The Bioscan 9(4): 1725-1731, 2014 (Supplement on Genetics and Plant Breeding)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

HETEROSIS STUDIES FOR YIELD COMPONENT TRAITS AND QUALITY IN SPRING WHEAT (*TRITICUM AESTIVUM* L.)

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KEYWORDS
Heterobeltiosis
Transgressive segregants
Diallel crosses
Quality traits
Wheat

Received on :
12.08.2014

Accepted on :
10.12.2014

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ABSTRACT

A study was conducted to estimate the extent of heterosis for yield and some quality in the experiment was planted in a RCBD with three replication and 45 F_1 crosses along with 10 diverse genotypes by diallel mating design in spring wheat. The estimation of high degree of heterosis in certain cross combination namely, DBW 58 × DBW 17 followed by MP 1236 × PBW 550, PBW 550 × PBW 590, PBW 550 × HD 2687, WH 1094 × PBW 590, MP 1236 × WH 1094 and PBW 590 × WH 711 which may be exploited for developing hybrids with better yield and quality in spring wheat. Out of these 11 crosses, the cross PBW 550 × PBW 373 and MP 1236 × PBW 373 which showed significant sca effect with good *per se* performance for grain yield may be used in cross breeding programme and might be expected to give transgressive segregants in F_2 as these two crosses are having the parents with low × high and high × high gca effect.

INTRODUCTION

Wheat is one of the most important cereal crops of the world. It is the leading grain quality and yield of world. Gluten which is a major part of wheat protein (about 75% of the total protein present in the wheat grain), have a unique quality for making the processed food puffly, with increase in perforated volume. Wheat constitute major staple food crop of rapidly increasing population of India and plays a most important role in food security and economic stability of the country. Because of its versatility in adaptation and utility of various ways, wheat is grown in more 44 countries at global level.

Heterotic studies can also be used for getting information about the increase or decrease of F_1s over better parent (heterobeltiosis). However, selection of superior parents represent the major step in development of high yielding new cultivars and the identification of superior hybrid combinations is another fundamental issue in hybrid breeding. The studies of heterosis in wheat have also been reported by by Singh *et al.* (2004), Chowdhry *et al.* (2005), Kumar and Raghavaiah (2005), Muhammad *et al.* (2010), Gowda *et al.* (2010), Kamaluddin Angrej Ali (2011), Karnwal *et al.* (2011), Singh and Sharma (2012), Devi *et al.* (2013), Singh *et al.* (2013) and Singh *et al.* (2014). The major objective of the present study was to estimate the heterosis over better parents (heterobeltiosis) for fourteen characters is a half diallel mating design involving ten diverse genotypes of spring wheat. The studies were conducted for identify these the best cross combination may be exploited through heterosis breeding programme for improvement in yield component and quality traits.

MATERIALS AND METHODS

The study material comprising ten wheat genotypes (MP 1236, PBW 550, WH 1094, PBW 590, PBW 373, RAJ 3765, DBW 58, HD 2687, DBW 17 and WH 711) was sown at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during *rabi* 2010-2011 for attempting of crossing programme in a diallel fashion (10 × 10).

Following season (*rabi* 2011-2012) experimental material comprising total 55 genotypes (10 parental line and 45 F_1's) was planted in a Randomized Block Design (RBD) having three replications. Each of the parental lines and crosses were sown by hand dibbling method in two rows plot (3m length keeping 25cm spacing between row and 10cm between plants). All the recommended agronomic practices were followed to raise good crop and for proper expression of material. Observations were recorded on 10 randomly selected competitive plants in each of three replications fifteen different characters namely days to 50% flowering, days to maturity, number of productive tillers per plant, plant height, flag leaf area, spike length, spikelets per spike, grains per spike, 1000-grain weight (g), biological yield per plant (g), grain yield per plant (g), harvest index, ash content (%), gluten content (%) and Phenol color reaction (grading). Observations were recorded on the fifteen characters from each replication and mean data on these traits except phenol colour reaction were subjected to statistical and biometrical analysis by commonly used statistical software (INDOSTATE 7.5). The data were first subjected to the usual analysis followed by a RCBD (Panse and Sukhatme, 1984). The heterosis over better parents show the heterobeltiosis was estimated over the check parent viz., PBW 373. The mean values of parents and hybrids were used for estimating heterosis over their respective better parents for above characters.

