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Heterosis for quality traits in wheat

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Abstract
The present investigation was conducted to estimate heterotic effects for four quality traits in F_1 hybrids of ten bread wheat genotypes crossed in half diallel fashion. The experiment was undertaken at G.B. Pant University of Agriculture and technology during Rabi season, 2016-17 in randomized complete block design with three replications. Results revealed that based on superior per se performance and high relative heterosis, heterobeltiosis and standard heterosis cross Raj 4419 x PBW 729 was found superior for protein content, UP 2762 x HD 2967 for sedimentation value, PBW 729 x DBW 50 for hectolitre weight and Raj 4419 x NIAW 1594 for phenol colour reaction. Therefore these superior cross combination can be further utilized to produce wheat hybrids with improved quality traits that can be utilized for different purposes.

Keywords: Quality, heterosis, heterobeltiosis, standard heterosis, bread wheat

Introduction
Bread wheat is an allohexaploid with a chromosome number of 42 and belongs to the Levant region. Being one the most widely cultivated food crop throughout the world it covers an area of 215.33 million hectares with 730.55 million tonnes production and a productivity of 3.39 t/ha (USDA, 2019). It also acts as a major provider of digestible sugar on global level contributing 55% carbohydrate and 20% of the total food calories (Breiman and Graur, 1995). China is the country producing maximum amount of wheat followed by India. Under Indian context wheat is an important staple food crop for many states and is grown over an area of 29.65 million hectares contributing 30% to the Indian food basket (Anonymous, 2016). Being one of the most important crop of the rabi season in India wheat gives a mammoth production of 99.87 million tonne and 3.37 t/ha productivity. Three species of wheat are grown in India viz., *Triticum aestivum*, *T. durum* and *T. dicoccum.* Out of these bread wheat (*Triticum aestivum* L.) is the most widely cultivated wheat under Indian scenario. Wheat production have already increased manifolds and self-sufficiency in terms of amount produce have been achieved. It is now required to improve quality of wheat in order to make it more desirable from product making point of view. Wheat quality refers to its suitability for a particular end-use based on physical, chemical and nutritional properties of wheat grain. Heterosis have been observed in wheat F_1s for various quality traits as protein content (Krystowiak *et al.*, 2009), sedimentation value (Li *et al.*, 2003) [6] etc. It refers to the superiority of F_1 over parents i.e., mid parent, better parent or standard check. Hybrids have not yet been exploited in wheat to a greater extent therefore the need is to identify superior hybrids for different quality traits and evaluate them so that they can be further released for commercial cultivation. Keeping this in mind the present investigation was conducted to identify best heterotic combinations for different quality traits in wheat.

Materials and Methods
The study was conducted at Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India. Ten genotypes of wheat namely, QLD 39, KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES, UP 2762, KFA/2*KACHU, Raj 4419, PBW 729, WH 1187, HD 2967, DBW 50 and NIAW 1594 having different desirable quality traits were crossed in half diallel fashion to produce 45 F_1s. The 10 parental lines, 45 F_1s and two checks viz., UP 2628 and WH 1105 were evaluated in randomized block design with three replications in rabi 2016-17 at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar and data for four quality traits i.e.,

protein content, sedimentation value, hectolitre weight and phenol colour reaction were recorded. NIT based Whole Grain Analyser (Infratech 1241 Grain Analyser) was used to determine protein content while sedimentation value was recorded by method recommended by Zeleny (1947) [8]. Hectolitre weight was recorded with the help of hectolitre weight instrument. Phenol colour reaction value of seed samples were determined by phenol colour reaction test conducted in four replication per sample. 100 seeds per sample were soaked in distilled water for 16 hours followed by draining of water and application of 1% phenol solution. After 4 hrs the readings were taken. Relative heterosis, heterobeltiosis and standard heterosis was computed according to the formula given by Hayes *et al*. (1995).

