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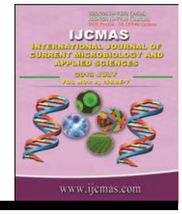

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Heterosis for Grain Yield and Yield Components in Bread Wheat (*Triticum aestivum* L.) Over Environments

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A B S T R A C T

Ten parents along with forty-five hybrids (developed by half-diallel) and one check (Lok 1) were evaluated in randomized block design with three replications in three environments [early sowing (E_1), normal sowing (E_2) and late sowing (E_3)] during *rabi* 2016-17. The significant and positive heterobeltiosis was recorded for grain yield per plant by seven crosses in E_1; nine crosses in E_2; and six crosses in E_3, while 31 crosses in E_1; 19 crosses in E_2; and 38 crosses in E_3 exhibited significant and positive standard heterosis. In general, magnitude of heterosis over better parent and standard check for grain yield per plant was medium and high, respectively. Comparison of crosses on the basis of *per se* performance, heterosis over better parent and standard check for grain yield per plant revealed that five crosses *viz*., GW 463 x DBW 110, GW 455 x MP 3288, GW 455 x MP 3288, GW 273 x Raj 4238 and GW 451 x HD 2932 manifested significant and desirable heterobeltiosis and standard heterosis in all the three environments (except GW 455 x MP 3288 for heterobeltiosis in E_3).

Keywords

Bread wheat, Heterobeltiosis, Standard heterosis, Grain yield

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Introduction

Wheat (*Tritium aestivum* L.) is the second most important crop that contributes significantly to the global food and food security (Thomas *et al.,* 2017). It provides food to 36 per cent of the global population contributing 20 per cent of total food calories for the world people and is a national staple in many countries. The total production of wheat in the world is around 749.46 million tonnes covering an area of about 220.10 million ha with an average productivity of 3405.0 kg ha^{-1} (Anon., 2016). The area and production of wheat in India during year 2016-17 was recorded 30.72 million ha and 97.44 million tonnes with an average productivity of 3172 kg ha^{-1} (Anon., 2017). Best vegetative and reproduction growth of wheat plant is obtained at temperature 18-22 ^{o}C (Hennessy *et al.,* 2008 and Reynolds *et al.,* 2010). In self-pollinated crop like wheat, where commercial hybrid seed production is not feasible due to lack of suitable mechanism to produce hybrid seed, exploitation of hybrid vigour is limited.

Therefore, at present heterosis *per se* may not be of economic value in this crop. Heterosis in wheat is used to select desirable crosses to obtain superior transgressive segregants in advance generations for additional enrichment of grain yield. In present study per cent increase or decrease over better parent (heterobeltiosis) and standard check, Lok 1 (standard heterosis) was used as a measure of heterosis.

Materials and Methods

The experiment was conducted at Wheat Research Station, J.A.U., Junagadh during *rabi* 2016-17. Ten parents (GW 451, GW 463, GW 455, GW 273, GW 477, DBW 110, HD 2932, Raj 4238, MP 3288 and UP 2672) along with forty-five hybrids (developed by diallel excluding reciprocals) and one check (Lok 1) were evaluated in randomized block design with three replications in three environments [early sowing (E_1), normal sowing (E_2) and late sowing (E_3)].

The planting material was received from breeding unit Wheat Research Station, Junagadh Agricultural University, Junagadh, Gujarat. Five competitive plants from each plot were randomly selected in all the three environments for recording observations on various characters. However, days to heading and days to maturity were recorded on plot basis. Observations were recorded for fifteen traits *viz*., days to 50 per cent heading, plant height, number of effective tillers, length of spike, peduncle length of main spike, days to maturity, number of grains per spike, grain weight per spike, 1000-grain weight, grain yield per plant, biological yield per plant, harvest index, canopy temperature, flag leaf area and chlorophyll content.

Estimation of heterobeltiosis and standard heterosis by Fonseca and Patterson (1968) and Briggle (1963), respectively were calculated for each character using the following formula

Heterosis over better parent (heterobeltiosis) $= \frac{F1-BP}{BP} \times 100$

Heterosis over check (standard heterosis) $= \frac{F1-CC}{CC} \times 100$

Where,

F_1=mean performance of F_1

BP= mean performance of better parent

CC= mean performance of the best commercial check.

