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Research Article

Heterosis for yield and grain quality parameters in basmati rice (*Oryza sativa* L.)

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Abstract
In the present study, heterobeltiosis and standard heterosis were estimated on 36 F_1s obtained through half-diallel mating design for yield and quality traits. For yield per plant trait, seven out of 36 hybrids recorded standard heterosis of more than 100 per cent. CSR-30 x HUBR10-9 (160.09 per cent) recorded the highest significant positive standard heterosis over yield check Pusa Basmati-1. For quality traits, hybrid Pusa Basmati-1121 X Pusa Basmati-1509 performed well, as it exhibited a significant desirable standard heterosis for kernel length, kernel length after cooking, kernel breadth after cooking, and length/breadth ratio. Other hybrids that performed well for quality traits were Pusa Basmati-1 X Pusa Basmati-1121, Type-3 X Pusa Basmati-1121, Type-3 X Pusa Basmati-1509 and Taraori Basmati X Pusa Basmati-1121. 17 hybrids were found to have the desired intermediate range of amylose content (20-25 per cent) and 22 hybrids showed a desirable range of 4-7 for alkali spreading value, based on *per se* performance.

Key words
Half-diallel, heterobeltiosis, standard heterosis, basmati

INTRODUCTION

Rice is the third highest produced cereal in the world and it is staple food to more than half of the world population. Rice is divided into aromatic and non-aromatic rice based on the presence of aroma. Basmati is a type of aromatic rice, which is cultivated in north-western region of India. The various quality traits of basmati rice *viz*., kernel length, kernel breadth, aroma, fluffy texture of cooked rice, high volume expansion during cooking, maximum linear kernel elongation with minimum breadth-wise swelling, palatability, easy digestibility and longer shelf-life (Singh *et al.* 1988) make it unique and class apart from other rice. It is the major agricultural export commodity of India and has an outstanding demand in national as well as international market. In year 2018-19, India earned a foreign exchange of 4,722.52 million US dollars by exporting 4414584.16 MT of basmati rice (APEDA 2018-19).

The prime objective of basmati breeding program is to increase the yield without compromising on the minimum eligibility criteria of variety to be notified as basmati variety. Traditional basmati varieties are tall, disease susceptible, give poor yield and possess less genetic variability (Siddiq *et al.* 2012). Exploitation of heterosis is practiced in crop improvement program which is a phenomenon where F_1 outperforms its either parents in the desired direction for any given trait. Nature and magnitude of heterosis shown by the F_1 can assist in predicting the potential of a hybrid. In cognizance of the above facts, a study was undertaken, by crossing nine basmati parents, employing half diallel mating design. 36 F_1s obtained from the crossing program were examined for 18 traits to study heterobeltiosis and standard heterosis.

MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh under irrigated conditions in *Kharif* 2016 and *Kharif* 2017. The experimental material included nine basmati rice varieties namely, Type-3 (T-3), Basmati-370 (B-370), Taraori Basmati (TB), and Ranbir Basmati (RB) which are traditional basmati vartities; Pusa Basmati-1 (PB-1), CSR-30, Pusa Basmati-1121 (PB-1121), HUBR10-9, and Pusa Basmati-1509 (PB-1509) which are evolved basmati varieties. The 36 F_1s were obtained by crossing the chosen 9 parents in half-diallel design in *Kharif* 2016. 45 entries (36 F_1s and nine parents) were sown in three replications in *Kharif* 2017, in a Randomized Block Design with spacing of (15 X 20) cm. 10 plants were randomly selected and tagged of each entry for collection of data on 18 traits (eight yield related biometrical traits and 10 quality traits) from each of the three replications. The 18 traits studied were days to 50 per cent flowering, days to maturity, plant height, main panicle length, the number of panicles per plant, total number of grains per panicle, 100-grain weight, yield per plant, kernel length, kernel breadth, kernel length/breadth ratio, kernel length after cooking, elongation ratio, kernel breadth after cooking, elongation index, aroma, alkali spreading value and amylose content. Agronomic practices were strictly followed to assure a healthy crop stand.

Standard heterosis was calculated over check varieties (PB-1 and TB for yield related biometrical traits and quality check, respectively) and heterobeltiosis was calculated as given by Liang *et al*. (1972). Analysis of variance for Randomized Block Design was done following Panse and Shukatme (1967). The significance of heterosis was analyzed by calculating "t" value at 5 per cent and 1 per cent level of significance. Among quality traits, kernel dimensions (length and breadth) were recorded in millimeters by digital electronic vernier caliper. Alkali digestion value was estimated by the test devised by Little *et al.* (1958) on scale of 1-7 (1=low; 2=low; 3=low or intermediate; 4=intermediate; 5=intermediate; 6=high; 7=high). Amylose content was calculated by calorimetric method described by Juliano *et al*. (1965). Aroma was estimated in accordance with the procedure mentioned in Standard Evaluation System for Rice, IRRI, (2013) on the scale from 1-3(1=absent or very weak; 2=weak; and 3= strong).

RESULTS AND DISCUSSION

Analysis of variance of F_1s and parents indicated the presence of significant differences at 1 per cent level of significance (**Table 1**).

For days to 50 per cent flowering, 32 hybrids showed highly significant negative heterobeltiosis. Hybrid PB-1 X CSR-30 recorded the highest significant negative heterobeltiosis (-17.30) and hybrid PB-1 X PB-1121, exhibited the highest significant negative standard heterosis (-9.00). Earliness in flowering is a desirable trait; hence the negative heterosis was desirable for days to 50 per cent flowering (Table-2). Similar results for the negative heterosis were reported by Veeresha *et al*., (2015) in rice. However, in works of Bano and Singh (2018), only few hybrids showed high negative standard heterosis.

