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HETEROSIS STUDIES 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. 36 F1 hybrids were derived from crosses between twelve female lines and three testers using line x tester analysis and these F_1s along with 15 parents and 2 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 UP 2596 X DBW 17 was recognized as the best heterotic cross for grain yield as it exhibited highly significant positive heterosis over both the standard checks UP 2554 and PBW 343. The cross HW 2019 x UP 2338 exhibited highest and significant positive heterosis over better parent, mid parent and over both the standard checks for number of grains per spike. 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.

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 12 lines and 3 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.

MATERIALS AND METHOD

Thirty six F_1s were obtained by crossing twelve lines *viz*. LFN/ II 58.57// PRL/3, MILAN/ KAUZ// PASTOR/3/ PASTOR, MILAN/ KAUZ//PRINIA/3/BABAX, WBLL*2/KKTS, PBW65/2*PASTOR, STAR//PVN/STAR /3/WH542/4/MILAN/ KAUZ, HW 2019 , HD 2834, UP 2596, PBW343*2/ KAKUN, UP 2774, UP 2762 (female parent) with three testers i.e., UP 2572, DBW 17, UP 2338 (male parents). The fifteen parents (male and female) and their resultant 36 F_1s were grown in a randomized block design with three replications during *rabi* 2010-11 at Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. Each replication consisted of 53 treatments consisting of 12 lines, 3 testers, 36 crosses and 2 commercial check varieties (UP 2554 and PBW 343). 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 eight characters viz., days to 75% heading, plant height, spike length, number of spikelets per spike, days to maturity, number of grains per spike, 1000 grain weight 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:

$$\text{Relative heterosis} \quad \frac{\overline{F}_1 \quad \overline{MP}}{\overline{MP}} \quad 100$$

$$\text{Heterobeltiosis} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis} = \frac{\overline{F}_1 - \overline{CP}}{\overline{CP}} \times 100$$

Where,

$\overline{F}_1$ = Mean performance of F_1 hybrid

$\overline{P}_1$ = Mean performance of parent one

$\overline{P}_2$ = Mean performance of parent two

$\overline{BP}$ = Mean performance of better parent

$\overline{CP}$ = Mean performance of check parent

$\overline{MP}$ = Mean mid-parental value i.e. $(P_1 + P_2)/2$

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 indicating that parents possess good amount of genetic variability (Table 1). The variance due to hybrids was also significant for all the characters studied except days to maturity 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 degree of heterosis however differed for different characters of thirty six crosses studied.

Heterobeltiosis for days to 75% heading ranged from -4.068% (UP 2596 × UP 2572) to 2.867% (PBW 65/2* PASTOR × UP 2572). The cross UP 2596 × UP 2572 emerged as a better cross than others with a negative heterosis of -4.068%, 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. Relative heterosis ranged from -4.068% (UP 2596×UP 2572) to 1.056% (PBW 65/ 2*PASTOR × UP 2572). Highest negative standard heterosis was exhibited by HD 2834 × UP 2338 which showed earliness over the standard check PBW 343. The importance of negative heterosis for days to 75% heading 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).

Two crosses viz. STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ × DBW 17 (-10.778%) and HD 2834 × UP 2572 (-7.583%) showed significant negative heterobeltiosis for plant height. The heterobeltiosis for this character ranged from -10.778% (STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ × DBW 17) to 26.738% (HW 2019 × UP 2572). The relative heterosis ranged from -10.972% (UP 2596 × UP 2338) to 19.241% (HW 2019 × UP 2572). The highest negative standard heterosis over both the standard checks viz., UP 2554 and PBW 343 was recorded in the cross HD 2834 X DBW 17 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 UP 2774 x UP 2572 showed the highest positive heterosis over both the better parent and mid parent. For standard heterosis, the best cross combination was MILAN/KAUZ//PRINIA/3/ BABAX × UP 2572 which exhibited the highly significant positive heterosis over both the standard checks viz., UP 2554 and PBW 343. 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 spikelets per spike in terms of heterobeltiosis and relative heterosis was recorded in the cross PBW 65/2* PASTOR × DBW 17. However, none of the

