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Heterosis and inbreeding depression for yield and kernel characters in scented rice

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ABSTRACT

An investigation was undertaken to study the nature and magnitude of heterosis and inbreeding depression in rice for yield components and kernel characters involving 10 parents, 45 F_1s and corresponding F_2s. High degree of heterosis was observed for plant height, productive tillers plant^{-1}, panicle length, filled grains panicle^{-1}, test weight and grain yield plant^{-1}, whereas in case of days to 50% flowering, kernel length (KL), kernel breadth (KB) and KL/KB ratio, it was low. Four cross combinations viz., Pakistani Basmati/Mahi Sugandha, Basmati 370/IET 13846, IET 16320/IET13846 and IET13846/Kasturi exhibited higher magnitudes of heterobeltiosis in F_1 coupled with high inbreeding depression in F_2 for grain yield plant^{-1}, indicating predominant role of non-additive gene action in its inheritance. Such high heterosis for grain yield was due to additive heterotic effect of one or more component traits.

Key words: *scented rice, inbreeding depression, heterosis, yield*

Millions of people depend on rice as a source of food and income. Thus, it requires a continuous improvement in productivity as well as grain quality. Commercial exploitation of heterosis for enhancing rice yield of quality rice is of great importance. Plenty of information is available on heterosis but information is meager on the extent of loss of vigour in the subsequent generation. Knowledge on the heterosis accompanied by the extent of inbreeding depression in subsequent generation is essential for maximum exploitation of such heterosis by adopting appropriate breeding methodology. The present study was therefore, undertaken to estimate the magnitude and direction of heterosis and inbreeding depression for important yield and quality characters of selected scented rice genotypes.

MATERIALS AND METHODS

The experimental material consisted of ten parents, 45 F_1s and corresponding F_2s. Ten parents *viz.*, Taroari Basmati, Basmati 370, Pakistani Basmati, IET 16320, IET 13549, Pusa Basmati 1, Mahi Sugandha, IET 13846, Kasturi and Haryana Basmati 1 were crossed in diallel fashion without reciprocals during wet season 2002 and the resultant 45 F_1s were advanced to F_2 during wet season 2003. The parents, F_1s and corresponding F_2s were evaluated during wet season, 2004 in a randomised block design with three replications adopting a spacing of 20 x 15 cm. Single seedling (25 days old) per hill was transplanted in a single row plot of 3 m length for parents and F_1s and 5 rows for F_2s. From each replication, 10 plants from parents and F_1s and 30 plants from F_2s were selected at random for recording observations on 11 important yield and quality traits *viz.*, days to 50% flowering, plant height, productive tillers plant^{-1}, panicle length, filled grains panicle^{-1}, spikelet sterility, test weight, grain yield plant^{-1}, kernel length, kernel breadth and L/B ratio. Heterosis was estimated as the percent change in F_1 over the mid parent (relative heterosis) and better parent (heterobeltiosis) following standard methods (Briggle, 1963 and Fonseca and Patterson, 1968, respectively). Inbreeding depression was computed as the percent change in F_2 over the F_1.

RESULTS AND DISCUSSION

The analysis of variance revealed that variance due to parents, F_1s and F_2s were highly significant indicating the presence of sufficient genetic diversity among the

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Table 1. Estimates of heterosis (h^1), heterobeltiosis (h^2) and inbreeding depression (ID) for yield attribute characters in scented rice.

