parents) were used for the study of combining ability and heterosis in F_1 generation for twelve characters in bread wheat. The genotypes under study were planted in a randomized complete block design (RCBD) with three replications per entry and one row (3m) per replication. The entries were sown in a single row plot of 3 m length with inter and intra-row spacing of 25 cm and 10 cm, respectively. Recommended agronomic practices were adopted to raise a good crop. The observations were recorded from the five randomly selected plants in parents and their F1s for all the following traits *viz.* days to 75% heading, number of tillers/plant, plant height (cm), days to maturity, length of spike (cm), number of spikelet/spike, number of grain/spike, grain yield/plant (g), weight of grain per spike(g), 1000 seed weight(g), biological yield/plant(g) and harvest index %.

Result and Discussion

The number of significantly superior crosses and range of heterosis have been presented in Table 2. Significantly better parent heterosis across the environments was found in 6 crosses for days to 75% heading, 13 crosses for plant height(cm), 12 crosses for days to maturity, 4 crosses for number of tillers/plant, 0 crosses for length of spike(cm), 1 crosses for number of spikelet/spike, 8 crosses for number of grain/spike, 1 crosses for 1000 seed weight(g), 0 crosses for weight of grain per spike(g), 3 crosses for biological yield/plant(g), 3 crosses for grain yield/plant(g), and 5 crosses for harvest index %.
The range of batter parent heterosis was observed -7.44 to 14.10 for days to 75% heading, -16.01 to 6.12 for plant height(cm), -7.92 to 2.43 for days to maturity, -32.67 to 22.01 for number of tillers/plant, -22.05 to 0.93 for length of spike(cm), -24.96 to 9.74 for number of spikelet/spike, -10.47 to 16.64 for number of grain/spike, -13.61 to 7.88 for 1000 seed weight(g), -33.58 to 10.48 for weight of grain per spike(g), -32.82 to 21.78 for biological yield/plant(g), -30.25 to 14.17 for grain yield/plant(g), and -18.83 to 20.76 for harvest index % respectively. Similar results were reported by (7).
The top five crosses with desirable heterosis (%) across the environments for 12 diverse attributes are given in Table 3. The cross combinations, WH147 x K307, K7903 x DBW14, HD3171 x K906, HD3171 x K 307, WH147 x K906 for days to 75% heading, K7903 x PBW502, K906 x PBW502, K7903 x DBW14, K906 x DBW14, WH147 x PBW502 for plant height(cm), K7903 x PBW502, DBW14 x PBW502, HD3171 x WH147, K1006 x PBW502, HD3171 x K307 for days to maturity, DBW14 x PBW502, WH147 x DBW14, WH147 x PBW502, WH147 x K79903 number of tillers/plant, WH147 x PBW502 for number of spikelet/spike, WH147 x K906, HD3171 x DBW14, K7903 x DBW14, HD3171 x WH147, K906 x K1006 for number of grain/spike,, WH147 x K1006 for 1000 seed weight(g), WH147 x DBW14, K1006 x K7903, K7903 x DBW14 for biological yield/plant(g), WH147 x DBW14, K7903 x DBW14, WH147 x K1006 for grain yield/plant(g), K1006 x DBW14, K307 x K1006, K7903 x PBW502, HD3171 x K906, WH147 x K1006 for harvest index %.
Batter parent heterosis for grain yield per plant was found to be significant and desirable in 4 out of 28 crosses (Table 4). The cross combination WH147 x DBW14 was exhibited maximum 14.17 per cent batter parent heterosis on pooled basis. Other 3 desirable heterotic crosses were K7903 x DBW14, WH147 x K1006 and K307 x K1006 for grain yield per plant, which revealed high SCA effects for other attributes contributing for economic value.
In the above mentioned crosses, heterosis for grain yield/plant might be due to desirable heterotic response for component traits such as number of tillers per plant, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000- grain weight, biological yield and harvest index followed by developmental traits like days to 75 per cent heading, plant height and days to maturity. These attributes were also showed desirable genotypic associations with grain yield. Therefore, the yielding ability in the present set of material might be increased by improving yield components.

Table 1: Analysis of variance of 8 parents and their 28F1s for twelve traits of bread wheat

Source of variance	d. f.	Days to Heading	Days to maturity	No. of tiller/ plant	Plant height (cm)	Spike length (cm)	No. of spkelets /spike	No. of grain /spike	Grain weight /spike (g)	1000 grain weight (g)	Grain yield/ plant (g)	Biological yield /plant(g)	Harvest index %
Replications	2	0.67	0.39	1.34	7.52	0.06	0.78	1.00	0.02	0.73	5.88	5.71	2.15
Treatments	35	44.60**	33.72**	6.34**	89.06**	3.05**	5.01**	26.73**	0.16**	17.61**	32.76**	216.70**	32.64**
Parents	7	73.08**	63.97**	3.90**	52.72**	3.28**	12.27**	17.88**	0.20**	16.16*	42.98**	344.85**	2.21
F_1s	27	26.97**	26.69**	6.95**	100.42**	3.10**	3.02**	28.63**	0.16**	18.40**	30.65**	181.84**	41.70**.
P vs F_1s	1	321.30**	11.87**	6.80**	36.72*	0.01	8.06**	37.40**	0.00	6.36	17.92**	260.83**	1.23
Error	70	2.76	0.69	0.93	5.90	0.06	0.41	1.54	0.03	6.05	2.14	3.79	1.37

*Significant at 5% level; **Significant at 1% level

Table 2: Range of heterosis and best cross with highest heterosis over batter parent for 12 characters in wheat.

