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RESEARCH ARTICLE

HYBRID PERFORMANCE AND HETEROSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

A study was conducted in bread wheat to estimate the magnitude of heterosis for grain yield and its seven yield components. 10 F_1 hybrids were derived from crosses between two female lines and five testers using line x tester analysis and these F_1s along with 7 parents and one commercial check varieties were evaluated during *Rabi* 2010-11 using Randomized Block Design. Highly significant differences were observed among the genotypes for all the traits studied. The cross GIANT-3 x AAI-347 was recognized as the best heterotic cross for grain yield as it exhibited highly significant positive heterosis over the standard checks HUW 510. The cross GIANT-3 x PBW-343 exhibited highest and significant positive heterosis over better parent, mid parent and over the standard checks for number of tillers per plant and 1000 grain weight. The present study reveals good scope for isolation of pure lines from the progenies of heterotic F_1s as well as commercial exploitation of heterosis in bread wheat.

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INTRODUCTION

Wheat is one of the most important and widely cultivated staple food crops among the cereals and is contributing about 30% to the food basket of the country. It is agronomically and nutritionally most important cereal essential for the food security, poverty alleviation and improved livelihoods. To feed the growing population, the country's wheat requirement by 2030 has been estimated at 100 million metric tons. To achieve this target, the wheat production has to be increased at the rate of <1mmt per annum (Sharma *et al*., 2011) and one way to achieve this is through heterosis breeding, which is one of the strongest tool to take a quantum jump in production and productivity under various agro- climatic conditions. Heterosis or hybrid vigour concept was started with the studies reported by Shull (1908). The exploitation of heterosis requires intensive evaluation of germplasm to find out diverse donors with high nicking of genes crossing elite genotypes and further identification of highly heterotic F_1s so that subsequently desirable segregants may be obtained from various combinations. Selection of potent parents represent the major step in the development of new high-yielding cultivars, and the efficient identification of superior hybrid combinations is a fundamental issue in wheat breeding programs (Gowda *et al*., 2010). Moreover, the study of heterosis helps the breeders in eliminating less productive crosses in F_1 generation itself. The rejection of crosses, which shows no heterosis, would enable the breeder to concentrate the attention to few, but possibly more productive crosses. The studies of heterosis in wheat have also been reported by Borghi and Perenzin (1994), Budak and Yildrim (1996), Saini *et al*. (2006), Ribadia *et al*. (2007), Dagustu (2008), Ashutosh *et al*. (2011), Amarah *et al*. (2013) and Beche *et al*. (2013). In views of the above facts, the present study was, therefore, undertaken to estimate the magnitude of genetic variability and heterosis for yield and its component traits by crossing 2 lines and 5 testers using line x tester mating design.

These studies would be helpful for selecting suitable parents for hybrid development and to select potent transgressive segregants which can be further evaluated for enhanced yield potential. The objective of this study was to determine the levels of heterosis, heterobeltiosis and standard heterosis of different traits to identify desirable parents and develop high-yield wheat varieties for the use of hybrids in wheat breeding programs.

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MATERIALS AND METHODS

Ten F_1s were obtained by crossing two lines v*iz.* GIANT-3 and AAI-2 (female parents) with five testers v*iz.* AAI-347, PBW-524, RAJ-4026, PBW-343 and HD-2733 (male parents) The seven parents (male and female) and their resultant 10 F_1s were grown in a randomized block design with two replications during *Rabi* 2009-10 to *Rabi* 2010-11 at Plant breeding Crop Research Centre of Allahabad Agriculture Institute, Deemed University, Allahabad. Each replication consisted of 18 treatments consisting of 2 lines, 5 testers, 10 crosses and one commercial check varieties (HUW-510). Each treatment was planted in a two rowed plot of two meter long with inter- row and inter- plant distances of 23 and 10 cm, respectively. Observations were recorded for Twelve characters *viz*., Days to 5o% flowering, Days to maturity, Effective tillers per plant, Flag leaf length, Flag leaf width, plant height, spike length, number of grains per spike, 1000 grain weight, Biological yield, Harvest index and grain yield per plant. The mean values of parents and hybrids were used for estimating heterosis over their respective better parents, mid parent and standard checks for above characters.

