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Heterosis studies for improvement in yield potential of wheat (*Triticum aestivum* L.)

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Abstract. The present study was undertaken with a set of diallel crosses involving six genotypes of bread wheat during *Rabi* 2008-09 to identify heterotic combinations expressing high hybrid vigour. These informations would be useful to investigate the performance and relationship of F1 hybrids and parents to select suitable parents and population for designing an effective wheat breeding programme. The cross combination Kalyansona x K-8962 followed by Sonalika x K-8962, K-8962 x HUW-234, Kalyansona x HUW234 and HUW-510 x HUW-234 were found top hybrids having high mid-parent heterosis. Negative heterosis for days to flowering and plant height in cross PBW-373 x Kalyansona and HUW-510 x PBW-373 was found desirable. Highly significant heterosis was found for spike length in cross Sonalika x K-8962, tillers per plant in cross HUW-510 x K-8962, number of grains per spike in cross Sonalika x K-8962, test weight in cross PBW-373 x Kalyansona and harvest index in cross Kalyansona x K-8962. It can concluded that the heterosis estimates over mid-parent in the crosses were more frequent for days to flowering, plant height, spike length, number of tillers per plant, grains per spike, test weight and harvest index.
Key words: wheat (*Triticum aestivum* L.), heterosis, grain yield and hybrid vigour.

Introduction. "Wheat" (*Triticum aestivum* L.) is considered as king of cereals as it provides foods to 36% of the global population contributing 20% of the food calories. It is an important staple food of many in the world and occupies a unique position as it is used for the preparation of a wide range of food stuffs. India is the second largest wheat growing country in the world after China. According to Malthus (1989) the food grains increase in Arithmetical progressions while the population increases in geometrical progression, thus improved technologies are required to bridge the gap to feed the increasing population. Therefore, for breaking the yield barrier level and make wheat cultivation more attractive, it is now necessary to explore alternative approaches. Among the all possible alternatives, heterosis is an important approach for increasing wheat production. Heterosis is the results of accumulation of favourable gene in one parent from two different parent or intra and inter-allelic interaction in F_1 generation. Exploitation of heterosis is considered to be one of the outstanding achievements of plant breeding. The presence of sufficient hybrid vigour is an important pre-requisite for successful production of hybrid varieties. Previously, exploitation of heterotic effects for grain yield was largely attributed to cross pollinated crops but Briggle (1963) reported presence of heterosis in considerable quantity for grain yield components in various F1 wheat crosses. It has earlier been reported (Sedeque & Ali 1991) that most of the hybrids showed negative heterosis for plant height over the tallest parent and maximum heterosis over the better parent, 141.7 and 18.9 percent for tillers per plant and grain yield per plant, respectively. Fida et al (2004) measured positive heterotic effects as 11.61, 61.90, 30.67 and 51.89 percent for plant height, tillers per plant, grains per spike and grain weight, respectively. Success of hybrid vigour in wheat besides other plants is directly proportional with effectively selection of parents. However results of different researchers on heterosis do not show parallelism in such a way. Busch et al (1974), Bailey & Comstock (1976) and Cox & Murphy (1990) claimed that in some cases, possibility of developing predominant genotype is greater if both parents have similar performance instead of one parent being inferior or superior in terms of one or more traits. However genetic distance between parents is necessary to develop superior hybrid (Martin et al 1995). Though the production of hybrid seed is technically feasible in wheat (Akbar et al 2007), at the practical approach of this concept needs further exploitation and perfection. Ansari et al (2005) and Bhatt et al (2006) observed that F_2 progeny performance was good indication of F_1 hybrid performance. The parents which are genetically superior and diverse in the traits of interest are utilized for varietal development programme. The possible heterosis exploitation in wheat crop continues to be a critical question. The choice of parental material used in the hybridization scheme does contribute significantly for the development of a suitable genotype. Keeping in view the general rule of breeding, the higher the heterosis and heritability, the simpler the selection process and greater the response to selection a diallel cross of bread wheat was employed for determination of the out yielding effects of wheat hybrids for 10 agronomic traits and their possible exploitation for commercial use.