Results and Discussion

In present investigation, the range of heterosis has been estimated for all the characters. Wide range of heterosis usually indicates the amount of variability for the heterosis. An overall appraisal of the Table 1 revealed range of heterosis over better parent for days to 50 per cent heading from -28.16 to 18.56in E_1, -29.65 to 23.03in E_2 and-18.35 to 21.58in E_3;for plant height from -32.86 to 26.71in E_1, -30.05 to 18.91in E_2 and -54.95 to 8.86in E_3;for number of effective tillers from -36.52 to 52.05in E_1,-39.32 to 44.69in E_2 and -42.84 to 21.93in E_3;for length of spike from -29.74 to 44.73in E_1, -27.44 to 44.16in E_2 and -25.29 to 37.99in E_3;for peduncle length of main spike from -36.76 to 52.25in E_1, -13.50 to 44.20in E_2 and -45.59 to 10.86in E_3;for days to maturity from -13.27 to 10.88in E_1, -13.56 to 23.92in E_2 and -11.96 to 23.85in E_3;for number of grains per spike from -23.20 to 48.34in E_1, -18.83 to

46.04in E_2 and -44.61 to 56.96in E_3;for grain weight per spike from -45.58 to 78.00in E_1, -30.04 to 136.04in E_2 and -56.76 to 57.26in E_3;for 1000-grain weight from -44.13 to 13.94 in E_1, -29.49 to 31.09 in E_2 and -46.29 to 39.31 in E_3; for grain yield per plant from -59.20 to 3.22 in E_1, -57.31 to 28.27 in E_2 and -59.16 to 29.39 in E_3; for biological yield per plant from -52.28 to 42.07 in E_1, -39.19 to 42.70 in E_2 and -56.80 to 1.07 in E_3; for harvest index from -52.39 to 19.61 in E_1, -43.41 to 30.47 in E_2 and -40.03 to 47.89 in E_3; for canopy temperature from -11.71 to 27.11 in E_1, -14.79 to 19.42 in E_2 and-8.69 to 20.40 in E_3; for flag leaf area from -30.61 to 16.01 in E_1,-20.53 to 27.02 in E_2 and -29.05 to 37.24 in E_3; for chlorophyll content from -42.69 to 25.39 in E_1, -27.35 to 37.38 in E_2 and -38.80 to 30.24 in E_3. In general magnitude of heterobeltiosis (%) was high in E_2 among all the three environments (Fig. 1), while heterosis over standard check (Lok 1) was found high in E_3 (Fig. 2).

While considering the performance of crosses in individual environment with respect to grain yield per plant, seven crosses in E_1, nine crosses in E_2 and six crosses in E_3 over better parent, while 31 crosses in E_1, 19 crosses in E_2 and 38 crosses in E_3 over standard check exhibited significant and positive heterosis. The range of heterosis over standard check for grain yield per plant in per cent was from -47.18 to 66.69in E_1;-48.46 to 52.84in E_2; and -35.27 to 98.14in E_3. Seventeen crosses *viz.*, GW 451 x HD 2932, GW 451 x UP 2672, GW 463 x DBW 110, GW 463 x HD 2932, GW 463 x Raj 4238, GW 455 x GW 273, GW 455 x GW 477, GW 455 x MP 3288, GW 273 x Raj 4238, GW 273 x MP 3288, GW 477 x HD 2932, GW 477 x Raj 4238, GW 477 x UP 2672, DBW 110 x HD 2932, HD 2932 x Raj 4238, HD 2932 x MP 3288 and MP 3288 x UP 2672 exhibited significant and positive economic heterosis in all the environments. High heterosis for grain yield has recently been reported by Barot *et al.*, (2014); Thomas *et al.*, (2017) and Aware and Potdukhe (2018). It is of profound interest to know the cause of heterosis for grain yield. Whitehouse *et al.*, (1958) and Grafius (1959) suggested that there may not be any gene system for grain yield *per se*, as grain yield is an end product of the multiplicative interaction among the yield components. This would indicate that the heterosis for grain yield should be through heterosis for the individual yield components or alternatively due to the multiplicative effect of partial dominance of component characters. Williams and Gilbert (1960) reported that even simple dominance in respect of yield components may lead to expression of heterosis for yield. Hagberg (1952) observed similar effects and termed it "combinational heterosis". In order to see whether similar situation exist in bread wheat or not, a comparison of six most heterotic crosses for grain yield was made with other yield related characters along with average grain yield per plant in all the three environments (Table 2 to Table 4). Six crosses *viz.*, GW 463 x DBW 110, GW 455 x MP 3288, HD 2932 x Raj 4238, GW 273 x Raj 4238, GW 451 x HD 2932 and GW 463 x HD 2932 manifested significant and desirable heterobeltiosis for grain yield per plant also recorded significant and positive heterobeltiosis for 1000-grain weight (6 cases) followed by number of effective tillers per plant, grain weight per spike and biological yield per plant (5 cases in each) in E_1 (Table 2).