Result and discussion

Relative heterosis, heterobeltiosis, standard heterosis over UP 2628 and standard heterosis over WH 1105 for protein content ranged from -9.23 to 12.32, -11.2 to 11.04, -11.14 to 13.97 and -12.55 to 12.17, respectively. Significant positive heterosis over mid parent, heterobeltiosis and standard heterosis over UP 2628 and WH 1105 was shown by 3, 1, 1 and 11 crosses, respectively. Highest significant positive relative heterosis of 12.32 was shown by cross KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x DBW 50. While highest significant positive heterobeltiosis was shown by KAUZ/ALTAR84/ 3/MILAN/KAUZ/4/HUITES x DBW 50 (11.04). Highest positive standard heterosis over check variety UP 2628 was shown by Raj 4419 x PBW 729 (13.97) and over check WH 1105 was shown by Raj 4419 x PBW 729 (12.17). High positive heterosis for protein content has also been reported by Krystowiak *et al.* (2009). Protein content is an important quality trait of wheat that decides the suitability of wheat for various purposes. High protein wheat is suitable for bread making while lower protein content wheat varieties can be used for biscuit making. Intermediate protein content varieties are suitable for chapatti making point of view. Cross Raj 4419 x PBW 729 shows high per se performance along with high significant positive estimates of relative heterosis, standard heterosis over UP 2628 and standard heterosis over WH 1105. Therefore this cross can be further utilized for development of high protein hybrid in wheat. Relative heterosis, heterobeltiosis, standard heterosis over UP 2628 and standard heterosis over WH 1105 for sedimentation value ranged from -45.52 to 38.01, -45.93 to 18.91, -29.12 to 62.15 and -44.70 to 26.52, respectively. Significant positive heterosis over mid parent, heterobeltiosis and standard heterosis over UP 2628 and WH 1105 was shown by 15, 4, 30 and 8 crosses, respectively. Highest significant positive relative heterosis of 38.01 was shown by cross KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762. While highest significant positive heterobeltiosis was shown by KAUZ/ALTAR84/3/MILAN/ KAUZ/4/HUITES x PBW 729 (18.91). Highest positive standard heterosis over check variety UP 2628 was shown by KAUZ/ALTAR84/ 3/MILAN/KAUZ/4/HUITES x UP 2762 (62.15) and over check WH 1105 was shown by KAUZ/ALTAR84/3/ MILAN/KAUZ/4/HUITES x UP 2762 (26.52). High positive heterosis for sedimentation value has also been reported by Li *et al.* (2003) [6]. Sedimentation value in wheat decides the quality of wheat gluten which ultimately decides the utility of wheat variety. High sedimentation value is desirable as it represents strong gluten hence the suitability of wheat for bread making. Cross UP 2762 x HD 2967 shows high per se performance along with high significant positive estimates of heterobeltiosis, standard heterosis over UP 2628 and standard heterosis over WH 1105. Therefore this cross can be further utilized for development of strong gluten hybrid in wheat.

Relative heterosis for phenol colour reaction varied from -3.52 to 5.54. Significant positive relative heterosis was shown by nineteen crosses while five crosses showed negative relative heterosis. Highest significant positive relative heterosis was shown by UP 2762 x KFA/2*KACHU (100) while Cross Raj 4419 x NIAW 1594 (-36.38) showed highest negative relative heterosis. Heterosis over better parent ranged from -33.33 to 214.74. Twenty seven and four crosses showed significant positive and negative heterobeltiosis, respectively. Highest positive heterobeltiosis was existent in KFA/2*KACHU x WH 1187, KFA/2*KACHU x DBW 50, KFA/2*KACHU x NIAW 1594 and KFA/2*KACHU x QLD 39 (214.74) while crosses Raj 4419 x NIAW 1594 (-33.33). KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x NIAW 1594, Raj 4419 x WH 1187, Raj 4419 x HD 2967, HD 2967 x DBW 50, NIAW 1594 x QLD 39 displayed highest significant negative heterobeltiosis. The range of standard heterosis over check variety UP 2628 for phenol colour reaction was from 225.81 to 501.50 while that over check WH1105 was 34.93 to 20.12. 45, 0 and 9, 3 crosses showed significant positive and negative standard heterosis over check UP 2628 and WH 1105, respectively. KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x WH 1187 and PBW 729 x HD 2967 (501.50) showed highest significant positive standard heterosis over UP 2628 and lowest positive standard heterosis was shown by UP 2762 x Raj 4419 (225.81). While PBW 729 x HD 2967 and KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x WH 1187 (20.12) was identified as cross with highest significant standard heterosis over WH 1105 while highest significant negative heterosis over check variety was found in cross UP 2762 x Raj 4419 (-34.93). Significance negative heterosis for phenol colour reaction has been estimated by Kumar and Kerkhi (2015) [5]. The crosses with high per se performance, high significant relative heterosis, heterobeltiosis and standard heterosis in desired direction along with superior crosses on basis of per se performance and heterosis are depicted in table 2. While mean value and heterosis in F_1 over mid parent (MP), better parent (BP) and checks for different quality traits in wheat are depicted in table 1.

