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Assessment of heterosis for grain yield and its component traits in bread wheat (*Triticum aestivum* L.)

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Abstract
The experiment carried out at Agriculture research farm, Lovely Professional University, Phagwara, Punjab. Heterosis for yield and its component traits were studied in 9 genotypes and their 36 F1`s in wheat (*Triticum aestivum* L.). The magnitude of heterotic effects was high for number of effective tillers per plant, number of spikelets per spike and Days to maturity; moderate for number of grains per spike, Days to 50% heading, harvest index, chlorophyll content, grain yield per plant and spike length; and low for biological yield per plant, plant height and protein content. The highest, positive and significant heterobeltiosis for grain yield per plant and some of its component traits were recorded in the crosses, IC 78749 X IC 532889, IC 78801 X IC 78737, IC 78749 X IC 138866, IC 66520 X IC 78801, IC 78751 X IC 55681, IC 78749 X IC 78737, and IC 55681 X IC 78737.

Keywords: Heterobeltiosis, standard heterosis, yield, wheat

Introduction
Wheat (*Triticum aestivum* L.) is the first important and staple cereal crop for the majority of the world's population. It has been described as the 'king of cereals' because of the acreage occupied and production compared to every other grain crop (Verma *et al*., 2019) [16]. Wheat is a self-pollinated crop belonging to tribe *Triticeae* of the grass family *Poaceae*. It is a Hexaploid wheat having 42 chromosomes with six groups of seven chromosomes each 2n=6x=42 (Choudhary *et al*., 2022) [10]. Wheat is the second most important staple food crop next to rice, consumed by nearly 35% of the world population and providing 20% of the total food calories (Askander *et al*., 2021) [7]. It is widely cultivated as a food crop of the world, known for its remarkable adoption to a wide range of environments and its role in world economy is well known. Wheat occupies about 32% of the total acreage under cereals in the world (Almutairi, 2022) [11]. The main wheat growing countries include China, India, U.S.A., Russia, France, Canada, Germany, Turkey, Australia and Ukraine. In India, wheat is mainly grown in the states of Uttar Pradesh, Madhya Pradesh, Punjab, Rajasthan, Haryana, Bihar, Maharashtra, Karnataka and Gujarat. India accounts an area of 31.27 million hectares and production of 93.50 million tonnes with a productivity of 3093 kg/ha. In Punjab, wheat is grown on 35 lakh ha area with total production of 164.72 lakh tonnes and a productivity of 2990 kg/ha (Anonymous, 2020-21) [2]. The present study assisted in exploring superior combinations that might be used for commercial hybrid seed production. Commercial use of heterosis is hindered in bread wheat due to practical difficulties of producing hybrid seed. Understanding the expression levels of heterosis will aid in selecting superior hybrid combinations and will help in selecting potential genotypes (Choudhary *et al*., 2022) [10]. Identification of superior parents is the foremost thing for an efficient and effective breeding programme (Kumar *et al*., 2020) [9]. Diallel cross analysis is an effective technique for selecting hybrid pairings with greatest potential for development and identifying superior lines in early generations (Amin *et al*.,2022; Choudhary *et al*., 2022) [1, 10].

Materials and Methods
The present investigation was carried out during *Rabi* season 2017-18 and 2018-19 under Department of Genetics and Plant Breeding, School of Agriculture at the Genetics & Breeding farm of Lovely Professional University, Phagwara, Punjab. The experimental material comprised of nine different genotypes of bread wheat *viz*., IC 78751, IC 532116, IC 66520, IC 78749, IC 138866, IC 78801, IC 55681, IC 78737, IC 532889. During *rabi* season 2017-18, these nine wheat genotypes were crossed in a half-diallel mating design excluding the reciprocals and 36 F1`s were obtained.

During the *rabi* season 2018-19, seeds of 36 F1 hybrids were sown along with 9 parents and one standard check in randomized block design maintaining optimum row to row spacing at plant breeding research farm, Lovely Professional University. The genotypes were diverse with respect to different morphological and quantitative characters. The characters include days to 50% flowering, plant height, days to maturity, number of effective tillers per plant, spike length, number of spikelets per spike, number of grains per spike, 1000 seed weight, grain yield per plant, biological yield per plant, harvest index, chlorophyll content and protein content of wheat and data was recorded whole plot basis. Data from five plants were averaged replication wise for each character and the mean value is subjected to statistical analysis. All the genotypes were taken from National Bureau of Plant Genetic Resources (NBPGR), New Delhi.