Hybrids	Days to 50% flowering			Plant height (cm)			Productive tillers plant^{-1}			Panicle length (cm)		
	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID
Taroari Basmati/ Basmati 370	9.40**	-	5.94**	-2.10	-0.18	-7.38**	15.17**	10.34**	10.71**	13.48**	13.30**	-1.09
Taroari Basmati/ Pak. Basmati	-0.67	-	-12.84**	-2.19	-1.10	-13.47**	8.88*	2.15	-2.11	1.64	-	7.21
Taroari Basmati/ IET 16320	-1.20	-	-10.42**	-3.06	-	-12.01**	73.75**	58.54**	20.42**	5.43	-	-7.25*
Taroari Basmati/ IET 13549	-6.80**	-6.16*	-7.66**	-16.91**	-8.14**	-24.52**	77.90**	54.35**	16.26**	4.74	1.06	-17.45**
Taroari Basmati/ Pusa Basmati 1	-3.10	-1.06	-11.39**	-4.86**	-	-4.60*	55.45**	35.67**	14.62**	9.38**	2.69	-5.87
Taroari Basmati/ Mahi Sugandha	11.53**	-	7.90**	-2.02	-	-6.39**	1.67	-	-30.05**	-0.68	-	-31.36**
Taroari Basmati/ IET 13846	-1.35	-1.01	-5.80*	-3.67*	-	3.83	14.36**	7.58*	-11.67**	11.89**	8.08*	3.64
Taroari Basmati/ Kasturi	-8.71**	-5.76*	-11.07**	-11.53**	-1.12	-14.82**	77.90**	75.27**	29.29**	1.03	-	-6.39
Taroari Basmati/ Haryana Basmati 1	-4.78*	-	-14.87**	-4.13*	-	0.22	3.56	1.55	-6.62	19.21**	8.41*	9.57**
Basmati 370/ Pak. Basmati	0.17	-	-8.47**	-2.92	-2.11	-22.04**	21.58**	9.61*	18.43**	4.70	2.83	-0.12
Basmati 370/ IET 16320	-1.04	-0.70	-2.46	1.91	-	7.51**	15.52**	9.76**	-18.59**	14.08**	7.62*	-8.35**
Basmati 370/ IET 13549	-2.24	-1.73	-14.08**	-12.51**	-5.27*	-7.68**	45.61**	31.23**	12.80**	14.89**	10.69**	1.51
Basmati 370/ Pusa Basmati 1	-8.90**	-8.10**	-11.11**	-8.46**	-3.43	-11.61**	58.90**	44.09**	45.20**	21.06**	13.49**	-2.79
Basmati 370/ Mahi Sugandha	-1.89	-1.04	-12.59**	-0.75	-	-5.08*	18.83**	10.34**	14.73**	-5.06	-	5.12
Basmati 370/ IET 13846	-10.73**	-9.34**	-12.21**	-6.66**	-	-11.18**	67.87**	64.69**	28.78**	16.31**	12.18**	-3.08
Basmati 370/ Kasturi	-6.17**	-4.32	-21.80**	-1.08	-	-14.60**	1.17	-	-4.64	10.17**	8.66*	-0.96
Basmati 370/ Haryana Basmati 1	0.00	-	-3.58	-11.77**	-1.34	-26.13**	27.36**	24.38**	20.40**	16.64**	6.23	-9.63**
Pak. Basmati/ IET 16320	-1.53	-	-10.73**	1.69	-	7.08**	41.57**	21.95**	23.27**	7.68*	3.35	4.00
Pak. Basmati/ IET 13549	1.01	-	-4.68	-17.02**	-9.36**	-22.00**	12.02**	-	-1.50	21.94**	19.57**	-0.02
Pak. Basmati/ Pusa Basmati 1	0.34	-	-10.92**	-5.67**	-	-10.52**	53.70**	27.05**	42.74**	5.41	0.51	1.07
Pak. Basmati/ Mahi Sugandha	-2.02	-1.02	-13.75**	17.69**	-	10.43**	94.36**	88.22**	20.00**	29.10**	21.28**	-4.52
Pak. Basmati/ IET 13846	-13.38**	-13.09**	-10.42**	-4.67*	-	0.01	18.18**	4.74	29.19**	2.17	0.30	-6.59
Pak. Basmati/ Kasturi	15.92**	-	8.96**	-1.78	-	-21.33**	-2.47	-	-20.00**	-8.72**	-	3.23

Table 1 Contd.....