Results revealed that based on superior per se performance and high relative heterosis, heterobeltiosis and standard heterosis cross Raj 4419 x PBW 729 was found superior for protein content, UP 2762 x HD 2967 for sedimentation value, PBW 729 x DBW 50 for hectolitre weight and Raj 4419 x NIAW 1594 for phenol colour reaction. Therefore these superior cross combination can be further utilized to produce wheat hybrids with improved quality traits that can be utilized for different purposes.

Table 1: Percentage heterosis in F_1 over mid parent (MP), better parent (BP) and checks for different quality traits in wheat

Sl No.	Crosses	F1 (mean)	Protein content				F1 (mean)	Sedimentation value (ml)			
			MP	BP	CP1	CP2		MP	BP	CP1	CP2
1.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762	11.21	2.20	2.16	0.15	-1.44	55.67	38.01**	13.61**	62.15**	26.52**
2.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x KFA/2*KACHU	10.94	-3.43	-6.44	-2.26	-3.81	38.33	-1.71	-17.26**	11.66*	-12.88**
3.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x Raj 4419	11.05	-0.58	-1.95	-1.25	-2.81	32.33	-18.14**	-31.69**	-5.82	-26.52**
4.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x PBW 729	11.11	-1.88	-4.91	-0.74	-2.32	50.33	36.04**	18.91**	46.62**	14.39**
5.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x WH 1187	10.97	-1.66	-3.35	-1.97	-3.52	41.00	11.31**	-2.38	19.43**	-6.82
6.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x HD 2967	11.15	0.66	-0.42	-0.33	-1.91	44.00	14.78**	-2.22	28.17**	0.00
7.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x DBW 50	12.17	12.32**	11.04*	8.76	7.04	42.33	11.40**	-4.50	23.31**	-3.79
8.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x NIAW 1594	11.12	5.28	1.49	-0.60	-2.17	33.33	16.27**	5.25	-2.90	-24.24**
9.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x QLD 39	10.70	-4.97	-7.44	-4.38	-5.89	50.00	12.78**	-12.28**	45.65**	13.64**
10.	UP 2762 x KFA/2*KACHU	11.31	-0.18	-3.25	1.07	-0.53	37.67	-20.98**	-23.13**	9.72	-14.39**
11.	UP 2762 x Raj 4419	11.56	3.99	2.60	3.34	1.70	52.33	8.65**	6.80*	52.44**	18.94**
12.	UP 2762 x PBW 729	11.59	2.31	-0.80	3.54	1.91	36.67	-19.71**	-25.17**	6.81	-16.67**
13.	UP 2762 x WH 1187	11.57	3.67	1.94	3.40	1.76	33.33	-26.74**	-31.97**	-2.90	-24.24**
14.	UP 2762 x HD 2967	10.71	-3.41	-4.40	-4.32	-5.83	55.00	17.02**	12.24**	60.21**	25.00**
15.	UP 2762 x DBW 50	12.05	11.13*	9.81	7.66	5.95	49.67	6.43*	1.36	44.67**	12.88**
16.	UP 2762 x NIAW 1594	10.53	-0.38	-4.01	-5.90	-7.39	42.67	14.28**	-12.93**	24.28**	-3.03
17.	UP 2762 x QLD 39	11.25	-0.13	-2.68	0.54	-1.06	49.00	-7.55**	-14.04**	42.73**	11.36**
18.	KFA/2*KACHU x Raj 4419	10.75	-6.33	-8.01	-3.90	-5.42	32.33	-30.96**	-31.69**	-5.82	-26.52**
19.	KFA/2*KACHU x PBW 729	11.55	-1.18	-1.23	3.19	1.55	33.33	-24.81**	-28.05**	-2.90	-24.24**
20.	KFA/2*KACHU x WH 1187	10.52	-8.71*	-10.04*	-6.02	-7.51	32.00	-27.54**	-30.93**	-6.79	-27.27**