On the other hand, six crosses *viz.*, GW 463 x DBW 110, GW 273 x Raj 4238, GW 451 x HD 2932, HD 2932 x Raj 4238, GW 455 x MP 3288 and GW 455 x GW 273manifested significant and desirable heterobeltiosis for grain yield per plant (except GW 455 x GW 273) also recorded significant and positive heterobeltiosis for various yield contributing characters on individual cross basis in E_2. For example, 1000-grain weight (5 cases) followed by number of effective tillers per plant, grain weight per spike, biological yield per plant, canopy temperature and chlorophyll content (3 case in each) in E_2 (Table 3). Similarly, six crosses *viz.*, GW 463 x DBW 110, GW 273 x Raj 4238, GW 455 x MP 3288, GW 451 x HD 2932, HD 2932 x Raj 4238 and GW 463 x HD 2932manifested significant and desirable heterobeltiosis for grain yield per plant also recorded significant and positive heterobeltiosis for peduncle length of main spike and harvest index (6 cases each) followed by 1000-grain weight, number of grains per spike (5 cases each) and chlorophyll content (4 cases) in E_3 (Table 4). Out of these six crosses, five crosses *viz.*, GW 463 x DBW 110, GW 273 x Raj 4238, GW 455 x MP 3288, GW 451 x HD 2932 and HD 2932 x Raj 4238 were founded common in all the three environments.

Fig.1 Radar showing trend of heterobeltiosis (%) of 45 crosses over the environments

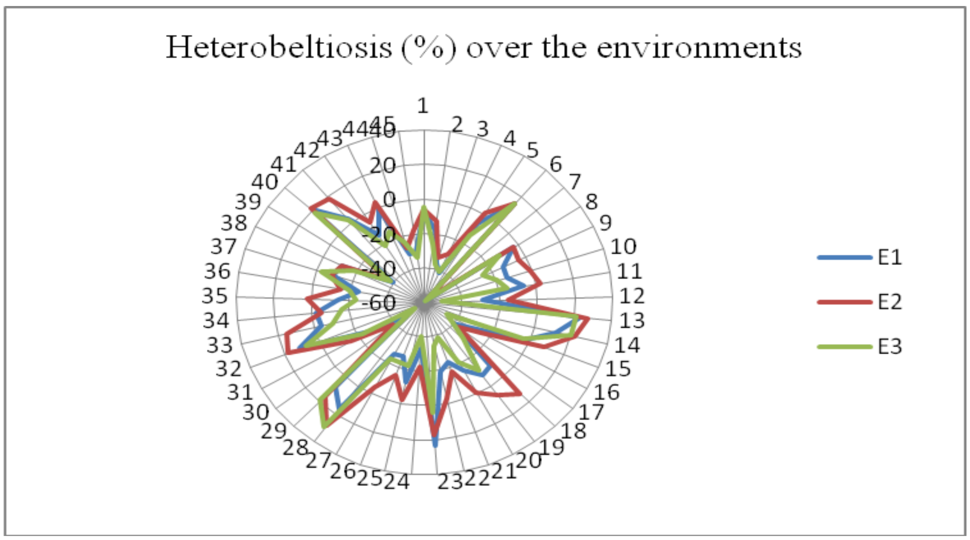

Fig.2 Radar showing trend of standard heterosis (%) of 45 crosses over the environments