The magnitude of heterosis over better parents was estimated by commonly used statistical software (INDOSTATE 7.5) and calculated with the help of the formulae given below:

$$\text{Heterosis over better parent (\%)} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

where,

BP = the value of the better parent.

Test of significance

Significance of heterosis better parents was tested by the method suggested by Panse and Sukhatme (1961).

S.E. of difference between any two values (BP) = $\sqrt{2VE/r}$

where,

VE = error variance

r = number of replications

C.D. = S.E. x t

RESULTS AND DISCUSSION

In the present investigation, the degree of heterosis was measured as mean superiority of F_1s over their respective better parents. Heterosis may be high or low depending upon the mean of the parent (P) in question. Obviously, there may be possibility of getting a cross with high *per se* performance but with low heterosis, in case the parental performance is also high. On the contrary, there can be a cross with poor *per se* performance but high % of heterosis. It means that the choice of best cross combination on the basis of high heterosis would not necessarily be one which would give the highest *per se* performance also. The *per se* performance being the realized value, and the heterotic response being an estimate, the former should be given preference with high percentage of heterosis while making selection of cross combination.

While analyzing the crosses for manifestation of hybrid vigour over better parent (Table 1), none of the crosses exhibited vigour for all the traits in the present investigation.

Manifestation of heterosis was found in both positive and negative direction for days to 50% flowering. The heterosis over better parent ranged from -6.52 (PBW 550 × WH 1094) to 0.73 (PBW 590 × RAJ 3765) percent. Out of 45 crosses, three crosses showed significant and high heterosis over better parent in negative direction (desirable) for early flowering. Crosses with highly significant and negative value were, PBW 550 × WH 1094 (-6.52) followed by MP 1236 × WH 711 (-5.52) and PBW 550 × PBW 590 (-5.09). Similar results on the importance of negative heterosis for days to 50% flowering has been highlighted by Ashutosh *et al.* (2011) and Singh *et al.* (2013).

In days to maturity magnitude of heterosis ranged from -2.63 (PBW 550 × HD 2687) to 0.24 (MP 1236 × DBW 58) for early maturity. This result showed that a neglible % of heterosis for this character was seen in present crosses. However none of the cross showed significant negative value against the check parent PBW 373. Negative estimates of heterosis for maturity were earlier reported by Devi *et al.* (2013) and Singh *et al.* (2013).

Higher numbers of tillers are required for getting high yields. At present almost all high yielding varieties have profuse tillering. For this character heterobeltiosis ranged from 11.54 (WH 1094 × PBW 590) to 40.06 (DBW 58 × HD 2687). Out of 45 crosses, 9 hybrids showed significant positive heterosis over better parent (more than 15%). Similar positive significant and heterosis for number of tillers per plant has been reported by Muhammad *et al.* (2010) and Singh *et al.* (2014).

A range of for plant height was -17.71 (WH 1094 × PBW 590) to -2.43 (PBW 373 × RAJ 3765). The highest and significant negative value was observed for crosses viz.; WH 1094 × PBW 590 (-17.71) followed by MP 1236 × PBW 550 (-15.43), MP 1236 × WH 711 (-13.41), PBW 550 × WH 711 (-13.37) and 1236 × DBW 17 (-13.34), which showed more than 13% heterosis. The present study in agreement with Abdel-Nour (2005) and Singh *et al.* (2013)

Heterobeltiosis for flag leaf area was found in the range of -19.37 (PBW 373 × DBW 58) to 23.35 (PBW 550 × WH 711). Out of 45 crosses, five crosses showed significant heterosis in positive direction. The maximum value of heterosis was recorded in the cross PBW 550 × WH 711 (23.35) followed by PBW 550 × DBW 17 (22.33), DBW 17 × WH 711 (20.66), WH 1094 × WH 711 (14.17) and PBW 550 × HD 2687 (13.87). Such types of findings were also reported by Chowdhry *et al.* (2005) and Ghulam *et al.* (2006).

The magnitude of heterosis for spike length ranged from -11.47 (WH 1094 × WH 711) to 11.91 (MP 1236 × PBW 550). A total of 20 crosses showed positive heterosis. The maximum positive heterosis was observed for crosses viz.; MP 1236 × PBW 550 (11.91) and PBW 550 × DBW 58 (8.04). Positive heterosis for spike length has been reported earlier by Chowdhry *et al.* (2005), Ghulam *et al.* (2006) and Muhammad *et al.* (2010).