21.	KFA/2*KACHU x HD 2967	10.85	-5.20	-7.19	-3.04	-4.57	46.33	1.46	0.01	34.96**	5.30
22.	KFA/2*KACHU x DBW 50	10.77	-3.81	-7.84	-3.72	-5.25	42.67	-5.88	-7.91*	24.28**	-3.03
23.	KFA/2*KACHU x NIAW 1594	10.68	-2.32	-8.67	-4.59	-6.10	37.00	2.78	-20.14**	7.78	-15.91**
24.	KFA/2*KACHU x QLD 39	10.88	-6.41	-6.93	-2.77	-4.31	44.00	-14.84**	-22.81**	28.17**	0.00
25.	Raj 4419 x PBW 729	12.75	11.14**	9.19	13.97**	12.17*	47.67	6.33*	0.71	38.85**	8.33*
26.	Raj 4419 x WH 1187	11.76	4.01	3.64	5.12	3.46	41.67	-6.71*	-11.97**	21.37**	-5.30
27.	Raj 4419 x HD 2967	11.68	3.93	3.61	4.35	2.70	39.33	-14.80**	-16.90**	14.57**	-10.61**
28.	Raj 4419 x DBW 50	11.28	2.67	0.12	0.83	-0.76	31.67	-30.90**	-33.09**	-7.76	-28.03**
29.	Raj 4419 x NIAW 1594	11.16	4.07	-1.01	-0.30	-1.88	28.33	-22.37**	-40.14**	-17.47**	-35.61**
30.	Raj 4419 x QLD 39	11.04	-3.26	-4.47	-1.31	-2.87	43.33	-16.93**	-23.98**	26.23**	-1.52
31.	PBW 729 x WH 1187	11.32	-1.66	-3.05	1.19	-0.41	39.00	-7.51*	-7.87*	13.60**	-11.36**
32.	PBW 729 x HD 2967	10.84	-5.27	-7.22	-3.16	-4.69	41.67	-4.58	-7.41*	21.37**	-5.30
33.	PBW 729 x DBW 50	10.95	-2.22	-6.28	-2.17	-3.72	42.33	-2.30	-4.50	23.31**	-3.79
34.	PBW 729 x NIAW 1594	11.16	2.12	-4.48	-0.30	-1.88	40.33	18.63**	-4.72	17.49**	-8.33*
35.	PBW 729 x QLD 39	10.63	-8.55*	-9.02	-5.03	-6.54	40.67	-18.12**	-28.65**	18.46**	-7.58*
36.	WH 1187 x HD 2967	11.41	1.20	0.53	1.97	0.35	39.33	-9.58**	-12.59**	14.57**	-10.61**
37.	WH 1187 x DBW 50	11.37	3.05	0.15	1.58	-0.03	43.67	1.16	-1.50	27.20**	-0.76
38.	WH 1187 x NIAW 1594	10.98	2.08	-3.23	-1.85	-3.40	33.33	-1.48	-20.63**	-2.90	-24.24**
39.	WH 1187 x QLD 39	11.92	4.09	3.14	6.55	4.87	46.33	-6.40*	-18.71**	34.96**	5.30
40.	HD 2967 x DBW 50	9.94	-9.23*	-11.22*	-11.14*	-12.55**	24.33	-45.52**	-45.93**	-29.12**	-44.70**
41.	HD 2967 x NIAW 1594	11.10	3.92	-0.86	-0.77	-2.35	43.33	22.64**	-3.70	26.23**	-1.52
42.	HD 2967 x QLD 39	10.98	-3.51	-5.02	-1.88	-3.43	36.00	-29.41**	-36.84**	4.86	-18.18**
43.	DBW 50 x NIAW 1594	11.09	6.26	3.58	-0.86	-2.43	41.33	18.10**	-6.76	20.40**	-6.06
44.	DBW 50 x QLD 39	11.49	3.22	-0.58	2.71	1.08	45.67	-9.87**	-19.88**	33.02**	3.79
45.	NIAW 1594 x QLD 39	11.05	1.67	-4.44	-1.28	-2.84	31.33	-24.20**	-45.03**	-8.73	-28.79**

Sl No.	Crosses	F1 (mean)	Hectolitre weight (Kg/hl)				F1 (mean)	Phenol colour reaction			
			MP	BP	CP1	CP2		MP	BP	CP1	CP2
1.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762	72.87	-0.01	-1.90	9.05**	13.29**	6.67	8.05	42.76**	401.25**	0.10
2.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x KFA/2*KACHU	73.80	-0.75	-0.85	10.45**	14.74**	7.00	40.00**	200.43**	426.32**	5.11
3.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x Raj 4419	75.13	2.52	1.15	12.44**	16.81**	6.33	-17.43**	-17.43**	376.19**	-4.90
4.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x PBW 729	72.57	-2.30	-2.31	8.60**	12.82**	7.67	12.17	27.78**	476.44**	15.12*
5.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/H	72.20	-0.99	-2.80	8.05**	12.25**	8.00	14.29*	26.38**	501.50**	20.12**

