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RESEARCH ARTICLE

HETEROSIS FOR GRAIN YIELD AND GRAIN QUALITY TRAITS IN AROMATIC RICE

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ABSTRACT

Twenty eight F_1 rice hybrids developed through 8x8 diallel analysis (without reciprocals) were evaluated to estimate relative heterosis, heterobeltiosis and standard heterosis for yield and grain quality traits *viz.,* days to 50 per cent flowering, 1000 grain weight, grain yield per plant, head rice recovery, kernel length, kernel breadth, kernel L/B ratio, kernel length after cooking and kernel elongation ratio. Based on the superior heterotic performance, the crosses NLR 145 x Sumathi, RNR 2354 x Basmati 370 and Akshyadhan x Pusa 1121 exhibited significant positive heterosis for yield and one or more grain quality traits.

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INTRODUCTION

Aromatic rice (*Oryza sativa* L.) with an aroma and flavor similar to popcorn, though constitute a small group of rice in the consideration of consumption, is a special group of rice that is regarded as best in quality (Singh *et al.*, 2000). Although, aromatic rices popular in world market are long-grain types forming the bulk of export, majority of the Indian indigenous aromatic rices are small and medium-grain types, mostly cultivated for home consumption. Some of the small and medium-grained aromatic rices possess excellent aroma and other quality traits like kernel elongation after cooking, taste etc. which could be excellent sources for improving quality in high yielding varieties. Presently, the yield potential of aromatic long and short-grain varieties is only 2.5 – 3.0 t ha^{-1} which is very low as compared to non-basmati high yielding varieties. Hence, there is a need to raise the present productivity levels to 5.5 – 6.0 t ha^{-1} which is possible through development of high yielding semi-dwarf aromatic varieties with resistance to biotic and abiotic stresses and improved productivity levels of aromatic short-grain types to replace the locally tall varieties which have got export potential. Keeping in view present study was undertaken to estimate the magnitude and direction of heterosis for yield and quality traits in aromatic rice.

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MATERIALS AND METHODS

The experimental material consisting of eight rice varieties – five aromatic (Pusa 1121, Improved Pusa Basmati, Basmati 370, Sumathi and RNR 2354) and three non-aromatic (BPT 5204, Akshyadhan and NLR 145). The twenty eight F_1 hybrids obtained through diallel analysis (without reciprocals), their parents along with check variety, raised in a randomized complete block design with three replications at Agricultural Research Station, Kampasagar, Nalgonda district of Telangana state. All the genotypes represented by single row of 3 m length adopting spacing of 20 x 15 cm and recommended package of practices were followed. The observations were recorded on ten randomly selected competitive plants in each replication for yield and quality characters *viz.*, days to 50 per cent flowering, 1000 grain weight, grain yield per plant, head rice recovery, kernel length, kernel breadth, kernel L/B ratio, kernel length after cooking and kernel elongation ratio. Heterosis over mid parent, better parent and standard check were estimated (Liang *et al.*, 1971).

RESULTS AND DISCUSSION

Mean values and heterosis expressed as percent increase or decrease in the mean value of F_1 hybrid over mid parent (MP), better parent (BP) and standard check Pusa 1121 (SH) are presented in Tables 1, 2 & 3.

Table 1. Mean performance of parents

Parent	Days to 50 % flowering	1000 grain weight (g)	Grain yield/ plant (g)	Kernel length (mm)	Kernel breadth (mm)	Kernel L/B ratio	Kernel length after cooking (mm)	Kernel elongation ratio	Head rice recovery (%)
BPT 5204	111	12.47	16.6	4.79	1.54	3.11	8.80	1.85	62.52
Akshyadhan	108	25.82	28.6	5.44	1.63	3.34	8.80	1.62	66.80
NLR 145	121	18.20	16.5	5.60	1.79	3.13	9.40	1.68	56.78
Pusa 1121	96	23.75	11.9	7.36	1.72	4.28	10.20	1.39	42.64
RNR 2354	106	15.41	19.3	5.68	1.76	3.23	9.50	1.68	52.82
Sumathi	109	22.20	22.4	6.86	1.61	4.26	10.60	1.55	52.82
Improved Pusa Basmati	115	18.80	10.5	6.83	1.59	4.30	14.00	2.05	60.76
Basmati 370	101	21.76	24.7	6.76	1.83	3.71	10.40	1.54	66.72

Table 2. Range of relative heterosis, heterobeltiosis and standard heterosis for different characters in aromatic rice

S. No.	Character	Relative heterosis	Heterobeltiosis	Standard heterosis
1	Days to 50 % flowering	-22.93 to 2.30	-17.99 to 4.72	-22.30 to 9.18
2	1000 grain weight (g)	-25.99 to 28.92	-33.70 to 21.01	-34.03 to 27.87
3	Grain yield/ plant (g)	-29.93 to 130.52	-42.20 to 97.92	-59.33 to 74.93
4	Kernel length (mm)	-14.24 to 21.32	-18.89 to 9.46	-33.70 to 13.04
5	Kernel breadth (mm)	-10.6 to 12.34	-14.97 to 9.82	-12.79 to 5.23
6	Kernel L/B ratio	-14.99 to 21.83	-22.98 to 130.1	-28.66 to 13.01
7	Kernel length after cooking (mm)	-14.29 to 43.96	-30.00 to 39.36	-25.49 to 35.29
8	Kernel elongation ratio	-21.49 to 40.82	-27.93 to 40.52	-11.87 to 5.79
9	Head rice recovery (%)	-37.18 to 8.30	-41.43 to 4.13	-14.12 to 51.50