For **days to maturity**, 33 hybrids out of 36 exhibited significant negative heterobeltiosis. Highest value of significant negative heterobeltiosis was expressed in TB X PB-1509 (-13.50). Hybrid TB X PB-1509 showed the highest significant negative standard heterosis (-5.97). Hybrids RB X HUBR10-9 and CSR-30 X HUBR10-9 recorded a positive significant value for both standard heterosis and heterobeltiosis (**Table 2**). Most of the hybrids giving negative heterosis suggesting hybrids matured early than better parent or check variety was also observed in work of Priyanka *et al.*, (2014), Veeresha *et al*., (2015) Waza *et al*. (2016) and Bano and Singh, (2018). However, Soni and Sharma, (2011)

Table 1. Analysis of variance of yield and quality traits in basmati rice

Sl no.	Trait	Replication (df=2)	Treatment (df=44)	Error (df=88)
1	**Days to fifty per cent flowering**	0.39	61.91**	1.06
2	**Days to Maturity**	0.92	69.61**	1.88
3	**Plant Height**	0.43	1163.76**	2.5
4	**No. Panicle Length**	1.35	15.03**	0.76
5	**No. Panicles/ Plant**	3.52*	21.73**	1.12
6	**No. Grains/panicle**	92.18	2149.84**	79.58
7	**100-Grain Weight**	0.003	0.25**	0.004
8	**Yield /Plant**	0.42	329.68**	3.53
9	**Kernel Length**	0.029	0.736**	0.016
10	**Kernel Breadth**	0.001	0.019**	0.001
11	**L/B RATIO**	0.017	0.325**	0.009
12	**Kernel length after cooking**	0.244	14.290**	0.18
13	**Elongation Ratio**	0.005	0.155**	0.002
14	**Kernel Breadth After Cooking**	0.018*	0.205**	0.006
15	**Elongation Index**	0.005	0.182**	0.003
16	**Alkali Spread Value**	0.005	7.398**	0.037
17	**Aroma**	0.004	0.811**	0.027
18	**Amylose Content**	0.196	9.612**	0.219

Significance Levels * = <.05, ** = <.01

observed positive standard heterosis in most of the rice hybrids studied by them.

The short stature of plant prevents lodging and may increase yield hence the negative heterosis for plant height is desirable. Only one hybrid TB X HUBR10-9 recorded a desirable negative standard heterosis (-8.79) for plant height and it also exhibited the highest significant negative values for heterobeltiosis (-41.94). 27 hybrids showed negative significant heterobeltiosis (**Table 2**).

Table 2. Estimation of heterobeltiosis (BPH) and standard heterosis (SH) against yield check Pusa Basmati

	Days to fifty per cent flowering		Days to maturity		Plant height		Panicle length	
CROSS	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**
Type3 X Basmati 370	-6.43**	-3.00**	-2.13**	2.99**	-17.43**	31.10**	2.40	1.52
Type3 X TB	-10.91**	-2.00*	-4.58**	3.73**	-10.38**	40.80**	2.82	1.93
Type3 X Ranbir Basmati	-5.47**	-2.00*	-6.62**	-1.74*	-16.98**	28.15**	1.57	0.69
Type3 X Pusa Basmati1	-4.50**	-1.00	-7.09**	-2.24**	8.14**	64.59**	11.69**	11.69**
Type3 X CSR-30	-13.78**	-2.00*	-4.96**	0.00	-17.59**	30.18**	-7.87**	-8.66**
Type3 X Pusa Basmati1121	-5.11**	-1.00	-5.91**	-1.00	-8.92**	38.64**	2.26	1.38
Type3 X HUBR10-9	-1.61	2.00*	-4.26**	0.75	-3.63**	46.68**	8.68**	7.75**
Type3 X Pusa Basmati1509	-9.35**	-3.00**	-5.67**	-0.75	-19.74**	22.16**	1.34	0.47
Basmati 370 X TB	-11.82**	-3.00**	-12.13**	-4.48**	-7.79**	46.41**	-0.20	-4.86*
Basmati 370 X Ranbir Basmati	-4.90**	-3.00**	-5.76**	-2.24**	-0.94	57.29**	17.11**	11.64**
Basmati 370 X Pusa Basmati1	-2.65**	-2.00*	-2.88**	0.75	-35.64**	2.19	10.39**	10.39**
Basmati 370 X CSR-30	-12.90**	-1.00	-5.23**	-0.75	-30.46**	10.42**	5.88*	0.93
Basmati 370 X Pusa Basmati1121	-2.24**	2.00*	-1.91**	1.99*	-12.62**	38.73**	-11.26**	-15.41**
Basmati 370 X HUBR10-9	4.26**	6.00**	2.16**	5.97**	-12.34**	39.18**	14.92**	9.55**
Basmati 370 X Pusa Basmati1509	-3.74**	3.00**	-2.16**	1.49	-0.02	58.74**	-5.03	-9.47**
Taraori Basmati X Ranbir Basmati	-10.00**	-1.00	-9.38**	-1.49	-26.33**	15.74**	15.33**	5.74*
Taraori Basmati X Pusa Basmati1	-9.09**	0.00	-7.32**	0.75	-14.72**	33.97**	3.32	3.32
Taraori Basmati X CSR-30	-13.78**	-2.00*	-8.01**	0.00	-36.88**	-0.29	2.20	-6.16*
Taraori Basmati X Pusa Basmati1121	-10.00**	-1.00	-10.07**	-2.24**	-18.34**	28.29**	13.94**	2.05
Taraori Basmati X HUBR10-9	-0.91	9.00**	-4.58**	3.73**	-41.94**	-8.79**	11.69**	4.33
Taraori Basmati X Pusa Basmati1509	-13.64**	-5.00**	-13.50**	-5.97**	3.07**	61.93**	10.14**	-0.65
Ranbir Basmati X Pusa Basmati1	-5.88**	-4.00**	-7.30**	-5.22**	-35.38**	-0.26	12.55**	12.55**
Ranbir Basmati X CSR-30	-13.49**	-1.67	-6.65**	-2.24**	-5.45**	49.35**	6.84*	-1.90
Ranbir Basmati X Pusa Basmati1121	-6.07**	-2.00*	-4.55**	-0.75	-15.02**	31.18**	10.43**	1.24
Ranbir Basmati X HUBR10-9	5.88**	8.00**	3.65**	5.97**	-9.97**	38.96**	21.63**	13.61**
Ranbir Basmati X Pusa Basmati1509	-7.48**	-1.00	-6.07**	-3.73**	-23.90**	17.46**	7.58**	-1.36
Pusa Basmati1 X CSR-30	-17.30**	-6.00**	-7.60**	-3.23**	-1.66	55.34**	-3.91	-3.91
Pusa Basmati1 X Pusa Basmati1121	-12.78**	-9.00**	-5.26**	-1.49	-5.57**	14.06**	0.97	0.97
Pusa Basmati1 X HUBR10-9	-3.61**	-2.00	-2.24**	-2.24**	-8.32**	6.64**	8.36**	8.36**
Pusa Basmati1 X Pusa Basmati1509	-9.35**	-3.00**	-6.07**	-3.73**	9.51**	10.72**	9.57**	9.57**
CSR 30 X Pusa Basmati1121	-14.66**	-3.00**	-4.28**	0.25	-30.29**	10.11**	1.47	-6.83**
CSR 30 X HUBR10-9	-4.99**	8.00**	4.04**	8.96**	-6.51**	47.67**	10.71**	3.41
CSR 30X Pusa Basmati1509	-12.02**	0.00	-1.66*	2.99**	-19.11**	27.78**	8.78**	-0.12
Pusa Basmati1121 X HUBR10-9	-7.99**	-4.00**	-7.42**	-3.73**	4.71**	26.48**	15.92**	8.27**
Pusa Basmati1121 X Pusa Basmati1509	-8.41**	-2.00*	-6.46**	-2.74**	14.88**	38.77**	1.47	-8.46**
HUBR10-9 X Pusa Basmati1509	-8.41**	-2.00*	-6.80**	-4.48**	10.16**	28.14**	16.39**	8.71**
Standard error	0.84	0.84	1.2	1.2	1.29	1.29	0.71	0.71
Range of heterosis	-17.3to 5.88	-9to 9	-13.5 to 4.04	-5.97 to 8.96	-41.94 to 14.88	-8.79 to 64.59	21.63 to11.26	13.61 to-15.41
No. of significant positive heterosis	2	7	3	8	6	32	21	12
No. of significant negative heterosis	32	20	33	15	27	1	2	7