Hybrids	Days to 50% flowering			Plant height (cm)			Productive tillers $plant^{-1}$			Panicle length (cm)		
	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID
Pak. Basmati/ Haryana Basmati 1	11.78**	-	7.23**	-11.74**	-0.41	-23.96**	84.01**	69.51**	20.58**	-6.41	-	-13.28**
IET 16320/ IET 13549	-12.26**	-11.50**	-14.57**	-13.07**	-10.32**	-11.69**	14.11**	7.91*	-45.24**	17.06**	14.53**	-4.38
IET 16320/ Pusa Basmati 1	0.88	-	-7.64**	-2.65	-2.03	0.89	13.47**	8.02*	-20.41**	4.20	3.50	0.53
IET 16320/ Mahi Sugandha	12.91**	-	11.59**	12.80**	-	11.01**	4.88	-	3.34	8.74**	-	-12.84**
IET 16320/ IET 13846	-9.74**	-8.01**	-17.80**	-12.82**	-9.95**	-14.54**	51.89**	47.01**	11.46**	8.93**	6.45	2.22
IET 16320/Kasturi	-5.13*	-3.60	-20.15**	16.82**	-	6.65**	-3.45	-	-44.13**	-7.29*	-	-7.45
IET 16320/ Haryana Basmati 1	-7.55**	-4.46	-18.68**	-9.19**	-3.38	-9.48**	10.26**	2.44	25.11**	-12.32**	-	-11.78**
IET 13549/ Pusa Basmati 1	-4.17	-2.82	-11.23**	11.03**	-	4.02*	17.61**	16.80**	-27.07**	12.39**	9.23**	-3.59
IET 13549/ Mahi Sugandha	2.05	-	-6.02*	-5.13**	-3.38	-22.46**	18.50**	-	8.30**	8.41*	-	-11.56**
IET 13549/ IET 13846	-4.75*	-3.77	-3.91	-11.29**	-11.18**	-12.05**	38.15**	26.68**	9.52**	17.67**	17.53**	-2.64
IET 13549/ Kasturi	16.14**	-	9.06**	-8.07**	-7.14**	-15.68**	23.88**	6.13	21.60**	-23.66**	-	-6.78
IET 13549/ Haryana Basmati 1	0.89	-	-0.35	-9.92**	-7.18**	-30.61**	53.42**	35.38**	10.36**	-9.40**	-	-19.43**
Pusa Basmati 1/ Mahi Sugandha	15.92**	-	6.87**	11.55**	-	8.78**	7.20*	-	12.78**	5.86	-	-11.84**
Pusa Basmati 1/ IET 13846	-5.50*	-3.17	-12.73**	-0.19	-	-6.14**	18.78**	9.62**	-28.88**	7.45*	4.32	-1.21
Pusa Basmati 1/ Kasturi	20.28**	-	9.76**	-5.66**	-2.32	-16.07**	12.56**	-	25.21**	7.31*	1.92	-8.01*
Pusa Basmati 1/ Haryana Basmati 1	-7.78**	-5.20	-16.86**	1.51	-	-11.21**	12.87**	0.20	23.60**	-12.13**	-	-16.07**
Mahi Sugandha/ IET 13846	-0.34	-	-7.80**	-12.10**	-10.37**	-28.99**	34.03**	22.27**	-10.08**	7.47*	-	-17.49**
Mahi Sugandha/ Kasturi	1.40	-	-13.45**	16.56**	-	11.41**	-2.40	-	-4.34	5.39	-	-0.50
Mahi Sugandha/ Haryana Basmati 1	-3.73	-	-14.39**	14.40**	-	5.56**	5.31	-	10.85**	4.72	-	-24.55**
IET 13846/Kasturi	13.89**	-	1.83	-6.29**	-5.48*	-11.51**	67.31**	55.21**	12.21**	-6.69*	-	-9.25*
IET 13846/ Haryana Basmati 1	-5.11*	-	-7.81**	-11.26**	-8.68**	-17.37**	59.21**	52.61**	19.25**	-19.26**	-	-5.14
Kasturi/Haryana Basmati 1	-2.74	-1.12	-14.29**	0.46	-	-19.34**	2.67	-	2.60	13.12**	1.74	-2.89

* & ** Significant at 5% and 1% level, respectively

genotypes for all the characters studied. Early flowering is desirable when the breeding objective is to evolve short duration varieties. In the present study, fifteen and seven crosses exhibited significant heterosis and heterobeltiosis respectively for earliness (Table 1). In seven crosses *viz.*, Pakistani Basmati/IET 13846, IET 16320/IET 13549, Basmati 370/IET 13846, Basmati 370/Pusa Basmati 1, IET 16320/IET 13846, Taroari Basmati/IET 13549 and Taroari Basmati/Kasturi, significant negative heterosis over better parent was observed followed by significant negative inbreeding depression. Similar findings were also reported earlier by Joshi *et al.* (2004) and Raju *et al.* (2005) concluding that this trait was predominantly governed by non-additive gene action and suggested heterosis breeding as most feasible method. Heterosis for plant height was mostly in negative direction. Eleven cross combinations which recorded significant performance over their respective better parents had significant negative inbreeding depression indicating the preponderance of non-additive gene action, confirming the results of Krishna Veni *et al.* (2005).