Results and Discussion

Estimation of heterobeltiosis and standard heterosis

The exploitation of heterosis in crop plants is one of the major breakthroughs in plant breeding. The relative heterosis, heterobeltiosis and standard heterosis were estimated for all the characters under study. The heterobeltiosis estimated over the better parent and standard heterosis obtained over the commercial check variety JWS-17. Salient features of the results for each of the character are presented as follows.

For days to 50% flowering, two crosses showed negative and significant heterobeltiosis. Highest significant negative heterobeltiosis was present in IC 78749 X IC 532889 (-10.86). Thirty crosses showed negative and significant standard heterosis. The magnitude of standard heterosis was highest in IC 78749 X IC 532889 (-23.66). Significant negative heterosis was found in two crosses for the trait plant height. The cross IC 78801 X IC 532889 (-20.55) showed highest significant negative heterobeltiosis for plant height. A total of 24 crosses showed significant positive standard heterosis for plant height whereas none of the crosses showed significant negative standard heterosis. Similar findings are observed in Kumar *et al.*, (2020) [9], Kaur *et al.*, (2020) [8], Kalhoro *et al.*, (2017) [6], Jaiswal *et al.*, (2018) [14].

Out of 36 crosses, for days to maturity, a total of 22 crosses showed significant and positive heterosis over better parent while none of the crosses showed significant negative heterobeltiosis and 10 crosses showed significant and negative standard heterosis. The highest magnitude of standard heterosis was found in IC 55681 X IC 532889 (-8.06). Similar findings observed by Bajaniya *et al.*, (2019) [4] Tomar *et al.*, (2020) [13], Kaur *et al.*, (2020) [8].

For number of effective tillers per plant, a number of 14 and 10 crosses showed significant and positive heterosis over better parent and standard heterosis respectively. Highest magnitude of positive heterosis was present in IC 78749 X IC 138866 (124.67). The highest significant and positive standard heterosis was present in IC 78751 X IC 78737 (47.85). Similar findings observed in (Bajaniya *et al.*, (2019) [4], Tomar *et al.*, (2020) [13], Choudhary *et al.*, (2022) [10].

Regarding the trait spike length, 20 crosses showed significant positive heterobeltiosis. Highest magnitude of heterobeltiosis was observed in IC 66520 X IC 78801 (86.11) whereas 18 crosses showed significant positive standard heterosis. Highest magnitude of positive standard heterosis was recorded in IC 138866 X IC 532889 (52.39). Similar findings observed in Yazici *et al.*, (2022) [5], Kaur *et al.*, (2020) [8], Choudhary *et al.*, (2022) [10], Kumar *et al.*, (2020) [9].

A number of 20 and 28 crosses showed significant positive heterobeltiosis and standard heterosis respectively for the character number of spikelets per spike. The cross IC 78751 X IC 55681 showed highest positive significance for heterobeltiosis (104.65) and standard heterosis (100.05). Similar observations were recorded by Kumar *et al.*, (2018) [3], Tomar *et al.*, (2020) [13], Kaur *et al.*, (2020) [8].

In the case of number of grains per spike, 21 crosses showed significant positive heterobeltiosis. The cross in IC 532116 X IC 55681 (50.38) showed significant positive standard heterobeltiosis. For standard heterosis, 26 crosses showed positive heterosis and highest standard heterosis was shown by IC 532116 X IC 55681 (75.22). Similar findings observed in Kumar *et al.*, (2020) [9], Patel *et al.*, (2018) [12], Choudhary *et al.*, (2022) [10], Kaur *et al.*, (2020) [8].

Only 3 crosses showed significant positive heterobeltiosis whereas 20 crosses showed significant negative heterosis for 1000 seed weight. Highest significant positive heterobeltiosis was present in IC 78749 X IC 55681 (28.32). Similar findings observed in Patel *et al.*, (2018) [12], Choudhary *et al.*, (2022) [10], Jaiswal *et al.*, (2018) [14], Tomar *et al.*, (2020) [13].