Estimation of heterosis

Heterosis, expressed as per cent increase or decrease in the performance of F_1 hybrid over the mid-parent (average or relative heterosis), better parent (heterobeltiosis) and check parent (standard heterosis) was computed for each character using the following formula:

The formula used for estimating relative heterosis is under:

$$di = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

di = Heterosis over mid parental value (relative heterosis)

$\overline{F_1}$ = Mean hybrid performance, and

$\overline{MP}$ = Mid parental value i.e., the arithmetic mean of two parents involved in the respective cross combination.

Heterobeltosis was calculated at the deviation of hybrid from the better parent as under:

$$dii = \frac{\overline{F1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

dii = Heterobeltosis *i.e*., heterosis over better parent

$\overline{F_1}$ = Mean hybrid performance, and

$\overline{BP}$ = Average performance of better parent in the respective cross combination.

The significance of different types of heterosis was carried out by adopting 't' test as suggested by Nadarajan and Gunasekaram (2005):

$$t \text{ (relative heterosis)} = \frac{\overline{F_{ij}} - \overline{MP_{ij}}}{SE}$$

$$t \text{ (heterobeltiosis)} = \frac{\overline{F_{ij}} - \overline{BP_{ij}}}{SE}$$

Where,

$\overline{F_{ij}}$ = Mean of ij^{th} cross

$\overline{MPij}$ = Mid parental value for i, j^{th} cross

$\overline{BPij}$ = Better parental value of i, j^{th} cross

SE= Standard error of heterosis

The differences in the magnitudes of relative heterosis, heterosis over male and female parents were tested as per the method proposed by Panse and Sukhatme (1961).

RESULTS AND DISCUSSION

The analysis of variance revealed significant variation due to parents for all the characters studied except thousands grain weight and harvest index indicating that parents possess good amount of genetic variability (Table 1). The variance due to hybrids was also significant for all the characters studied suggesting the generation of good amount of variability among the hybrids and also the possibilities of identifying the superior hybrids from the study. Comparison of means of hybrids with mean of parents as a group was found to be significant for most of the characters which suggested that the hybrids differ considerably from the parents for most of the traits and also the existence of substantial heterosis for most of the characters studied. Moreover, the importance of non additive genetic effects in determining these characters can also be revealed. Almost all the characters had shown considerable amount of heterosis over better parent, mid parent and standard checks (Table 2). The highest average heterosis (39.93%) for grain yield per plant was observed by cross of GIANT-3 x PBW-343 followed by GIANT x AAI-347 (34.47%) and GIANT x RAJ-4026 (22.70%).

GIANT-3 x AAI-347 recorded highest heterobeltiosis value (30.61%) for grain yield per plant followed by GIANT-3 x PBW-343 (27.37%).

Heterobeltiosis for days to 50% flowering ranged from -11.36 (GIANT-3 x PBW-343) to 2.65 (AAI-2 x RAJ-4026). The highest heterobeltiosis estimates by GIANT-3 x PBW-343 (-11.36), showing significant earliness than the better parent. Negative heterosis for days taken to heading is desirable if these have significant correlation with grain yield per plant for selecting higher yielding and short duration plants. The highest economic heterosis estimates by AAI-2 x AAI-347 (6.52) which showed earliness over the standard check HUW-510. The importance of negative heterosis for days to 50% flowering has been highlighted by Bedo *et al*. (1983), Palve *et al*. (1986), Gawande and Dhumale (2002), Muhammad *et al*. (2010) and Ashutosh *et al*. (2011).

Table 1. Analysis of Variance for Line x Tester and combining ability

Source of Variation	Character												
	Df	1	2	3	4	5	6	7	8	9	10	11	12
Replication	1	0.47	0.12	0.17	7.40	0.01	1.32	0.29	1.06	13.35	0.22	3.47	0.68
Parents	6	15.81*	10.12**	11.05*	25.44*	0.10*	79.36**	3.37*	213.57**	7.05	182.05**	8.29	42.45**
Hybrids	9	52.53**	23.01**	12.74**	39.53**	0.18**	66.85*	4.62*	540.83**	47.75**	169.43**	32.56**	11.92**
Parent vs. hybrids	1	56.28**	18.70**	59.07**	30.67**	0.07*	180.47**	11.3**	724.36**	4.95	142.06**	47.20**	83.69**
Lines	1	84.32	25.82	8.41	59.31	0.07	94.40	2.97	448.30	69.01	278.66**	21.07	23.04**
Testers	4	39.2	22.05	67.27**	41.58	0.10	85.44	0.01	31.25	41.20	290.86**	87.73	5.82
Line x Tester	4	24.07**	20.42**	3.43	19.24*	0.32**	34.67*	7.42**	760.75**	28.14*	29.85**	30.24**	2.33
Error	16	3.03	0.74	1.45	3.36	0.01	8.49	0.54	3.99	4.56	0.90	2.50	0.63