One of the most important yield determining factors is tillering habit of a genotype. High magnitude of heterosis (>20%) was observed in eighteen F_1s manifesting superior performance for productive tillers plant^{-1}. Increase in tiller number has earlier been observed by Verma *et al.* (2002) and Raju *et al.* (2005). These heterotic crosses involved at least one parent with moderate or high tillering habit. All these crosses except Mahi Sugandha/IET 13846 had subsequently exhibited inbreeding depression indicating prevalence of non-additive gene action in its inheritance as reported earlier by Reddy and Nerkar (1995), Reddy (1996) and Raju *et al.* (2005). Positive and significant heterosis and heterobeltiosis were observed for panicle length in Pakistani Basmati/Mahi Sugandha, Pakistani Basmati/IET 13549, IET 13549/IET 13846, IET 16320/IET 13549, Basmati 370/Pusa Basmati 1, Taroari Basmati/Basmati 370, Basmati 370/IET 13846, Basmati 370/IET 13549, IET 13549/Pusa Basmati 1, Basmati 370/Kasturi, Taroari Basmati/Haryana Basmati 1, Taroari Basmati/IET 13846 and Basmati 370/IET 16320. All these crosses except Basmati 370/IET 13549, Taroari Basmati/Haryana Basmati 1 and Taroari Basmati/IET 13846 showed favourable inbreeding depression. Negative inbreeding depression observed for panicle length and some other characters indicated that the genes with lack of dominance might not exhibit heterosis in F_1 and the increased performance in F_2 might be attributed due to fixation of additive genes in the respective crosses as reported earlier by Krishna Veni *et al.* (2005).

In respect of filled grains panicle^{-1}, nine crosses exhibited positive and significant heterosis and heterobeltosis, of which Taroari Basmati/Kasturi, IET 16320/Kasturi and Taroari Basmati/IET 13549 were the top rankers (Table 2). All these crosses except IET 16320/Kasturi and IET 13549/IET 13846 exhibited inbreeding depression in F_2 and the maximum value (36.34) was recorded in Basmati 370/IET 13846. Test weight is one of the most important yield attributing characters. Out of 45 crosses studied, 17 F_1s manifested positive and significant heterosis and heterobeltiosis for test weight, of which IET 13846/Haryana Basmati 1, Taroari Basmati/Pakistani Basmati and IET 16320/IET 13846 were the top rankers in that order. All these crosses exhibited inbreeding depression indicating the preponderance of non-additive gene action. Occurrence of positive heterosis for test weight was observed previously by Joshi *et al.* (2004) and Krishna Veni *et al.* (2005). One of the important limiting factors for grain yields in F_1 was the sterility percentage. In the present study, four crosses *viz.*, Pakistani Basmati/Kasturi, Pusa Basmati 1/IET 13846, IET 16320/Haryana Basmati 1 and IET 13549/IET 13846 depicted negative and significant heterosis and heterobeltiosis for this trait, which is desirable. The sterility percentage decreased in F_2 and a favourable inbreeding depression was observed because of which many of the crosses with low grain yield plant^{-1} in F_1 exhibited increased yield performance in F_2 confirming the earlier findings of Chauhan and Chauhan (1995) and Krishna Veni *et al.* (2005).

Out of 45 crosses evaluated, 29 crosses expressed heterosis for grain yield plant^{-1}, and among these 24 crosses were significantly superior to their respective better parents. According to Swaminathan *et al.* (1972), heterosis of 20-50% over better parent could offset the cost of hybrid seed. As such, the crosses Pakistani Basmati/Mahi Sugandha, Basmati 370/IET 13846, IET 16320/IET 13846, IET 13846/Kasturi, Taroari Basmati/IET 13549, Taroari Basmati/IET 16320 and IET 13846/Haryana Basmati 1 revealed higher magnitude of heterobeltiosis in F_1 coupled with high

Table 2. Estimates of heterosis (h^1), heterobeltiosis (h^2) and inbreeding depression (ID) for yield and yield attribute characters in scented rice.

