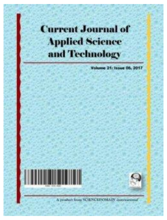

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Heterosis for Yield and Quality Traits in Aromatic Rice (*Oryza sativa. L.*) Genotypes

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present investigation in aromatic rice (*Oryza sativa* L.) was undertaken for studying the magnitude of heterosis in 28 hybrids (F1s) made by following 8x8 one way diallel mating design for yields and quality traits. Twenty eight hybrids were measured as per cent increase or decrease over the mean of better parent and over the checks using Pusa Basmati 1 and Taraori Basmati as best checks for yield and quality traits. For the trait days to 50% flowering and days to maturity, superior performer over better parents showed in cross: Pusa Sugandh-2 x Pusa Basmati-1and Pusa-2517-2-51-1x Type-3. Cross combination, Kasturi Basmati x Pusa -2517-251-1 performed superior over better parents and check for number of effective tillers/plant and main panicle length. The other crosses *viz*., Pusa Sugandh-5 x Pusa Sugandh-2 (kernel length), Pusa Sugandh-5 x Type-3 (amylose content) and Pusa Sugandh-5 x Pusa Basmati-1(Kernel Length, Kernel Length After Cooking, Length/Breadth ratio before cooking) exhibited significant heterosis for important grain quality traits. None of the high yielding hybrids recorded desirable performance over better parents and standard checks for all the yield and quality traits studied. Thus, these hybrids need to be further tested in observational/ multi-location trials before the commercial exploitation of its heterotic potential.

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Keywords: Heterosis; diallel; rice hybrids; quality traits.

1. INTRODUCTION

Rice is one of the most crucial food crops in the world. As more than 50 per cent of the world population depends on rice for their staple diet. It is cultivated in 114 countries across the globe, but 90 percent of world's rice is grown and consumed in Asia. Global rice production for 2015-16 was estimated as 476.7 million tones (on milled basis), over an area of 161.0 million ha [1]. Rice is the staple food for two thirds of Indian population and holds the key to food security. India has occupied largest area under rice of 43.5 M ha and it ranks second in production (106.6 Mt) after China with an area and production of 30.21 Mha and 145.77 Mt, respectively [2]. Rice is grown in almost all the states of India, but major rice producing states fall in the regions of middle and lower Ganga plains, as well as the coastal lowlands of peninsular India.

Nowadays, the quality considerations assume enhanced importance, especially in the countries which are self-sufficient in their production. As per capita income increases the consumption preference of common man is shifting towards quality rice. Aromatic rices constitute a small but special group of rices which are considered best in quality. Among the quality rices, Basmati is the unique aromatic quality rice. It is a nature's gift to Indian sub-continent. As living standards are improving steadily, human demand for high quality rice is continuously on an increase. This entails in incorporation of preferred grain quality features as the most important objective next to yield enhancement. Based on the survey of 11 major rice growing countries, [3] concluded that grain quality is second only to yield as the major breeding objective.

In the future, improvement of grain quality traits will be even more enhanced as once the very poor, many of whom depend largely on rice for their staple food become better off and begin to demand higher quality rice [4]. Thus, the most important challenge in hybrid rice breeding is to ensure that the heterotic rice hybrids possess grain quality that is at least comparable, if not superior, to that of popular inbred varieties grown by farmers. Thus, it is imperative that along with the yield and yield attributes, higher magnitude of heterosis for quality traits be taken into consideration during the commercial development of rice hybrids [5]. Diallel mating design serves as one of the important breeding technique for yield and grain quality traits in rice such as grain length, grain width, grain shape and elongation, along with the better yield [6]. Diallel analysis helps in the selection of suitable parents for use in hybridisation programme as well as in the choice of the appropriate breeding procedure for genetic improvement of various traits. Keeping in view the above points the present investigation was formulated to study the heterosis in rice.

2. MATERIALS AND METHODS

The present study was carried out during two seasons' *viz.,* kharif-2015 and kharif-2016 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (UP). The site of study is situated at 25^0 18´ N latitude and 83^0 03´ E longitude, at an elevation of 80.71 m above mean sea level. The research material consists of eight genotypes selected for crossing programme namely Pusa Basmati 1, Pusa Sugandh 2, Pusa Sugandh 3, Pusa Sugandh 5, Type 3, Kasturi Basmati, Ranbir Basmati and Pusa-2517-2-51-1. Pusa Basamti-1 was used as check for yield traits and Taraori Basmati was used as check for quality trait. Taraori Basmati is a low yielding traditional Basmati variety known for its quality traits and used as a national check for quality traits in rice. However, Pusa Basmati-1 is a high yielding improved Basmati variety with quality relatively lower than that of Taraori Basmati. Hence, used as yield check for Basmati varieties.

All the genotypes were obtained from the 'All India Coordinated Rice Improvement Project' (AICRIP) at the Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.).

During kharif-2015, eight genotypes were selected on the basis of their quality and quantitative traits (Table 1) for making F_1 crosses and all the genotypes were seeded in nursery at 3 dates, 10 days apart and transplanted in crossing blocks at 21 days after sowing. Crosses were made in diallel fashion (excluding reciprocals) developing 28 F_1s, using model I

Table 1. Experimental material used in present study

Genotypes	Parentage	Salient Features
Parent used for mating		
Pusa Sugandh-5	Pusa 3A × Haryana Basmati	Semi dwarf, high yield per plant, high alkali spread value
Pusa Sugandh-3	Basmati restorer line from IARI	High tillering, high grain weight, long kernel length and high kernel length after cooking
Kasturi Basmati	Basmati-370 × CRR 88-17-1-5	Low yield Low yield per plant, low grain breadth, low alkali spread value and low amylose content
Pusa Basmati-1	Pusa 150 × Karnal local	Medium dwarf, high tillering, late maturity, long grain and strongly scented
Pusa 2517-2-51-1	Selection from IARI	Semi dwarf, high test weight, low amylose content and high aroma
Pusa Sugandh-2	Basmati restorer line from IARI	Semi dwarf , medium test weight, medium kernel length after cooking and high alkali spread value
Ranbir Basmati	Pure line Selection of Basmati-370-90-95	Early flowering, low yield per plant and low kernel length after cooking
Type-3	Selection from Dehradun Basmati	Late maturity, low grain weight and relatively short kernel length
Check		
Taraori Basmati	Pureline selection from HBC-19	Tall, long slender grain and strongly scented(for quality traits)
Pusa Basmati-1	Pusa 150 × Karnal local	Medium dwarf, high tillering, late maturity, long grain and strongly scented(for yield traits)

and method II, [7]. Thus, the set of 28 rice hybrids were generated. In kharif-2016, the seed of F_1 hybrids generated during the previous season along with the parental lines and checks (Pusa Basmati-1 and Taraori Basmati) was raised at a standard spacing of 20 x 15 cm in 5 m rows in randomized block design with three replications. The recommended package of practices was followed to raise a good crop.

Mean performance of hybrids along with their parental lines and checks were studied for both yield and quality traits. Heterosis was estimated for various yield and quality traits over respective better parent and over the standard variety for all the 28 hybrids following the procedure out lined by Liang et al. [8]. For yield traits, the heterosis was estimated for days to 50 percent flowering, days to maturity, plant height at maturity, main panicle length, number of effective tillers per plant, filled spikelet per panicle, unfilled spikelet per panicle, 100 seed weight and seed yield per plant using Pusa Basmati-1 as best check. In case of quality traits, heterosis was estimated for kernel length before cooking, kernel breadth before cooking, kernel length after cooking and kernel breadth after cooking, kernel length/breadth ratio before cooking, kernel length/breadth ratio after cooking, kernel elongation ratio, elongation index, alkali spread value, amylose content and aroma,. The significance of different types of heterosis was evaluated by the estimates of critical differences (C.D.) for various traits at 0.05 and 0.01 levels of significance.

Kernel dimensional analysis was done with the help of graph paper and small millimeter scale. Alkali digestion was estimated by the test devised by Little et al. [9]. The simplified calorimetric method described by Juliano, [10] was followed for the estimation of amylose content. Aroma was estimated on the scale from 1-4 (1= non aromatic; 2= slightly aromatic; 3= moderately aromatic and 4= strongly aromatic) following the method suggested by Sood and Siddiq, [11]. Pusa Basmati 1(yield) and Taraori Basmati (quality) check was used as standard variety for comparison of the F_1 hybrids.

3. RESULTS AND DISCUSSION

Analysis of variance for the treatments (parents and hybrids) revealed that all the genotype expressed significant differences ($P< 0.01$ level of significance) for both yield and quality traits (Table 2).

3.1 Estimation of Heterosis for Yield and Yield Traits

Heterosis for yield and yield traits in rice over the respective better parents and over the standard check have been presented in Tables 3 to 5. For some of the traits, negative heterotic value is considered desirable, while in others positive heterotic estimates are usually preferable.

For days to 50 % flowering, crosses Pusa-2517-2-51-1x Type-3 followed by Pusa Sugandh-2 x Pusa Basmati-1 showed significant heterosis for early flowering and early maturing over the mid parent, better parents and standard check. Similar findings were also reported by Priyanka et al. [12] and Waza et al. [5]. Significant estimates of heterobeltiosis in desired direction were recorded in Pusa Sugandh-2 x Pusa Basmati-1and Pusa-2517-2-51-1x Type-3. Higher magnitudes of negative heterosis for earliness was reported by Kumar et al. [13] and Tiwari et al. [14], Veeresha et al. [15] and Borah et al. [16].