Table 1 : Analysis of variance for different characters

Characters	Mean squares	Source of variation	
d.f	Replication 2	Treatment 50	Error 100
Days to 75% heading	66.79	6.38**	3.29
Plant height (cm)	83.87	78.84**	19.14
Spike length (cm)	0.28	3.28**	0.45
No. of spikelets per spike	3.75	1.71**	0.52
Days to maturity	4.88	4.79*	3.07
Total no. of grains per spike	3.65	175.30**	1.36
1000 grain weight (g)	8.59	69.72**	0.78
Grain yield per plant	2.00	45.88**	3.35

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

Table 2: Estimation of heterosis for different characters studied

Crosses	Days to 75% heading				Days to maturity				Plant height				Spike length (cm)			
	Hetero-beltiosis	Mid parent heterosis	Standard heterosis UP2554	Standard heterosis PBW 343	Hetero-beltiosis	Mid parent heterosis	Standard heterosis UP2554	Standard heterosis PBW 343	Hetero-beltiosis	Mid Parent heterosis	Standard Heterosis UP2554	Standard Heterosis PBW 343	Hetero-beltiosis	Mid parent heterosis	Standard heterosis UP2554	Standard heterosis PBW 343
LFN/ II 58.57// PRL/ 3 X DBW 17	1.356	0.504	3.819*	2.013	-0.711	-1.063	-0.238	-0.734	-0.400	-1.795	-0.007	7.794	-7.515	-5.889	-8.618	-7.107
LFN/ II 58.57// PRL/ 3 X UP 2572	0.000	-2.041	0.000	-1.740	-1.663	-2.128*	-1.429	-1.919	10.047*	5.094	0.965	8.842*	-0.057	5.235	-4.661	-3.085
LFN/ II 58.57// PRL/ 3 X UP 2338	1.384	-0.509	1.736	-0.034	-1.655	-1.887*	-0.952	-1.445	3.553	-0.147	3.962	12.072**	-2.746	-0.138	-2.114	-0.496
MILAN/ KAUZ// PASTOR/ 3/ PASTOR X DBW 17	-2.062	-2.730*	-1.042	-2.764	-2.138*	-2.254*	-1.905	-2.393*	-1.218	-2.684	-0.994	6.730	-1.700	1.243	-2.873	-1.267
MILAN/ KAUZ// PASTOR/ 3/ PASTOR X UP 2572	0.000	-0.518	0.000	-1.740	-1.425	-1.425	-1.190	-1.682	12.366**	7.402*	3.092	11.135**	9.959*	14.424**	2.331	4.022
MILAN/ KAUZ// PASTOR/ 3/ PASTOR X UP 2338	1.038	0.690	1.389	-0.375	-1.188	-1.422	-0.952	-1.445	0.934	-2.758	1.162	9.054*	-0.269	3.637	0.379	2.039
MILAN/ KAUZ// PRINIA/ 3/ BABAX X UP 2338	0.339	0.339	2.778	0.989	-1.190	-1.425	-1.190	-1.682	9.988*	5.325	4.320	12.459**	6.693	11.686**	15.772**	17.686**
MILAN/ KAUZ// PRINIA/ 3/ BABAX X DBW 17	0.347	-0.858	0.347	-1.399	0.714	0.595	0.714	0.213	4.908	3.165	-3.750	3.759	-1.099	10.460**	7.317	9.091*
MILAN/ KAUZ// PRINIA/ 3/ BABAX X UP 2572	-0.346	-1.370	0.000	-1.740	-0.952	-1.305	-0.952	-1.445	6.042	-0.754	0.577	8.424*	14.186**	18.476**	23.902**	25.950**
WBLL*2/ KKTS X UP 2572	-2.397	-2.896*	-1.042	-2.764	0.239	-0.119	0.000	-0.498	3.352	1.307	2.566	10.567*	12.139**	13.566**	13.659**	15.537**
WBLL*2/ KKTS X DBW 17	0.000	-0.690	0.000	-1.740	0.477	0.238	0.238	-0.261	13.704**	9.243*	4.320	12.459**	-2.299	5.821	-0.976	0.661
WBLL*2/ KKTS X UP 2338	0.692	0.172	1.042	-0.716	-0.239	-0.713	-0.476	-0.971	-4.316	-8.289*	-5.044	2.364	2.674	3.032	4.065	5.785
PBW 65/ 2* PASTOR X UP2338	1.075	-1.742	-2.083	-3.787*	0.481	-0.239	-0.476	-0.971	8.472*	3.066	1.360	9.267*	5.321	11.758**	4.065	5.785
PBW 65/ 2* PASTOR X DBW 17	2.151	0.529	-1.042	-2.764	0.962	0.358	0.000	-0.498	4.119	3.166	-4.474	2.979	11.035*	12.078**	-2.927	-1.322