Hybrids	Filled grains panicle^{-1}			Spikelet sterility (%)			Test weight (g)			Grain yield plant^{-1} (g)		
	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID
Taroari Basmati/ Basmati 370	-0.11	-	-16.61**	44.32**	-	18.64**	3.51	2.76	20.11**	33.95**	27.31**	32.13**
Taroari Basmati/ Pak. Basmati	-5.01*	-	-2.00	39.74**	-	4.86	18.71**	15.07**	20.02**	-10.51*	-	-26.88**
Taroari Basmati/ IET 16320	-2.52	-	2.03	20.96**	-	23.73**	17.08**	10.37**	19.03**	62.40**	42.81**	24.57**
Taroari Basmati/ IET 13549	27.07**	14.96**	15.69**	9.21*	-	-2.49	8.47**	7.62**	18.51**	72.81**	42.83**	32.14**
Taroari Basmati/ Pusa Basmati 1	11.31**	-	-3.40	13.24**	-	11.87**	9.23**	9.04**	21.55**	50.48**	21.00**	33.43**
Taroari Basmati/ Mahi Sugandha	7.08**	1.71	-6.62**	12.52**	-	8.42*	2.29	-	7.39**	28.69**	24.33**	-7.50*
Taroari Basmati/ IET 13846	0.14	-	-2.35	5.82	-	24.87**	8.29**	3.30	17.91**	5.82	-	13.64**
Taroari Basmati/ Kasturi	24.07**	21.32**	24.10**	21.70**	-	38.46**	4.80*	-	16.79**	37.41**	31.64**	-0.44
Taroari Basmati/ Haryana Basmati 1	5.63**	4.58*	5.37*	23.77**	-	16.17**	-8.22**	-	15.31**	-1.39	-	24.87**
Basmati 370/ Pak. Basmati	-4.50*	-	-4.02	34.05**	-	21.95**	-12.98**	-	5.22	5.38	1.68	24.83**
Basmati 370/ IET 16320	-8.64**	-	-4.29	22.97**	-	21.65**	0.07	-	9.68**	-14.86**	-	-28.31**
Basmati 370/ IET 13549	7.36**	-	8.62**	17.20**	-	20.96**	1.55	1.49	16.96**	36.95**	8.75**	26.49**
Basmati 370/ Pusa Basmati 1	4.89**	-	-16.99**	31.22**	-	2.50	7.98**	7.39**	5.01*	41.36**	9.40**	-25.28**
Basmati 370/ Mahi Sugandha	3.62	-	-3.16	23.54**	-	47.72**	6.68**	4.61	28.76**	34.03**	23.28**	37.01**
Basmati 370/ IET 13846	33.37**	14.21**	36.34**	32.29**	-	-4.37	-0.37	-	18.08**	100.52**	77.93**	39.17**
Basmati 370/ Kasturi	-11.12**	-	-11.76**	35.10**	-	7.20*	0.14	-	12.99**	-3.22	-	-8.23
Basmati 370/ Haryana Basmati 1	-10.47**	-	-6.54*	-5.88	-	12.18**	-2.52	-	8.17**	9.50*	-	38.42**
Pak. Basmati/ IET 16320	9.49**	4.20	6.32**	35.99**	-	8.83**	11.81**	8.64**	15.62**	30.32**	6.56	22.11**
Pak. Basmati/ IET 13549	-7.58**	-	-17.57**	5.69	-	20.04**	6.70**	4.22	10.26**	-13.12**	-	-38.79**
Pak. Basmati/ Pusa Basmati 1	-0.50	-	-11.45**	-5.85	-	12.30**	17.82**	14.40**	7.11**	63.66**	23.51**	26.20**
Pak. Basmati/ Mahi Sugandha	21.32**	13.65**	9.57**	4.57	-	41.73**	15.06**	14.53**	17.36**	102.70**	80.46**	36.63**
Pak. Basmati/ IET 13846	4.32*	-	6.05**	3.19	-	-11.18**	10.95**	9.13**	9.91**	49.08**	28.23**	35.03**

Table 2 Contd.....