* Significant at 5% level and ** Significant at 1%

1. Days to 50% flowering
2. Days to maturity
3. Effective tillers per plant
4. Flag leaf length (cm)
5. Flag leaf width (cm)
6. Plant height (cm)
7. Spike length (cm)
8. No. of grains per spike
9. Thousands grain weight
10. Biological yield
11. Harvest Index
12. Grain yield per plant (g)

Table 2. Heterosis (Ha), Heterobeltiosis (Hb) and economic heterosis (He) in wheat

S. No.	CROSSES	Days to 50% flowering			Days to Maturity			Effective tillers per plant		
		Ha	Hb	He	Ha	Hb	He	Ha	Hb	He
1.	GINAT-3 × AAI-347	2.60	1.28	14.49**	2.60	1.28	1.30	61.68**	36.09*	17.26
2.	GIANT-3 × PBW- 524	0.00	-2.63	7.25*	0.00	-2.63	4.34**	53.74**	10.58	48.60**
3.	GIANT-3 × RAJ-4026	-1.32	-1.97	7.97*	-1.32	-1.97	-0.43	87.49**	58.27**	35.57*
4.	GIANT-3 × PBW- 343	-4.88*	-11.36**	13.04	-4.88*	-11.36**	1.30	67.25**	48.04*	13.24
5.	GIANT-3 × HD- 2733	-1.23	-7.47**	16.67	-1.23	-7.47**	4.78**	46.15*	44.74	-14.68
6.	AAI-2 × AAI-347	-4.23	-5.77*	6.52	-4.27	-5.77	2.61	10.80	-4.08	-17.26
7.	AAI-2 × HD-2733	-1.54	-8.05**	15.94**	-1.54	-8.05**	0.43	35.59	29.92	-18.09
8.	AAI-2 × PBW- 524	1.02	-1.32	7.97	1.02	-1.32	0.43	24.08	-8.85	22.44
9.	AAI-2 × PBW- 343	-2.14	-9.09**	15.94**	-2.14	-9.09**	1.30	60.00**	45.95*	11.27
10.	AAI-2 × RAJ-4026	2.99	2.65	12.32**	2.99	2.65	2.17	57.80**	36.99*	17.37
S. No.	CROSSES	Flag leaf length (cm)			Flag leaf width (cm)			Plant height (cm)		
		Ha	Hb	He	Ha	Hb	He	Ha	Hb	He
1.	GINAT-3 × AAI-347	-27.77**	-30.76**	-1.16	-6.83	-15.94**	13.72*	-8.85**	-11.46**	6.53
2.	GIANT-3 × PBW- 524	2.78	-8.54	30.57**	8.25	-7.25	25.00**	9.30	0.62	14.12*
3.	GIANT-3 × RAJ-4026	14.05*	-4.84	35.85**	5.31	-10.14*	21.56**	7.33	6.25	22.99**
4.	GIANT-3 × PBW- 343	3.32	-14.88*	21.13**	1.05	-12.68*	18.14*	11.45**	9.24*	29.00**
5.	GIANT-3 × HD- 2733	-10.48	-27.44**	3.58	-12.90*	-26.63**	-0.98	5.77	4.51	18.53*
6.	AAI-2 × AAI-347	0.93	-6.05	22.98**	14.10*	10.04	28.43**	0.11	-4.97	14.33*
7.	AAI-2 × HD-2733	12.36	0.33	13.20*	-12.90*	-26.63**	19.11*	-3.70	-4.84	5.58
8.	AAI-2 × PBW- 524	7.74	7.02	20.75*	-3.44	-11.92*	2.94	7.66*	1.34	9.79*