PBW 65/ 2* PASTOR X UP2572	2.867	1.056	-0.347	-2.081	1.923	1.073	0.952	0.450	8.339*	0.592	1.235	9.133*	-5.627	1.009	-5.014	-3.444
STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ X UP 2572	-0.344	-1.024	0.694	-1.058	1.185	1.065	1.667	1.161	0.271	-1.462	0.007	7.809	15.963**	16.667**	14.580**	16.474**
STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ X UP 2338	0.347	-0.173	0.347	-1.399	1.425	1.185	1.667	1.161	19.305**	14.327**	9.459*	17.998**	9.162*	16.194**	6.558	8.320
STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ X DBW 17	-1.384	-1.724	-1.042	-2.764	-1.418	-1.418	-0.714	-1.208	-10.778**	-7.297*	-3.787	3.719	0.700	2.242	1.355	3.030
HD 2834 X UP 2572	-2.740	-3.237	-1.389	-3.105*	-0.237	-0.941	0.238	-0.261	-7.583*	-9.586**	-4.583	2.861	-0.200	4.496	8.347	10.138*
HD 2834 X DBW 17	-1.389	-2.069	-1.389	-3.105*	-1.663	-2.473**	-1.429	-1.919	-0.327	-8.355*	-8.553	-1.418	-9.685*	0.892	-1.951	-0.331
HD 2834 X UP 2338	-3.114	-3.614**	-2.778	-4.469**	-0.946	-1.528	-0.238	-0.734	-4.149	-4.156	3.348	11.411**	1.997	5.855	10.732*	12.562**
HW 2019 X DBW 17	0.000	-1.027	0.347	-1.399	-1.659	-1.891*	-1.190	-1.682	16.898**	3.138	-4.730	2.703	-4.114	8.202	-5.257	-3.691
HW 2019 X UP 2572	0.000	-0.173	0.000	-1.740	-0.238	-0.592	0.000	-0.498	26.738**	19.241**	3.289	11.348**	8.907	15.279**	-6.558	-5.014
HW 2019 X UP 2338	-2.422	-2.422	-2.083	-3.787*	-0.946	-1.063	-0.238	-0.734	17.759**	1.378	-4.028	3.459	-6.247	6.646	-5.637	-4.077
UP 2596 X UP 2572	-4.068**	-4.068**	-1.736	-3.446*	-0.474	-0.474	0.000	-0.498	4.468	-3.350	7.858*	16.273**	8.886	11.926**	7.588	9.366*
UP 2596 X DBW 17	-1.389	-2.573	-1.389	-3.105*	-0.713	-0.830	-0.476	-0.971	10.453*	-4.261	1.338	9.243*	6.845	11.400**	-0.163	1.488
UP 2596 X UP 2338	-0.692	-1.712	-0.347	-2.081	-0.711	-0.828	-0.238	-0.734	-5.972	-10.972**	1.396	9.307*	-7.162	-3.714	-6.558	-5.014
PBW 343*2/ KAKUN X UP 2338	-0.692	-1.712	-0.347	-2.081	-1.659	-1.775*	-1.190	-1.682	-4.091	-5.423	-3.692	3.822	-3.620	-1.098	-4.770	-3.196
PBW 343*2/ KAKUN X UP 2572	-1.042	-1.213	-1.042	-2.764	-1.663	-1.896*	-1.429	-1.919	6.247	1.453	-2.522	5.083	8.844	13.673**	2.060	3.747
PBW 343*2/ KAKUN X DBW 17	-0.346	-0.346	0.000	-1.740	-0.473	-0.473	0.238	-0.261	-1.492	-5.002	-1.082	6.635	-5.654	-2.314	-5.041	-3.471
UP 2774 X UP 2338	1.413	-0.692	-0.347	-2.081	1.439	0.834	0.714	0.213	0.573	0.328	3.838	11.939**	-0.165	2.018	-1.355	0.275
UP 2774 X UP 2572	1.413	0.525	-0.347	-2.081	1.439	0.955	0.714	0.213	11.760**	4.898	2.537	10.536*	18.567**	24.339**	12.141**	13.994**
UP 2774 X DBW 17	1.413	0.350	-0.347	-2.081	0.719	0.000	0.000	-0.498	0.747	-1.199	4.525	12.679**	-7.539	-4.664	-6.938	-5.399
UP 2762 X UP 2338	1.049	-0.516	0.347	-1.399	1.928	1.075	0.714	0.213	3.579	0.463	0.694	8.550*	3.236	3.863	2.005	3.691
UP 2762 X UP 2572	1.049	0.697	0.347	-1.399	2.410*	1.675	1.190	0.687	10.453*	7.257*	1.338	9.243*	17.324**	24.882**	14.526**	16.419**
UP 2762 X DBW 17	1.399	0.870	0.694	-1.058	0.482	-0.477	-0.714	-1.208	-2.203	-7.269*	-4.927	2.490	-0.539	0.984	0.108	1.763