Significance Levels * = <.05, ** = <.01

Negative standard heterosis for plant height in rice has been observed by Rahimi *et al*. (2010), and Waza *et al*. (2016) in their studies. However, the positive significant standard heterosis and heterobeltiosis has also been reported by Kumar *et al.* (2012). For main panicle length, RB X HUBR10-9 recorded the highest significant positive heterobeltiosis (21.63) and standard heterosis (13.61). B-370 X PB-1121 showed the highest significant negative results for both heterobeltiosis and standard heterosis. Faiz *et al*. (2006), Rahimi *et al*. (2010) and Veeresha *et al*. (2015) also observed positive heterosis in their study on main panicle length. However, Priyanka *et al.* (2014)

Table 3. Estimation of heterobeltiosis (BPH) and standard heterosis (SH) against yield check Pusa Basmati

	No. of Panicles/ Plant		No. Of Grains/ Panicle		100-grain weight		Grian yield per plant	
CROSS	BPH	SH	BPH	SH	BPH	SH	BPH	SH
Type3 X Basmati 370	20.45*	14.39	-15.13	-27.60**	-2.25	3.50	-6.46	-8.52
Type3 X TB	-16.67	-17.27	1.37	-13.53	-4.89*	11.02**	0.29	0.89
Type3 X Ranbir Basmati	-20.25*	-9.35	-8.17	-21.67**	-2.84	2.88	-8.70	-10.71
Type3 X Pusa Basmati1	20.86*	20.86*	7.07	7.07	5.29*	11.48**	21.37**	21.37**
Type3 X CSR-30	-5.64	14.39	-20.86**	-18.52**	-17.48**	9.29**	-25.00**	-4.41
Type3 X Pusa Basmati1121	18.67*	34.89**	-6.36	-20.13**	-0.98	34.25**	36.12**	47.17**
Type3 X HUBR10-9	33.75**	52.52**	-19.61**	11.32	6.25**	23.11**	10.95*	80.45**
Type3 X Pusa Basmati1509	-31.24**	6.12	-8.39	-21.86**	-4.67**	29.40**	-11.82*	15.20*
Basmati 370 X TB	54.35**	53.24**	43.84**	1.32	-2.35	13.99**	5.80	6.43
Basmati 370 X Ranbir Basmati	34.49**	52.88**	63.74**	37.03**	4.29	8.90**	104.78**	81.72**
Basmati 370 X Pusa Basmati1	31.29**	31.29**	33.06**	33.06**	8.71**	13.52**	59.23**	59.23**
Basmati 370 X CSR-30	45.40**	76.26**	-15.47*	-12.97	-16.48**	10.62**	5.17	34.04**
Basmati 370 X Pusa Basmati1121	28.48**	46.04**	22.08*	-14.01*	-8.25**	24.39**	33.44**	44.27**
Basmati 370 X HUBR10-9	37.85**	57.19**	-21.32**	8.96	0.88	16.88**	14.65**	86.46**
Basmati 370 X Pusa Basmati1509	-26.81**	12.95	10.30	-22.30**	-1.86	33.22**	-6.63	21.98**
Taraori Basmati X Ranbir Basmati	12.66	28.06**	8.07	-9.56	-6.34**	9.33**	19.57**	20.28**
Taraori Basmati X Pusa Basmati1	18.35	18.35	16.09*	16.09*	1.68	18.68**	53.98**	54.89**
Taraori Basmati X CSR-30	44.21**	74.82**	-25.40**	-23.19**	-15.42**	12.03**	-6.64	18.99*
Taraori Basmati X Pusa Basmati1121	14.87	30.58**	31.66**	-23.91**	9.52**	48.49**	25.28**	35.45**
Taraori Basmati X HUBR10-9	42.59**	62.59**	-1.12	36.94**	2.68	19.86**	32.65**	115.74**
Taraori Basmati X Pusa Basmati1509	-14.45*	32.01**	69.93**	4.15	5.89**	43.73**	-9.11	18.73*
Ranbir Basmati X Pusa Basmati1	1.27	15.11	12.20	12.20	11.49**	15.65**	28.69**	28.69**
Ranbir Basmati X CSR-30	-29.97**	-15.11	-0.79	2.15	-13.83**	14.13**	-22.14**	-0.76
Ranbir Basmati X Pusa Basmati1121	24.05**	41.01**	-5.24	-20.69**	-0.61	34.75**	17.93**	27.51**
Ranbir Basmati X HUBR10-9	33.44**	52.16**	2.05	41.32**	7.29**	24.32**	33.53**	117.18**
Ranbir Basmati X Pusa Basmati1509	-19.58**	24.10*	7.31	-10.19	-24.63**	2.30	-3.45	26.13**
Pusa Basmati1 X CSR-30	38.87**	68.35**	-21.69**	-19.37**	-13.90**	14.04**	46.79**	87.09**
Pusa Basmati1 X Pusa Basmati1121	-16.46	-5.04	-23.34**	-23.34**	-11.43**	20.09**	28.23**	38.64**
Pusa Basmati1 X HUBR10-9	9.78	25.18**	6.85	47.97**	3.77	20.23**	52.31**	147.72**
Pusa Basmati1 X Pusa Basmati1509	9.56	69.06**	2.81	2.81	-5.42**	28.38**	78.67**	133.40**
CSR 30 X Pusa Basmati1121	6.82	29.50**	-42.59**	-40.88**	1.71	37.90**	-30.57**	-11.50
CSR 30 X HUBR10-9	81.60**	120.14**	-12.60*	21.04**	1.91	34.99**	59.92**	160.09**
CSR 30X Pusa Basmati1509	-31.47**	5.76	-18.84**	-16.44*	8.47**	47.24**	-10.27	17.22*
Pusa Basmati1121 X HUBR10-9	27.76**	45.68**	-17.59**	14.13*	1.53	37.66**	52.32**	147.74**
Pusa Basmati1121 X Pusa Basmati1509	-27.04**	12.59	-8.29	-43.79**	4.67**	42.07**	-18.73**	6.16
HUBR10-9 X Pusa Basmati1509	11.19	71.58**	-6.88	28.96**	1.71	38.05**	51.68**	146.70**
Standard error	0.86	0.86	7.28	7.28	0.05	0.05	1.53	1.53
Range of heterosis	81.6 to- 31.47	120.14 to20.86	69.93 to- 42.59	47.97 to- 43.79	11.49 to -24.63	48.49 to 8.9	104.78 to-30.57	160.09 to 15.2
No. of significant positive heterosis	17	24	7	9	9	33	21	28
No. of significant negative heterosis	7	0	10	15	12	0	5	0