9.	AAI-2 × PBW- 343	13.42*	3.18	16.41*	1.05	-12.68*	23.04**	-1.51	-5.68	22.75**
10.	AAI-2 × RAJ-4026	10.14	1.67	14.71*	17.51**	6.69	24.51**	-3.36	-6.56	8.16
S. No.	CROSSES	Biological Yield(g)			Harvest Index(%)			Grain yield per plant(g)		
		Ha	Hb	He	Ha	Hb	He	Ha	Hb	He
1.	GINAT-3 × AAI-347	7.89**	-6.55**	30.70**	21.01**	2.19	2.37**	34.47**	30.61**	33.80**
2.	GIANT-3 × PBW- 524	-3.21	-29.67**	-1.63*	9.03*	-8.09	-7.52*	13.51*	-5.75	-8.99
3.	GIANT-3 × RAJ-4026	-11.08**	-28.95**	-0.62*	34.90**	23.80**	2.27*	22.70**	5.27	1.63
4.	GIANT-3 × PBW- 343	6.87	-14.80**	5.13*	24.21**	7.10	2.02	39.93**	27.37**	23.02**
5.	GIANT-3 × HD- 2733	-22.79**	-35.09**	-9.21*	14.51**	-0.79	-6.55	-8.92	-12.11*	-15.17
6.	AAI-2 × AAI-347	-24.35**	-32.30**	-30.65**	-2.17	-5.75	-5.57	-26.29**	-36.11**	-12.46
7.	AAI-2 × HD-2733	-12.17**	-18.81**	-22.60**	2.34	1.61	-4.27	-10.16	-17.49**	-25.95**
8.	AAI-2 × PBW- 524	2.37	-8.71*	-26.15**	-3.41	-7.14	-6.57	7.15	-0.94	-12.57
9.	AAI-2 × PBW- 343	-0.99	-2.33	-18.78**	-0.12	-1.38	-6.05	-1.14	-3.69	-10.73
10.	AAI-2 × RAJ-4026	-15.55**	-16.94**	-30.52**	4.99	-0.80	-7.89	-11.26	-14.81*	-35.97**
S. No.	CROSSES	Spike length (cm)			Grains per spike			Test weight (g)		
		Ha	Hb	He	Ha	Hb	He	Ha	Hb	He
1.	GINAT-3 × AAI-347	3.75	-4.71	29.94**	-7.05*	-25.26**	45.84**	-17.52**	-20.71**	-10.02*
2.	GIANT-3 × PBW- 524	6.29	-11.23	21.04**	17.69**	-15.98**	63.95**	0.56	-11.12*	-6.93
3.	GIANT-3 × RAJ-4026	8.46	-9.42	23.51**	12.86**	-18.56**	58.92**	-2.72	-8.37	-4.04
4.	GIANT-3 × PBW- 343	4.45	-6.52	27.47**	-9.51**	-28.87**	38.80**	-3.48	-8.56	-4.22
5.	GIANT-3 × HD- 2733	0.42	-14.13*	17.09**	-18.06**	-39.18**	18.68**	-11.91**	-12.29*	-7.31
6.	AAI-2 × AAI-347	18.32**	15.16*	38.73**	14.52**	12.20**	38.80**	-3.83	-11.17*	0.80
7.	AAI-2 × HD-2733	1.36	-8.61	10.18*	19.82**	5.69	30.76**	-11.13*	-15.12**	-10.30*
8.	AAI-2 × PBW- 524	-7.69	-18.85*	-2.17	1.94	-14.63**	5.61	1.69	-6.65	-10.21*
9.	AAI-2 × PBW- 343	-4.03	-9.14	9.48	-9.40*	-13.82**	6.62	0.54	-0.75	-4.53
10.	AAI-2 × RAJ-4026	21.21**	6.56	28.45**	39.71**	18.70**	46.85**	-10.76*	-12.43*	-15.79*