Hybrids	Filled grains panicle^{-1}			Spikelet sterility (%)			Test weight (g)			Grain yield plant^{-1} (g)		
	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID
Pak. Basmati/ Kasturi	4.60*	0.83	-6.35**	-20.66**	-18.95**	-12.69**	-1.51	-	8.35**	4.24	-	16.91**
Pak. Basmati/ Haryana Basmati 1	16.62**	13.81**	24.21**	-5.37	-	23.23**	-21.33**	-	4.71	35.12**	18.79**	38.48**
IET 16320/ IET 13549	2.35	-	-16.18**	-8.62*	-3.51	16.29**	17.84**	11.91**	7.93**	18.45**	10.19**	-42.98**
IET 16320/ Pusa Basmati 1	6.49**	-	-2.86	1.85	-	24.84**	7.71**	1.71	3.08	22.61**	10.44**	-22.59**
IET 16320/ Mahi Sugandha	4.70*	2.97	15.93**	31.36**	-	26.88**	3.15	-	19.27**	9.85**	-	28.84**
IET 16320/ IET 13846	21.62**	11.07**	27.36**	-5.11	-3.00	21.13**	16.14**	14.70**	4.99*	83.97**	73.14**	33.24**
IET 16320/ Kasturi	17.91**	16.35**	-6.01**	-12.17**	-3.25	5.34	12.73**	11.23**	13.56**	13.26**	-	16.32**
IET 16320/ Haryana Basmati 1	1.89	-	7.71**	-26.07**	-12.86**	-34.94**	-4.02	-	14.41**	-25.24**	-	3.12
IET 13549/ Pusa Basmati 1	4.72**	0.77	-15.78**	-10.79**	-5.45	2.73	11.82**	11.14**	7.13**	19.27**	15.18**	-24.56**
IET 13549/ Mahi Sugandha	-6.72**	-	18.13**	6.66*	-	17.27**	-4.11	-	26.90**	10.79**	-	32.23**
IET 13549/ IET 13846	11.28**	8.51**	-2.19	-12.33**	-9.51*	13.33**	-5.32*	-	17.27**	25.17**	10.10**	-11.95**
IET 13549/ Kasturi	-12.22**	-	7.65**	1.36	-	3.88	14.03**	6.93**	26.95**	2.15	-	12.31**
IET 13549/ Haryana Basmati 1	-3.36	-	2.94	11.19**	-	-5.81	10.27**	4.90	17.20**	30.55**	12.35**	26.93**
Pusa Basmati 1/ Mahi Sugandha	-6.06**	-	17.40**	2.80	-	26.13**	-20.58**	-	2.64	-20.05**	-	11.43*
Pusa Basmati 1/ IET 13846	-0.78	-	-2.24	-16.72**	-14.56**	-19.34**	-1.07	-	0.04	32.20**	12.84**	-9.02**
Pusa Basmati 1/ Kasturi	-11.39**	-	-20.72**	21.09**	-	20.52**	-10.75**	-	15.85**	-18.68**	-	-7.69
Pusa Basmati 1/ Haryana Basmati 1	-17.76**	-	-11.41**	19.30**	-	8.96**	-9.50**	-	0.93	-30.39**	-	-11.83*
Mahi Sugandha/ IET 13846	-15.32**	-	10.19**	46.10**	-	16.84**	12.93**	10.58**	1.63	14.87**	10.43*	31.98**
Mahi Sugandha/ Kasturi	-10.38**	-	13.21**	3.01	-	25.41**	-10.63**	-	1.03	-15.20**	-	9.15
Mahi Sugandha/ Haryana Basmati 1	-14.81**	-	-14.28**	-2.34	-	41.96**	-6.81**	-	7.29*	-32.28**	-	-32.84**
IET 13846/ Kasturi	9.28**	-	5.95**	-8.35*	-	31.44**	7.72**	4.99	10.60**	83.84**	64.34**	29.16**
IET 13846/Haryana Basmati 1	-14.33**	-	-13.20**	-18.41**	-1.36	-15.02**	20.64**	19.36**	27.35**	45.74**	42.09**	36.13**
Kasturi/Haryana Basmati 1	2.65	1.37	-4.49*	-9.30**	-3.49	15.13**	9.91**	8.25**	8.43**	-24.77**	-	-35.19**

* & ** Significant at 5% and 1% level, respectively

inbreeding depression in F_2 indicating the prevalence of non-additive gene action in its inheritance. These results were in conformity with earlier findings of Reddy and Nerkar (1995), Raju *et al.* (2005) and Sanjeev Kumar *et al.* (2007), and these crosses could be utilized in breeding programme. These F_1s also exhibited higher magnitudes of heterosis for component traits such as productive tillers plant^{-1}, panicle length, filled grains panicle^{-1} and test weight. Reddy *et al.* (1991) opined that it would be possible to spot high yielding segregants through pedigree selection in crosses having less or desirable negative inbreeding depression for improvement of yield in rice. Accordingly, the crosses Taroari Basmati/Mahi Sugandha, IET 13549/Pusa Basmati 1, Pusa Basmati 1/IET 13846, IET 16320/Pusa Basmati 1, IET 16320/IET 13549, IET 13549/IET13846 and Basmati 370/Pusa Basmati 1 with highly desirable negative inbreeding depression could be utilized for improvement through selection of the superior hybrid derivatives transgressing the limits of the parental expression for yield and yield components which was in accordance with the findings of Chauhan and Chauhan (1995), Verma *et al.* (2002) and Krishna Veni *et al.* (2005).

Though yield is one of the prime objectives, grain quality is yet another important aspect, as the market value of milled rice ultimately depends on kernel

Table 3. Estimates of heterosis (h^1), heterobeltiosis (h^2) and inbreeding depression (ID) for kernel characters in scented rice.