Significance Levels * = <.05, ** = <.01

reported the negative heterosis in most of the hybrids studied by them for main panicle length (**Table 2**).

Positive heterosis is desirable for the number of panicles per plant; hybrid CSR-30 X HUBR10-9 exhibited the highest significant positive result for both heterobeltiosis (81.60) and standard heterosis (120.14). CSR-30 X PB-1509 recorded the highest negative heterobeltiosis. Hybrid Type3 X TB showed the highest significant negative result for standard heterosis (**Table 3**). Similar findings were also reported by Rani *et al.* (2015) for the trait. However, Bano and Singh (2018) have reported the negative heterosis for this trait in most of the hybrids studied.

Total number of grains per panicle is directly proportional to yield per plant, for this trait highest significant positive result was recorded in hybrid TB X PB-1509 for heterobeltiosis (69.93) and PB-1 X HUBR10-9 for standard heterosis (47.97). The hybrids CSR-30 X PB-1121 and PB-1121 X PB-1509 exhibited the high significant negative heterobeltiosis and standard heterosis respectively. 10 hybrids recorded the significant negative heterobeltiosis and 15 hybrids showed the negative significant standard heterosis for the trait. Rani *et al.* (2015) reported both positive and negative magnitude of heterosis in their studies (**Table 3**).

For 100-grain weight, hybrids RB X PB-1 and TB X PB-1121 recorded the highest positive results for heterobeltiosis (11.49) and standard heterosis (48.49), respectively. Out of 36 hybrids, 33 hybrids expressed significant positive result for standard heterosis. Similar findings have been observed by Rahimi *et al*. (2010). However, the negative heterosis for 100-grain weight has been reported by Latha *et al.* (2013) in their studies (**Table 3)**.

The main objective of a breeding program is to increase yield. In the present study for yield per plant highest significant positive standard heterosis was observed in hybrid CSR-30 X HUBR10-9(160.09). Hybrid B-370 x RB showed a highest positive significant heterobeltiosis (104.78). This hybrid also exhibited high standard heterosis (81.72). None of the hybrids expressed a significant negative standard heterosis for yield/per plant (Table-3). For heterobeltiosis, hybrid CSR-30 X PB-1121 recorded the highest significant negative value. 28 hybrids exhibited the positive significant standard heterosis, out of which seven hybrids gave standard heterosis of more than 100 per cent; more than 80 per cent standard heterosis was found in three hybrids and more than 50 per cent standard heterosis was found in two hybrids. Kumar *et al.,* (2012), Waza *et al.* (2016) and Akanksha *et al.* (2018) have reported a positive standard heterosis and heterobeltiosis for most of the hybrids studied by them. However, more number of hybrids showed the cnegative standard heterosis and heterobeltiosis in work of Priyanka *et al*. (2014), and Bano and Singh (2018).

Long kernel is one of the consumer preferred quality traits of basmati rice hence the positive heterosis is desirable for this trait. For **kernel length**, PB-1 X CSR-30 and TB X PB-1121 exhibited the highest positive significant heterobeltiosis (9.94) and standard heterosis (17.6) respectively. Few hybrids expressed significant positive heterobeltiosis and similar observation was observed in work of Verma and Srivastava (2005). 22 hybrids exhibited significant positive standard heterosis for kernel length. Akanksha *et al.* (2018) have recorded similar findings for standard heterosis in their studies which supports the present findings. Negative significant result for standard heterosis was exhibited only in hybrid T-3X B-370. Significant positive heterobeltiosis was recorded in 10 hybrids (**Table 4**). B-370 X PB-1121 had the highest negative heterobeltiosis. However, Kumar *et al.* (2012) reported no positive significant standard heterosis for kernel length in his study.

Kernel breadth exhibited significant negative heterobeltiosis in 29 hybrids; the highest significant negative heterobeltiosis was observed in the hybrid RB X CSR-30 (-17.05). High significant negative standard heterosis was observed in 27 hybrids among which hybrid Type3 X B-370 showed the highest value (-11.9). Significant positive results were not observed for heterobeltiosis and standard heterosis. Similar findings have been observed by Rahimi *et al.* (2010), Reddy *et al.* (2012) and Waza *et al.* (2016). However Kumar *et al*. (2012), Bano and Singh (2018), and Akanksha *et al.* (2018) reported significant positive heterosis for kernel breadth in their findings (**Table 4**).

L/B ratio showed significant positive heterobeltiosis for 24 hybrids and standard heterosis for 31 hybrids. Priyanka *et al.* (2014) reported similar findings for standard heterosis for the traits studied by them. Highest significant positive results were obtained in hybrid T-3X CSR-30 for heterobeltiosis (22.26) and in hybrid PB-1121 X PB-1509 for standard heterosis (25.55). Negative significant result was observed in four hybrids for heterobeltiosis. Kumar *et al*. (2012), Sravan *et al.* (2017), and Bano and Singh (2018) have observed negative standard heterosis for L/B ratio in their study (**Table 4**).