* Significant at 5% level and ** Significant at 1%

Table 3. Promising hybrids identified on the basis of economic heterosis for grain yield per plant

S.No.	Hybrids	Per se performance for seed yield per plant (g)	Economic heterosis over the best check	Heterobeltiosis over the best check	No. of tillers per plant	Days to 50% flowering	1000 grain weight
1	GIANT-3 x AAI-347	24.70	33.80	30.61	13.15	79.00	43.64
2	GIANT-3 x PBW-343	22.71	23.02	27.37	12.90	78.00	46.45
3	GIANT-3 x RAJ-4026	18.76	1.63	5.27	13.11	74.50	46.54

Three crosses viz. GIANT-3 x AAI-347(-11.46) followed by AAI-2 x RAJ-4026(-6.56) and AAI-2 x PBW-343(-5.68) showed significant negative heterobeltiosis for plant height. The heterobeltiosis for this character ranged from -11.46 (GIANT-3 x AAI-347) to 9.24 (GIANT-3 x PBW-343). The relative heterosis ranged from -8.85 (GIANT-3 x AAI-347) to 11.45 (GIANT-3 x PBW-343). The highest negative standard heterosis over the standard check recorded in the cross AAI-2 x HD-2733(5.58) for plant height. Negative heterosis for plant height has also been reported by Yadav and Murty (1976), Palve *et al*. (1986), Budak and Yildrim (1996), Gawande and Dhumale (2002), Muhammad *et al*. (2010). Spike length is one of the most important yield components, which contributes towards productivity and should be taken into consideration during selection. Thus, positive heterosis for spike length is desirable. In the present study, the cross AAI-2 x RAJ-4026 showed the highest positive heterosis over both the better parent and mid parent. For standard heterosis, the best cross combination was AAI-2 x AAI-347 which exhibited the highly significant positive heterosis over the standard check. The results for spike length are in agreement with Ribadia (2007), Dagustu (2008), Muhammad *et al*. (2010) and Ashutosh *et al*. (2011). In the present study, the highest magnitude of positive heterotic response for number of grains per spike in terms of heterobeltiosis and relative heterosis was recorded in the cross AAI-2 x RAJ-4026. GIANT-3 x PBW-524 showed significant positive standard heterosis. Positive heterosis for this character has been highlighted by Palve *et al*. (1986), Chakraborty and Tewari (1995), Prasad *et al*. (1998), Gawande and Dhumale (2002), Dagustu (2008), Muhammad *et al*. (2010) and Amarah *et al*. (2013). The promising cross GIANT-3 x PBW-343 was recorded to have the highest negative estimates of better parent heterosis and relative heterosis for days to maturity, while highest negative estimate of standard heterosis over check was exhibited by the crosses GIANT-3 x RAJ-4026. These crosses could be utilized to generate early maturing transgressive segregants in the later generations. These results are in agreement with Bedo *et al*. (1983), Gawande and Dhumale (2002) and Muhammad *et al*. (2010) who reported negative estimates of heterosis.

Positive heterosis is favoured in case of 1000 grain weight, as it has a direct bearing on yield. In the present study, the cross AAI-2 x PBW-343 exhibited the highest magnitude of positive heterosis over the better parent and AAI-2 x PBW-524 over the mid parent, while the cross AAI-2 x AAI-347 exhibited highest positive standard heterosis over the standard check. Positive heterosis for 1000-grain weight was earlier reported by Palve *et al*. (1986), Chakraborty and Tewari (1995), Prasad *et al*. (1998), Muhammad *et al*. (2010) and Ashutosh *et al*. (2011).

In case of grain yield per plant, the cross GIANT-3 x PBW-343 exhibited the highest magnitude of positive heterosis over the mid parent, while the cross GIANT-3 x AAI-347 showed the highest significant positive heterosis over both the better parent and the check. The results reporting positive heterosis for grain yield per plant are in complete agreement with Borghi and Perenzin (1994), Budak and Yildrim (1996), Saini *et al*. (2006), Ribadia *et al*. (2007), Dagustu (2008), Muhammad *et al*. (2010), Ashutosh *et al*. (2011) and Amarah *et al*. (2013).

Conclusion

The present study reveals ample variability among the parents and high scope for the exploitation of heterosis for advancement of grain yield in wheat. The cross GIANT-3 x AAI-347, GIANT-3 x PBW-343 and GIANT-3 x RAJ 4026 was recognized as the best heterotic cross for grain yield and it exhibited highly significant positive heterosis over the standard check HUW 510 (Table 3). Therefore, this cross can be further evaluated and used in hybrid breeding programme to boost up the grain yield. Moreover, the cross GIANT-3 x AAI-347 exhibited highest and significant positive heterosis over better parent, mid parent and over the standard check for 1000 grain weight, Days to 50% flowering, Plant height and No. of tillers per plant which poses a possibility of getting higher yield in future through their exploitation in breeding programme.

REFERENCES

Amarah, B., Ijaz, R.N., Muhammad, A. and Ali, H.S. 2013. Estimation of heterosis, heterobeltiosis and potence ratio over environments among pre and post Green Revolution Spring wheat in Pakistan. *J. Basic & Applied Sciences*, 9: 36-43.