Material and Methods. The diallel crosses among all possible combinations excluding reciprocals involving six wheat genotypes *viz*; HUW-510, Sonalika, PBW-373, Kalyansona, K-8962 and HUW-234 were made in *Rabi* (Winter season) 2008 to study the extent of heterosis. Further the 21 genotypes (6 parents + 15 F_1s) were laid out in Randomized Block Design with 3 replications during *Rabi* 2009 at the Field Experimentation centre of the Department of Genetics and Plant Breeding, Allahabad Agricultural Institute, Deemed University. The methodology used to maintain two seeds per hole keeping plant to plant distance of 15 cm and row to row distance of 30 cm. The recommended agronomic practices were done timely to raise good crop stand. The observations were recorded on 10 randomly selected plants in each genotype for ten characters, *viz;* days to flowering, days to maturity, plant height, tillers per plant, spike length, grains per spike, test weight, biological yield, grain yield per plant and harvest index. The percent increase or decrease of F_1 hybrids over mid parent as well as better parent was calculated to estimate possible heterotic effects for above mentioned parameters (Fonseca & Patterson 1968).

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

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

Where, Ht = Heterosis; Hbt = Heterobeltiosis. To estimate significant differences among hybrids and parents, the mean data of each character were subjected to analysis of variance (ANOVA) as suggested by Steel & Torrie (1980). The characters showing significant differences were subjected to heterosis calculation. Deviation of F1 from its mid parents or either of the parental values was interpreted by Mather & Jink (1977) depicting type of gene action operating for controlling the trait. The t' test was applied to determine significant difference of F1 hybrid means from respective mid parent and better parent values using formulae as reported by Wynne et al (1970).

Results and Discussion. The analysis of variance (Table 1) due to parents, crosses and parents V/s crosses were significant for all the characters except for flag leaf width which showed, the presence of significant amount of variability among parents, their crosses (F_1) and among parents V/s crosses (F_1s) for all characters studied. This suggested that the parental lines selected were quite variable, considerable amount of variability existed among the hybrids and presence of overall heterosis for most of the characters. Earlier such findings were reported by Thebo et al (2005). The estimates of heterosis over mid parent in F_1 generation were presented in Table 2. The salient results of the study and conclusion drawn from the experiment are summarized below.

Days to flowering: The magnitude of estimated heterosis for days to flowering over mid-parent varied from: -13.42 (PBW-373 x Kalyansona) to 4.00 (PBW-373 x HUW-234) where maximum significant negative heterosis was obtained in cross PBW-373 x Kalyansona followed by HUW-510 x PBW-373 and HUW-510 x Kalyansona. Similar result reported by Ansari et al (2005)) and Farooq et al (2005).

Days to maturity: Genotypes with early maturing habits are generally wanted; negative heterosis for days to maturity is therefore a useful parameter. Heterosis for days to maturity range from: -6.01 (HUW-510 x Sonalika) to 5.35 (PBW-373 x HUW-234). It was significant in 10 crosses of which 8 crosses depicted negative heterosis. Maximum significant heterosis was obtained in cross HUW-510 x Sonalika followed by Sonalika x PBW-373 and HUW-510 x Kalyansona, which indicates earliness and beneficial for escaping disease as well as more yield. Simon (1989) also observed that heterosis studies could be effectively used for incorporating early maturity in wheat.

Plant height: In wheat crop, dwarfism is a desirable trait. Hence, negative heterosis is favoured to avoid lodging. The range of heterosis for plant height was: -15.80 (HUW-510 x PBW-373) to 1.10 (HUW-510 x PBW-373). The heterotic effect was significant in twelve crosses which depicted negative significant heterosis. Maximum significant negative heterosis was obtained in cross HUW-510 x PBW-373. The highest and desirable heterosis for plant height with significant and negative values was expressed by the crosses and exhibited frequent occurrence of dwarf or semi dwarf plants. Similar finding were also reported by Bhatt et al (2006). McNeal et al (1965) and Fonseca & Patterson (1968) observed intermedier inheritance for plant height for all F1 hybrids in their studies. Abdullah et al (2002) reported super-dominance gene actions for plant height in some cross combinations.

Spike length: Percentages of positive heterosis for spike length over mid parent in 12 cross combinations were found to be highly significant with positive desirable heterotic effects. The relative heterosis for spike length ranged from: 7.48 (K-8962 x HUW-234) to 25.65 (Sonalika x K-8962). The cross combination Sonalika x K-8962 (25.65) exhibited highest heterosis. This difference may be attributed to diversity in materials or other environmental factors. Similar results were also reported by Vanpariya et al (2006). Mackey (1976) described over dominance as favourable interaction between two alleles at the same locus i.e. intra locus or inter allelic interactions and Singh et al (2004) also reported that heterosis resulting from inter allelic interactions of dominant types is not possible to fix in homozygous condition in subsequent generations.