Heterosis over better parent for spikelets per spike ranged from -5.67 (MP 1236 × RAJ 3765) to 10.55 (PBW 590 × PBW 373). Out of 45 cross combinations, 10 crosses were found desirable with significant and positive heterosis over better parent. Cross combination PBW 590 × PBW 373 had shown maximum heterobeltiosis of 10.55 percent. Other meritorious combinations with high heterosis were PBW 373 × RAJ 3765 (10.00), PBW 373 × DBW 58 (7.31) and PBW 590 × RAJ 3765 (7.09). Positive heterosis for number of spikelets per spike has been reported by Muhammad *et al.* (2010) and Gite *et al.* (2014).

Heterobeltiosis for grains per spike, ranged from -22.75 (PBW 550 × DBW 17) to 11.38 (PBW 373 × RAJ 3765). Five crosses showed significant and positive heterosis. The cross PBW 373 × RAJ 3765 recorded highest value (11.38), followed by HD

Table 1: Extent of heterosis over better parent (BP) in 45 crosses for 14 characters in wheat

Crosses	Days to 50% Flowering BP	Days to maturity BP	Number of productive tillers/plant BP	Plant height BP	Flag leaf area BP	Spike length BP	Spikeles/ spike BP	Grains/ spike BP	1000 grain weight BP	Biological yield/ plant BP	Grain yield/ plant BP	Harvest index BP	Ash content BP	Gluten content BP
MP 1236 × PBW 550	0.40	0.00	19.53**	-5.37**	12.30**	11.91**	1.13	2.53	-7.57	14.05**	25.88**	10.36	0.81	3.57
MP 1236 × WH 1094	-2.17**	-0.96	16.02**	-15.43**	0.87	6.27*	0.65	0.27	-3.28	12.25**	20.61**	7.27	4.64	2.05
MP 1236 × PBW 590	-2.18**	-2.38**	0.36	-10.29**	-15.36**	1.89	-1.94	-6.59*	-7.08	-0.69	9.50	9.26	2.02	0.54
MP 1236 × PBW 373	0.74	-1.18*	10.94	-5.53**	-5.98	-0.84	-1.94	-6.01*	-6.21	4.71	-3.53	-7.84	-18.75**	-1.98
MP 1236 × RAJ 3765	-2.55**	-0.71	7.42	-5.50**	-8.59**	3.86	-5.67**	-16.96**	-8.21	-0.25	-0.31	-0.73	-21.98**	-1.36
MP 1236 × DBW 58	0.00	0.24	-4.30	-9.58**	-13.78**	5.98*	-3.57**	-9.78**	-9.39*	-1.30	11.55*	9.38	-11.29*	2.75
MP 1236 × HD 2687	-1.74*	-0.72	-0.78	-9.39**	0.19	-4.06	-1.78	-8.29**	-18.20**	-8.24*	10.06	19.96**	0.00	-2.37
MP 1236 × DBW 17	-2.79**	0.00	-5.86	-13.34**	4.81	2.48	-3.40**	-19.78**	-17.51**	-4.77	12.48*	18.66**	-7.26	-0.46
MP 1236 × WH 711	-5.52**	-1.41**	7.81	-13.41**	13.40**	1.53	-1.30	-6.33*	-4.62	-3.30	14.71*	18.73**	-2.62	-8.70**
PBW 550 × WH 1094	-6.52**	-2.15**	7.06	-6.79**	-4.48	4.66	0.33	-3.90	-12.87**	4.28	12.37*	7.62	3.81	-4.64*
PBW 550 × PBW 590	-5.09**	-0.95	12.46*	-4.18**	-1.14	-0.34	-0.33	-8.58**	-1.19	5.76	24.02**	13.86*	32.90**	5.53**
PBW 550 × PBW 373	-4.44**	-1.42**	4.71	-8.97**	10.78**	-8.30**	-1.48	-8.27**	-15.46**	8.16**	-1.53	-8.94*	14.10*	-3.82*
PBW 550 × RAJ 3765	-1.45	-2.36**	0.00	-5.61**	1.39	6.67*	-3.94**	-16.59**	-7.21	6.39	-2.29	-8.87*	14.78*	-3.71*
PBW 550 × DBW 58	-2.13**	-1.66**	-1.18	-4.18**	2.36	8.04**	-2.46	-20.38**	-9.89*	6.52	16.57**	6.21	19.37**	2.51
PBW 550 × HD 2687	-3.13**	-2.63**	0.00	-4.18**	13.87**	2.29	-2.63*	-19.43**	-15.57**	7.83*	21.19**	12.42*	14.89**	-5.63**
PBW 550 × DBW 17	-4.18**	-2.36**	2.35	-7.38**	22.33**	1.52	-5.42**	-22.75**	-1.94	1.45	14.23*	12.57*	0.67	7.31**
PBW 550 × WH 711	-3.79**	-0.23	3.14	-13.37**	23.35**	-1.28	-2.96*	-19.43**	-1.11	7.41*	18.96**	10.81*	4.35	-2.92
WH 1094 × PBW 590	-1.09	-0.71	11.54*	-17.71**	-4.41	3.44	1.85	-4.95	-8.61*	12.08**	20.97**	7.83	0.85	2.36
WH 1094 × PBW 373	-1.81*	-1.18*	9.54	-8.87**	-6.37*	-0.52	-0.67	0.33	-10.15**	-4.05	-13.39**	-9.49*	3.81	3.88*
WH 1094 × RAJ 3765	-1.81*	-0.47	12.07*	-10.18**	1.66	-3.41	-1.17	-18.60**	-11.36**	2.10	-3.21	-6.03	-9.09	4.77**
WH 1094 × DBW 58	-2.13**	-0.95	12.89*	-5.04**	-13.99**	3.76	-0.17	-16.42**	-4.73	6.94*	11.83*	3.95	-1.48	2.89
WH 1094 × HD 2687	-2.43**	-0.48	15.11*	-3.94**	-0.47	2.29	-0.50	-10.01**	-18.42**	-2.40	5.83	7.85	0.85	2.07
WH 1094 × DBW 17	-1.74*	-1.18*	14.22*	-0.25	6.84	-4.30	1.51	-10.98**	-10.68*	0.60	6.99	6.23	5.71	7.38**