	UITES x WH 1187									
6.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x HD 2967	72.33	-0.08	-2.62	8.25**	12.46**	7.33	4.76	15.85*	451.38**	10.11
7.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x DBW 50	73.57	0.36	-0.96	10.10**	14.38**	7.67	6.93	14.94*	476.44**	15.12*
8.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x NIAW 1594	73.10	-0.26	-1.59	9.40**	13.65**	7.00	-4.57	0.00	426.32**	5.11
9.	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x QLD 39	71.70	-1.16	-3.47	7.30*	11.47**	6.67	-14.91**	-13.08*	401.25**	0.10
10.	UP 2762 x KFA/2*KACHU	73.89	1.29	-0.73	10.58**	14.88**	7.00	100.00**	200.43**	426.32**	5.11
11.	UP 2762 x Raj 4419	73.07	1.65	1.07	9.35**	13.60**	4.33	-29.77**	-7.21	225.81**	-34.93**
12.	UP 2762 x PBW 729	70.31	-3.52	-5.34**	5.22	9.31**	7.67	43.71**	64.17**	476.44**	15.12*
13.	UP 2762 x WH 1187	71.79	0.37	0.30	7.43*	11.61**	7.67	39.39**	64.17**	476.44**	15.12*
14.	UP 2762 x HD 2967	71.79	1.13	0.44	7.43*	11.61**	6.33	15.15	35.62**	376.19**	-4.90*
15.	UP 2762 x DBW 50	71.10	-1.10	-1.68	6.41*	10.55**	7.67	35.21**	64.17**	476.44**	15.12*
16.	UP 2762 x NIAW 1594	73.77	2.62	2.03	10.40**	14.69**	7.33	25.68**	57.03**	451.38**	10.11
17.	UP 2762 x QLD 39	72.27	1.59	1.11	8.15**	12.35**	7.00	10.50	49.89**	426.32**	5.11
18.	KFA/2*KACHU x Raj 4419	73.65	0.39	-1.04	10.23**	14.51**	6.00	20.00*	157.51**	351.13**	-9.91
19.	KFA/2*KACHU x PBW 729	74.53	0.24	0.13	11.54**	15.87**	7.00	68.07**	200.43**	426.32**	5.11
20.	KFA/2*KACHU x WH 1187	71.70	-1.78	-3.67	7.30*	11.47**	7.33	69.36**	214.74**	451.38**	10.11
21.	KFA/2*KACHU x HD 2967	72.57	0.14	-2.50	8.61**	12.83**	6.67	53.96**	186.12**	401.25**	0.10
22.	KFA/2*KACHU x DBW 50	73.94	0.77	-0.66	10.65**	14.95**	7.33	62.96**	214.74**	451.38**	10.11
23.	KFA/2*KACHU x NIAW 1594	73.69	0.45	-0.99	10.29**	14.57**	7.33	57.20**	214.74**	451.38**	10.11
24.	KFA/2*KACHU x QLD 39	73.91	1.78	-0.70	10.61**	14.91**	7.33	41.98**	214.74**	451.38**	10.11
25.	Raj 4419 x PBW 729	72.45	-1.14	-2.46	8.42**	12.63**	6.67	-2.46	11.11	401.25**	0.10
26.	Raj 4419 x WH 1187	73.36	1.98	1.46	9.78**	14.05**	6.33	-9.52	0.00	376.19**	-4.90
27.	Raj 4419 x HD 2967	73.83	3.41	2.12	10.50**	14.79**	6.33	-9.52	0.00	376.19**	-4.90
28.	Raj 4419 x DBW 50	73.18	1.20	1.19	9.52**	13.77**	6.33	-11.67	-5.05	376.19**	-4.90
29.	Raj 4419 x NIAW 1594	73.25	1.31	1.31	9.62**	13.88**	4.67	-36.38**	-33.33**	250.88**	-29.93**
30.	Raj 4419 x QLD 39	75.51	5.54*	4.44	13.01**	17.40**	6.67	-14.91**	-13.08*	401.25**	0.10
31.	PBW 729 x WH 1187	73.26	0.46	-1.36	9.63**	13.89**	6.33	2.73	5.56	376.19**	-4.90
32.	PBW 729 x HD 2967	71.90	-0.67	-3.20	7.60*	11.78**	8.00	29.76**	33.33**	501.50**	20.12**
33.	PBW 729 x DBW 50	76.58	4.48	3.11	14.60**	19.06**	7.33	15.76*	22.22**	451.38**	10.11
34.	PBW 729 x NIAW 1594	72.25	-1.41	-2.72	8.13**	12.33**	6.33	-2.56	5.56	376.19**	-4.90
35.	PBW 729 x QLD 39	73.71	1.62	-0.76	10.31**	14.59**	7.00	0.00	16.67*	426.32**	5.11
36.	WH 1187 x HD 2967	71.63	0.83	0.08	7.19*	11.36**	7.33	15.85*	15.85*	451.38**	10.11
37.	WH 1187 x DBW 50	70.96	-1.36	-1.88	6.20*	10.33**	7.67	17.95**	21.12**	476.44**	15.12*
38.	WH 1187 x NIAW 1594	69.69	-3.12	-3.61	4.30	8.35**	7.33	10.03	15.85*	451.38**	10.11
39.	WH 1187 x QLD 39	70.27	-1.29	-1.82	5.16	9.25**	7.00	-2.30	10.58	426.32**	5.11
40.	HD 2967 x DBW 50	73.17	2.46	1.17	9.50**	13.75**	6.33	-2.56	0.00	376.19**	-4.90
41.	HD 2967 x NIAW 1594	70.64	-1.06	-2.30	5.72	9.83**	7.67	15.03*	21.12**	476.44**	15.12*
42.	HD 2967 x QLD 39	69.68	-1.38	-1.59	4.28	8.33**	6.33	-11.61	0.00	376.19**	-4.90
43.	DBW 50 x NIAW 1594	71.56	-1.03	-1.05	7.10*	11.26**	7.33	7.29	9.95	451.38**	10.11
44.	DBW 50 x QLD 39	70.34	-1.70	-2.74	5.27	9.36**	7.33	-0.02	9.95	451.38**	10.11
45.	NIAW 1594 x QLD 39	71.03	-0.73	-1.76	6.30*	10.43**	7.00	-6.67	0.00	426.32**	5.11