Semi-dwarf plant height and hence negative value of heterosis is desirable for recording high yield in rice as vigour in plant height may lead to unfavourable grain/straw ratio and below optimum yield due to lodging. Tall plants require more energy to translocate solutes to the sink (grain) and thereby lower grain weight [17]. Significant estimates of heterobeltiosis along with standard heterosis in a negative direction was estimated in two crosses viz., Pusa Sugandh-2 x Pusa Basmati-1 and Pusa -2517-2-51-1x Pusa Basmati-1. Out of 28 crosses, nine cross combination exhibited significant negative standard heterosis over the check (Pusa Basmati1) which was desirable for improving yield attributes of plant height. Negative heterotic values for plant height in rice were observed by Khoyumthem et al. [18] and Gawas et al. [19]. Similar findings were also reported by Rahimi et al. [20], Tiwari et al. [14], Patil et al. [21], Sunil Kumar et al. [22] and Waza et al. [5].

Main panicle length is an important yield contributing trait. The longer the length of the panicle, the more the capacity in bearing more spikelets. Highest and significant estimates of

Table 2. Analysis of variance for yield and quality traits in Rice

S. No.	Character	Mean sum of square		
		Replication (d.f.= 2)	Treatments (d.f.= 35)	Error (d.f.= 70)
1	Days to 50% Flowering	1.8817	142.81**	0.9407
2	Days to Maturity	1.2700	148.12**	0.8952
3	Plant Height at maturity	0.8155	1301.24*	0.7923
4	Main Panicle Length	0.0731	47.79**	0.8054
5	Effective Tillers/ Plant	0.5190	9.49**	0.5685
6	Filled Spikelets per panicle	0.3408	1644.99**	5.2644
7	Unfilled Spikelets per panicle	0.2565	507.87**	3.9055
8	100 Seed Weight	0.0076	0.12**	0.0053
9	Yield Per Plant	1.0758	100.16**	1.6194
10	Kernel Length before cooking	0.0007	0.61**	0.0063
11	Kernel Breadth before cooking	0.0005	0.047**	0.0089
12	L/B Ratio Before Cooking	0.0514	0.474**	0.1288
13	Kernel Length After Cooking	0.0133	1.80**	0.0138
14	Kernel Breadth After Cooking	0.0023	0.0375**	0.0026
15	L/B After Cooking	0.0047	0.38**	0.0109
16	Elongation Ratio	0.0003	0.04**	0.0005
17	Elongation Index	0.0012	0.045**	0.0064
18	ASV/GT Value	0.0314	4.070**	0.0155
19	Amylose Content	0.0541	19.764**	0.0678

**, ** = Significant at 0.05 and 0.01 levels, respectively*

heterobeltiosis and standard heterosis in desirable direction were recorded in cross Kasturi Basmati x Pusa -2517-2-51-1 and Kasturi Basmati x Pusa Basmati-1, whereas most of the crosses recorded negative heterosis, presented in table 4. Patil et al. [23] and Eradasappa et al. [24] also were of similar opinion. Heterobeltiosis in both positive and negative directions were studied earlier also, in studies of Yadav et al. [25] and Borah and Barman et al. [26]. Cross Type-3 x Pusa Basmati-1 exhibited highest and significant positive standard heterosis over the check (Pusa Basmati-1). These findings were similar to those of Faiz et al. [27], Rahimi et al. [20], Tiwari et al. [14], Patil et al. [21], and Borah et al. [16].

The positive value of heterosis for number of effective tillers per plant is desirable as more number of panicle bearing tillers is believed to be closely associated with higher grain yield. In the present study, both positive and negative heterotic values for number of effective tillers per plant were observed over better parent and over check. Crosses Kasturi Basmati x Pusa Sugandh5, Kasturi Basmati x Pusa Sugandh-3 and Kasturi Basmati x Pusa -2517-2-51-1 exhibited highest significant heterosis over better-parent for productive tillers per plants. While the crosses Ranbir Basmati x Pusa Basmati-1 and Kasturi Basmati x Pusa -2517-2-51-1 showed highest positive significant heterosis over check (Pusa Basmati-1) for number of effective tillers per plants. These results agreed with Lokaprakash et al. [28], Vaithiyalingam and Nadarajan, [29] and Sharma et al. [30]. Most of the crosses recorded negative standard heterosis over check. Both positive and negative heterotic values for number of effective tillers per plant in different cross combinations were also reported by Tiwari et al. [30] and Waza et al. [5].

Table 3. Estimation of heterosis over mid parent, better parent and standard heterosis for days to 50 per cent flowering, days to maturity and plant height

Crosses	Days to 50% Flowering				Days to Maturity				Plant Height at Maturity			
	Mean	MP	BP	SH	Mean	MP	BP	SH	Mean	MP	BP	SH
Ranbir Basmati × Kasturi Basmati	88.40	-1.60*	6.16**	-17.64**	118.40	-0.67	5.87**	-13.75**	149.67	7.47**	22.95**	40.44**
Ranbir Basmati × Pusa Sugandh-3	98.20	-0.86	1.87*	-8.51**	128.40	-0.67	1.45*	-6.46**	131.57	-2.42**	16.57**	23.46**
Ranbir Basmati × Pusa Sugandh-5	104.63	2.45**	8.54**	-2.51**	134.70	1.97**	6.43**	-1.87*	123.73	-4.23**	21.78**	16.11**
Ranbir Basmati × Pusa-2517-2-51-1	96.63	-1.23	0.24	-9.97**	126.87	-0.91	0.24	-7.58**	133.37	4.33**	34.90**	25.14**
Ranbir Basmati × Pusa Sugandh-2	108.20	7.36**	12.24**	0.81	138.00	5.29**	9.03**	0.53	119.33	-4.33**	28.78**	11.98**
Ranbir Basmati × Type-3	106.37	-0.55	10.34**	-0.90	136.47	-0.41	7.82**	-0.59	158.77	-1.17**	1.25**	48.98**
Ranbir Basmati × Pusa Basmati-1	100.50	-1.34	4.25**	-6.36**	130.50	-1.07*	3.11**	-4.93**	135.57	2.95**	27.21**	27.21**
Kasturi Basmati × Pusa Sugandh-3	98.40	6.40**	18.17**	-8.32**	128.60	5.50**	14.99**	-6.32**	116.43	-0.74	3.16**	9.26**
Kasturi Basmati × Pusa Sugandh-5	103.40	8.20**	24.18**	-3.66**	134.50	7.83**	20.27**	-2.02**	109.60	-1.85**	7.87**	2.84*
Kasturi Basmati × Pusa-2517-2-51-1	93.77	2.74**	12.61**	-12.64**	123.87	2.65**	10.76**	-9.76**	115.50	4.71**	16.82**	8.38**
Kasturi Basmati × Pusa Sugandh-2	88.73	-5.82**	6.57**	-17.33**	119.77	-3.18**	7.09**	-12.75**	103.57	-3.39**	11.76**	-2.82**
Kasturi Basmati × Type-3	104.17	3.77**	25.10**	-2.95**	133.53	2.98**	19.40**	-2.72*	148.93	4.06**	22.34**	39.75**
Kasturi Basmati × Pusa Basmati-1	96.50	1.26	15.89**	-10.09**	126.37	1.46**	13.00**	-7.94**	110.80	-2.93**	3.97**	3.97**
Pusa Sugandh-3 × Pusa Sugandh-5	102.70	-1.99**	0.98	-4.31**	132.77	-1.51**	0.61	-3.28**	114.03	6.34**	12.24**	7.00**
Pusa Sugandh-3 × Pusa-2517-2-51-1	99.60	-0.88	0.34	-7.20**	130.07	-0.51	0.44	-5.25**	100.87	-4.72**	2.02**	-5.35**
Pusa Sugandh-3 × Pusa Sugandh-2	103.07	-0.35	1.34	-3.98**	133.17	-0.45	0.91	-2.99*	97.57	-5.06**	5.29**	-8.45**
Pusa Sugandh-3 × Type-3	103.73	-5.35**	2.00*	-3.35**	132.97	-4.84**	0.76	-3.13*	142.50	2.75**	26.26**	33.71**
Pusa Sugandh-3 × Pusa Basmati-1	104.40	-0.11	2.65**	-2.73*	134.07	-0.41	1.59**	-2.33*	108.97	-0.68	2.25**	2.25*
Pusa Sugandh-5 × Pusa-2517-2-51-1	105.80	2.16**	6.58**	-1.43*	135.83	1.70**	4.89**	-1.05*	103.10	2.86**	4.28**	-3.26**
Pusa Sugandh-5 × Pusa Sugandh-2	103.90	-2.46**	-1.20	-3.20**	134.07	-1.85**	-1.11	-2.33**	96.87	-0.27	4.53**	-9.11**
Pusa Sugandh-5 × Type-3	113.27	0.52	5.01**	5.53**	143.27	0.49	4.09**	4.37**	133.00	-0.04	30.91**	24.80**
Pusa Sugandh-5 × Pusa Basmati-1	107.03	-0.53	-0.28	-0.28	137.50	0.04	0.17	0.17	104.10	0.02	2.46**	-2.32*
Pusa-2517-2-51-1 × Pusa Sugandh-2	100.07	-2.10**	0.81	-6.77**	130.47	-1.56**	0.75	-4.96**	95.87	0.10	3.45**	-10.04**
Pusa-2517-2-51-1 × Type-3	95.80	-11.61**	-3.49**	-10.74**	125.03	-9.72**	-3.45**	-8.91**	120.60	-8.42**	21.98**	13.17**
Pusa-2517-2-51-1 × Pusa Basmati-1	101.33	-1.90**	2.08**	-5.59**	132.20	-0.89	2.08**	-3.69**	105.30	2.52**	-6.51**	-1.19*
Pusa Sugandh-2 × Type-3	110.50	-0.75	5.07**	2.95*	140.83	-0.49	3.88**	2.60	126.50	-1.62	36.51**	18.70**
Pusa Sugandh-2 × Pusa Basmati-1	99.43	-6.42**	-5.45**	-7.36**	129.87	-4.80**	-4.20**	-5.39**	99.60	-0.02	-7.48**	-6.54**
Type-3 × Pusa Basmati-1	110.37	-1.82**	2.83**	2.83**	139.67	-1.91**	1.75**	1.75*	134.57	-0.71	26.27**	26.27**
SED		0.67	0.78	0.78		0.66	0.76	0.76		0.62	0.72	0.72
CD (95%)		1.38	1.59	1.59		1.35	1.56	1.56		1.28	1.48	1.48
CD (99%)		1.78	2.05	2.05		1.75	2.02	2.02		1.65	1.91	1.91