A high elongation ratio suggests that the kernel length will increase more after cooking and therefore, the positive heterosis is desirable for this trait. Only two hybrids PB-1 X HUBR10-9 and B-370 X TB recorded the positive significant result for heterobeltiosis, while 13 hybrids exhibited positive significant standard heterosis (Table-4). Hybrid T-3X PB-1509 showed a highest positive significant standard heterosis (18.15). Hybrid TB X PB-1121 expressed a highest negative significant value for both heterobeltiosis and standard heterosis. Similar findings have been observed in studied of Kumar *et al.* (2012) for elongation ratio.

Table 4. Estimation of heterobeltiosis (BPH) and standard heterosis (SH) against quality check Taraori Basmati

	Kernel length		Kernel Breadth (mm)		Length/Breadth ratio		Elongation ratio	
CROSS	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**	**BPH**	**SH**
Type3 X Basmati 370	0.24	-5.13**	-15.61 **	-11.90 **	12.03 **	7.57 **	2.42	3.72
Type3 X TB	1.39	1.2	-12.28 **	-8.42 **	9.81 **	10.65 **	-11.07 **	-12.20 **
Type3 X Ranbir Basmati	-1.69	-2.28	-14.04 **	-10.26 **	8.13 **	8.77 **	-21.45 **	-17.60 **
Type3 X Pusa Basmati1	6.12 **	0.74	-5.26 **	-1.10	7.09 **	6.90 **	-19.53 **	-16.75 **
Type3 X CSR-30	3.17 *	0.87	-15.95 **	-10.26 **	22.26 **	12.20 **	-12.87 **	-13.50 **
Type3 X Pusa Basmati1121	-4.28 **	13.86 **	-3.51 *	0.73	-2.24	11.03 **	-7.35 **	18.04 **
Type3 X HUBR10-9	-3.76 **	-1.56	-1.58	2.75	-8.46 **	-3.95	2.39	-0.4
Type3 X Pusa Basmati1509	-0.1	13.44 **	-8.95 **	-4.95 **	6.10 **	19.24 **	0.93	18.15 **
Basmati 370 X TB	9.70 **	9.49 **	-7.22 **	-8.24 **	16.92 **	17.81 **	5.45 **	6.79 **
Basmati 370 X Ranbir Basmati	1.24	0.62	-3.52 *	-4.58 **	4.35 *	4.97 *	0.24	5.15 **
Basmati 370 X Pusa Basmati1	6.01 **	0.62	-3.96 **	-6.78 **	7.92 **	7.74 **	-2.58	0.78
Basmati 370 X CSR-30	7.44 **	5.04 **	-14.24 **	-8.42 **	19.98 **	15.20 **	-19.09 **	-18.06 **
Basmati 370 X Pusa Basmati1121	-14.39 **	1.84	-11.75 **	-7.88 **	-2.53	10.70 **	-18.33 **	4.05 *
Basmati 370 X HUBR10-9	-4.54 **	-2.36	2.63	0.00	-6.21 **	-1.59	-6.24 **	-5.05 **
Basmati 370 X Pusa Basmati1509	-0.64	12.83**	-3.44 *	-2.38	2.79	15.52 **	-10.22 **	5.10 **
Taraori Basmati X Ranbir Basmati	4.12 **	3.92**	-6.85 **	-7.88 **	11.52 **	12.37 **	-23.98 **	-20.25 **
Taraori Basmati X Pusa Basmati1	8.56 **	8.36 **	-2.41	-3.48 *	11.41 **	12.26 **	-19.02 **	-16.23 **
Taraori Basmati X CSR-30	7.53 **	7.33 **	-14.41 **	-8.61 **	16.33 **	17.22 **	-20.49 **	-21.07 **
Taraori Basmati X Pusa Basmati1121	-1.14	17.60 **	-6.14 **	-2.01	5.59 **	19.92 **	-40.03 **	-23.59 **
Taraori Basmati X HUBR10-9	0.93	3.23 *	2.22	1.10	-2.6	2.19	-0.37	-1.63
Taraori Basmati X Pusa Basmati1509	1.16	14.88 **	-5.36 **	-4.32 **	6.90 **	20.14 **	-0.05	17.01 **
Ranbir Basmati X Pusa Basmati1	3.96 **	3.33 *	-3.52 *	-4.58 **	7.66 **	8.30 **	-16.61 **	-12.52 **
Ranbir Basmati X CSR-30	2.08	1.46	-17.05 **	-11.43 **	13.95 **	14.62 **	-17.40 **	-13.36 **
Ranbir Basmati X Pusa Basmati1121	-6.91 **	10.74 **	-6.49 **	-2.38	0.15	13.74 **	-22.78 **	-1.62
Ranbir Basmati X HUBR10-9	-3.50 *	-1.29	2.22	1.1	-6.94 **	-2.36	1.51	6.48 **
Ranbir Basmati X Pusa Basmati1509	-13.21 **	-1.44	-2.17	-1.1	-11.25 **	-0.25	-11.01 **	4.17 *
Pusa Basmati1 X CSR-30	9.94 **	7.48 **	-10.81 **	-4.76 **	13.25 **	13.06 **	-25.12 **	-22.54 **
Pusa Basmati1 X Pusa Basmati1121	-6.06 **	11.75 **	-10.35 **	-6.41 **	5.15 **	19.42 **	-14.09 **	9.46 **
Pusa Basmati1 X HUBR10-9	0.26	2.54	-2.44	-4.95 **	2.88	7.94 **	5.79 **	9.44 **
Pusa Basmati1 X Pusa Basmati1509	-2.49	10.72 **	-5.98 **	-4.95 **	3.56	16.39 **	-21.12 **	-7.66 **
CSR 30 X Pusa Basmati1121	-6.88 **	10.78 **	-14.24 **	-8.42 **	6.29 **	20.71 **	-18.38 **	3.99 *
CSR 30 X HUBR10-9	1.55	3.87 **	-11.49 **	-5.49 **	4.69 *	9.84 **	-17.62 **	-18.22 **
CSR 30X Pusa Basmati1509	-0.61	12.86 **	-10.46 **	-4.40 **	4.86 **	17.85 **	-27.10 **	-14.66 **
Pusa Basmati1121 X HUBR10-9	-5.95 **	11.88 **	-10.18 **	-6.23 **	5.12 **	19.39 **	-23.19 **	-2.14
Pusa Basmati1121 X Pusa Basmati1509	-1.5	17.17 **	-10.70 **	-6.78 **	10.55 **	25.55 **	-18.80 **	3.45
HUBR10-9 X Pusa Basmati1509	-5.87 **	6.88 **	-7.07 **	-6.04 **	1.93	14.55 **	-7.91 **	7.80 **
Standard error	0.10	0.10	0.02	0.02	0.08	0.08	0.03	0.03
Range of heterosis	9.94 to -14.39	17.6 to -5.13	-17.05 to -3.44	-11.9to -2.38	22.26 to -11.25	25.55 to 4.97	5.79 to -40.03	18.15 to -23.59
No. of significant positive heterosis	10	22	0	0	24	31	2	13
No. of significant negative heterosis	11	1	29	27	4	0	26	16