2687 × WH 711 (10.61), PBW 373 × DBW 17 (10.11), PBW 373 × HD 2687 (8.28), PBW 373 × WH 711 (6.48). However, grains per spike are one of the important component characters of yield. Thus, positive and significant heterosis for this character is important as this traits is contributing to yield in a considerable way. Similar studies were reported by Jahanzeb-Farooq and Ihsan-Khaliq (2004).

A negligible amount of positive heterobeltiosis was observed for 1000-grain weight. Only two crosses e × hibited heterosis in positive derection namely RAJ 3765 × WH 711 (2.62) and PBW 590 × RAJ 3765 (0.82). Heterosis for 1000 grain weight was earlier reported by Hassan and Saad (1996).

Heterobeltiosis value for biological yield/ plant ranged from -13.87 (RAJ 3765 × WH 711) to 26.82 (DBW 58 × DBW 17). The highest significant positive heterosis was displayed by five hybrids. The hybrid DBW 58 × DBW 17 showed highest degree of significant positive heterosis (26.82), followed by MP 1236 × PBW 550 (14.05), RAJ 3765 × DBW 58 (12.86), MP 1236 × WH 1094 (12.25) and WH 1094 × PBW 590 (12.08), which showed heterosis (%) more than 10%. Similar results for biological yield were reported by Desale, *et al.* (2013).

The range of heterosis over better parent for grain yield per plant varied from -21.08 (PBW 373 × DBW 17) to 34.19 (DBW 58 × DBW 17). While selecting the plants, grain yield received maximum attention of plant breeder. Therefore, positive heterosis for grain yield is desirable. In case of grain yield per plant, 20 crosses showed significant and positive over better parent more than 11%. Similar results on positive heterosis for grain yield per plant has been reported by Muhammad *et al.* (2010), Kamaluddin Angrej Ali (2011), Karnwal *et al.* (2011), Singh and Sharma (2012), Singh *et al.* (2013), Devi *et al.* (2013), Desale *et al.* (2013) and Singh *et al.* (2014).