Tillers per plant: Significant heterosis was observed for twelve crosses, out of which eleven crosses showed positive significant heterosis and one cross exhibited negative but significant heterosis. Estimates of average heterosis for tillers per plant varied from: 0.12 (Sonalika x PBW-373) to 60.80 (HUW-510 x K-8962). Highest heterosis was shown by HUW-510 x K-8962. These findings are in conformity with the findings of Vanpariya et al (2006).

Grains per spike: Grains per spike directly determine the yield potential of a genotype. The relative heterosis for number of grains per spike range from: 6.18 (Sonalika x Kalyansona) to 36.18 (Sonalika x K-8962). Out of 15 crosses, 13 crosses depicted significant positive heterosis. The highest significant heterosis was exhibited by the cross Sonalika x K 8962 (36.18).

Test weight: Grain weight is an essential component contributing for yield production, so positive heterosis is desirable for this trait**.** The relative heterosis for test weight ranged from: – 0.03 (Sonalika x K 8962) to 30.80 (PBW 373 x Kalyansona). Out of 15 crosses, 7 crosses showed significant but positive and 4 crosses showed significant but negative heterosis. The highest significant positive heterosis was exhibited by the cross PBW 373 x Kalyansona (30.80).The relative heterosis for biological yield per plant ranged from 0.33 (Sonalika x Kalyansona) to 36.09 (Kalyansona x K 8962). Out of 15 crosses, 14 crosses depicted significant heterosis in positive direction. The highest heterosis was recorded in cross Kalyansona x K 8962. The predominant heterotic interaction with respect to test weight in all the hybrids showed the effectiveness of heterosis for increased grain yield.

Harvest index: The estimates of relative heterosis for harvest index ranged from – 0.83 (PBW 373 x Kalyansona) to 28.94 (Kalyansona x K 8962). Significant heterosis observed for 7 crosses, of which all crosses had positive heterotic effect. The highest heterosis was recorded in cross Kalyansona x K 8962.

Grain yield: Exploitation of heterotic effect for grain yield increase was largely attributed to cross-pollinated crops. The possibility of commercial use of F1 hybrids in wheat, received a little attention. The estimates of relative heterosis for grain yield ranged from – 4.55 (Sonalika x K 8962) to 68.14** (Kalyansona x K 8962). It was significant in 14 crosses, of which all crosses exhibited positive heterotic effect. The cross combination Kalyansona x K 8962 had highest positive significant heterosis (68.14**). Similar findings were also reported by Akbar et al (2007), Chowdhry et al (2007) Shehzad et al (2004) and Vanpariya et al (2006). In addition, Morgan (1998) who obtained same results for some crosses, pointed out that the parents showing negative heterosis for grain yield either did not contain useful alleles or they were not expressed. Furthermore, these parents may have deleterious alleles at different loci. An overall perusal of estimates of heterosis revealed that in the present study out of 15 crosses, 13 crosses for days to 50 percent flowering, 8 crosses for days to maturity, 12 crosses for plant height, 5 crosses for flag leaf length, 12 crosses for spike length, 12 crosses for tillers per plant, 13 crosses for number of grains per spike, 11 crosses for test weight, 14 crosses for biological yield, 7 crosses for harvest index and 14 crosses for grain yield per plant depicted significant relative heterosis in desired direction. Hybrids Kalyansona x K8962 and K 8962 x HUW 234 showed significant heterosis effect of grain yield along with earliness. Since days to flowering, days to maturity and plant height majority of the hybrids exhibited negative significant relative heterosis, indicating that for these traits the genes with negative effects were dominant on the other hand grains per spike, spike length, number of tillers per plant, biological yield, harvest index and grain yield per plant majority of hybrids exhibited positive significant relative heterosis, indicating that for genes for these characters were dominant. Crosses showing significantly positive heterosis and heterobeltiosis had over-dominant type of gene action for all traits studied except plant height, tillers per plant and harvest index. These crosses should be given due consideration to develop potential variety by selecting transgressive segregants in late segregating generations. The crosses showing significant heterosis but negative or non-significant positive heterobeltiosis had partially dominant type of gene action. The choice of parental material used in hybridization scheme is of prime importance for the development of suitable genotype. The parents who are genetically superior and diverse in traits if selected and utilized for designing a meaningful breeding programme can contribute to develop better quality and high yielding wheat varieties.