Significance Levels * = <.05, ** = <.01

Kernel length after cooking trait exhibited significant positive heterobeltiosis for two hybrids B-370 X TB and PB-1 X HUBR10-9 while 26 hybrids expressed the negative heterobeltiosis. Significant positive results for standard heterosis were observed in 14 hybrids and TB X PB-1509 recorded the highest value (34.33) of **kernel length after cooking** (Table-5). Hybrid Basmati 370 X PB-1121 showed the least significant positive standard heterosis. Highest negative significant value for standard heterosis and heterobeltiosis were shown by hybrids T-3X RB and TB X PB-1121, respectively. Similar results have been observed by Kumar *et al.*(2012), Waza *et al.* (2016), Sravan and Jaiswal (2017), and Bano and Singh (2018) in their studies. Slender cooked rice kernels are preferred by consumers, so minimum breadth wise expansion of cooked kernels is desirable. Kernel breadth after cooking trait expressed desirable significant negative heterobeltiosis in 10 hybrids. Hybrid CSR-30 X HUBR10-9 recorded the highest value for heterobeltiosis (-16.01). Hybrids RB X CSR-30 and CSR-30 X PB-1121 exhibited a similar value for the negative standard heterosis (-8.98). Only four hybrids showed significant negative standard heterosis. Highest significant positive value for heterobeltiosis was observed in hybrid RB X Pusa Basmati1 and for standard heterosis in hybrid Type3 X Basmati 370 (**Table 5**). Kumar *et al.* (2012), Waza *et al.* (2016), and Sravan and Jaiswal (2017) have observed similar findings in their studies.

Elongation index is also an important trait, which is the ratio of kernel length/breadth before cooking and after

Table 5. Estimation of heterobeltiosis (BPH) and standard heterosis (SH) against quality check Taraori Basmati

	Kernel length after cooking		Kernel Breadth after cooking		Elongation index		Aroma	
CROSS	BPH	SH	BPH	SH	BPH	SH	BPH	SH
Type3 X Basmati 370	3.94	-1.65	19.55 **	26.07 **	-24.32 **	-27.42 **	-13.14 **	-12.63 **
Type3 X TB	-10.03 **	-11.17 **	18.28 **	23.86 **	-33.19 **	-35.16 **	-51.74 **	-51.46 **
Type3 X Ranbir Basmati	-22.97 **	-19.62 **	19.55 **	25.18 **	-47.21 **	-40.94 **	-10.81 *	-10.29 *
Type3 X Pusa Basmati1	-14.89 **	-16.41 **	16.46 **	21.94 **	-36.34 **	-35.84 **	-14.88 **	-14.39 **
Type3 X CSR-30	-10.38 **	-12.98 **	7.07 **	15.91 **	-31.33 **	-32.81 **	-13.84 **	-13.33 **
Type3 X Pusa Basmati1121	-11.24 **	34.16 **	16.46 **	21.94 **	-24.89 **	-0.9	-37.44 **	-37.08 **
Type3 X HUBR10-9	-1.91	-2.31	4.37	16.20 **	-8.59 **	-12.33 **	-42.67 **	-42.34 **
Type3 X Pusa Basmati1509	0.73	33.81 **	13.08 **	18.41 **	-18.61 **	-5.17	-42.21 **	-41.87 **
Basmati 370 X TB	18.17 **	16.67 **	-7.68 **	-2.65	5.54	2.42	-53.14 **	-52.87 **
Basmati 370 X Ranbir Basmati	1.45	5.87 *	-9.50 **	-4.57	-5.41 *	5.83	-42.79 **	-42.46 **
Basmati 370 X Pusa Basmati1	2.85	1.02	14.80 **	21.06 **	-23.08 **	-22.47 **	-37.56 **	-37.19 **
Basmati 370 X CSR-30	-10.51 **	-13.11 **	-0.41	7.81 **	-28.37 **	-29.92 **	-47.21 **	-46.90 **
Basmati 370 X Pusa Basmati1121	-30.00 **	5.79 *	5.31 *	11.05 **	-34.75 **	-13.91 **	-65.12 **	-64.91 **
Basmati 370 X HUBR10-9	-7.13 **	-7.51 **	8.47 **	20.77 **	-16.61 **	-22.02 **	-48.60 **	-48.30 **
Basmati 370 X Pusa Basmati1509	-10.90 **	18.36 **	8.24 **	14.14 **	-22.89 **	-10.16 **	-41.05 **	-40.70 **
Taraori Basmati X Ranbir Basmati	-20.82 **	-17.37 **	22.16 **	23.42 **	-46.73 **	-40.40 **	-48.30 **	-48.30 **
Taraori Basmati X Pusa Basmati1	-8.13 **	-9.29 **	20.55 **	21.80 **	-34.10 **	-33.58 **	-40.58 **	-40.58 **
Taraori Basmati X CSR-30	-14.34 **	-15.43 **	7.76 **	16.64 **	-36.75 **	-38.12 **	-41.99 **	-41.99 **
Taraori Basmati X Pusa Basmati1121	-43.30 **	-14.30 **	-1.75	-0.74	-45.41 **	-27.98 **	-49.47 **	-49.47 **
Taraori Basmati X HUBR10-9	1.79	1.37	4.63	16.49 **	-11.94 **	-14.54 **	-55.32 **	-55.32 **
Taraori Basmati X Pusa Basmati1509	1.12	34.33 **	6.52 *	8.25 **	-11.28 **	3.36	-42.11 **	-42.11 **
Ranbir Basmati X Pusa Basmati1	-13.36 **	-9.59 **	24.10 **	21.35 **	-38.43 **	-31.12 **	-64.03 **	-64.91 **
Ranbir Basmati X CSR-30	-15.98 **	-12.32 **	-15.92 **	-8.98 **	-24.81 **	-15.88 **	-47.12 **	-48.42 **
Ranbir Basmati X Pusa Basmati1121	-28.05 **	8.74 **	-5.99 *	-5.15	-23.52 **	0.9	-50.60 **	-51.81 **
Ranbir Basmati X HUBR10-9	0.61	4.99	9.13 **	21.50 **	-20.85 **	-11.45 **	-64.03 **	-64.91 **
Ranbir Basmati X Pusa Basmati1509	-22.64 **	2.77	-5.51 *	-3.98	-7.75 **	7.48 *	-46.40 **	-47.72 **
Pusa Basmati1 X CSR-30	-15.57 **	-17.07 **	-9.12 **	-1.62	-25.97 **	-25.38 **	2.07	-48.07 **
Pusa Basmati1 X Pusa Basmati1121	-19.19 **	22.14 **	20.15 **	21.21 **	-35.98 **	-15.54 **	-31.03 **	-64.91 **
Pusa Basmati1 X HUBR10-9	12.73 **	12.27 **	9.26 **	21.65 **	-15.17 **	-14.50 **	2.07	-48.07 **
Pusa Basmati1 X Pusa Basmati1509	-23.12 **	2.13	23.77 **	25.77 **	-40.09 **	-30.19 **	5.2	-45.61 **
CSR 30 X Pusa Basmati1121	-23.96 **	14.93 **	-15.92 **	-8.98 **	-20.68 **	4.65	-25.93 *	-64.91 **
CSR 30 X HUBR10-9	-14.81 **	-15.15 **	-16.01 **	-6.48 *	-15.40 **	-17.23 **	11.63	-49.47 **
CSR 30X Pusa Basmati1509	-27.66 **	-3.91	-6.12 *	1.62	-31.01 **	-19.63 **	0	-48.30 **
Pusa Basmati1121 X HUBR10-9	-27.59 **	9.44 **	11.38 **	24.01 **	-43.91 **	-25.99 **	6.67	-49.47 **
Pusa Basmati1121 X Pusa Basmati1509	-19.79 **	21.24 **	-8.12 **	-6.63 *	-21.57 **	3.48	0.45	-48.07 **
HUBR10-9 X Pusa Basmati1509	-13.18 **	15.33 **	1.59	13.11 **	-23.57 **	-10.95 **	9.05	-43.63 **
Standard error	0.35	0.35	0.06	0.06	0.04	0.04	0.13	0.13
Range of heterosis	18.17 to -43.3	34.33 to -19.62	-16.01 to 24.1	-8.98 to 26.07	-5.41 to -47.21	7.48 to -40.94	11.63 to -65.12	-10.29 to -64.91
No. of significant positive heterosis	2	14	21	25	0	1	0	0
No. of significant negative heterosis	26	14	10	4	35	27	28	36