**, ** = Significant at 0.05 and 0.01 levels, respectively*

Table 4. Estimation of heterosis over mid parent, better parent and standard heterosis for Panicle length, Effective tillers per plants and filled spikelet per plants

Crosses	Main Panicle Length				Effective Tillers/Plants				Filled Spikelets/Panicle			
	Mean	MP	BP	SH	Mean	MP	BP	SH	Mean	MP	BP	SH
Ranbir Basmati × Kasturi Basmati	33.03	-0.05**	-4.80*	13.40**	13.97	35.82**	5.54	2.92*	140.43	10.61**	1.20	-7.81**
Ranbir Basmati × Pusa Sugandh-3	28.10	-9.01*	-19.02**	-3.54	12.37	8.01	-6.55	-8.87**	151.40	7.87**	6.67**	-0.61
Ranbir Basmati × Pusa Sugandh-5	30.37	-4.31*	-12.49**	4.25	13.53	18.54**	2.27	-0.27	118.80	-1.03	-14.39**	-22.01**
Ranbir Basmati × Pusa-2517-2-51-1	26.47	-10.23**	-23.73**	-9.14**	11.57	-7.10	-12.59**	-14.76**	154.90	9.99**	8.40**	1.69
Ranbir Basmati × Pusa Sugandh-2	34.00	20.64**	-2.02	16.72**	14.07	21.09**	6.30	3.66*	144.33	-2.18	-7.68**	-5.25
Ranbir Basmati × Type-3	33.77	-6.12**	-9.31**	15.92**	13.67	8.18	3.27	0.71	129.10	-7.41**	-7.85**	-15.25**
Ranbir Basmati × Pusa Basmati-1	34.60	8.41**	-0.29	18.78**	15.17	13.18**	11.79*	11.77**	122.87	-15.58**	-19.34**	-19.34**
Kasturi Basmati × Pusa Sugandh-3	35.67	22.01**	13.59**	22.44**	11.47	34.90**	18.62**	-15.50**	128.67	0.09	-9.35**	-15.53**
Kasturi Basmati × Pusa Sugandh-5	29.77	-1.05	-5.20*	2.19	12.00	41.73**	25.00**	-11.57**	83.67	-22.70**	-27.35**	-45.08**
Kasturi Basmati × Pusa-2517-2-51-1	35.77	28.50**	13.91**	22.78**	15.37	61.75**	31.71**	13.24**	140.90	9.20**	-1.40	-7.50*
Kasturi Basmati × Pusa Sugandh-2	31.90	20.23**	1.59	9.51**	9.77	12.69*	-2.33	-28.03**	117.33	-13.57**	-24.95**	-22.97**
Kasturi Basmati × Type-3	35.10	2.28	-5.73**	20.49**	13.87	43.20**	15.24**	2.19	141.57	10.92**	1.05	-7.07*
Kasturi Basmati × Pusa Basmati-1	36.23	19.71**	15.39**	24.38**	12.83	22.81**	-5.41	-5.43**	135.43	1.26	-11.09**	-11.09**
Pusa Sugandh-3 × Pusa Sugandh-5	29.00	3.88	0.81	-0.45	8.93	-7.27	-7.59	-34.17**	92.43	-24.00**	-34.88**	-39.32**
Pusa Sugandh-3 × Pusa-2517-2-51-1	24.33	-5.19*	-10.10**	-16.47**	12.53	17.50**	7.43	-7.64**	144.57	1.51	1.17	-5.10*
Pusa Sugandh-3 × Pusa Sugandh-2	25.93	6.43*	-4.19	-10.97**	11.33	15.25**	13.33*	-16.48**	181.23	21.52**	15.93**	18.97**
Pusa Sugandh-3 × Type-3	34.90	8.55**	-6.27**	19.81**	13.07	20.43**	8.59	-3.71*	147.47	4.57	3.90**	-3.19*
Pusa Sugandh-3 × Pusa Basmati-1	31.33	11.51**	7.55**	7.56*	12.57	8.18	-7.37	-7.39**	119.57	-18.74**	-21.51**	-21.51**
Pusa Sugandh-5 × Pusa-2517-2-51-1	29.43	11.00**	2.32	1.04	12.10	13.79**	3.71	-10.83**	131.43	7.64**	-8.02**	-13.72**
Pusa Sugandh-5 × Pusa Sugandh-2	30.00	18.97**	4.29	2.99	10.63	8.50	6.33	-21.64**	92.53	-28.17**	-40.81**	-39.25**
Pusa Sugandh-5 × Type-3	33.77	2.32	-9.31**	15.92**	14.13	30.66**	17.45**	4.15*	141.90	17.56**	1.28	-6.85*
Pusa Sugandh-5 × Pusa Basmati-1	31.17	7.66**	6.98**	6.99*	13.83	19.42**	1.97	1.94	123.57	-2.56	-18.88**	-18.88**
Pusa-2517-2-51-1 × Pusa Sugandh-2	24.73	7.69**	1.92	-15.09**	11.50	6.15	-1.43	-15.25**	103.43	-30.87**	-33.84**	-32.10**
Pusa-2517-2-51-1 × Type-3	35.77	16.31**	-3.94	22.78**	13.00	9.70*	8.03	-4.20*	147.63	4.33**	3.31*	-3.08*
Pusa-2517-2-51-1 × Pusa Basmati-1	29.47	10.36**	1.14	1.16	11.93	-5.42	-12.04*	-12.06**	169.83	15.05**	11.49**	11.49**
Pusa Sugandh-2 × Type-3	32.77	11.26**	-12.00**	12.48**	13.33	21.03**	10.80*	-1.74	183.00	23.47**	17.06**	20.13**
Pusa Sugandh-2 × Pusa Basmati-1	32.40	27.56**	11.21**	11.23**	14.33	21.64**	5.65	5.63**	107.63	-30.26**	-31.15**	-29.34**
Type-3 × Pusa Basmati-1	37.37	12.61**	0.36	28.28**	12.50	-2.34	-7.86	-7.89**	136.47	-6.67**	-10.42**	-10.41**
SED		0.64	0.74	0.74		0.54	0.62	0.62		1.64	1.89	1.89
CD (95%)		1.31	1.52	1.52		1.10	1.27	1.27		3.36	3.88	3.88
CD (99%)		1.69	1.96	1.96		1.42	1.64	1.64		4.33	5.00	5.00

**, ** = Significant at 0.05 and 0.01 levels, respectively*

Table 5. Estimation of heterosis over mid parent, better parent and standard heterosis for Unfilled Spikelet/ plants, 100 Grain Weight and Yield Per Plants