For Grain yield per plant, 10 crosses showed significant positive heterobeltiosis. Highest significant positive heterobeltiosis was recorded in IC 55681 X IC 78737 (53.35). The same cross recorded highest significant positive heterosis (17.13). Only three crosses showed positive standard heterosis for grain yield per plant. Similar findings were observed in Bajaniya *et al.*, (2019) [4], Yazici *et al.*, (2022) [5], Kumar *et al.*, (2020) [9].

Regarding biological yield per plant, 20 crosses showed significant positive heterobeltiosis whereas only one cross showed positive standard heterosis. Highest significant positive heterobeltiosis was recorded in IC 55681 X IC 78737 (59.47) and highest significant positive heterosis was recorded in IC 66520 X IC 138866 (8.26). For the trait harvest index, only one cross showed significant positive heterobeltiosis. Highest significant positive heterobeltiosis was recorded in IC 78749 X IC 78737 (12.11). For the same trait, 24 crosses showed significant positive heterosis. Highest significant positive heterosis was recorded in IC 78749 X IC 78737 (60.30). Similar findings were reported by Kumar *et al.*, (2020) [9], Choudhary *et al.*, (2022) [10], Kumar *et al.*, (2018) [3].

For chlorophyll content of wheat, 17 crosses showed significant positive heterobeltiosis and 21 crosses showed significant positive standard heterosis. Highest significant positive heterobeltiosis (38.54) and standard heterosis (35.58) was recorded in IC 66520 X IC 78749. Similar observations were recorded by Sharma *et al.*, (2020) [15].

Regarding the estimation of protein content in wheat, 7 crosses showed significant positive heterobeltiosis whereas 19 crosses showed significant positive standard heterosis. Highest significant positive heterobeltiosis was recorded in IC 78751 X IC 532889 (22.54) and Highest significant positive standard heterosis was present in IC 78749 X IC 78801 (18.00). Similar findings were observed by Kumar *et al.*, (2018) [3], Sharma *et al.*, (2020) [15].

Table 1: Heterobeltiosis and Standard heterosis values for days to 50% flowering, plant height, days to maturity, effective tillers