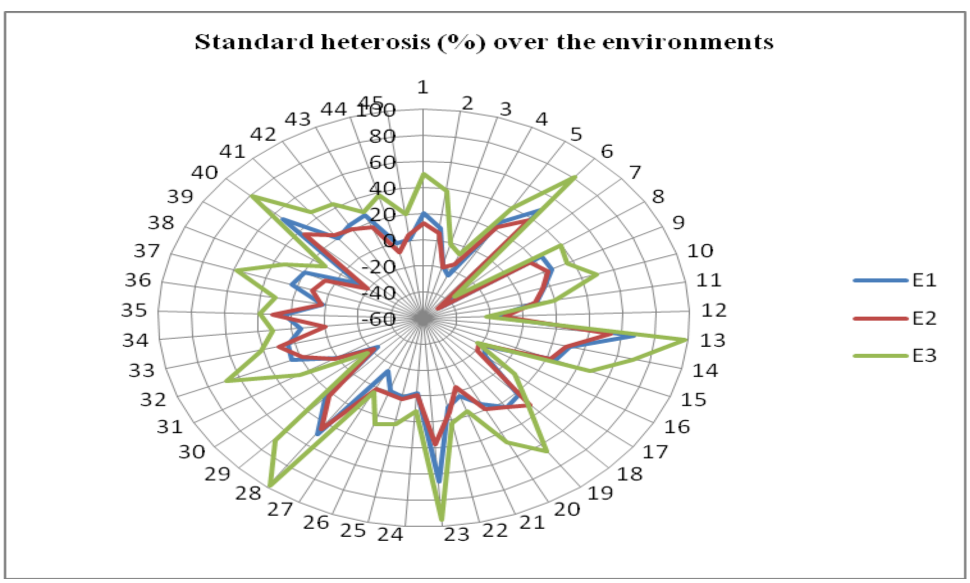

Table.1 Magnitude of heterobeltiosis and standard heterosis for various characters in bread wheat

S.N.	*Crosses*	Env	Desirable aspect	Range		Number of crosses with significant heterosis			
				H (%)	SH (%)	H (%)		SH (%)	
						+ve	-ve	+ve	-ve
1.	Day to 50% heading	E_1	Early	-28.16 to 18.56	-14.38 to 40.41	6	8	38	6
		E_2		-29.65 to 23.03	-15.38 to 32.17	-	10	30	9
		E_3		-18.35 to 21.58	-16.11 to 13.42	5	10	2	13
2.	Plant height (cm)	E_1	Dwarf	-32.86 to 26.71	-10.55 to 40.37	-	14	25	10
		E_2		-30.05 to 18.91	-16.19 to 23.02	1	14	6	12
		E_3		-54.95 to 8.86	-43.68 to 14.82	2	31	14	19
3.	No. of effective tillers	E_1	High	-36.52 to 52.05	-22.41 to 72.36	18	7	29	6
		E_2		-39.32 to 44.69	-40.42 to 45.32	19	2	18	3
		E_3		-42.84 to 21.93	-31.33 to 22.64	1	15	3	13
4.	Length of spike (cm)	E_1	High	-29.74 to 44.73	2.38 to 70.00	18	16	45	-
		E_2		-27.44 to 44.16	-3.25 to 60.57	19	15	42	1
		E_3		-25.29 to 37.99	0.00 to 72.31	24	13	43	-
5.	Peduncle length of main spike	E_1	Short	-36.76 to 52.25	-12.99 to 40.97	11	5	36	7
		E_2		-13.50 to 44.20	-14.36 to 22.00	8	5	14	8
		E_3		-45.59 to 10.86	-41.47 to -1.44	6	37	-	43
6.	Days to maturity	E_1	Early	-13.27 to 10.88	-5.39 to 14.81	-	10	-	10
		E_2		-13.56 to 23.92	-15.95 to 4.98	2	9	-	11
		E_3		-11.96 to 23.85	-11.81 to 9.23	1	3	-	4
7.	Number of grains per spike	E_1	High	-23.20 to 48.34	11.90 to 63.07	6	2	42	-
		E_2		-18.83 to 46.04	-1.92 to 28.22	8	1	14	1
		E_3		-44.61 to 56.96	-33.07 to 27.13	2	25	10	17
8.	Grain weight per spike	E_1	High	-45.58 to 78.00	-35.35 to 16.76	5	18	6	26
		E_2		-30.04 to 136.04	-21.09 to 29.23	14	7	18	6
		E_3		-56.76 to 57.26	-39.96 to 51.95	3	16	3	15

Table.1 Contd….