Crosses	Unfilled Spikelet/Panicle				100 Seed Weight				Yield per Plants			
	Mean	**MP**	**BP**	**SH**	**Mean**	**MP**	**BP**	**SH**	**Mean**	**MP**	**BP**	**SH**
Ranbir Basmati × Kasturi Basmati	38.33	5.89	28.35**	41.98**	2.23	5.51*	1.52	4.85**	32.33	24.20**	4.75	-22.22**
Ranbir Basmati × Pusa Sugandh-3	61.23	52.51**	62.14**	126.79**	2.43	3.55	-8.75**	14.24**	38.33	28.28**	24.19**	-7.79**
Ranbir Basmati × Pusa Sugandh-5	45.00	-16.72**	5.80	66.67**	2.43	6.57**	-3.95	14.24**	27.67	4.21	-10.37**	-33.45**
Ranbir Basmati × Pusa-2517-2-51-1	53.33	12.60**	25.39**	97.53**	2.83	21.43*	7.59**	33.02**	35.67	6.89*	-0.56	-14.20**
Ranbir Basmati × Pusa Sugandh-2	80.23	114.62**	148.91**	197.16**	2.60	16.42**	6.85**	22.07**	36.00	4.20	-5.84*	-13.40**
Ranbir Basmati × Type-3	29.57	-15.12**	8.97	9.51**	2.20	11.86**	8.20**	3.29*	33.00	10.68**	6.91	-20.62**
Ranbir Basmati × Pusa Basmati-1	53.33	19.90**	25.39**	97.53**	2.23	7.20**	4.69	4.85**	40.00	10.45**	-3.77	-3.78
Kasturi Basmati × Pusa Sugandh-3	61.77	82.65**	106.81**	128.77**	2.50	2.74	-6.25**	17.37**	32.00	27.74**	10.73**	-23.02**
Kasturi Basmati × Pusa Sugandh-5	46.87	-1.75	56.92**	73.58**	2.30	-2.82	-9.21*	7.98**	22.00	1.30	-1.05	-47.08**
Kasturi Basmati × Pusa-2517-2-51-1	44.13	7.55**	47.77**	63.46**	2.57	6.21**	-2.53	20.50**	41.33	44.86**	15.24**	-0.57
Kasturi Basmati × Pusa Sugandh-2	67.00	115.78**	124.33**	148.15**	2.50	7.91**	2.74	17.37**	38.33	29.00**	0.26	-7.79*
Kasturi Basmati × Type-3	58.43	105.03**	115.36**	116.42**	2.07	0.81	-6.06*	-2.97	33.33	33.42**	15.87**	-19.81**
Kasturi Basmati × Pusa Basmati-1	49.80	30.54**	66.74**	84.44**	2.27	4.62	3.03	6.42**	41.00	30.64**	-1.36	1.37
Pusa Sugandh-3 × Pusa Sugandh-5	60.43	17.01**	60.02**	123.83**	2.43	-6.41**	-8.75**	14.24**	32.67	27.77**	13.03**	-21.42**
Pusa Sugandh-3 × Pusa-2517-2-51-1	37.43	-16.78**	-0.88	38.64**	2.60	-1.89	-2.50	22.07**	33.67	3.96	-6.13*	-19.01**
Pusa Sugandh-3 × Pusa Sugandh-2	39.90	14.00**	23.78**	47.78**	2.53	-0.65	-5.00*	18.94**	42.67	27.11**	11.60**	4.64**
Pusa Sugandh-3 × Type-3	50.77	56.45**	87.10**	88.02**	2.60	13.87**	-2.50	22.07**	34.33	19.08**	18.80**	-17.41**
Pusa Sugandh-3 × Pusa Basmati-1	56.57	34.36**	49.78**	109.51**	2.43	1.39	-8.75**	14.24**	38.00	7.85**	-8.58**	-8.59**
Pusa Sugandh-5 × Pusa-2517-2-51-1	55.43	-5.83	6.19	105.31**	2.57	-0.65	-2.53	20.50**	27.67	-4.76	-22.86**	-33.45**
Pusa Sugandh-5 × Pusa Sugandh-2	49.57	1.40	53.77**	83.58**	2.33	-6.04**	-7.89**	9.55**	40.00	32.30**	4.62	-3.78**
Pusa Sugandh-5 × Type-3	52.97	14.32**	95.21**	96.17**	2.50	12.78**	-1.32	17.37**	36.33	42.48**	26.30**	-12.60**
Pusa Sugandh-5 × Pusa Basmati-1	63.30	13.07**	36.32**	134.44**	2.43	4.29	-3.95	14.24**	40.00	25.39**	-3.77	-3.78**
Pusa-2517-2-51-1 × Pusa Sugandh-2	63.33	50.02**	96.48**	134.57**	2.53	0.00	-3.80	18.94**	36.33	-1.93	-4.97	-12.60**
Pusa-2517-2-51-1 × Type-3	40.87	3.03	50.61**	51.36**	2.43	7.35**	-7.59**	14.24**	36.67	13.46**	2.23	-11.80**
Pusa-2517-2-51-1 × Pusa Basmati-1	35.10	-28.83**	-24.41**	30.00**	2.30	-3.50	-12.66**	7.98**	39.67	2.45	-4.57	4.58**
Pusa Sugandh-2 × Type-3	34.67	16.79**	27.76**	28.40**	2.27	4.62	-6.85**	6.42*	30.00	-10.45**	-21.53**	-27.83
Pusa Sugandh-2 × Pusa Basmati-1	66.13	68.14**	105.17**	144.94**	2.43	6.57**	0.00	14.24**	42.33	6.10**	1.84	1.84**
Type-3 × Pusa Basmati-1	59.90	62.85**	120.76**	121.85**	2.00	-0.83	-6.25*	-6.10*	41.67	18.48**	0.24	0.23
SED		1.41	1.63	1.63		0.05	0.06	0.06		0.91	1.05	1.05
CD (95%)		2.89	3.34	3.34		0.11	0.12	0.12		1.87	2.15	2.15
CD (99%)		3.73	4.31	4.31		0.14	0.16	0.16		2.41	2.78	2.78

**, ** = Significant at 0.05 and 0.01 levels, respectively*

Table 6. Estimation of heterosis over mid parent, better parent and standard heterosis for Kernel length, Kernel breadth, L/B ratio before cooking

Crosses	Kernel Length Before Cooking				Kernel Breadth Before Cooking				L/B Ratio Before Cooking			
	Mean	MP	BP	SH	Mean	MP	BP	SH	Mean	MP	BP	SH
Ranbir Basmati × Kasturi Basmati	7.87	7.76**	5.36**	9.77**	1.53	-5.15	0.00	-10.68*	5.57	22.34**	18.44**	33.60**
Ranbir Basmati × Pusa Sugandh-3	8.30	6.18**	1.63	15.81**	1.93	12.62**	13.73**	12.62**	4.33	-4.06	-6.47	4.00
Ranbir Basmati × Pusa Sugandh-5	8.20	6.49**	3.36**	14.42**	1.83	7.84	7.84	6.80	4.47	-2.19	-5.63	7.20
Ranbir Basmati × Pusa-2517-2-51-1	7.53	-0.22	-1.31	5.12**	1.93	9.43*	13.73**	12.62**	3.87	-10.42	-12.12	-7.20
Ranbir Basmati × Pusa Sugandh-2	7.63	1.10	0.00	6.51**	1.87	4.67	9.80*	8.74	4.07	-4.31	-7.58	-2.40
Ranbir Basmati × Type-3	7.20	1.17	-3.57**	0.47	1.73	-3.70	1.96	0.97	4.17	4.60	-5.30	0.00
Ranbir Basmati × Pusa Basmati-1	7.30	-1.57*	-2.23	1.86	1.70	0.00	0.00	-0.97	4.30	-1.90	-2.27	3.20
Kasturi Basmati × Pusa Sugandh-3	7.87	2.83**	-3.67**	9.77**	1.83	12.24**	19.57**	6.80	4.30	-7.86	-8.51	3.20
Kasturi Basmati × Pusa Sugandh-5	7.60	0.88	-4.20**	6.05**	1.57	-3.09	2.17	-8.74	4.87	3.18	2.82	16.80*
Kasturi Basmati ×Pusa-2517-2-51-1	7.70	4.29**	0.87	7.44**	1.93	14.85**	26.09**	12.62**	4.03	-9.70	-14.18*	-3.20
Kasturi Basmati × Pusa Sugandh-2	7.13	-3.39**	-6.55**	-0.47	1.90	11.76**	23.91**	10.68*	3.73	-15.15*	-20.57**	-10.40
Kasturi Basmati × Type-3	7.20	3.60**	0.93	0.47	1.73	0.97	13.04*	0.97	4.13	0.00	-12.06	-0.80
Kasturi Basmati × Pusa Basmati-1	7.33	1.15	-0.45	2.33	1.60	-1.03	4.35	-6.80	4.63	2.21	-1.42	11.20
Pusa Sugandh-3 × Pusa Sugandh-5	8.07	0.21	-1.22	12.56**	1.90	10.68**	11.76*	10.68*	4.27	-8.90	-9.86	2.40
Pusa Sugandh-3 ×Pusa-2517-2-51-1	7.90	0.00	-3.27**	10.23**	1.77	-0.93	1.92	2.91	4.50	1.50	-2.88	8.00
Pusa Sgandh-3 × Pusa Sugandh-2	8.13	2.95**	-0.41	13.49**	1.90	5.56	9.62*	10.68*	4.33	-0.76	-6.47	4.00
Pusa Sugandh-3 × Type-3	7.90	5.80**	-3.27**	10.23**	1.97	8.26*	13.46**	14.56**	4.03	-1.63	-12.95	-3.20
Pusa Sugandh-3 × Pusa Basmati-1	7.33	-5.58**	-10.20**	2.33*	1.60	-6.80	-5.88	-6.80	4.60	2.22	-0.72	10.40
Pusa Sugandh-5 ×Pusa-2517-2-51-1	7.93	1.93*	0.00	10.70**	1.93	9.43*	13.73**	12.62**	4.13	-7.81	-12.68	-0.80
Pusa Sugandh-5 × Pusa Sugandh-2	8.63	10.92**	8.82**	20.47**	1.93	8.41*	13.73**	12.62**	4.47	1.13	-5.63	7.20
Pusa Sugandh-5 × Type-3	8.53	16.10**	7.56**	19.07**	1.83	1.85	7.84	6.80	4.63	11.65	-2.11	11.20
Pusa Sugandh-5 × Pusa Basmati-1	8.67	13.29**	9.24**	20.93**	1.70	0.00	0.00	-0.97	5.10	12.09*	7.75**	22.40**
Pusa-2517-2-51-1 ×Pusa Sugandh-2	7.53	-1.31	-1.31	5.12**	1.83	-0.90	0.00	6.80	4.07	-2.40	-3.94	-2.40
Pusa-517-2-51-1 × Type-3	7.33	1.85*	-3.93**	2.33*	1.90	1.79	3.64	10.68*	3.83	-1.71	-9.45	-8.00
Pusa-2517-2-51-1 × Pusa Basmati-1	7.93	5.78**	3.93**	10.70**	1.77	0.00	3.92	2.91	4.47	3.88	2.29	7.20
Pusa Sugandh-2 × Type-3	7.47	3.70**	-2.18*	4.19**	1.93	2.65	3.57	12.62**	3.83	0.00	-6.50	-8.00
Pusa Sugandh-2 × Pusa Basmati-1	7.40	-1.33	-3.06**	3.26**	1.73	-2.80	1.96	0.97	4.30	1.57	-1.53	3.20
Type-3 ×Pusa Basmati-1	7.23	2.36**	-1.81	0.93	1.93	7.41	13.73**	12.62**	3.70	-6.72	-15.27*	-11.20
SED		0.06	0.07	0.07		0.07	0.08	0.08		0.26	0.30	0.30
CD (95%)		0.12	0.13	0.13		0.14	0.16	0.16		0.53	0.61	0.61
CD (99%)		0.15	0.17	0.17		0.18	0.21	0.21		0.68	0.79	0.79