Table 1

Analysis of variance for different quantitative characters in wheat

SN	*Characters*	*Replications*	*Genotypes*	*Parents(P)*	*F_1*	*P vs F_1*	*Error*
		[2]	[20]	[5]	[14]	[1]	[40]
1	Days to 50% flowering	1.25	54.54**	118.32**	25.26**	145.72**	1.38
2	Days to maturity	1.45	51.19**	75.52**	44.45**	24.01**	1.59
3	Plant height	8.3	109.55**	47.57**	98.59**	572.85**	5.48
4	Spike length	0.006	2.70**	1.00*	1.31**	30.62**	0.39
5	Tillers per plant	0.97	9.04**	8.19**	6.04**	55.38**	0.39
6	Number of grains per spike	0.021	64.06**	9.58*	46.44**	583.10**	3.78
7	Test weight	6.96	49.66**	63.12**	45.29**	43.53**	0.49
8	Biological yield	26.46	9.35**	16.04**	7.19**	6.10*	0.86
9	Harvest index	26.35	27.70**	16.44**	23.04**	149.21**	1.8
10	Grain yield per plant	2.7	4.29**	5.09**	3.78**	7.37**	0.24

* Significant at 5% level and ** Significant at 1% level; [ ] value in parenthesis represents degree of freedom.

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Table 2

Heterosis estimates in percentage of ten characters in bread wheat of mid parent

Crosses	*Days to flowering*	*Days to maturity*	*Plant height*	*Spike length*	*Tillers/ plant*	*Grains/ spike*	*Test weight*	*Biological yield*	*Grain yield*	*Harvest index*
HUW510 x Sonalika	-8.35**	-6.01**	-1.10	21.31**	14.85**	26.08**	9.81**	12.12**	28.31**	15.63**
HUW510 x PBW373	-11.42**	-3.94**	-15.80**	14.84**	11.74*	9.61*	10.78**	14.13**	20.16**	4.37*
HUW510xKalyansona	-8.45**	-0.29	-10.95**	20.43**	16.37**	19.37**	15.21**	13.86**	15.57**	1.50
HUW510 x K8962	-4.79**	-2.05*	0.08	22.24**	60.08**	24.49**	-0.99	33.34**	34.70**	1.29
HUW510 x HUW234	3.34*	2.35**	1.69	18.00**	57.94**	19.22**	17.60**	26.09**	38.53**	18.94**
Sonalika x PBW373	-8.13**	-4.17**	-12.35**	19.76**	-0.13	22.75**	-3.60*	6.66*	28.67**	-3.68
Sonalika x Kalyansona	-7.90**	-2.34**	-5.65**	9.12*	-9.96*	6.18	0.89	0.33	-4.55	-2.24
Sonalika x K8962	2.42	1.26	-6.92**	25.65**	39.87**	36.18**	-0.03	20.70**	48.29**	17.98**
Sonalika x HUW234	-0.99	-1.82*	-12.54**	19.07**	4.90	27.83**	-6.13**	5.92*	3.29	-1.43
PBW373 xKalyansona	-13.42**	-2.22**	-12.53**	11.70*	-6.57	12.55**	30.80**	8.95*	7.97*	-0.83
PBW 373 x K 8962	-5.77**	0.56	-10.21**	8.00	38.65**	7.51*	8.39**	13.45**	19.80**	3.48
PBW 373 x HUW 234	4.00**	5.35**	5.02**	22.73**	33.20**	13.44**	12.05**	15.20**	23.61**	3.01
Kalyansona x K 8962	-5.46**	0.87	-11.70**	19.92**	51.12**	21.93**	-11.45**	36.09**	68.14**	28.94**
KalyansonaxHUW234	-2.66	-1.16	-7.05**	8.47	18.60**	6.54	-9.98**	15.42**	41.45**	20.24**
K 8962 x HUW 234	-1.56	-3.52**	-4.49**	7.48	42.27**	10.20**	1.15	16.27**	41.94**	15.65**

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