The magnitude of heterosis for harvest index ranged from -20.45 (PBW 373 × DBW 58) to 19.96 (MP 1236 × HD 2687). Significant positive heterosis was demonstrated by five hybrids, i.e. MP 1236 × HD 2687 (19.96), MP 1236 × WH 711 (18.73), MP 1236 × DBW 17 (18.66), PBW 590 × WH 711 (17.95) and PBW 550 × PBW 590 (13.86). These crosses could be of greater value if exploited in breeding programme. Positive heterosis for harvest index were reported by Singh *et al.* (2013).

The expression of heterosis over better parent for ash content ranged from -21.98 (MP 1236 × RAJ 3765) to 32.90 (PBW 550 × PBW 590). 12 crosses showed positive heterosis (Table 4). However, 7 crosses showed significant positive heterosis for this traits.

The magnitude of heterosis for gluten content ranged from -8.70 (MP 1236 × WH 711) to 7.38 (WH 1094 × DBW 17). Total numbers of crosses with positive value were 11 out of which 6 were having significant positive heterosis (Table 3). Similar results for gluten content were reported by Krystkowiak *et al.* (2009), Singh and Sharma (2012), Gite *et al.* (2014) and Singh *et al.* (2014).

Data recorded on this trait was not statistically analyzed. Parents and F_1s were categorized on the basis of colour observed on grains after phenol reaction. The colour on the

Table 1: Cont.......

Crosses	Days to 50% Flowering BP	Days to maturity BP	Number of productive tillers/ Plant BP	Plant height BP	Flag leaf area BP	Spike length BP	Spikeles/ spike BP	Grains/ spike BP	1000 grain weight BP	Biological yield/ plant BP	Grain yield/ plant BP	Harvest index BP	Ash content BP	Gluten content BP
WH 1094 × WH 711	-3.79**	-0.94	10.30	-1.36	14.17**	-11.47**	0.17	-15.55**	-5.03	-8.65*	-3.76	5.24	9.30	0.07
PBW 590 × PBW 373	-0.73	-0.24	13.52*	-6.08**	-0.01	-1.17	10.55**	-6.55*	-13.90**	4.58	-6.24	-10.29*	3.47	2.06
PBW 590 × RAJ 3765	0.73	0.00	-4.63	-4.31**	-11.41**	-5.16*	7.09**	5.34	0.82	-0.08	-8.56	-9.15*	13.16*	0.15
PBW 590 × DBW 58	-1.42	-0.24	1.42	-4.46**	-5.16	-5.51*	6.60**	5.15	-10.50*	-0.69	13.87*	4.99	13.08*	6.83**
PBW 590 × HD 2687	-3.13**	0.24	0.71	-0.25	11.54**	-5.68*	-1.50	-6.25*	-7.47	-0.43	13.28*	13.68*	-14.89**	2.59
PBW 590 × DBW 17	-2.09**	-0.47	3.56	-1.97	9.70*	-4.48	-0.51	-3.63	-2.73	-5.07	9.77	10.67*	-3.80	-0.99
PBW 590 × WH 711	-1.72*	-0.47	3.20	-11.29**	6.42	-6.54**	-1.03	-5.43	-5.36	-2.67	20.70**	17.95**	-7.83	-0.29
PBW 373 × RAJ 3765	-2.18**	-1.42**	7.05	-2.43*	7.82*	-5.38*	10.00**	11.38**	-12.95**	-0.40	-19.67**	-19.21**	4.99	2.46
PBW 373 × DBW 58	-2.13**	-0.47	7.47	-8.41**	-19.37**	-2.79	7.31**	5.72	-15.28**	-0.46	-20.85**	-20.45**	1.30	1.56
PBW 373 × HD 2687	-4.17**	-1.18*	4.15	-7.76**	-14.79**	-10.56**	2.83*	8.28**	-20.99**	-0.13	-20.14**	-19.90**	7.23	1.89
PBW 373 × DBW 17	-4.53**	-1.89**	9.13	-11.11**	-13.64**	1.59	4.10**	10.11**	-16.45**	-7.10**	-21.08**	-15.04**	-4.56	2.36
PBW 373 × WH 711	-1.72*	-0.70	7.05	-6.57**	5.43	-3.43	3.25*	6.48*	-10.12**	-5.24	-17.20**	-12.61**	3.90	-1.67
RAJ 3765 × DBW 58	-0.71	-0.71	15.52*	-7.26**	-4.79	-7.48**	6.06**	-1.32	-2.46	12.86**	0.46	-11.71**	9.47	1.14
RAJ 3765 × HD 2687	-1.39	-1.18*	11.64*	-4.44**	-8.96**	-0.35	-0.17	4.36	-11.58**	10.17**	-0.46	-10.31*	-9.36	2.30
RAJ 3765 × DBW 17	-2.79**	-0.47	9.48	-9.62**	-7.88*	1.71	2.73*	2.29	-8.20	5.80	-5.81	-11.71**	9.62	0.23
RAJ 3765 × WH 711	-1.72*	-0.70	19.74**	-8.69**	-2.89	3.67	2.05	-0.68	2.62	-13.87**	-20.49**	-8.29	-2.17	1.50
DBW 58 × HD 2687	-2.43**	-0.95	43.06**	-3.84**	-7.57*	-9.70**	-0.17	1.39	-19.63**	9.51*	12.57*	1.79	-11.49*	2.96
DBW 58 × DBW 17	0.35	-1.65**	30.57**	-8.60**	-13.57**	2.62	1.71	1.12	-10.79**	26.82**	34.19**	1.10	-10.51	2.63
DBW 58 × WH 711	0.00	-0.70	12.88*	-7.71**	11.53**	5.61*	2.05	-2.24	-10.34*	-6.21	0.60	3.42	-7.17	-0.93
HD 2687 × DBW 17	-1.04	-1.65**	28.71**	-3.51**	-8.70*	-7.05**	0.33	-5.05	-4.52	4.27	14.43*	9.68	-8.51	3.52
HD 2687 × WH 711	-1.03	0.00	17.17**	-4.80**	-0.52	-0.88	2.50	10.61**	-4.83	7.88*	14.77*	6.41	-5.74	0.68
DBW 17 × WH 711	-0.69	-0.23	10.30	-0.21	20.66**	-0.95	0.85	-2.02	-1.56	-5.27	3.56	8.38	2.17	1.18
S.E.	0.761	0.711	0.505	1.044	1.487	0.235	0.263	1.619	1.743	1.322	0.996	2.403	0.086	0.157