S. N.	*Crosses*	Env	Desirable aspect	Range H (%)	Range SH (%)	Number of crosses with significant heterosis H (%) +ve	H (%) -ve	SH (%) +ve	SH (%) -ve
9.	1000-Grain weight	E_1	High	-44.13 to 13.94	-37.04 to 16.78	2	38	1	44
		E_2		-29.49 to 31.09	-21.36 to 21.32	8	31	8	36
		E_3		-46.29 to 39.31	-39.82 to 17.69	5	33	2	42
10.	Grain yield per plant	E_1	High	-59.20 to 3.22	-47.18 to 66.69	7	26	31	12
		E_2		-57.31 to 28.27	-48.46 to 52.84	9	16	19	12
		E_3		-59.16 to 29.39	-35.27 to 98.14	6	32	38	6
11.	Biological yield per plant	E_1	High	-52.28 to 42.07	-31.19 to 62.05	9	20	43	2
		E_2		-39.19 to 42.70	-26.63 to 44.34	3	17	28	3
		E_3		-56.80 to 1.07	-13.47 to 86.17	-	33	43	1
12.	Harvest index	E_1	High	-52.39 to 19.61	-48.04 to 16.35	6	32	8	31
		E_2		-43.41 to 30.47	-38.66 to 17.29	5	14	5	14
		E_3		-40.03 to 47.89	-41.86 to 18.99	11	10	9	14
13.	Canopy temperature	E_1	Low	-11.71 to 27.11	-5.48 to 24.60	5	3	12	1
		E_2		-14.79 to 19.42	-8.86 to 18.90	1	11	5	11
		E_3		-8.69 to 20.40	-8.39 to 12.50	4	1	4	1
14.	Flag leaf area	E_1	High	-30.61 to 16.01	-28.71 to 10.31	2	16	2	18
		E_2		-20.53 to 27.02	-17.03 to 36.16	2	8	3	8
		E_3		-29.05 to 37.24	-22.94 to 26.27	9	6	9	6
15.	Chlorophyll content	E_1	High	-42.69 to 25.39	-23.83 to 43.65	11	11	33	4
		E_2		-27.35 to 37.38	-16.09 to 42.45	19	2	25	2
		E_3		-38.80 to 30.24	-38.15 to 13.53	7	15	8	18

Table.2 Comparative study of six most heterobeltiotic crosses and *per se* performances for grain yield per plant and its component characters in bread wheat for E_1 environment

Sr. No.	Crosses	Mean grain yield per plant (g)	Heterobeltiosis for grain yield per plant	Significant heterobeltiosis for component traits in desirable direction
1.	GW 463 x DBW 110	25.72	23.22**	Number of effective tillers, length of spike, peduncle length of main spike, **1000-grain weight**, biological yield per plant, canopy temperature, flag leaf area, chlorophyll content
2.	GW 455 x MP 3288	25.51	23.14**	Plant height, number of effective tillers, peduncle length of main spike, grain weight per spike, **1000-grain weight**, biological yield per plant, harvest index, chlorophyll content
3.	HD 2932 x Raj 4238	23.78	20.18**	Length of spike, peduncle length of main spike, grain weight per spike, **1000-grain weight**, biological yield per plant, harvest index, flag leaf area, chlorophyll content
4.	GW 273 x Raj 4238	23.07	16.59**	Number of effective tillers, length of spike, number of grains per spike, grain weight per spike, **1000-grain weight**, harvest index, flag leaf area, chlorophyll content
5.	GW 451 x HD 2932	22.90	14.62**	Days to 50 per cent heading, plant height, number of effective tillers, length of spike, peduncle length of main spike, grain weight per spike, **1000-grain weight**, biological yield per plant, flag leaf area,
6.	GW 463 x HD 2932	20.11	12.08*	Plant height, number of effective tillers, length of spike, number of grains per spike, grain weight per spike, **1000-grain weight**, biological yield per plant,

*, ** Significant at 5 and 1 per cent, respectively

Table.3 Comparative study of six most heterobeltiotic crosses and *per se* performances for grain yield per plant and its component characters in bread wheat for E_2 environment