S. No	Crosses	Days to 50% flowering		Plant Height		Days to maturity		Effective tillers	
		BP	SH	BP	SH	BP	SH	BP	SH
1	IC 78751 X IC 532116	20.63 **	-2.82	33.12 **	25.74 **	12.89 **	3.05	-4.94	-28.05 **
2	IC 78751 X IC 66520	3.56	-18.03 **	26.38 **	19.37 *	5.25 **	-3.92 *	-19.04 **	-14.85 **
3	IC 78751 X IC 78749	0.35	-19.15 **	33.23 **	25.84 **	1.67	-7.19 **	123.32 **	19.69 **
4	IC 78751 X IC 138866	16.90 **	-6.48 **	18.17	11.62	9.79 **	0.22	28.00 **	-36.63 **
5	IC 78751 X IC 78801	0.73	-22.25 **	35.43 **	27.92 **	3.58	-5.45 **	18.52 **	-1.43
6	IC 78751 X IC 55681	23.74 **	-3.1	1.68	-3.96	10.98 **	1.31	120.00 **	40.37 **
7	IC 78751 X IC 78737	-1.75	-20.85 **	58.84 **	50.03 **	2.15	-6.75 **	72.31 **	47.85 **
8	IC 78751 X IC 532889	11.89 **	-9.86 **	43.33 **	35.38 **	8.11 **	-1.31	-1.75	-26.07 **
9	IC 532116 X IC 66520	1.78	-19.44 **	52.06 **	45.94 **	2.29	-2.61	-20.50 **	-16.39 **
10	IC 532116 X IC 78749	0	-14.37 **	43.05 **	37.29 **	2.5	-1.74	-1.74	-25.63 **
11	IC 532116 X IC 138866	0	-20.00 **	48.83 **	42.84 **	5.65 **	-2.18	36.05 **	2.97
12	IC 532116 X IC 78801	22.63 **	-5.35 *	18.12	13.37	1.83	-3.27	-5.29	-21.23 **
13	IC 532116 X IC 55681	13.67 **	-10.99 **	1.03	-3.04	7.78 **	2.61	50.00 **	13.53 **
14	IC 532116 X IC 78737	8.77 **	-5.63 *	50.89 **	44.82 **	3.52 *	2.4	-20.51 **	-31.79 **
15	IC 532116 X IC 532889	6.54 *	-8.17 **	-10.21	-13.83	7.97 **	3.27	-25.58 **	-43.67 **
16	IC 66520 X IC 78749	6.05 *	-16.06 **	-6.12	5.28	2.29	-2.61	-29.50 **	-25.85 **
17	IC 66520 X IC 138866	2.14	-19.15 **	8.83	22.05 *	4.24 *	-3.49 *	-31.38 **	-27.83 **
18	IC 66520 X IC 78801	3.65	-20.00 **	30.43 **	46.27 **	5.50 **	0.22	-32.85 **	-29.37 **
19	IC 66520 X IC 55681	6.47 *	-16.62 **	17.01 *	31.22 **	6.41 **	1.31	-20.08 **	-15.95 **
20	IC 66520 X 78737	2.85	-18.59 **	19.31 *	33.80 **	2.06	-2.83	18.83 **	24.97 **
21	IC 66520 X IC 532889	1.42	-19.72 **	16.63 *	26.40 **	5.72 **	0.65	38.70 **	45.87 **
22	IC 78749 X IC 138866	16.55 **	-6.76 **	-13.34	11.88	7.76 **	-0.22	124.67 **	20.42 **
23	IC 78749 X IC 78801	1.82	-21.41 **	20.76 **	49.14 **	-1.38	-6.32 **	-4.74	-20.77 **
24	IC 78749 X IC 55681	15.47 **	-9.58 **	12.49	31.95 **	7.32 **	2.18	8.62	-30.69 **
25	IC 78749 X IC 78737	-8.22 **	-21.41 **	-14.74 *	11.25	4.09 *	-0.22	-11.79 *	-24.31 **
26	IC 78749 X IC 532889	-10.86 **	-23.66 **	22.50 **	32.77 **	-3.42	-7.63 **	95.15 **	46.84 **
27	IC 138866 X IC 78801	24.45 **	-3.94	17.21 *	44.75 **	9.18 **	1.09	1.59	-15.51 **
28	IC 138866 X IC 55681	22.66 **	-3.94	5.04	23.20 *	10.35 **	2.18	80.00 **	14.85 **
29	IC 138866 X IC 78737	12.68 **	-9.86 **	19.68 **	54.52 **	8.94 **	0.87	41.54 **	21.45 **
30	IC 138866 X IC 532889	5.99 *	-15.21 **	42.33 **	54.26 **	9.41 **	1.31	6.73	-19.69 **
31	IC 78801 X IC 55681	7.30 *	-17.18 **	-3.77	12.87	0.46	-4.58 **	-16.40 **	-30.47 **
32	IC 78801 X IC 78737	0.73	-22.25 **	-20.55 **	-1.88	0.46	-4.58 **	-19.49 **	-30.91 **
33	IC 78801 X IC 532889	7.30 *	-17.18 **	23.63 **	33.99 **	3.90 *	-1.31	-0.26	-17.05 **
34	IC 55681 X IC 78737	15.11 **	-9.86 **	24.68 **	46.24 **	6.86 **	1.74	44.10 **	23.65 **
35	IC 55681 X 532889	5.76 *	-17.18 **	4.51	13.27	-3.43	-8.06 **	0	-24.75 **
36	IC 78737 X IC 532889	-4.9	-18.03 **	16.57	26.34 **	1.37	-3.05	-17.44 **	-29.15 **

Table 2: Heterobeltiosis and standard heterosis for spike length, spikelets and grains per spike, 1000 seed weight