Significance Levels * = <.05, ** = <.01

cooking. Kumar (1989) suggested in his study that elongation index can be more reliable measure of kernel expansion. **For elongation index**, (**Table 5**) none of the hybrids were found to have a positive significant value for heterobeltiosis while only one hybrid RB X PB-1509, showed a positive significant standard heterosis (7.48). Sravan and Jaiswal (2017) had observed similar findings where they reported one hybrid which gave significant positive standard heterosis estimates for elongation index. Highest negative significant values for heterobeltiosis and standard heterosis were observed in hybrid Type3 X RB. Lowest significant negative value for standard heterosis was found in hybrid B-370 X PB-1509 and for heterobeltiosis was found in hybrid B-370 X RB. Bano and Singh (2018) reported similar findings in their study.

A pleasant appealing aroma is the most important quality parameter of basmati rice**.** For aroma, none of the hybrids showed a significant positive heterobeltiosis, while significant negative heterobeltiosis was observed in 28 out of 36 hybrids (**Table 5**). For standard heterosis, all hybrids exhibited highly significant negative values in which the lowest significant negative standard heterosis was shown by hybrid Type3 X RB (-10.29). Similar observations were

Table 6. Mean value of F_1s and quality check Taraori Basmati

	ASV(scale1-7)	Gelatinization Temperature (degree centigrade)	Amylose content
CROSS	**MEAN VALUE**		**MEAN VALUE**
Type3 X Basmati 370	1.97 (low)	>74° (high)	23.02 (intermediate)
Type3 X TB	2.39 (low)	>74° (high)	25.2 (high)
Type3 X Ranbir Basmati	1.91 (low)	>74° (high)	22.82 (intermediate)
Type3 X Pusa Basmati1	2.53 (low)	>74° (high)	24.15 (intermediate)
Type3 X CSR-30	2.42 (low)	>74° (high)	21.98 (intermediate)
Type3 X Pusa Basmati1121	4.39 (intermediate)	70°-74°(intermediate)	24.02 (intermediate)
Type3 X HUBR10-9	2.98 (low)	>74° (high)	23.12 (intermediate)
Type3 X Pusa Basmati1509	6.05 (high)	65°-69° (low)	21.86 (intermediate)
Basmati 370 X TB	6.66(high)	65°-69° (low)	26.84 (high)
Basmati 370 X Ranbir Basmati	2.44 (low)	>74° (high)	25.78 (high)
Basmati 370 X Pusa Basmati1	6.73 (high)	65°-69° (low)	22.62 (intermediate)
Basmati 370 X CSR-30	3.29 (low)	>74° (high)	25.82 (high)
Basmati 370 X Pusa Basmati1121	4.73(intermediate)	70°-74°(intermediate)	27.43 (high)
Basmati 370 X HUBR10-9	3.72 (intermediate)	70°-74°(intermediate)	26.98 (high)
Basmati 370 X Pusa Basmati1509	3.32 (low)	>74° (high)	26.49 (high)
Taraori Basmati X Ranbir Basmati	1.85 (low)	>74° (high)	23.49 (intermediate)
Taraori Basmati X Pusa Basmati1	5.76 (high)	65°-69° (low)	24.1 (intermediate)
Taraori Basmati X CSR-30	3.37 (low)	>74° (high)	25.78 (high)
Taraori Basmati X Pusa Basmati1121	5.8 (high)	65°-69° (low)	26.64 (high)
Taraori Basmati X HUBR10-9	4.48 (intermediate)	70°-74°(intermediate)	26.73 (high)
Taraori Basmati X Pusa Basmati1509	3.8 (intermediate)	70°-74°(intermediate)	25.64 (high)
Ranbir Basmati X Pusa Basmati1	4.41 (intermediate)	70°-74°(intermediate)	22.55 (intermediate)
Ranbir Basmati X CSR-30	2.14 (low)	>74° (high)	23.17 (intermediate)
Ranbir Basmati X Pusa Basmati1121	4.51 (intermediate)	70°-74°(intermediate)	24.53 (intermediate)
Ranbir Basmati X HUBR10-9	2.71 (low)	>74° (high)	27.44 (high)
Ranbir Basmati X Pusa Basmati1509	4.36 (intermediate)	70°-74°(intermediate)	22.96 (intermediate)
Pusa Basmati1 X CSR-30	5.46 (intermediate)	70°-74°(intermediate)	25.22 (high)
Pusa Basmati1 X Pusa Basmati1121	5.33 (intermediate)	70°-74°(intermediate)	25.64 (high)
Pusa Basmati1 X HUBR10-9	5.49 (intermediate)	70°-74°(intermediate)	26.28 (high)
Pusa Basmati1 X Pusa Basmati1509	5.65 (high)	65°-69° (low)	24.61 (intermediate)
CSR 30 X Pusa Basmati1121	5.46 (intermediate)	70°-74°(intermediate)	26.64 (high)
CSR 30 X HUBR10-9	3.34 (low)	>74°(high)	26.16 (high)
CSR 30X Pusa Basmati1509	3.76 (intermediate)	70°-74°(intermediate)	25.45 (high)
Pusa Basmati1121 X HUBR10-9	6.78 (high)	65°-69° (low)	24.45 (intermediate)
Pusa Basmati1121 X Pusa Basmati1509	6.66 (high)	65°-69° (low)	26.21 (high)
HUBR10-9 X Pusa Basmati1509	5.53 (intermediate)	70°-74°(intermediate)	24.35 (intermediate)
Check variety			
Taraori Basmati	4.48 (intermediate)	70°-74°(intermediate)	22.41 (intermediate)

also observed in studies of Sravan and Jaiswal (2017) and Bano and Singh (2018). However, Gonya *et al*. (2016) reported the positive standard heterosis ranging from 7.4 per cent to 35.2 per cent in their study. This may be due to variability in the experimental material studied by them.