Sr. No.	Crosses	Mean grain yield per plant (g)	Heterobeltiosis for grain yield per plant	Significant heterobeltiosis for component traits in desirable direction
1.	GW 463 x DBW 110	29.31	27.25**	Length of spike, number of grains per spike, grain weight per spike, biological yield per plant, canopy temperature, flag leaf area, chlorophyll content
2.	GW 273 x Raj 4238	27.72	28.27**	Number of effective tillers, length of spike, number of grains per spike, grain weight per spike, 1000-grain weight, harvest index, flag leaf area, chlorophyll content
3.	GW 451 x HD 2932	26.50	14.46*	Days to 50% heading, Number of effective tillers, length of spike, peduncle length of main spike, grain weight per spike, 1000-grain weight, biological yield per plant,
4.	HD 2932 x Raj 4238	26.24	21.43**	Length of spike, peduncle length of main spike, days to maturity, 1000-grain weight, biological yield per plant,
5.	GW 455 x MP 3288	26.18	17.10*	Plant height, number of effective tillers, 1000-grain weight, canopy temperature,
6.	GW 455 x GW 273	25.36	13.44	Plant height, length of spike, 1000-grain weight, harvest index, canopy temperature, chlorophyll content

*, ** Significant at 5 and 1 per cent, respectively

Table.4 Comparative study of six most heterobeltiotic crosses and *per se* performances for grain yield per plant and its component characters in bread wheat for E_3 environment

Sr. No.	Crosses	Mean grain yield per plant (g)	Heterobeltiosis for grain yield per plant	Significant heterobeltiosis for component traits in desirable direction
1.	GW 463 x DBW 110	21.33	21.04**	Days to 50% heading, plant height, length of spike, **peduncle length of main spike**, number of grains per spike, 1000-grain weight, **harvest index**, chlorophyll content
2.	GW 273 x Raj 4238	21.32	29.39**	Days to 50% heading, plant height, length of spike, **peduncle length of main spike**, 1000-grain weight, **harvest index**, flag leaf area, chlorophyll content
3.	GW 455 x MP 3288	20.92	4.48	Plant height, **peduncle length of main spike**, number of grains per spike, biological yield per plant, **harvest index**, chlorophyll content
4.	GW 451 x HD 2932	19.53	14.46**	**Peduncle length of main spike**, number of grains per spike, grain weight per spike, 1000-grain weight, biological yield per plant, **harvest index**
5.	HD 2932 x Raj 4238	19.31	17.19**	Days to 50% heading, length of spike, **peduncle length of main spike**, number of grains per spike, grain weight per spike, 1000-grain weight, biological yield per plant, **harvest index**, chlorophyll content
6.	GW 463 x HD 2932	18.27	20.22**	Length of spike, **peduncle length of main spike**, number of grains per spike, grain weight per spike, 1000-grain weight, biological yield per plant, **harvest index**, flag leaf area

*, ** Significant at 5 and 1 per cent, respectively

Table.5 Correlation coefficient between *per se* performance and heterobeltiosis as well as heterobeltiosis and standard heterosisin bread wheat

Sr. No.	Characters	*Per se* performance and heterobeltiosis				Heterobeltiosis and standard heterosis			
		E_1	E_2	E_3	pooled	E_1	E_2	E_3	pooled
1.	Day to 50% heading	0.95**	0.93**	0.79**	0.91**	0.95**	0.93**	0.79**	0.91**
2.	Plant height (cm)	0.91**	0.86**	0.91**	0.86**	0.91**	0.86**	0.91**	0.86**
3.	No. of effective tillers	0.89**	0.88**	0.86**	0.83**	0.89**	0.88**	0.86**	0.83**
4.	Length of spike (cm)	0.85**	0.89**	0.86**	0.88**	0.85**	0.89**	0.86**	0.88**
5.	Peduncle length of main spike	0.66**	0.56**	0.68**	0.50**	0.66**	0.56**	0.68**	0.50**
6.	Days to maturity	0.76**	0.70**	0.71**	0.67**	0.76**	0.70**	0.71**	0.67**
7.	Number of grains per spike	0.64**	0.38**	0.65**	0.51**	0.64**	0.38*	0.65**	0.51**
8.	Grain weight per spike (g)	0.72**	0.64**	0.79**	0.69**	0.72**	0.64**	0.79**	0.69**
9.	1000-Grain weight (g)	0.57**	0.52**	0.58**	0.57**	0.57**	0.52**	0.58**	0.57**
10.	Grain yield per plant (g)	0.94**	0.94**	0.62**	0.93**	0.94**	0.94**	-0.13	0.93**
11.	Biological yield per plant (g)	0.81**	0.82**	0.32*	0.80**	0.81**	0.82**	0.38**	0.80**
12.	Harvest index (g)	0.94**	0.92**	0.89**	0.92**	0.94**	0.92**	0.70**	0.92**
13.	Canopy temperature (^{0}C)	0.84**	0.88**	0.86**	0.87**	0.84**	0.88**	-0.16	0.87**
14.	Flag leaf area (cm^2)	0.91**	0.92**	0.88**	0.91**	0.91**	0.92**	0.00	0.91**
15.	Chlorophyll content	0.82**	0.80**	0.73**	0.77**	0.82**	0.80**	0.10	0.77**