Character	No. of significantly superior crosses	Range of heterosis	Best cross
Days to 75 % heading	6	-7.44 to 14.10	WH147 X K307
Plant height (cm)	13	-16.01 to 6.12	K7903 X PBW502
Days to maturity	12	-7.92 to 2.43	K7903 X PBW502
Number of tiller per plant	4	-32.67 to 22.01	DBW14 X PBW502
Spike length/plant (cm)	Nil	-22.05 to 0.93	HD317S X DBW14
Number of spikelets/spike	1	-24.96 to 9.74	WH147 X PBW502
Number of grains/spike	8	-10.47 to 16.64	WH147 X K906
1000-grain weight (g)	1	-13.61 to 7.88	WH147 X K1006
Grain weight/spike (g)	Nil	-33.58 to 10.48	HD3171 X WH147
Biological yield/plant	3	-32.82 to 21.78	WH147 X DBW14
Grain yield/plant	3	-30.25 to 14.17	WH147 X DBW14
Harvest index (%)	5	-18.83 to 20.76	K1006 X DBW14

Table 3: Desirable heterosis (%) over batter parent for Grain yield/plant in wheat.

Character	Crosses	Economic heterosis	GCA effect	
			P_1	P_2
Days to 75 % heading	WH147 x K307	-7.44**	-1.84**	1.29**
	K7903 x DBW14	-5.31**	-2.69**	-0.30
	HD3171 x K906	-5.28**	-0.24	1.42**
	HD3171 x K 307	-3.72*	-0.24	1.29**
	WH147 x K906	-3.66*	-1.84**	1.42**
	SE±	1.35		
Plant height (cm)	K7903 x PBW502	-16.01**	-3.42**	0.59
	K906 x PBW502	-15.03**	-2.59**	0.59
	K7903 x DBW14	-12.89**	-3.42**	0.67
	K906 x DBW14	-11.90**	-2.59**	0.67
	WH147 x PBW502	-10.67**	-2.39**	0.59
	SE±	1.98		
Days to maturity	K7903 x PBW502	-7.92**	-3.06**	0.23
	DBW14 x PBW502	-4.75**	-1.86**	0.23
	HD3171 x WH147	-4.24**	0.13	1.90**
	K1006 x PBW502	-4.22**	0.53**	0.23
	HD3171 x K307	-3.46**	0.13	1.43**
	SE±	0.67		
Number of tiller per plant	DBW14 x PBW502	22.01**	-0.03	0.26
	WH147 x DBW14	14.15*	0.34*	-0.03
	WH147 x PBW502	13.88*	0.34*	0.26
	WH147 x K79903	11.74*	0.34*	0.34*
	SE±	0.78		
Spike length/plant (cm)				
Number of spikelets/spike	WH147 x PBW502	9.74**	-0.79**	-0.14
	SE±	0.52		
Number of grains/spike	WH147 x K906	16.64**	0.09	-0.77**
	HD3171 x DBW14	11.03**	0.12	0.43*
	K7903 x DBW14	8.44**	-0.34	0.43*
	HD3171 x WH147	8.16*	0.12	0.09
	K906 x K1006	7.89**	-0.77**	1.20**
	SE±	1.01		
1000-grain weight (g)	WH147 x K1006	7.88*	0.93*	-0.58
	SE±	2.00		
Grain weight/spike (g)	Nil	Nil	Nil	Nil
Biological yield/plant	WH147 x DBW14	21.71**	-0.92**	-0.48
	K1006 x K7903	11.66**	-3.44**	-4.55**
	K7903 x DBW14	10.98**	-4.55**	-0.48
	SE±	1.59		
Grain yield/plant	WH147 x DBW14	14.17*	-0.80**	-0.81**

	K7903 x DBW14	14.06*	-1.53**	-0.81**
	WH147 x K1006	11.72*	-0.80**	-0.16
	SE±	1.19		
Harvest index (%)	K1006 x DBW14	20.76**	1.93**	-1.26**
	K307 x K1006	19.53**	-0.43**	1.93**
	K7903 x PBW502	14.31**	0.17	0.48*
	HD3171 x K906	12.10**	-0.54**	-0.34
	WH147 x K1006	8.69**	-0.00	1.93**
	SE±	0.95		

Table 4: Significant economic crosses for grain yield/plant in relation to other parameters and component traits in wheat

Crosses	Batter parent heterosis (%)	GCA effect		SCA effect	Desirable heterosis in other component traits
		P_1	P_2		
WH147 x DBW14	14.17*	-0.80**	-0.81**	2.14**	V**,
K7903 x DBW14	14.06*	-1.53**	-0.81**	2.84**	I**, II**,III**, V**,
WH147 x K1006	11.72*	-0.80**	-0.16	2.00*	III*, IV**, VI**
K307 x K1006	6.04**	1.70**	-0.16	4.98**	V**, VI**

Note: (I) Days to 75% heading, (II) Plant height (cm), (III) Number of grains/spike, (IV) 1000-grain weight (g), (V) Biological yield (g) and (VI) Harvest index (%)
* Significant at p =0.05; ** Significant at p = 0.01

Conclusion

The cross combinations namely, WH147 x DBW14, K7903 x DBW14, WH147 x K1006 and K307 x K1006 were exhibited significantly positive heterosis. Heterosis breeding may be useful for enhancement of grain yield. Some suitable devices conferring cross pollination like cytoplasmic male sterility or self-incompatibility may be helpful in commercial production of hybrid seed in this crop for developing the varieties of high yield potential with stable performance in all kinds of environments.

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