S. No	Crosses	Spike length		Spikelets per spike		Grains per spike		1000 seed weight	
		BP	SH	BP	SH	BP	SH	BP	SH
1	IC 78751 X IC 532116	-21.11 **	-25.44 **	-27.74 **	-15.05 **	17.88 **	44.20 **	-22.02 **	-34.69 **
2	IC 78751 X IC 66520	-14.88 **	-19.56 **	34.07 **	36.49 **	10.58 **	35.27 **	12.47 **	-8.04 *
3	IC 78751 X IC 78749	0.35	-5.17	-18.60 **	-11.26 **	-28.10 **	-12.05 **	-7.27	-32.14 **
4	IC 78751 X IC 138866	-1.04	-6.47 *	14.00 **	28.38 **	4.01	27.23 **	-5.77	-24.00 **
5	IC 78751 X IC 78801	-13.49 **	-18.25 **	18.78 **	13.96 **	-7.66 **	12.95 **	-13.70 **	-36.52 **
6	IC 78751 X IC 55681	39.10 **	31.46 **	104.65 **	100.05 **	-39.05 **	-25.45 **	-15.37 **	-38.07 **
7	IC 78751 X IC 78737	25.29 **	39.31 **	-0.77	94.03 **	-20.19 **	-2.38	-10.81 *	-30.04 **
8	IC 78751 X IC 532889	-7.30 **	-3.6	53.33 **	34.68 **	9.12 **	33.48 **	-11.69 **	-31.36 **
9	IC 532116 X IC 66520	19.66 **	-8.44 **	4.21	22.52 **	4.21	21.43 **	-17.39 **	-30.81 **
10	IC 532116 X IC 78749	2.25	-19.75 **	3.64	21.85 **	3.64	20.76 **	-23.15 **	-35.63 **
11	IC 532116 X IC 138866	-11.02 **	-31.33 **	-18.77 **	-4.5	-18.77 **	-5.36	-3.77	-19.40 **
12	IC 532116 X IC 78801	55.13 **	18.71 **	39.50 **	64.01 **	-39.46 **	-29.46 **	11.38 **	-6.71 *
13	IC 532116 X IC 55681	56.58 **	43.88 **	50.38 **	76.80 **	50.38 **	75.22 **	-4.23	-19.79 **
14	IC 532116 X IC 78737	1.18	12.49 **	-16.15 **	63.96 **	39.46 **	62.50 **	-16.40 **	-29.98 **
15	IC 532116 X IC 532889	-11.95 **	-8.44 **	18.77 **	39.64 **	20.05 **	39.88 **	-7.61	-22.61 **
16	IC 66520 X IC 78749	7.50 *	-15.63 **	40.29 **	52.93 **	40.29 **	51.56 **	-14.32 **	-29.95 **
17	IC 66520 X IC 138866	54.24 **	19.03 **	-18.80 **	-8.56 **	-18.80 **	-9.38 **	-7.25	-24.16 **
18	IC 66520 X IC 78801	86.11 **	31.46 **	-13.72 **	-12.16 **	-13.72 **	-12.95 **	-15.85 **	-31.20 **
19	IC 66520 X IC 55681	12.46 **	3.34	26.99 **	29.28 **	26.99 **	28.13 **	-3.73	-21.28 **
20	IC 66520 X 78737	-37.06 **	-30.02 **	-32.96 **	31.08 **	28.76 **	29.91 **	-10.91 **	-27.15 **
21	IC 66520 X IC 532889	-22.01 **	-18.90 **	48.23 **	50.90 **	48.23 **	49.55 **	-24.73 **	-38.46 **
22	IC 78749 X IC 138866	83.75 **	44.21 **	75.64 **	97.79 **	31.20 **	46.43 **	-19.16 **	-34.80 **
23	IC 78749 X IC 78801	82.50 **	43.23 **	76.98 **	92.93 **	30.17 **	40.63 **	-12.35 **	-35.52 **

24	IC 78749 X IC 55681	51.25 **	38.98 **	49.79 **	63.29 **	49.79 **	61.83 **	-12.92 **	-36.90 **
25	IC 78749 X IC 78737	10.00 **	22.30 **	-56.23 **	-14.41 **	-21.49 **	-15.18 **	28.32 **	0.65
26	IC 78749 X IC 532889	5.66 *	9.88 **	0.83	9.91 **	0.83	8.93 **	0.78	-21.67 **
27	IC 138866 X IC 78801	33.05 **	2.68	15.60 **	30.18 **	15.60 **	29.02 **	7.55	-13.25 **
28	IC 138866 X IC 55681	-11.74 **	-18.90 **	13.00 **	27.25 **	13.00 **	26.12 **	2.82	-17.07 **
29	IC 138866 X IC 78737	-19.41 **	-10.40 **	-56.35 **	-14.64 **	-24.20 **	-15.40 **	-7.01	-24.99 **
30	IC 138866 X IC 532889	46.54 **	52.39 **	37.60 **	54.95 **	37.60 **	53.57 **	-11.33 **	-28.48 **
31	IC 78801 X IC 55681	46.98 **	35.06 **	47.93 **	44.59 **	47.93 **	43.30 **	5.27	-22.56 **
32	IC 78801 X IC 78737	7.94 **	20.01 **	-50.47 **	-3.15	0.94	-4.02	-10.24 *	-29.59 **
33	IC 78801 X IC 532889	12.26 **	16.74 **	43.66 **	37.84 **	41.31 **	34.38 **	-7.98	-28.48 **
34	IC 55681 X IC 78737	-7.35 **	3.01	-30.89 **	35.14 **	49.00 **	44.35 **	-9.89 *	-29.32 **
35	IC 55681 X 532889	23.27 **	28.19 **	27.19 **	24.32 **	27.19 **	23.21 **	-14.33 **	-33.41 **
36	IC 78737 X IC 532889	8.53 **	20.67 **	-35.38 **	26.35 **	43.85 **	25.22 **	-20.27 **	-37.46 **