*, ** Significant at 5 and 1 per cent, respectively

Highly significant heterobeltiosis in desirable direction was exhibited for number of effective tillers, peduncle length of main spike, 1000-grain weight, grain yield per plant, biological yield per plant and chlorophyll content by cross GW 463 x DBW 110 and GW 455 x MP 3288 in E_1 (Table 2); for length of spike, number of grains per spike, grain weight per spike, grain yield per plant, flag leaf area and chlorophyll content by cross GW 463 x DBW 110 and GW 273 x Raj 4238in E_2 (Table 3); and for days to 50% heading, plant height, length of spike, peduncle length of main spike, grain yield per plant, harvest index and chlorophyll content by cross GW 463 x DBW 110 and GW 273 x Raj 4238 in E_3 (Table 4) which indicated that in different crosses, pathway for releasing heterotic effects varied from cross to cross and also from environment to environment. These results revealed that number of effective tillers, peduncle length of main spike, 1000-grain weight, number of grains per spike, grain weight per spike and chlorophyll content were the main contributor towards increased grain yield.

Thus, heterobeltiosis for various yield contributing characters might be result in the expression of heterobeltiosis for grain yield. However, the crosses showing heterotic expression for grain yield per plant were not heterotic for all the characters. It was also noted that the expression of heterobeltiosis was influenced by the environments for almost all the characters. This was because of significant G x E interaction. The results are in harmony with findings of Thomas *et al.*, (2017).

Several research workers have also reported heterosis in wheat for various component characters like days to 50 per cent heading (Aware and Potdukhe, 2018 and Jaiswal *et* *al.*, 2018),plant height (Thomas *et al.*, 2017), number of effective tillers (Jaiswal *et al.*, 2018), length of spike (Singh *et al.*, 2014; Kumar *et al.*, 2015), peduncle length of main spike (Jaiswal *et al.*, 2018), days to maturity (Lal *et al.*, 2013; Barot*et al.*, 2014), number of grains per spike (Kumar *et al.*, 2011), grain weight per spike (Barot *et al.*, 2014), 1000-grain weight (Kumar *et al.*, 2015 and Jaiswal *et al.*, 2018), grain yield per plant (Lal *et al.*, 2013; Gaur *et al.*, 2014), biological yield per plant (Ribadia *et al.*, 2007; Kumar *et al.*, 2014; Kumar *et al.*, 2015 and Jaiswal *et al.*, 2018), harvest index (Desale and Mehta, 2013) and chlorophyll content (Desale and Mehta, 2013).

On the other hand, *per se* performance of crosses was compared with heterobeltiosis revealed significant and positive correlation between both the parameters for all the characters in E_1, E_2, E_3 and pooled (Table 5). Similarly, there was also significant and positive correlation between heterobeltiosis and standard heterosis in all the three individual environments and over environments for all the traits except grain yield per plant, canopy temperature, flag leaf area and chlorophyll content in E_3 environment.

A comparison of best performing six crosses in order with six most heterotic crosses further revealed that the selection of crosses for grain yield and yield components on the basis of either *per se* performance or heterotic response would be equally important, but the former is more desirable. Similar findings have been reported by Kumar *et al.*, (2014) and Jaiswal *et al.*, (2018).

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