**, ** = Significant at 0.05 and 0.01 levels, respectively*

Table 7. Estimation of heterosis over mid parent, better parent and standard heterosis for KLAC, KBAC, and L/B after cooking

Crosses	Kernel Length After Cooking				Kernel Breadth After Cooking				L/B Ratio After Cooking			
	Mean	MP	BP	SH	Mean	MP	BP	SH	Mean	MP	BP	Sh
Ranbir Basmati×Kasturi Basmati	12.37	1.78**	-0.27	-5.60**	2.57	-0.65	1.32	6.94**	4.83	3.20*	-0.68	-12.65**
Ranbir Basmati × Pusa Sugandh-3	14.40	9.09**	-0.69	9.92**	2.70	2.53	2.53	12.50**	5.37	6.98**	-3.01	-3.01
Ranbir Basmati × Pusa Sugandh-5	13.57	4.09**	-4.24**	3.56**	2.63	3.95**	8.22**	9.72**	5.20	0.00	-11.86**	-6.02**
Ranbir Basmati × Pusa-2517-2-51-1	13.50	6.86**	1.00	3.05**	2.60	0.65	2.63	8.33**	5.20	5.05**	-3.70*	-6.02**
Ranbir Basmati × Pusa Sugandh-2	12.40	0.95	-2.11**	-5.34**	2.50	-1.32	2.74	4.17*	4.97	2.05	-5.10**	-10.24**
Ranbir Basmati × Type-3	12.23	0.96	-0.81	-6.62**	2.43	-3.31*	1.39	1.39	5.07	5.56**	-0.65	-8.43**
Ranbir Basmati × Pusa Basmati-1	14.20	8.67**	-0.23	8.40**	2.30	-8.61**	-4.17*	-4.17*	6.20	18.85**	4.49**	12.05**
Kasturi Basmati × Pusa Sugandh-3	13.37	-0.62	-7.82**	2.04**	2.60	0.65	2.63	8.33**	5.20	0.00	-6.02**	-6.02**
Kasturi Basmati × Pusa Sugandh-5	12.87	-3.14**	-9.18**	-1.78*	2.50	0.67	2.74	4.17*	5.13	-4.64**	-12.99**	-7.23**
Kasturi Basmati × Pusa-2517-2-51-1	12.90	0.13	-3.49**	-1.53*	2.40	-5.26**	-5.26**	0.00	5.47	6.49**	1.23	-1.20
Kasturi Basmati × Pusa Sugandh-2	12.80	2.13**	1.05	-2.29**	2.60	4.70**	6.85**	8.33**	4.90	-2.97*	-6.37**	-11.45**
Kasturi Basmati × Type-3	12.33	-0.27	-0.54	-5.85**	2.27	-8.11**	-5.56**	-5.56**	5.43	9.03**	6.54**	-1.81
Kasturi Basmati × Pusa Basmati-1	14.30	7.38**	0.47	9.16**	2.47	0.00	2.78	2.78	5.80	7.41**	-2.25	4.82**
Pusa Sugandh-3 × Pusa Sugandh-5	14.30	-0.23	-1.38*	9.16**	2.50	-1.32	2.74	4.17*	5.77	0.87	-2.26	4.22**
Pusa Sugandh-3 × Pusa-2517-2-51-1	13.67	-1.91**	-5.75**	4.33**	2.60	0.65	2.63	8.33**	5.23	-4.27**	-5.42**	-5.42**
Pusa Sugandh-3 × Pusa Sugandh-2	13.33	-1.84**	-8.05**	1.78*	2.57	1.32	5.48**	6.94**	5.20	-3.41*	-6.02**	-6.02**
Pusa Sugandh-3 × Type-3	12.20	-9.07**	-15.86**	-6.87**	2.30	-8.61**	-4.17*	-4.17*	5.30	-0.31	-4.22**	-4.22**
Pusa Sugandh-3 × Pusa Basmati-1	14.67	2.09**	1.15	11.96**	2.70	7.28**	12.50**	12.50**	5.43	-5.23**	-8.43**	-1.81
Pusa Sugandh-5 × Pusa-2517-2-51-1	13.37	-2.91**	-5.65*	2.04**	2.50	0.67	2.74	4.17*	5.37	-5.01**	-9.04**	-3.01
Pusa Sugandh-5 × Pusa Sugandh-2	12.90	-3.85**	-8.94**	-1.53*	2.40	-1.37	-1.37	0.00	5.43	-2.40	-7.91**	-1.81
Pusa Sugandh-5 × Type-3	13.10	-1.13	-7.53**	0.00	2.43	0.69	1.39	1.39	5.40	-1.82	-8.47**	-2.41
Pusa Sugandh-5 × Pusa Basmati-1	14.53	2.35**	2.11**	10.94**	2.47	2.07	2.78	2.78	5.93	0.28	0.00	7.23**
Pusa-2517-2-51-1 × Pusa Sugandh-2	13.40	2.94**	0.25	2.29**	2.50	0.67	2.74	4.17*	5.40	1.57	0.00	-2.41
Pusa-2517-2-51-1 × Type-3	13.20	2.72**	-1.25	0.76	2.50	1.35	4.17*	4.17*	5.33	1.59	-1.23	-3.61*
Pusa-2517-2-51-1 × Pusa Basmati-1	13.73	-0.48	-3.51**	4.83**	2.40	-2.70	0.00	0.00	5.77	1.76	-2.81	4.22**
Pusa Sugandh-2 × Type-3	12.50	0.00	-1.32	-4.58**	2.40	-0.69	0.00	0.00	5.23	1.29	0.00	-5.42**
Pusa Sugandh-2 × Pusa Basmati-1	13.67	1.61**	-3.98**	4.33**	2.40	-0.69	0.00	0.00	5.77	3.28*	-2.81	4.22**
Type-3 ×Pusa Basmati-1	13.40	0.88	-5.85**	2.29**	2.30	-4.17**	-4.17*	-4.17*	5.83	5.74**	-1.69	5.42**
SED		0.08	0.09	0.09		0.04	0.04	0.04		0.07	0.08	0.08
CD (95%)		0.17	0.19	0.19		0.08	0.09	0.09		0.15	0.17	0.17
CD (99%)		0.22	0.25	0.25		0.10	0.11	0.11		0.19	0.22	0.22

**, ** = Significant at 0.05 and 0.01 levels, respectively*

Table 8. Estimation of heterosis over mid parent, better parent and standard heterosis for elongation ratio and elongation index