Ashutosh, K., Mishra, V.K., Vyas, R.P. and Singh, V. 2011. Heterosis and combining ability analysis in bread wheat (Triticum aestivum L.). *J. Pl. Breeding and Crop Sc.,* 3(10): 209- 217.

Beche, E., da Silva, C.L., Pagliosa, E.S., Capelin, M.A., Franke, J., Matei, G. and Benin, G. 2013. Hybrid performance and heterosis in early segregant populations of Brazilian spring wheat. *Australian J. Crop Sc*., 7(1): 51-57.

Bedo, Z., Balla, L. and Abranyi, A. 1983. Inheritance of heading date in stem rust resistantwheat varieties, and disease escape. *Acta Agronomica Academiae Scientiarum Hungaricae.* 32: 284-288.

Borghi, B. and Perenzin, M. 1994. Diallel analysis to predict heterosis and combining ability for grain yield, yield components and breadmaking quality in bread wheat (Triticum aestivum). *Theoretical and Applied Genetics* (Germany). 89(7-8):975-981.

Budak, N. and Yildirim, M.B. 1996. Heterosis in bread wheat. *Turkish-Journal-of-Agriculture-and-Forestry (Turkey)*. 20(4): 345-347.

Chakraborty, S.K and Tewari, V. 1995. Heterosis in bread wheat. *Journal of Research, Birsa Agricultural University*, 7(2): 109-111.

Dagustu, N. 2008. Combining ability analysis in relation to heterosis for grain yield per spike and agronomic traits in bread wheat (Triticum aestivum L.). *Turkish J. Field Crops*, 13(2): 49-61.

Devi, E.L., Goel, S.P., Singh, M. and Jaiswal J.P. 2013. Heterosis studies for yield and yield contributing traits in bread wheat (*Triticum aestivum* L.) *The Bioscan* 8(3):905-909.

Gawande, V.L and Dhumale, D.B. 2002. Heterosis and combining ability studies in durum wheat. *J. Maharashtra Agricultural Universities*. 27(1): 96-97.

Gowda, M., Kling, C., Würschum, T., Liu, W., Maurer, H.P., Hahn,V. and Reif, J.C. 2010. Hybrid Breeding in Durum Wheat: Heterosis and Combining Ability. *Crop Sci.* 50: 2224-2230.

Muhammad, A., Javed, A., Hussain, M., Muhammad, M. I. and Waseem, S. 2010. Heterosis and heterobeltiosis for grain yield improvement in bread wheat. *J. Agric. Res.* 48(1): 15-23.

Nadarajan, N. and Gunasekaran, M., 2005. Quantitative Genetics and Biometrical Techniques in Plant Breeding. *Kalyani Publishers, New Delhi, India*. pp:100-108.

Palve, S.M., Thete, R.Y., Dumbre, A.D and Hapase, R.S. 1986. Heterosis in wheat Triticum aestivum L.) from line x tester analysis. *Current Research Reporter, Mahatma Phule Agricultural University,* 2(2): 179-183.

Panse and Sukhatme, 1961. Statistical methods for agricultural workers., I.C.A.R., New Delhi, pp:228-232.

Prasad, K.D., Haque, M.F. and Ganguly, D.K., 1998. Heterosis studies for yields and its components in bread wheat. *Indian J. Genet. Pl. Breed.* 58(1): 97-100.

Ribadia, K.H., Ponkia, H.P., Dobariya, K.L. and Jivani, L.L. 2007. Relationship between phenotypic and genetic diversity of parental genotypes and the specific combining ability and heterosis effects in wheat (Triticum aestivum L.). *Euphytica,* 165(3): 419-434.

Saini, D.D., Prakash, V. and Chaudhary, S.P.S. 2006. Combining ability and heterosis for seed yield and its components in durum wheat (Triticum durum Desf.) under late sown conditions. *Research on Crops*. 7(1): 159-164.

Sharma, I., Shoran, J., Singh, G. and Tyagi, B.S. 2011. Wheat Improvement in India. Souvenir of 50th All India Wheat and Barley Research workers' Meet, p. 11. New Delhi. Shull, G.F. 1908. The composition of a field of maize. *Rep. Am. Breed. Assoc.* 5: 51-59.

Yadav, S.P. and Murty, B.R. 1976. Heterosis and combining ability in crosses of different height categories in bread wheat. *Indian J. Genet. Pl. Breed*. 36(2): 184-196.

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