* and ** Significant at 5% and 1%, respectively

crosses showed significant positive standard heterosis. Positive heterosis for this character has been highlighted by Prasad *et al*. (1998), Ribadia (2007), Dagustu (2008) and Muhammad *et al*. (2010).

The promising cross MILAN/KAUZ//PASTOR/3/PASTOR X DBW 17 was recorded to have the highest negative estimates of better parent heterosis and standard heterosis over check PBW 343 for days to maturity, while highest negative estimate of relative heterosis was exhibited by the crosses HD 2834×UP 2338, but none of the crosses exhibited significant negative heterosis over check UP 2554. 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.

The cross HW 2019 × UP 2338 showed superiority over better parent, mid parent and over both the checks for number of grains per spike. Thus, this particular cross can be exploited for improvement in yield. Reports on significant positive heterosis for number of grains per spike have presented 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).

Positive heterosis is favoured in case of 1000-grain weight, as it has a direct bearing on yield. In the present study, the cross PBW 65/2*PASTOR × UP 2338 exhibited the highest magnitude of positive heterosis over both the better parent and the mid parent, while the cross STAR//PVN/STAR/3/WH542/4/MILAN/KAUZ × UP 2338 exhibited highest positive standard heterosis over both the standard checks. 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 UP 2774 × UP 2338 showed the highest significant positive heterosis over both better parent and mid parent, while the cross UP 2596 × DBW 17 exhibited the highest significant positive standard heterosis over both the checks. 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),

Table 2: Cont.....