Crosses	Elongation Ratio				Elongation Index			
	Mean	MP	BP	SH	Mean	MP	BP	SH
Ranbir Basmati × Kasturi Basmati	1.58	-5.49**	-9.39**	-13.69**	0.93	-9.68	-9.68	-30.00**
Ranbir Basmati × Pusa Sugandh-3	1.73	2.67**	-2.62*	-5.11**	1.27	13.43*	5.56	-5.00
Ranbir Basmati × Pusa Sugandh-5	1.65	-2.66**	-7.84**	-9.85**	1.17	2.94	-5.41	-12.50*
Ranbir Basmati × Pusa-2517-2-51-1	1.79	6.97**	2.29*	-2.01	1.33	14.29**	2.56	0.00
Ranbir Basmati × Pusa Sugandh-2	1.62	-0.31	-2.21	-11.13**	1.23	5.71	-5.13	-7.50
Ranbir Basmati × Type-3	1.70	-0.58	-6.76**	-6.93**	1.23	1.37	-11.90*	-7.50
Ranbir Basmati × Pusa Basmati-1	1.95	10.40**	0.86	6.57**	1.43	19.44**	4.88	7.50
Kasturi Basmati × Pusa Sugandh-3	1.70	-3.22**	-4.31**	-6.75**	1.20	7.46	0.00	-10.00
Kasturi Basmati × Pusa Sugandh-5	1.69	-3.97**	-5.22**	-7.30**	1.07	-5.88	-13.51*	-20.00**
Kasturi Basmati × Pusa-2517-2-51-1	1.68	-3.92**	-4.19**	-8.21**	1.33	14.29**	2.56	0.00
Kasturi Basmati × Pusa Sugandh-2	1.79	5.49**	3.07**	-1.82	1.30	11.43*	0.00	-2.50
Kasturi Basmati × Type-3	1.71	-3.84**	-6.03**	-6.20**	1.33	9.59	-4.76	0.00
Kasturi Basmati × Pusa Basmati-1	1.95	6.27**	1.04	6.75**	1.27	5.56	-7.32	-5.00
Pusa Sugandh-3 × Pusa Sugandh-5	1.78	-0.37	-0.56	-2.74**	1.37	12.33*	10.81	2.50
Pusa Sugandh-3 × Pusa-2517-2-51-1	1.73	-2.17*	-3.00**	-5.47**	1.17	-6.67	-10.26	-12.50*
Pusa Sugandh-3 × Pusa Sugandh-2	1.64	-4.65**	-7.87**	-10.22**	1.20	-4.00	-7.69	-10.00
Pusa Sugandh-3 × Type-3	1.54	-14.52**	-15.54**	-15.69**	1.30	0.00	-7.14	-2.50
Pusa Sugandh-3 × Pusa Basmati-1	1.99	7.46**	3.28**	9.12**	1.20	-6.49	-12.20*	-10.00
Pusa Sugandh-5 × Pusa-2517-2-51-1	1.69	-4.62**	-5.60**	-7.66**	1.30	2.63	0.00	-2.50
Pusa Sugandh-5 × Pusa Sugandh-2	1.50	-13.15**	-16.23**	-18.07**	1.20	-5.26	-7.69	-10.00
Pusa Sugandh-5 × Type-3	1.54	-14.50**	-15.36**	-15.51**	1.17	-11.39*	-16.67**	-12.50*
Pusa Sugandh-5 × Pusa Basmati-1	1.68	-9.78**	-13.13**	-8.21**	1.13	-12.82**	-17.07**	-15.00**
Pusa-2517-2-51-1 × Pusa Sugandh-2	1.78	4.40**	1.71	-2.55*	1.33	2.56	2.56	0.00
Pusa-2517-2-51-1 × Type-3	1.80	0.93	-1.10	-1.28	1.40	3.70	0.00	5.00
Pusa-2517-2-51-1 × Pusa Basmati-1	1.73	-5.98**	-10.36**	-5.29**	1.27	-5.00	-7.32	-5.00
Pusa Sugandh-2 × Type-3	1.68	-3.54**	-7.86**	-8.03**	1.33	-1.23	-4.76	0.00
Pusa Sugandh-2 × Pusa Basmati-1	1.84	2.51**	-4.66**	0.73	1.33	0.00	-2.44	0.00
Type-3 × Pusa Basmati-1	1.85	-1.24	-3.97**	1.46	1.57	13.25**	11.90*	17.50**
SED		0.02	0.02	0.02		0.06	0.07	0.07
CD (95%)		0.03	0.04	0.04		0.12	0.14	0.14
CD (99%)		0.04	0.05	0.05		0.15	0.18	0.18

**, ** = Significant at 0.05 and 0.01 levels, respectively*

Table 9. Mean performance of hybrids and the check variety for alkali digestion, gelatinization temperature, amylose content and aroma

Cross Combination	Alkali Spread Value	Gelatinization Temperature (^{0}C)	Amylose Content (%)	Aroma
Ranbir Basmati × Kasturi Basmati	5.87(High)	65-69(Low)	25.63(Intermediate)	2(slight)
Ranbir Basmati × Pusa Sugandh-3	4.03(Intermediate)	70-74(Intermediate)	17.67(Low)	4(strong)
Ranbir Basmati × Pusa Sugandh-5	6.03(High)	65-69(Low)	25.13(Intermediate)	4(strong)
Ranbir Basmati × Pusa-2517-2-51-1	5.40(High)	65-69(Low)	19.80(Low)	2(slight)
Ranbir Basmati × Pusa Sugandh-2	6.13(High)	65-69(Low)	24.50(Intermediate)	2(Slight)
Ranbir Basmati × Type-3	5.27(High)	65-69(Low)	21.33(Intermediate)	3(Moderate)
Ranbir Basmati × Pusa Basmati-1	6.57(High)	65-69(Low)	23.37(Intermediate)	3(Moderate)
Kasturi Basmati × Pusa Sugandh-3	6.17(High)	65-69(Low)	23.13(Intermediate)	3(Moderate)
Kasturi Basmati × Pusa Sugandh-5	6.67(High)	65-69(Low)	24.17(Intermediate)	3(Moderate)
Kasturi Basmati × Pusa-2517-2-51-1	6.60(High)	65-69(Low)	23.63(Intermediate)	3(Moderate)
Kasturi Basmati × Pusa Sugandh-2	5.20(High)	65-69(Low)	19.60(Low)	1(Absent)
Kasturi Basmati × Type-3	4.50(Intermediate)	70-74(Intermediate)	16.43(Low)	1(Absent)
Kasturi Basmati × Pusa Basmati-1	5.50(High)	65-69(Low)	20.70(Intermediate)	4(strong)
Pusa Sugandh-3 × Pusa Sugandh-5	5.43(High)	65-69(Low)	21.53(Intermediate)	3(Moderate)
Pusa Sugandh-3 × Pusa-2517-2-51-1	2.70(Low)	75-79(High)	18.63(Low)	1(Absent)
Pusa Sugandh-3 × Pusa Sugandh-2	5.83(High)	65-69(Low)	21.23(Intermediate)	2(slight)
Pusa Sugandh-3 × Type-3	6.43(High)	65-69(Low)	22.70(Intermediate)	2(slight)
Pusa Sugandh-3 × Pusa Basmati-1	5.30(High)	65-69(Low)	21.17(Intermediate)	3(Moderate)
Pusa Sugandh-5 × Pusa-2517-2-51-1	6.33(High)	65-69(Low)	21.60(Intermediate)	3(Moderate)
Pusa Sugandh-5 × Pusa Sugandh-2	4.63(Intermediate)	70-74(Intermediate)	19.43(Low)	4(strong)
Pusa Sugandh-5 × Type-3	6.30(High)	65-69(Low)	22.50(Intermediate)	3(Moderate)
Pusa Sugandh-5 × Pusa Basmati-1	7.00(High)	65-69(Low)	27.17(Intermediate)	2(slight)
Pusa-2517-2-51-1 × Pusa Sugandh-2	6.17(High)	65-69(Low)	21.60(Intermediate)	3(Moderate)
Pusa-2517-2-51-1 × Type-3	4.47(Intermediate)	70-74(Intermediate)	19.53(Low)	2(slight)
Pusa-2517-2-51-1 × Pusa Basmati-1	5.83(High)	65-69(Low)	23.37(Intermediate)	4(strong)
Pusa Sugandh-2 × Type-3	6.30(High)	65-69(Low)	25.47(Intermediate)	1(Absent)
Pusa Sugandh-2 × Pusa Basmati-1	5.23(High)	65-69(Low)	23.53(Intermediate)	3(Moderate)
Type-3 × Pusa Basmati-1	4.60(Intermediate)	70-74(Intermediate)	21.47(Intermediate)	3(Moderate)
Taraori Basmati (Check)	5.08 (Intermediate)	70-74(Intermediate)	20.52 (Intermediate)	4(Strong)

**, ** = Significant at 0.05 and 0.01 levels, respectively*

A close examination for the estimates of heterosis revealed that most of the crosses exhibited negative to positive manifestation of heterosis over the mid-parents, better-parents and checks for number of filled spikelets per panicle. For the trait number of filled spikelets per panicle highest and highly significant better parent heterosis and standard heterosis over check (Pusa Basmati1) was observed in Pusa Sugandh-3 x Pusa Sugandh-2, Pusa-2517-2-51-1 × Pusa Basmati-1 and Pusa Sugandh-2 × Type-3. Heterosis over mid parent was reported by Aananthi and Jebaraj [31], Deoraj et al. [32] and Tiwari et al. [14] whereas the higher amount of heterobeltiosis for filled grains per panicle was observed by Rahimi et al. [20].

The positive estimate of heterosis for 100 grain weight is desirable as it is an important trait influencing yield. Both positive and negative heterotic values for 100 grain weight among different cross combinations were observed in the present study. Out of twenty eight crosses studied for heterobeltiosis, only three crosses (Ranbir Basmati × Pusa-2517-2-51-1, Ranbir Basmati × Pusa Sugandh-2, Ranbir Basmati × Type-3) recorded significantly positive. However, most of the crosses revealed (Table 5) positively significant estimates for standard heterosis over check. Similar heterotic values for 100 grain weight were observed by Virmani et al. [33], Rahimi et al. [20], Tiwari et al. [14], and Gokulakrishnan and Kumar [34]. However, Vaithiyalingan and Nadarajan, [29] reported only negative heterotic values for test weight.

Heterosis for seed yield in positive direction is desirable as higher grain yield is the main objective for almost all the breeding programmes. Virmani et al. [33] suggested that the yield advantage of 20% to 30% over best available standard variety should be sufficient to encourage farmers for adapting the hybrid rice varieties. Out of 28 crosses, ninteen hybrids revealed higher heterotic values for grain yield per plant over their mid parents. Eight crosses revealed significant over better parent for seed yield as shown in table 5. Out of that, three top performers were Pusa Sugandh-5 x Type-3, Ranbir Basmati x Pusa Sugandh-3 and Pusa Sugandh-3 x Type-3. Whereas, twenty hybrids recorded non significant over better parents. However, only three crosses revealed significant over check (Pusa Basmati-1). High magnitude of standard heterosis for grain yield in rice as observed in the present study, have also been reported by Pandey et al. [35], Kumar et al. [13], Rahimi et al. [20] and Reddy et al. [36]. However, a wide range of heterosis between negative and positive values for grain yield have been reported by Vaithiyalingan and Nadarajan [29], Tiwari et al. [14], Gokulakrishnan and Kumar [34] and Latha et al. [37].