grains after phenol colour reaction were categorized in five groups viz; Black, Dark brown to brown, light brown, slight colour on the edge and no colour. On the basis of different grade the parents and cross-combinations were grouped in different categories. Out of 55 genotypes (10 parental lines and 45 F_1s) 4 parents and 10 crosses were found in black category; one parent and 13 crosses were in Dark brown to brown category; two parents and 14 crosses were in light brown category and slight colour on the edge category these were three parents and eight crosses namely MP1236, PBW373 and RAJ3765 (parents) and crosses viz; MP1236 × PBW373, MP1236 × RAJ3765, PBW550 × PBW373, PBW550 × RAJ3765, PBW550 × HD2687, WH1094 × PBW373, WH1094 × RAJ3765 and PBW373 × RAJ3765 which showed that the 3 parents and 8 crosses might be suitable for chapatti quality which in cross breeding programme. Similar studies were reported by Abrol and Uprety, (1970).

Out of 45 cross combinations, 20 crosses showed significant and positive heterosis over better parents with a range of heterosis (%) from 11. 55 to 34.19 for grain yield (Table 2). Among these crosses the cross viz; DBW 58 × DBW 17 (34.19), MP 1236 × PBW 550 (25.88), PBW 550 × PBW 590 (24.02), PBW 550 × HD 26876 (21.19), WH 1094 × PBW 590 (20.94) and MP 1236 × WH 1094 (20.61), exhibited more than 20% heterosis for yield and also for major yield component traits. These crosses may be exploited for heterosis breeding programme. Since these crosses involved high × low or high × average or average × average or average × low or low ×low gca value of parent and significant sca for indicated involved of non additive gene action and response of dominance and dominance × dominance type gene effect. A high heterotic result for yield might be obtained by exploiting these individual cross for developing hybrids through heterosis breeding programme. On the other hand, crosses PBW550 × HD2687, WH1094 × RAJ3765, PBW550 × PBW590, PBW590 × DBW58, PBW550 × DBW58 and PBW550 × DBW17 were common for gluten content, ash content and grain yield per plant and were graded for low phenol reaction. These cross combination may be exploited through heterosis breeding programme for improvement in yield along with quality traits.