Crosses	No. of spikelets per spike				1000 grain weight				No. of grains per spike				Grain yield per plant			
	Hetero-beltiosis	Mid parent heterosis	Standard heterosis UP2554	PBW 343	Hetero-beltiosis	Mid parent heterosis	Standard heterosis UP2554	PBW 343	Hetero-beltiosis	Mid Parent heterosis	Standard Heterosis UP2554	PBW 343	Hetero-beltiosis	Mid parent heterosis	Standard heterosis UP2554	PBW 343
LFN/ II 58.57// PRL/ 3 X DBW 17	-0.669	1.712	-1.493	-2.463	10.645**	20.450**	-13.131**	0.089	-17.892**	-4.950**	0.339	-6.477**	12.129	24.285**	9.017	20.543**
LFN/ II 58.57// PRL/ 3 X UP 2572	-2.676	1.394	-3.483	-4.433	6.650**	13.582**	-4.626**	9.887**	-16.320**	-11.621**	2.260	-4.687**	-14.660**	1.608	-1.819	8.561
LFN/ II 58.57// PRL/ 3 X UP 2338	-2.007	0.342	-2.819	-3.777	-15.042**	-4.765**	-14.941**	-1.997	-19.279**	-0.739	-1.356	-8.057**	-22.513**	-6.508	-7.849	1.894
MILAN/ KAUZ// PASTOR/ 3/ PASTOR X DBW 17	-2.606	1.014	-0.829	-1.806	-3.418*	13.999**	-8.581**	5.330**	14.730**	19.280**	10.452**	2.949	-20.155**	-9.137*	2.483	13.319*
MILAN/ KAUZ// PASTOR/ 3/ PASTOR X UP 2572	-3.583	1.718	-1.824	-2.791	-18.309**	-15.990**	-22.676**	-10.910**	-0.052	6.241**	9.153**	1.738	-23.135**	-18.933**	-1.341	9.090
MILAN/ KAUZ// PASTOR/ 3/ PASTOR X UP 2338	-6.515*	-3.041	-4.809	-5.747	-11.147**	-8.654**	-11.041**	2.496	9.566**	22.066**	5.480**	-1.685	-37.124**	-34.726**	-19.296**	-10.764
MILAN/ KAUZ// PRINIA/ 3/ BABAX X UP 2338	-3.884	0.000	-1.493	-2.463	-8.050**	12.499**	-4.773**	9.718**	17.279**	26.795**	22.712**	14.376**	-4.207	1.074	-6.866	2.981
MILAN/ KAUZ// PRINIA/ 3/ BABAX X DBW 17	-1.294	4.452	1.161	0.164	-9.811**	-3.205*	-6.597**	7.617**	-12.209**	-10.330**	-4.124*	-10.637**	-10.874*	1.465	2.537	13.377*
MILAN/ KAUZ// PRINIA/ 3/ BABAX X UP 2572	-0.324	3.704	2.156	1.149	-5.762**	-4.169**	-2.404	12.448**	-8.639**	5.519**	-4.407**	-10.900**	-8.800	5.306	8.459	
19.927**WBLL*2/ KKTS X UP 2572	-8.723**	-3.300	-2.819	-3.777	21.262**	37.969**	5.178**	21.184**	7.803**	22.959**	27.232**	18.589**	-32.258**	-23.860**	-15.498*	-6.564
WBLL*2/ KKTS X DBW 17	-6.854*	0.336	-0.829	-1.806	-1.102	0.409	-11.558**	1.900	-16.180**	-12.929**	-1.073	-7.794**	-18.013**	-14.699**	2.271	13.084*
WBLL*2/ KKTS X UP 2338	-8.100**	-2.640	-2.156	-3.120	-2.289	4.708**	-2.173	12.713**	-13.499**	4.936**	2.090	-4.845**	-24.359**	-22.553**	-5.644	4.332
PBW 65/ 2* PASTOR X UP2338	-2.105	1.455	-7.463*	-8.374**	46.690**	47.427**	-2.607	12.214**	17.702**	26.201**	20.960**	12.744**	-9.020	-8.909	-11.328	-1.953
PBW 65/ 2* PASTOR X DBW 17	9.091**	11.111**	-0.498	-1.478	4.329*	19.751**	-6.702**	7.496**	-9.674**	-6.930**	-1.356	-8.057**	-31.871**	-26.234**	-21.620**	-13.333*
PBW 65/ 2* PASTOR X UP2572	-2.105	1.455	-7.463*	-8.374**	-5.347**	13.824**	-5.234**	9.187**	-16.163**	-3.907*	-13.842**	-19.695**	-38.157**	-32.024**	-26.454**	-18.678**
STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ X UP 2572	-5.607*	0.000	0.498	-0.493	9.960**	22.360**	-9.350**	4.444*	-12.110**	-3.316*	-4.463**	-10.953**	-17.308**	-15.838**	-16.693**	-7.885
STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ X UP 2338	-3.115	4.362	3.151	2.135	27.460**	32.642**	13.983**	31.328**	-14.382**	-14.182**	-6.497**	-12.849**	-13.506*	-7.773	-0.491	10.029
STAR// PVN/ STAR/3 /WH542/ 4/ MILAN/ KAUZ X DBW 17	-12.461**	-7.261**	-6.799*	-7.718**	-18.259**	-10.343**	-18.162**	-5.709**	9.979**	29.064**	19.548**	11.427**	-0.101	8.168	18.805**	31.366**
HD 2834 X UP 2572	-1.024	0.346	-3.814	-4.762	22.312**	31.261**	-6.911**	7.254**	-8.981**	6.656**	14.520**	6.740**	11.870	13.206*	11.394	23.172**
HD 2834 X DBW 17	2.730	5.986*	-0.166	-1.149	-2.743	5.083**	-13.026**	0.209	-3.143*	3.702**	21.864**	13.586**	-9.696	-3.187	3.891	14.875*
HD 2834 X UP 2338	-0.683	0.692	-3.483	-4.433	-6.791**	5.908**	-6.681**	7.520**	-8.711**	13.512**	14.859**	7.056**	-22.881**	-16.052**	-8.287	1.410
HW 2019 X DBW 17	-4.651	-2.048	-4.809	-5.747	7.942**	18.911**	-12.998**	0.242	26.112**	26.959**	12.147**	4.529**	2.950	9.997	0.093	10.675
HW 2019 X UP 2572	-6.312*	-2.083	-6.468*	-7.389*	-0.297	4.879**	-10.839**	2.729	2.069	13.196**	11.469**	3.897*	-24.887**	-13.505*	-13.586*	-4.449
HW 2019 X UP 2338	-5.316	-2.730	-5.473	-6.404*	-13.450**	-4.103**	-13.347**	-0.161	49.066**	59.216**	30.791**	21.906**	-19.564**	-6.076	-4.343	5.771
UP 2596 X UP 2572	3.136	3.497	-1.824	-2.791	11.045**	22.762**	-9.790**	3.937*	-5.019**	-4.928**	-15.537**	-21.274**	3.598	6.010	5.525	16.681*
UP 2596 X DBW 17	1.742	3.915	-3.151	-4.105	3.993*	8.984**	-7.002**	7.150**	-3.259*	6.735**	5.650**	-1.527	17.200**	24.325**	34.834**	49.090**
UP 2596 X UP 2338	1.394	1.748	-3.483	-4.433	3.120*	13.856**	3.242*	18.953**	5.347**	13.124**	-6.497**	-12.849**	-28.118**	-22.562**	-14.515*	-5.477
PBW 343*2/ KAKUN X UP 2338	-1.993	0.683	-2.156	-3.120	9.957**	27.989**	0.629	15.942**	-30.489**	-18.201**	-11.638**	-17.641**	20.476**	27.189**	30.956**	44.802**
PBW 343*2/ KAKUN X UP 2572	-1.329	3.125	-1.493	-2.463	19.838**	21.222**	9.672**	26.361**	-8.667**	-1.745	16.102**	8.215**	-10.297*	-7.752	3.201	14.112*
PBW 343*2/ KAKUN X DBW 17	-5.316	-2.730	-5.473	-6.404*	5.430**	10.163**	5.556**	21.618**	-20.889**	-1.248	0.565	-6.266**	-14.618**	-10.782*	1.540	12.276
UP 2774 X UP 2338	-3.425	-2.253	-6.468*	-7.389*	18.167**	30.388**	-4.410**	10.137**	13.675**	20.561**	14.124**	6.372**	28.466**	35.460**	24.900**	38.106**
UP 2774 X UP 2572	1.027	4.056	-2.156	-3.120	8.330**	13.757**	-3.124*	11.618**	-3.001*	1.078	5.932**	-1.264	16.680**	32.755**	34.236**	48.429**
UP 2774 X DBW 17	-0.685	0.520	-3.814	-4.762	3.623*	14.628**	3.746*	19.533**	3.770*	17.752**	4.181*	-2.896	-16.683**	-3.853	-0.916	9.559
UP 2762 X UP 2338	-5.016	0.331	0.498	-0.493	15.406**	36.252**	9.301**	25.934**	-25.135**	-12.322**	-5.932**	-12.322**	25.543**	33.270**	22.058**	34.963**
UP 2762 X UP 2572	-2.508	4.714	3.151	2.135	-7.113**	-4.448**	-12.027**	1.361	-4.856**	1.804	19.548**	11.427**	11.186*	27.281**	27.915**	41.439**
UP 2762 X DBW 17	-8.150**	-2.980	-2.819	-3.777	3.588*	6.463**	3.711*	19.493**	-18.840**	0.866	1.977	-4.950**	-26.153**	-14.267**	-12.178*	-2.893