Intermediate values are desirable for amylose content (AC) and a range of 4-7 for alkali spreading value (ASV). Traits for which intermediate values are preferred cannot be interpreted in terms of heterosis. Thus for such traits *per se* performance or mean values are considered to examine the performance of hybrids.

In the present findings, alkali spreading value for hybrids fall into all range from low, intermediate to high. The time required to cook a particular type of rice is calculated by its gelatinization temperature (the temperature at which 90 per cent starch molecules present in rice kernel becomes irreversibly swollen in hot water). Gelatinization temperature is indexed in terms of Alkali spreading value; a high value of alkali spreading value suggests low gelatinization temperature and vice-versa. While an intermediate alkali spreading value suggests intermediate value for gelatinization temperature (Table 8). Rice with high gelatinization temperature takes a longer time to cook and expand very little (Juliano *et al.,* 1965). 22 hybrids exhibited desirable ASV value of 4 to 7. Out of 36 hybrids, 14 hybrids exhibited low ASV of 2-3 (Table-6). Waza *et al.* (2016), and Sravan and Jaiswal (2017) have also recorded low, intermediate, and high values for ASV in the experimental material studied by them.

Amount of amylose content in rice kernel influences its cooking and eating characteristics (hardness, gloss, water uptake of cooked rice). A high value of amylose content (>25 per cent) indicate that cooked rice will turn dry, less tender upon cooling; intermediate value (20-25 per cent) indicates that the cooked rice will remain moist and tender after cooling while a low value (10-19 per cent) indicates the cooked rice will become moist and sticky upon cooling. When amylose content was calculated for each hybrid in the present experiment, results indicated that the 17 hybrids fall under intermediate range of amylose content, while 19 hybrids showed higher value (more than 25 per cent). Hybrid RB X HUBR10-9 (27.3 per cent) given the highest value and hybrid T-3X PB-1509 (21.86 per cent) recorded the lowest value for amylose content (**Table 6**). Rice varieties with an intermediate range of amylose content are most preferred by Indian consumers because it cook soft and non-sticky and do not harden upon cooling. Kumar and Khush (1986), Sravan and Jaiswal (2017), Bano and Singh (2018), and Waza *et al.* (2016) have also observed similar findings in the hybrids studied by them.

In the present study, hybrid vigor for yield was observed in most of the hybrids studied. Among the F_1s which outperformed their parents for yield/plant trait; HUBR10-9 X PB-1509 was best and recorded desirable high standard heterosis for the number of panicles per plant, 100-grain weight, and early maturity. CSR-30 X HUBR10-9 gave the highest significant positive standard heterosis for yield per plant and the number of panicles per plant. PB-1 X HUBR10-9 hybrid showed the highest significant standard heterosis for the number grains per panicle and yield per plant trait. The aforementioned results suggest that the increase in the number of panicles per plant, the number of grains per panicle and 100-grain weight, have significant positive effect on yield per plant. Considering the quality traits *viz.,* kernel length, kernel breadth, kernel length/breadth ratio, kernel length after cooking, and elongation ratio some of the hybrids recorded desirable heterosis. However, for elongation index and kernel breadth after cooking only a few hybrids had given significant results in the desired direction. None of the hybrids showed significant positive standard heterosis for aroma over quality check TB. The magnitude of heterosis is directly proportional to genetic diversity of experimental material; consequently hybrids which showed high heterosis for most of the traits in the present study were evolved x evolved type or traditional x evolved type of basmati varieties. Such results indicate that the evolved varieties might have provided different alleles to the traditional basmati background and thus broaden the genetic base resulting in high heterosis. Eventually, in view of such findings, it can be suggested that the superior hybrids found in the experiment can be exploited by advancing to subsequent generations until the recombinants reach homozygosity.

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