Table 2: Superior crosses based on per se performance, relative heterosis, heterobeltiosis and standard heterosis for different quality traits in wheat

Characters	High per se performance	Heterosis over mid parent	Heterosis over better parent	Heterosis over UP 2628	Heterosis over WH 1105	Common cross
Protein content	Raj 4419 x PBW 729 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x DBW 50 UP 2762 x DBW 50	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x DBW 50 Raj 4419 x PBW 729 UP 2762 x DBW 50	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x DBW 50	Raj 4419 x PBW 729	Raj 4419 x PBW 729	Raj 4419 x PBW 729
Sedimentation value	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762 UP 2762 x HD 2967 UP 2762 x Raj 4419	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x PBW 729 HD 2967 x NIAW 1594	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x PBW 729 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762 UP 2762 x HD 2967	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762 UP 2762 x HD 2967 UP 2762 x Raj 4419	KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762 UP 2762 x HD 2967 UP 2762 x Raj 4419	UP 2762 x HD 2967 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x UP 2762
Hectolitre weight	PBW 729 x DBW 50 KAUZ/ALTAR84/3/MILAN/K	Raj 4419 x QLD 39	-	PBW 729 x DBW 50 Raj 4419 x QLD 39 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUI	PBW 729 x DBW 50 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x Raj 4419	PBW 729 x DBW 50 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x Raj 4419

	AUZ/4/HUITES x Raj 4419 KFA/2*KACHU x PBW 729			TES x Raj 4419	KFA/2*KACHU x PBW 729	
Phenol colour reaction	UP 2762 x Raj 4419 Raj 4419 x NIAW 1594	Raj 4419 x NIAW 1594 UP 2762 x Raj 4419 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x Raj 4419	Raj 4419 x NIAW 1594 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x Raj 4419 KAUZ/ALTAR84/3/MILAN/KAUZ/4/HUITES x QLD 39	-	UP 2762 x Raj 4419 Raj 4419 x NIAW 1594 UP 2762 x HD 2967	Raj 4419 x NIAW 1594 UP 2762 x Raj 4419

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