* and ** Significant at 5% and 1%, respectively

Table 3 : Promising heterotic crosses for various characters

Character	Heterobeltosis	Relative heterosis	Standard heterosis CHECK UP 2554	CHECK PBW 343
Days to 75% heading	UP 2596 X UP 2572 (-4.068)	HD 2834 X UP 2338 (-3.614)	-	HD 2834 X UP 2338 (-4.469)
Days to maturity	MILAN/KAUZ//PASTOR/3/PASTOR × DBW 17 (-2.138)	HD 2834 X DBW 17 (-2.473)	-	MILAN/KAUZ//PASTOR/3/ PASTOR X DBW 17 (-2.393)
Plant height	STAR//PVN/STAR/3/WH542/4/MILAN/ KAUZ X DBW 17 (-10.778)	UP 2596 X UP 2338 (-10.972)	HD 2834 X DBW 17 (-8.553)	HD 2834 X DBW 17 (-1.418)
Spike length	UP 2774 X UP 2572 (18.567)	UP 2762 X UP 2572 (24.882)	MILAN/KAUZ//PRINIA/3/ BABAX X UP 2572 (23.902)	MILAN/KAUZ//PRINIA/3/ BABAX X UP 2572 (25.950)
Number of spikelets per spike	PBW 65/2* PASTOR X DBW 17 (9.091)	PBW 65/2* PASTOR X DBW 17 (11.111)	-	-
1000 grain weight	PBW 65/2* PASTOR X UP 2338 (46.690)	PBW 65/2* PASTOR X UP 2338 (47.427)	STAR//PVN/STAR/3/WH542/ 4/MILAN/KAUZ X UP 2338 (13.983)	STAR//PVN/STAR/ 3/WH542/4/MILAN/KAUZ × UP 2338 (31.328)
Number of grains per spike	HW 2019 X UP 2338 (49.066)	HW 2019 X UP 2338 (59.216)	HW 2019 X UP 2338 (30.791)	HW 2019 X UP 2338 (21.906)
Grain yield per plant	UP 2774 X UP 2338 (28.466)	UP 2774 X UP 2338 (35.460)	UP 2596 X DBW 17 (34.834)	UP 2596 X DBW 17 (49.090)

Dagustu (2008), Muhammad *et al*. (2010), Ashutosh *et al*. (2011) and Amarah *et al*. (2013).

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 UP 2596 X DBW 17 was recognized as the best heterotic cross for grain yield and it exhibited highly significant positive heterosis over both the standard checks UP 2554 and PBW 343 (Table 3). Therefore, this cross can be further evaluated and used in hybrid breeding programme to boost up the grain yield. Moreover, the cross HW 2019 x UP 2338 exhibited highest and significant positive heterosis over better parent, mid parent and over both the standard checks for number of grains per spike which poses a possibility of getting higher yield in future through their exploitation in breeding programme.

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