3.2 Estimation of Heterosis for Quality Traits

Heterosis for various quality traits over the respective better parents and over the standard checks have been presented in Table 6 to 9. For the quality traits where usual calculations of heterosis were not applied, the mean values of F_1s and that of standard check have been given (Tables 9). In all the quality traits, Taraori Basmati was used for evaluating the performance of F_1 hybrids over pureline check, respectively. For some of the quality traits, negative heterotic value is considered to be desirable, while in others positive heterotic estimates are usually preferable.

Kernel length before cooking is one of the important grain quality parameters and its higher value is perceived to be desirable. Higher as well as lower values of kernel length before cooking over better parents and standard checks for different cross combinations were observed in the present study. Significant magnitude of positive relative heterosis, heterobeltiosis and standard heterosis over check was exhibited in the cross Pusa Sugandh-5 x Pusa Sugandh-2, Pusa Sugandh-5 x Type-3 and Pusa Sugandh-5 x Pusa Basmati-1 for kernel length before cooking for improving the quality character of grain. Estimates of negative relative heterosis, heterobeltiosis was observed in crosses Pusa Sugandh-3 x Pusa Basmati-1 and Kasturi Basmati x Pusa Sugandh2 for kernel length over better parent. Vivekananda and Giridharan [38] also reported negative as well as positive heterobeltiosis for kernel length. Magnitude of significant negative standard heterosis was not observed for any crosses for kernel length over standard check (Taraori Basmati). However, Rahimi et al. [20], Sanghera and Hussain [39], Reddy et al. [36] and Priyanka et al. [12] reported positive estimates of standard heterosis for kernel length. In contrast, Sarawgi et al. [40] reported the estimates of standard heterosis in negative direction only.

Lower value of kernel breadth before cooking ensures grain fineness. Thus, negative value of heterosis for kernel breadth before cooking would be desirable. Heterobeltiosis and heterosis over the checks for kernel breadth before cooking revealed both positive and negative values depending upon the cross combination. None of the crosses in the present study revealed significant negative relative heterosis and Heterobeltiosis for the traits. Almost, all 28 hybrids studied registered positive significant heterosis, which is undesirable for the traits. Out of 28 crosses only one cross exhibited significant negative standard heterosis over check (Taraori Basmati) for kernel breadth before cooking shown in Table 6 (Ranbir Basmati x Kasturi Basmati) which is desirable for improving quality character in rice grain. Both positive and negative heterotic values with most of the hybrids exhibiting significant positive heterosis for kernel breadth were reported by Sarawgi et al. [40], Rahimi et al. [20], Sanghera and Hussain [39], and Reddy et al. [36] and Waza et al. [5].

Kernel length/breadth ratio before cooking is one of the important physical traits determining the quality of rice grain. A higher value of kernel length/breadth ratio before cooking is conceived as desirable. Kernel length/breadth ratio in the present study revealed both positive and negative values depending upon the cross combination. Out of 28 crosses only two hybrids reported positively significant over better parent's viz., Ranbir Basmati x Kasturi Basmati and Pusa Sugandh-5 x Pusa Basmati-1. Whereas, remaining crosses recorded negative value for the traits. The highest and significant value of kernel length/breadth ratio before cooking was recorded for three crosses (Ranbir Basmati x Kasturi Basmati and Pusa Sugandh-5 x Pusa Basmati-1 and Kasturi Basmati x Pusa Sugandh-5) over check shown in (table 6) while rest of the crosses exhibited negative heterosis. Both high and low value for kernel length/breadth ratio over the standard checks has been reported by Sanghera and Hussain [39]. However, studies of Vivekanandan and Giridharan [38], Sarawgi et al. [40], Reddy et al. [36] and Waza et al. [5] have evinced lower values for kernel length/breadth ratio than the check varieties in most of the cross combinations studied.

Kernel length after cooking is one of the important grain quality parameters and its higher value is perceived to be desirable. Higher as well as lower values of kernel length after cooking over their mid parents, better parents and standard checks for different cross combinations were observed in the present study. Significant positive value of heterosis over the better parent was exhibited by single cross combination (Pusa Sugandh-5 x Pusa Basmati-1). Sixteen crosses exhibited positively significant heterosis over check. A range of values from low to high for kernel length after cooking has been observed by Kumar et al. [13]. Srivastava and Jaiswal [41], Waza et al. [5].

Lower values of kernel breadth after cooking and thus its heterosis in negative direction is desirable. Both higher and lower estimates of kernel breadth after cooking than their mid parents, better parents and standard checks were observed in different cross combinations. Five cross combinations revealed significant negative heterosis, whereas five crosses shown significant positive heterosis and rest of the crosses revealed nonsignificant over better parents. Four cross combinations revealed significant negative heterosis over standard check (Taraori Basmati), whereas, most of the crosses revealed positive heterosis over check. A range of values from low to high for kernel breadth after cooking has been observed by Kumar et al. [13]. Srivastava and Jaiswal [41] and Waza et al. [5].

A higher value of kernel length/breadth ratio after cooking is desirable. Kernel length/breadth ratio after cooking for different cross combinations revealed both higher and lower values than the standard checks. Only two cross (Ranbir Basmati x Pusa Basmati-1 and Kasturi Basmati x Type-3) recorded significant heterobeltiosis, where as seven crosses recorded significant standard heterosis over check. These findings were similar to the results obtained by Waza et al. [5].

Kernel elongation ratio is an important cooking quality character of the rice grain. Length wise expansion of kernel (measured as elongation ratio) upon cooking without increase in girth is considered as desirable trait in Basmati rice, which elongate almost 100% upon cooking [42]. During cooking, rice grains absorb water and increase in length, breadth and volume. This increase may be accompanied by length-wise or breadth-wise splitting of grains, which is a non-desirable character. All the hybrids in present study show lower and higher value of kernel elongation ratio than the standard checks. Sarawgi et al. [40] reported both higher and lower values for kernel elongation ratio than the standard checks.

Elongation index is an important measure of kernel expansion upon cooking that involves both length-wise and breadth-wise components. Kumar [43] proposed that elongation index is a more reliable measure of kernel expansion. Higher value of elongation index is considered to be desirable. Except one cross (Type-3 × Pusa Basmati-1), all other hybrids in the present study showed significantly negative value for elongation index than the mid parents, better parents and standard check.

As the values of alkali digestion is scored on scale of 1 to 7 and its intermediate value is preferable, the value of heterosis obtained by usual calculations is not suitable for selection of desirable cross combinations. The hybrids with intermediate alkali spread value are sorted through the mean value (*per se* performance) of observations. The alkali spread value is the basis for estimation of gelatinization temperature (Table. 9). Gelatinization temperature (GT) is the physical property of starch and refers to the range of temperature within which starch granules start swelling irreversibly in hot water. Thus, GT determines the time required for swelling of the starch granules at a particular temperature on cooking. The rice varieties with intermediate GT and alkali spread value (4-5) are preferred as they exhibit desirable volume expansion and linear kernel elongation under standard cooking procedures without being undercooked and/or overcooked. In the present study, alkali spread value varied from intermediate to high and gelatinization temperature from low to intermediate for hybrids as well as check varieties. Tomar and Nanda, [44], Waza et al. [5] also observed that most of the hybrids recorded intermediate alkali digestion value and gelatinization temperature in their studies.

Amylose content is considered one of most important indices of rice cooking and processing behavior, as it determines the hardness, gloss and rice to water ratio of cooked rice (Waza et al. [5]. Rice with low amylose content is waxy, sticky and remains firm after cooking. In contrast, nonwaxy, non-sticky rice which cooks moist and tender, and does not become hard upon cooking is the consequence of intermediate amylose content (20-25%). The genotypes with intermediate amylose content are considered to be most desirable especially in the Indian context. Therefore, the value of heterosis for amylose content as obtained by usual calculations is not considered suitable for selection of desirable cross combinations. In the present study, estimates of amylose content varied from low to intermediate for various cross combinations. Except seven cross combinations, all the hybrids, as shown in table 9 were observed to show an intermediate value of amylose content. Thus, most of the cross combinations revealed at par performance to the check variety. These findings were in close conformity with the findings of Kumar and Khush [45], who reported intermediate amylose content in most of the rice hybrids they studied.

The presence of aroma is one of the most desirable quality features of rice. The aroma was scored as 1 (Absent) to 4 (Strong) and therefore the usual calculations for estimation of heterosis cannot be applied for the selection of desirable cross combinations. In the present study, four cross combinations (Kasturi Basmati × Pusa Sugandh-2, Kasturi Basmati × Type-3, Pusa.

Sugandh-3 × Pusa-2517-2-51-1 and Pusa Sugandh-2 × Type-3) were non-aromatic, seven crosses revealed the presence of slight aroma and five crosses (Ranbir Basmati × Pusa Sugandh-3, Ranbir Basmati × Pusa Sugandh-5, Kasturi Basmati × Pusa Basmati-1, Pusa Sugandh-5 × Pusa Sugandh-2 and Pusa-2517-2-51-1 × Pusa Basmati-1) was found to be strongly scented. The remaining twelve crosses recorded the presence of mild (moderate) aroma. Estimates of aroma for Taraori Basmati was observed to be strong. Thus five crosses revealed similar value and rest of the crosses showed below value with respect to check, Taraori Basmati.