*, ** indicate the level of significance at 5% and 1% respectively

Table 3: Heterobeltiosis and standard heterosis for grain yield per plant, biological yield, harvest index, chlorophyll, protein content

S. No	Crosses	Grain yield per plant		Biological yield		Harvest index		Chlorophyll content		Protein content	
		BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
1	IC 78751 X IC 532116	-24.40 **	-29.10 **	-3.07	-39.99 **	-34.11 **	12.93 *	16.42 **	12.36 **	-18.72 **	-7.17 **
2	IC 78751 X IC 66520	-4.27	-10.22 **	-2.12	-36.64 **	-6.51	41.76 **	12.56 **	10.06 **	-16.71 **	-6.90 **
3	IC 78751 X IC 78749	-29.46 **	-33.84 **	-4.24	-38.17 **	-29.39 **	7.07	12.39 **	9.98 **	-17.23 **	-14.21 **
4	IC 78751 X IC 138866	-29.01 **	-25.97 **	-38.41 **	-48.86 **	-4.38	44.99 **	1.34	1.90	-6.19 *	2.57
5	IC 78751 X IC 78801	7.22	0.55	17.39 **	-27.32 **	-8.78 **	38.32 **	-4.9	9.19 **	14.08 **	9.61 **
6	IC 78751 X IC 55681	5.45	-1.10	19.53 **	-23.14 **	-15.09 **	28.75 **	-1.55	11.01 **	-0.23	15.29 **
7	IC 78751 X IC 78737	-14.87 **	-20.17 **	9.10 **	-32.46 **	-22.00 **	18.28 **	5.00	4.83	-0.84	-4.47
8	IC 78751 X IC 532889	-6.33	-12.15 **	6.16 *	-31.13 **	-15.83 **	27.63 **	6.62 *	0.87	22.54 **	17.73 **
9	IC 532116 X IC 66520	8.07	-3.87	14.93 **	-25.61 **	-24.60 **	29.22 **	10.05 **	7.61 **	-29.86 **	-19.89 **
10	IC 532116 X IC 78749	13.93 **	-5.11	7.98 **	-30.27 **	-20.56 **	36.14 **	16.28 **	13.79 **	-3.55	10.15 **
11	IC 532116 X IC 138866	1.85	6.22	5.06 *	-12.77 **	-28.07 **	23.28 **	10.24 **	10.86 **	-16.82 **	-5.01
12	IC 532116 X IC 78801	11.47 *	-8.70 *	37.62 **	-19.62 **	-32.66 **	15.42 **	12.15 **	28.76 **	-10.66 **	2.03
13	IC 532116 X IC 55681	-4.72	-21.96 **	0.89	-35.12 **	-29.81 **	20.30 **	8.71 **	22.58 **	1.17	16.91 **
14	IC 532116 X IC 78737	-16.86 **	-31.91 **	-1.44	-46.63 **	-25.52 **	27.64 **	10.16 **	9.98 **	2.61	17.19 **
15	IC 532116 X IC 532889	16.53 **	-4.56	36.66 **	-11.34 **	-37.18 **	7.67	26.93 **	22.50 **	-2.37	11.50 **
16	IC 66520 X IC 78749	-4.66	-15.19 **	7.14 *	-30.65 **	-13.84 **	20.81 **	38.54 **	35.58 **	-14.29 **	-4.19
17	IC 66520 X IC 138866	9.67 **	14.36 **	30.38 **	8.26 **	-24.63 **	5.68	11.82 **	12.44 **	2.42	14.48 **
18	IC 66520 X IC 78801	-0.93	-11.88 **	4.47	-32.38 **	-7.04	30.34 **	-13.80 **	-1.03	-9.20 **	1.49
19	IC 66520 X IC 55681	-8.98 *	-19.03 **	-2.18	-36.68 **	-14.08 **	20.47 **	-22.21 **	-12.28 **	-4.45	10.42 **
20	IC 66520 X 78737	7.69	-4.21	42.86 **	-7.53 **	-24.02 **	8.64	5	4.83	-1.45	10.15 **
21	IC 66520 X IC 532889	4.97	-6.63	32.26 **	-14.19 **	-22.36 **	8.86	12.24 **	9.75 **	-13.80 **	-3.65
22	IC 78749 X IC 138866	-39.34 **	-36.74 **	-27.93 **	-40.16 **	-20.93 **	5.74	1.34	1.90	-6.44 **	2.3