Hybrids	Kernel length (mm)			Kernel breadth (mm)			Kernel L / B ratio		
	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID
Taroari Basmati/ Basmati 370	1.10	-	-7.70*	-0.09	-	-2.62	1.20	-	-4.92
Taroari Basmati/ Pak. Basmati	8.30**	7.48*	12.17**	-1.10	-	1.68	9.39*	6.24	10.53*
Taroari Basmati/ IET 16320	-4.90	-	7.32*	-2.86	-0.94	-8.17*	-2.38	-	14.11**
Taroari Basmati/ IET 13549	1.96	1.22	3.31	1.87	-	6.04	0.37	0.08	-2.51
Taroari Basmati/ Pusa Basmati 1	1.68	1.47	9.77**	-2.41	-0.94	-7.22	3.96	2.27	15.86**
Taroari Basmati/ Mahi Sugandha	-5.36*	-	2.27	-1.46	-	-3.14	-4.21	-	5.17
Taroari Basmati/ IET 13846	-6.86*	-	1.36	-11.63**	-10.55**	-10.53*	5.70	2.35	11.17*
Taroari Basmati/ Kasturi	2.94	1.19	8.98**	-2.34	-1.69	6.13	5.36	2.84	2.92
Taroari Basmati/ Haryana Basmati 1	0.97	-	7.37*	5.86	-	11.43**	-4.65	-	-4.70
Basmati 370/ Pak. Basmati	-3.62	-	-14.86**	-5.21	-3.89	-4.05	2.05	1.45	-9.89
Basmati 370/ IET 16320	-1.37	-	8.50**	-2.56	-1.48	-4.32	1.20	0.60	12.43*
Basmati 370/ IET 13549	-0.25	-	-0.00	-1.02	-0.93	-4.86	0.83	-	4.71
Basmati 370/ Pusa Basmati 1	-2.34	-	5.93	-0.09	-	1.47	-2.32	-	4.41
Basmati 370/ Mahi Sugandha	-7.94**	-	-7.68*	3.16	-	0.70	-11.04*	-	-8.51
Basmati 370/ IET 13846	2.62	2.08	4.59	-4.24	-3.89	4.05	7.08	6.12	0.64
Basmati 370/ Kasturi	5.34*	5.11	12.25**	-7.05*	-6.88	-7.19	13.36**	13.27**	18.17**
Basmati 370/ Haryana Basmati 1	4.07	2.93	6.30*	-9.28**	-8.16*	-13.02**	15.09**	15.04**	17.06**
Pak. Basmati/ IET 16320	-2.06	-	-3.58	-0.63	-0.36	1.82	-1.46	-	-5.41

Table 3 contd...