4. CONCLUSION

In the present findings, desirable performance for all yield and quality traits was not expressed in a single hybrid combination. The relative magnitude of superiority differed from character to character and crosses to cross. For day to 50 per cent flowering and days to maturity, superior performer over better parents recorded in cross: Pusa Sugandh-2 x Pusa Basmati-1and Pusa-2517-2-51-1x Type-3. Kasturi Basmati x Pusa - 2517-2-51-1 performed superior over mid parents, better parents and checks for a number of effective tillers per plant and main panicle length. Pusa Sugandh-3 x Pusa Sugandh-2 were recorded superior for yield traits like filled spikelets per plants and seed yield per plants over mid parents, better parents and checks. Ranbir Basmati x Pusa Sugandh-2 exhibited the highest performer for 100 grain weight over better parents and check. The high magnitude of standard heterosis for grain yield as observed in the present study. The crosses Pusa Sugandh-5 x Pusa Basmati-1 and Ranbir Basmati x Pusa Basmati-1 observed best performer for most of the quality traits. None of the high yielding hybrids recorded desirable performance over mid parents, better parents and standard checks for all the quality traits studied. The crosses Ranbir Basmati × Kasturi Basmati exhibited high heterosis (over commercial checks) for most of the yield as well as quality traits. Thus, these hybrids need to be further tested in observational/ multi-location trials before the commercial exploitation of its heterotic potential.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. USDA (United States Department of Agriculture) Post, February 2017.
2. USDA (United States Department of Agriculture) Rice Outlook, May 2017.
3. Juliano BO, Duff B. Rice grain quality as an emerging priority in national breeding programs. *In:* Rice Grain Marketing and Quality Issues. International Rice Research Institute, Los Banos, Philippines. 1991;55-64.
4. Welch RM, Graham RD. Breeding crops for enhanced micronutrient content. Plant Soil. 2002;245(1):205-214.
5. Waza SA, Jaiswal HK, Sravan T, Bano DA, Priyanka K, Singh PK, Umesh. Heterosis for yield and quality traits in rice (*O. sativa* L.). Journal of Applied and Natural Science. 2016;8(3):1510-1522.
6. Sharifi P, Dehghani H, Mumeni A, Moghaddam M. Genetic and Genotype× Environment interaction effects for appearance quality of rice. Agricultural Sciences in China. 2009;8(8):891-901.
7. Griffing B. Concept of general and specific combining ability in relation to diallel crossing system. Australian Journal of Biology. 1956;9:463-493.
8. Liang CH, Reddy CR, Dayton AD. Heterosis, inbreeding depression and heritability in a systematic series of grain sorghum genotypes. Crop Sci. 1972;12(4): 409-411.
9. Little RR, Hilder GB, Dawson EH. Differential effect of dilute alkali on 25 varieties of milled white rice. Cereal Chem. 1958;35:111-126.
10. Juliano BO. A simplified assay for milled rice amylose. Cereal Sci. Today. 1971*;*16: 334338, 340, 360.
11. Sood BC, Siddiq EA. A rapid technique for scent determination in rice. Indian J. Genet. Plant Breed. 1978;38(2):268-271.
12. Priyanka K, Jaiswal HK, Waza SA. Combining ability and heterosis for yield, its component traits and some grain quality parameters in rice (*Oryza sativa* L.). J. Appl. & Nat. Sci. 2014;6(2):495-506.
13. Kumar S, Singh HB, Sharma JK, Sood S. Heterosis for morpho-physiological and qualitative traits in rice. Oryza. 2010;47(1): 17-21.
14. Tiwari DK, Pandey P, Giri SP, Dwivedi JL. Heterosis studies for yield and its components in rice hybrids using CMS system. Asian J. Plant Sci. 2011;10(1):29-42.
15. Veeresha BA, Hanamaratti NG, Salimath PM. Heterosis and combining ability studies for yield and productivity traits in rice: A review. International Journal of Current Agricultural Research. 2015;4(5): 120-126.
16. Borah SP, Sarma D, Hazarika GN. Magnitude of heterosis for yield and its components in hybrid rice (*oryza sativa* l.). International Journal of Agricultural Science and Research. 2017;7(2):2321-0087.
17. Sen C, Singh RP. Study on heterosis in boro x high yielding rice hybrids. Int. J. Pl. Br. Genet. 2011;5(2):141-149.

18. Khoyumthem P, Sharma PR, Singh NB, Singh MRK. Heterosis for grain yield and its component characters in rice (*Oryza sativa* L.). Environ. Ecol. 2005;23(Special 4):687691.
19. Gawas YK, Bhave SG, Bendale VW, Sawant SS, Jadhav BB. Nature and magnitude of heterosis for growth yield and yield components in hybrid rice. J. Maharastra Agric. Univ. 2007;32(1):52-56.
20. Rahimi M, Rabiei B, Samizadeh H, Ghasemi AK. Combining ability and heterosis in rice (*Oryza sativa* L.) cultivars. J. Agr. Sci. Tech. 2010;12(2): 223-231.
21. Patil PP, Vashi RD, Shinde DA, Lodam VA. Nature and magnitude of heterosis for grain yield and yield attributing traits in rice (*Oryza sativa* L.). Plant Archives. 2011;11(1):423-427.
22. Sunil Kumar, Satish K, Narendra P, Dwivedi DK. Estimation of heterosis for grain yield and yield attributing traits in rice (*Oryza sativa* L.). Plant Archives. 2012;12(1):159-164.
23. Patil DV, Thiyagrajan K, Pushpa K. Heterosis exploration in two line hybrid rice (*Oryza sativa* L.). Crop Res. 2003;25(3): 514-519.
24. Eradasappa E, Ganapathy KN, Satish RG, Shanthala J, Nadarajan N. Heterosis studies for yield and yield components using CMS lines in rice (*Oryza sativa* L.). Crop Res. 2007;34(1, 2 & 3):152-155.
25. Yadav LS, Maurya DM, Giri SP, Singh SB. Nature and magnitude of heterosis for growth, yield and yield components in hybrid rice. Oryza. 2004;41(1&2): 1-3.
26. Borah SP, Barman D. Heterosis for yield components in inter-mutant hybrids of rice. Oryza. 2010;47(1):13-16.
27. Faiz FA, Sabar M, Awan TH, Ijaz M, Manzoor M. Heterosis and Combining ability analysis in Basmati rice hybrids. J. Anim. Pl. Sci. 2006;16(1-2):56-59.
28. Lokaprakash R, Shivashankan G, Mahadevappa M, Shankaregowda, Kulkarni RS. Heterosis in rice. Oryza. 1992;29:293-297.
29. Vaithialingan M, Nadarajan N. Heterosis for yield and yield contributing characters in inter sub-specific crosses of rice. Electron. J. Plant Breed. 2010;1(3):305-310.
30. Sharma A, Singh SK, Nandan R, Ravindra Kumar, Kumar V, Singh MK. Estimation of heterosis and inbreeding depression for yield and yield related traits in rice (*Oryza sativa* L.). Molecular Plant Breeding. 2013;4(29):238-246.
31. Aananthi N, Jebaraj S. Heterosis in two line rice hybrids. Indian Journal of Agriculture Research. 2006;40(3):178-183.
32. Deoraj, Singh DN, Madhuviarya, Praveen Singh. Heterosis in rainfed transplanted rice. Oryza. 2007;44(3):264-267.
33. Virmani SS, Chaudhary RC, Khush GS. Current outlook on hybrid rice. Oryza. 1981;18(3):67-84.
34. Gokulakrishnan J, Kumar S. Heterotic studies using cytoplasmic male sterile lines for enhancing yield attributed traits in rice (*Oryza sativa* L.). Int. J. Curr. Res. 2013;5(1):27-29.
35. Pandey MP, Singh JP, Singh H. Heterosis breeding for grain yield and other agronomic characters in rice (*Oryza sativa* L.). Indian J. Genet. 1995;55(4):438-445.
36. Reddy MR, Raju CHS, Sarvani T, Reddy D, Reddy N. Heterosis for yield and kernal size in aromatic rice (*Oryza sativa.* L). Ann. Biol. Res. 2012;3(6):2662-2666.
37. Latha S, Sharma D, Sanghera GS. Combining ability and heterosis for grain yield and its component trait in rice (*Oryza sativa* L.). Not. Sci. Biol. 2013;5(1): 90-97.
38. Vivekanandan P, Giridharan S. Heterosis and inbreeding depression for kernel traits in rice. Madras Agric. J. 1996;83(12):773-774.
39. Sanghera GS, Hussain W. Heterosis in relation to combining ability per se performance in temperate rice (*Oryza sativa* L.). Pakistan J. Agri. Res. 2012;25(3):1216.
40. Sarawgi AK, Rastogi NK, Munhot MK. Heterosis among line x tester crosses for grain yield and quality components in rice. Trop. Agric. Res. Ext. 2000;3(2):90-93.
41. Srivastava AK, Jaiswal HK. Grain characteristics and cooking quality of indigenous aromatic and non-aromatic

genotypes of rice (*Oryza sativa* L.). Int. J. Sci. Res. Rev. 2013;2(1):36-41.

42. Khush GS, Phule CM, Delacruz NM. Rice grain quality evaluation and improvement at IRRI. *In*: Chemical aspects of rice gain quality. International Rice Research Institute, Los Banos, Philippines. 1979;21-31.
43. Kumar MS. Genetic analysis of height and cooking quality traits in basmati rices. MSc Thesis. 1989; IARI, New Delhi, India.
44. Tomar JB, Nanda JS. Genetics and association studies of kernel shape in rice. Indian J. Genet. 1985;45(2):278-283.
45. Kumar I, Kush GS. Genetics analysis of different amylose levels in rice. Crop Sci. 1987;27:1167-1172.

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