Out of these 11 crosses, the cross PBW 550 × PBW 373 and MP 1236 × PBW 373 which showed significant sca effect with good *per se* performance for grain yield may be used in cross breeding programme and might be expected to give transgressive segregants in F_2 as these two crosses are having the parents with low x high and high x high gca effect. On the other hand crosses PBW550 × PBW373, MP1236 × PBW373, WH1094 × PBW590, MP1236 × PBW550 and RAJ3765 × DBW58 with good *per se* performance and significant gca effect were common for gluten content, ash content and grain yield per plant. These crosses also showed light colouration on grains when tested with phenol solution (1%). Hence these crosses may be exploited for developing hybrid/genotypes with better yield and quality including *chapati* quality.

Out of 45 crosses 20 crosses showed significant heterobeltiosis (superiority over better parent) more than 11%, for grain yield.

Table 2: Twenty crosses showing maximum heterosis over better parents for grain yield per plant in spring wheat.

Crosses	Heterosis (%)	SCA effect	GCA effects P_1	GCA effects P_2	*Per se* F_1	BP	Other character exhibiting significant heterosis in desirable direction.
DBW 58 × DBW 17	34.19**	3.93**	-0.84**	-0.97**	22.63	16.86	Days to maturity**, Number of productive tillers/plant**, Plant height**, Biological yield/plant**
MP 1236 × PBW 550	25.88**	1.79**	0.34	-0.11	22.53	17.90	Number of productive tillers/plant**, Plant height**, Flag leaf area**, Spike length**, Biological yield/plant**
PBW 550 × PBW 590	24.02**	1.07	-0.11	-0.31	21.17	17.06	Days to 50 % flowering**, Number of productive tillers/plant**, Plant height **, Harvest index*, Ash content**, Gluten content**
PBW 550 × HD 2687	21.19**	0.58	-0.11	-1.36**	19.63	16.20	Days to 50 % flowering**, Days to maturity**, Plant height**, Flag leaf area**, Biological yield/plant** , Harvest index*, Ash content**, Phenol colour reaction
WH 1094 × PBW 590	20.97**	2.19**	0.10	-0.31	22.50	18.60	Plant height*, Number of productive tillers/plant*, Biological yield/plant**
PBW 590 × WH 711	20.70**	1.99**	-0.31	-1.60**	20.60	17.06	Days to 50 % flowering**, Plant height**, Harvest index**
MP 1236 × WH 1094	20.61**	1.48*	0.34	0.10	22.43	18.60	Days to 50 % flowering**, Plant height**, Number of productive tillers/plant**, Spike length*, Biological yield/plant**
PBW 550 × WH 711	18.96**	1.05	-0.11	1.60**	19.87	16.70	Days to 50 % flowering**, Plant height**, Flag leaf area**, Biological yield/ plant*, Harvest inde x*
PBW 550 × DBW 58	16.57**	-0.10	-0.11	-0.84**	19.47	16.70	Days to 50 % flowering**, Days to maturity**, Plant height**, Spike length **, Ash content**
HD 2687 × WH 711	14.77*	1.61*	-1.36**	-1.60**	19.17	16.70	Plant height**, Number of productive tillers/ plant**, Grains/spike** Biological yield/plant **
MP 1236 × WH 711	14.71**	1.28	0.34	-1.60**	20.53	17.90	Days to 50 % flowering**, Days to maturity**, Plant height**, Flag leaf area**, Harvest index**
HD 2687 × DBW 17	14.43*	1.11	-1.36**	-0.97**	19.30	16.86	Days to maturity**, Number of productive tillers/plant**, Plant height**
PBW 550 × DBW 17	14.23*	-0.17	0.11	-0.97**	19.27	16.86	Days to 50 % flowering**, Days to maturity**, Plant height**, Flag leaf area**, Harvest index*, Gluten content**
PBW 590 × DBW 58	13.87*	0.07	-0.31	-0.84**	19.43	17.06	Plant height**, Spikelelets/ spike**, Ash content*, Gluten content**
PBW 590 × HD 2687	13.28*	0.49	-0.31	-1.36**	19.33	17.06	Days to 50 % flowering**, Flag leaf area**, Harvest index *
DBW 58 × HD 2687	12.57*	0.48	-0.84**	-1.36**	18.80	16.70	Days to 50 % flowering**, Number of productive tillers/plant**, Plant height**, Biological yield/plant*
MP 1236 × DBW 17	12.48*	0.25	0.34	-0.97**	20.13	17.70	Days to 50 % flowering**, Plant height **, Harvest index**
PBW 550 × WH 1094	12.37*	0.39	-0.11	0.10	20.90	18.60	Days to 50 % flowering**, Days to maturity**, Plant height**,
WH 1094 × DBW 58	11.83*	1.02	0.10	-0.84**	20.80	18.60	Days to 50 % flowering*, Number of productive tiller/ plant*, Plant height **, Biological yield/plant*
MP 1236 × DBW 58	11.55*	-0.05	0.34	-0.84**	19.97	17.90	Plant height**, Spike length*