Hybrids	Kernel length (mm)			Kernel breadth (mm)			Kernel L / B ratio		
	H^1	H^2	ID	H^1	H^2	ID	H^1	H^2	ID
Pak. Basmati/ IET 13549	2.55	1.04	7.17*	-4.74	-3.51	-16.67**	7.79	4.98	20.59**
Pak. Basmati/ Pusa Basmati 1	7.51**	6.92*	10.82**	4.90	-	0.35	2.34	1.01	10.54*
Pak. Basmati/ Mahi Sugandha	6.20*	3.08	15.69**	-5.70	-4.68	-12.29**	12.99**	8.52	25.38**
Pak. Basmati/ IET 13846	-7.70**	-	-21.64**	-2.82	-1.84	2.62	-5.14	-	-25.30**
Pak. Basmati/ Kasturi	-3.27	-	12.85**	-4.12	-2.60	9.16*	1.03	0.51	4.24
Pak. Basmati/ Haryana Basmati 1	10.83**	8.81**	18.04**	0.37	-	-1.10	10.39*	9.69	18.90**
IET 16320/ IET 13549	0.99	-	11.04**	0.27	-	0.18	0.59	-	10.82*
IET 16320/ Pusa Basmati 1	7.16**	6.22*	10.59**	-1.00	-0.55	-5.51	8.11	6.71	15.48**
IET 16320/ Mahi Sugandha	1.69	-	8.72**	0.09	-	7.14	1.43	-	1.59
IET 16320/ IET 13846	3.22	2.25	16.29**	-6.93*	-6.25	0.59	10.83*	10.50*	15.81**
IET 16320/ Kasturi	9.56**	8.87**	16.64**	-4.22	-2.97	-3.26	14.21**	13.63**	19.34**
IET 16320/ Haryana Basmati 1	-0.57	-	4.17	2.13	-	0.36	-2.61	-	3.78
IET 13549/ Pusa Basmati 1	-2.03	-	-3.82	-5.33	-4.81	-7.57	3.60	2.20	3.67
IET 13549/ Mahi Sugandha	4.52	0.00	12.90**	0.72	-	-11.29**	3.66	-	21.85**
IET 13549/ IET 13846	-5.00	-	2.64	-3.78	-3.51	-1.72	-1.13	-	4.50
IET 13549/ Kasturi	5.24*	2.71	13.48**	-12.70**	-12.45**	-14.23**	20.67**	18.11**	24.31**
IET 13549/ Haryana Basmati 1	2.60	-	17.50**	-1.69	-0.38	5.71	4.54	2.45	12.66**
Pusa Basmati 1/ Mahi Sugandha	3.96	0.37	10.15**	-2.87	-1.10	-4.07	7.03	1.51	13.96**
Pusa Basmati 1/ IET 13846	4.18	2.31	9.55**	-3.02	-2.76	6.99	7.33	5.62	2.86
Pusa Basmati 1/ Kasturi	1.99	0.46	10.83**	-4.70	-3.90	-6.00	6.97	6.12	15.96**
Pusa Basmati 1/ Haryana Basmati 1	1.23	-	8.96**	-7.26*	-5.50	-6.63	9.11*	8.38	14.69**
Mahi Sugandha/ IET 13846	0.19	-	12.63**	-2.43	-0.37	-5.72	2.56	-	17.35**
Mahi Sugandha/ Kasturi	-4.05	-	-17.34**	8.96**	-	10.96**	-12.12**	-	-32.05**
Mahi Sugandha/ Haryana Basmati 1	-8.22**	-	4.59	-7.86*	-4.36	-24.80**	-0.40	-	23.77**
IET 13846/Kasturi	5.08	4.75	15.15**	-0.37	-	6.86	5.28	4.43	8.89
IET 13846/ Haryana Basmati 1	3.08	2.49	3.92	-2.89	-1.33	-5.58	6.09	5.10	8.81
Kasturi/ Haryana Basmati 1	-8.89**	-	-15.42**	0.09	-	7.13	-8.89*	-	-24.18**

* & ** Significant at 5% and 1% level, respectively

length and L/B ratio. In general, the magnitude of heterosis was low for grain quality characters when compared to heterosis for yield and yield attributes (Table 3). Five crosses exhibited positive and significant heterosis and heterobeltiosis for kernel length of which two crosses *viz.*, IET 16320/Kasturi and Pakistani Basmati/Haryana Basmati 1 with higher H^2 values followed by high inbreeding depression in F_2 would be feasible for heterosis breeding, confirming the earlier findings of Raju *et al.* (2005). The extent of heterosis for kernel breadth was low but desirable direction in most of the crosses. Three cross combinations *viz.*, IET 13549/Kasturi, Taroari Basmati/IET 13846 and Basmati 370/Kasturi which recorded significant performance over their respective better parents had again exhibited inbreeding depression, indicating the preponderance of non-additive gene action. In respect of kernel L/B ratio, five crosses exhibited positive and significant heterosis and heterobeltiosis of which IET 13549/Kasturi and Basmati 370/Haryana Basmati 1 revealed higher magnitudes of heterobeltiosis in F_1 followed by high inbreeding depression in F_2 would be feasible for heterosis breeding. Poor manifestation of heterosis for grain L/B ratio was observed by Venkatesan *et al.* (2008).

Results of the study indicated that the inheritance of yield and yield components was mostly regulated by non-additive type of gene action as evident from high heterosis followed by high inbreeding depression. High amount of heterosis was observed for plant height, productive tillers plant^{-1}, panicle length, filled grains panicle^{-1}, test weight and grain yield plant^{-1}, where as it was of low magnitude for days to 50% flowering, kernel length, kernel breadth and L/B ratio. Cross combinations showing high heterosis in F_1 and high inbreeding depression in F_2 for grain yield plant^{-1} *viz.*, Pakistani Basmati/Mahi Sugandha, Basmati 370/IET 13846, IET 16320/IET 13846 and IET 13846/Kasturi may be exploited for heterosis breeding programme. Simultaneously, selection in certain specific crosses showing increased performance in F_2 generation *viz.*, IET 16320/IET 13549, Basmati 370/Pusa Basmati 1, IET 13549/Pusa Basmati 1 and IET 16320/Pusa Basmati 1 would also be fruitful for generating superior hybrid derivatives transgressing the limits of the parental expression for yield and quality traits.

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