23	IC 78749 X IC 78801	-24.88 **	-37.43 **	-7.78 **	-40.45 **	-21.40 **	5.11	-14.01 **	-1.27	13.84 **	18.00 **
24	IC 78749 X IC 55681	-26.20 **	-38.54 **	-3.65	-37.79 **	-26.10 **	-1.17	-10.40 **	1.03	-2.58	12.58 **
25	IC 78749 X IC 78737	19.40 **	-0.55	-3.95	-37.98 **	12.11 **	60.30 **	12.54 **	12.36 **	11.75 **	15.83 **
26	IC 78749 X IC 532889	12.94 **	-5.94	34.90 **	-12.48 **	-18.14 **	9.48	3.81	1.58	4.44	8.25 **
27	IC 138866 X IC 78801	-14.36 **	-10.69 **	4.95 *	-12.86 **	-16.39 **	2.76	-9.11 **	4.36	7.43 **	17.46 **
28	IC 138866 X IC 55681	-22.78 **	-19.48 **	-22.46 **	-35.62 **	2.17	25.56 **	-2.46	9.98 **	-18.27 **	-5.55 *
29	IC 138866 X IC 78737	-25.43 **	-22.24 **	-18.65 **	-32.46 **	-19.26 **	15.44 **	4.26	4.83	7.43 **	17.46 **
30	IC 138866 X IC 532889	-29.02 **	-25.98 **	-22.91 **	-36.00 **	-7.78	13.34 **	8.67 **	9.27 **	-0.74	8.53 **
31	IC 78801 X IC 55681	0.37	-24.59 **	3.55	-33.41 **	-7.55	13.30 **	-11.59 **	1.51	-20.14 **	-7.71 **
32	IC 78801 X IC 78737	-5.9	-28.12 **	11.07 **	-35.12 **	-28.25 **	2.59	2.83	18.07 **	13.76 **	9.61 **
33	IC 78801 X IC 532889	30.63 **	2.49	49.27 **	-3.16	-13.53 **	5.97	-0.07	14.74 **	4.79	0.68
34	IC 55681 X IC 78737	53.35 **	17.13 **	59.47 **	2.55	-20.10 **	14.23 **	-9.21 **	2.38	-17.56 **	-4.74
35	IC 55681 X 532889	36.62 **	7.18	38.71 **	-10.01 **	-1.53	19.14 **	-7.80 **	3.96	2.11	18.00 **
36	IC 78737 X IC 532889	43.49 **	12.57 **	49.27 **	-3.16	-18.67 **	16.28 **	8.17 **	8.00 **	-14.61 **	-17.73 **

*, ** indicate the level of significance at 5% and 1% respectively

Conclusion

Assessments of better parent heterosis and standard heterosis were calculated in this study to find superior cross combinations for prospective application in hybrid breeding programmes. A marked degree of useful and significant heterosis over better and standard parent (JWS-17) was observed in individual crosses for different traits. The magnitude of heterotic effects was high for number of effective tillers per plant, number of spikelets per spike and Days to maturity; moderate for number of grains per spike, Days to 50% heading, harvest index, chlorophyll content, grain yield per plant and spike length; and low for biological yield per plant, plant height and protein content. The highest, positive and significant heterobeltiosis for grain yield per plant and some of its component traits were recorded in the crosses, IC 78749 X IC 532889, IC 78801 X IC 78737, IC 78749 X IC 138866, IC 66520 X IC 78801, IC 78751 X IC 55681, IC 78749 X IC 78737, and IC 55681 X IC 78737. Such crosses could be exploited for practical plant breeding programme in bread wheat.

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