Table 3: Crosses showing significant and high % of heterosis for gluten content (%) in wheat

Crosses	Heterosis (%)	SCA effect	GCA effects		Desirable heterosis in other component traits
			P_1	P_2	
WH1094 × HD2687	7.38**	0.03	0.07*	0.15*	Days to 50% flowering**, number of productive tillers/plant* and plant height**
PBW550 × DBW17	7.31**	0.64**	-0.26**	0.08*	Days to 50% flowering**, days to maturity**, plant height**, flag leaf area, grain yield/plant*and harvest index**
PBW590 × DBW58	6.83**	0.35**	0.01	-0.02	Plant height**, spikelets per spike, grain yield/plant and ash content
PBW550 × PBW590	5.53**	0.48**	-0.26**	0.01	Days to 50% flowering**, number of productive tillers/plant*, Harvest inde × *, plant height**, grain yield/plant* , harvest index ** and ash content
WH1094 × RAJ3765	4.77**	0.22*	0.07*	0.00	Days to 50% flowering*
WH1094 × PBW373	3.88*	0.16	0.07*	-0.05	Days to 50% flowering*, days to maturity* and plant height**

Table 4: Heterosis over better parent for ash content in relation to other parameters and components traits.

Crosses	Heterosis (%)	SCA effect	GCA effects		Desirable heterosis in other component traits
			P_1	P_2	
PBW550 × PBW590	32.90**	0.173**	0.032	-0.036*	Days to 50% flowering**, number of productive tillers/plant*, plant height **, grain yield/plant**, harvest index** and gluten content**.
PBW550 × DBW58	19.37**	0.129*	0.032	-0.058**	Days to 50% flowering**, days to maturity**, plant height**, spike length**and grain yield/plant**.
PBW550 × HD2687	14.89**	0.231**	0.032	-0.003	Days to 50% flowering**, days to maturity**, plant height**, flag leaf area**, biological yield per plant*, grain yield/plant** and harvest index*.
PBW550 × RAJ3765	14.78*	0.110	0.032	-0.025	Days to maturity**, plant height** and spike length*.
PBW550 × PBW373	14.10*	0.151**	0.032	0.030	Days to 50% flowering**, days to maturity**, plant height**, flag leaf area** and biological yield/plant**.
PBW590 × RAJ3765	13.16*	0.153**	-0.036*	-0.025	Plant height** and spikelets per spike**.
PBW590 × DBW58	13.08*	0.110	-0.036*	-0.058**	Plant height**, spikelets per spike**, grain yield /plant * and gluten conten**.

Among these, crosses DBW 58 × DBW 17 (34.19), MP 1236 × PBW 550 (25.88), PBW 550 × PBW 590 (24.02), PBW 550 × HD 2687 (21.19), WH 1094 × PBW 590 (20.97) and MP 1236 × WH 1094 (20.61), showed more than 20% heterobeltiosis over better parents. These individual crosses may be exploited in heterosis breeding programme for improvement in yield. However, it may be crosses PBW550 × HD2687, WH1094 × RAJ3765, PBW550 × PBW590, PBW590 × DBW58, PBW550 × DBW58 and PBW550 × DBW17 were common for gluten content, ash content, phenol colour reaction and grain yield per plant which can be exploited for hybrid development for better grain yield and quality. Out of these 11 crosses, the cross PBW 550 × PBW 373 and MP 1236 × PBW 373 which showed significant sca effect with good *per se* performance for grain yield may be used in cross breeding programme and might be expected to give transgressive segregants in F_2 as these two crosses are having the parents with low × high and high × high gca effect.

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