Table 3. Estimation of heterosis over mid parent, better parent and standard heterosis for yield and quality traits

Crosses	Days to 50% flowering				1000 grain weight (g)				Grain yield/plant (g)			
	Mean	**MP**	**BP**	**SH**	**Mean**	**MP**	**BP**	**SH**	**Mean**	**MP**	**BP**	**SH**
BPT 5204 x Akshyadhan	104	-5.02 **	-3.70 **	2.30 *	20.53	7.26 **	-20.48 **	-8.86 **	42.8	89.21 **	49.65 **	74.93 **
BPT 5204 x NLR 145	111	-4.31 **	0.00	9.18 **	16.21	5.70 *	-10.95 **	-28.07 **	19.1	15.18	14.58 *	-22.07 **
BPT 5204 x Pusa 1121	98	-5.14 **	2.08	-3.28 **	20.57	13.58 **	-13.40 **	-8.71 **	32.9	130.52 **	97.92 **	34.60 **
BPT 5204 x RNR 2354	111	2.30 *	4.72 **	9.18 **	14.86	6.64 *	-3.55	-34.03 **	18.9	5.26	-2.07	-22.62 **
BPT 5204 x Sumathi	98	-10.47 **	-9.51 **	-3.28 **	18.61	7.35 **	-16.19 **	-17.41 **	29.7	52.19 **	32.54 **	21.53 **
BPT 5204 x I.P. Basmati	110	-3.09 **	-1.20	7.87 **	18.03	15.32 **	-4.11	-19.97 **	20.1	47.88 **	20.59 *	-17.98 **
BPT 5204 x Basmati 370	103	-2.52 *	2.31 *	1.64	15.07	-11.93 **	-30.73 **	-33.11 **	28.0	35.48 **	13.32 *	14.55 *
Akshyadhan x NLR 145	99	-13.54 **	-8.33 **	-2.62 *	24.00	9.03 **	-7.06 **	6.51 **	28.3	25.74 **	-0.93	15.80 *
Akshyadhan x Pusa 1121	89	-12.89 **	-7.61 **	-12.46 **	28.81	16.24 **	11.58 **	27.87 **	27.9	37.50 **	-2.56	13.90 *
Akshyadhan x RNR 2354	94	-11.84 **	-11.01 **	-7.21 **	23.46	13.80 **	-9.14 **	4.13	29.0	20.79 **	1.22	18.32 **
Akshyadhan x Sumathi	95	-12.00 **	-11.73 **	-6.23 **	25.96	8.14 **	0.56	15.24 **	30.9	21.10 **	8.04	26.29 **
Akshyadhan x I.P. Basmati	97	-13.13 **	-10.19 **	-4.59 **	24.18	8.39 **	-6.34 **	7.34 **	23.7	21.24 **	-17.12 **	-3.12
Akshyadhan x Basmati 370	98	-5.90 **	-2.64 *	-3.28 **	22.93	-3.62 *	-11.21 **	1.76	26.1	-2.13	-8.74	6.68
NLR 145 x Pusa 1121	98	-9.82 **	1.73	-3.61 **	27.04	28.92 **	13.85 **	20.02 **	10.0	-29.93 **	-39.57 **	-59.33 **
NLR 145 x RNR 2354	107	-6.02 **	0.63	4.92 **	19.82	17.96 **	8.92 **	-12.01 **	21.3	18.86 *	10.05	-13.04 *
NLR 145 x Sumathi	99	-13.50 **	-8.59 **	-2.30 *	23.88	18.22 **	7.57 **	5.99 **	28.5	46.43 **	26.95 **	16.40 *
NLR 145 x I.P. Basmati	98	-17.07 **	-15.03 **	-3.61 **	22.75	22.98 **	21.01 **	0.99	17.5	29.91 **	6.38	-28.41 **
NLR 145 x Basmati 370	100	-9.61 **	-0.66	-1.31	22.95	14.89 **	5.50 *	1.88	22.3	8.43	-9.69	-8.71
Pusa 1121 x RNR 2354	90	-10.71 **	-6.23 **	-11.15 **	21.85	11.61 **	-7.99 **	-3.00	19.0	21.71 *	-1.59	-22.23 **
Pusa 1121 x Sumathi	79	-22.93 **	-17.99 **	-22.30 **	25.17	9.55 **	5.98 **	11.72 **	13.0	-24.54 **	-42.20 **	-47.00 **
Pusa 1121 x I.P. Basmati	86	-18.43 **	-10.38 **	-15.08 **	15.75	-25.99 **	-33.70 **	-30.11 **	12.6	12.36	5.61	-48.49 **

Pusa 1121 x Basmati 370	86	-12.50 **	-10.38 **	-15.08 **	20.15	-11.46 **	-15.17 **	-10.58 **	17.2	-6.07	-30.38 **	-29.62 **
RNR 2354 x Sumathi	93	-13.04 **	-11.95 **	-8.20 **	19.06	1.34	-14.16 **	-15.42 **	15.8	-24.18 **	-29.42 **	-35.29 **
RNR 2354 x I.P. Basmati	96	-13.55 **	-9.75 **	-5.90 **	20.75	21.28 **	10.34 **	-7.92 **	27.7	85.65 **	43.24 **	13.19 *
RNR 2354 x Basmati 370	99	-4.03 **	-1.65	-2.30 *	17.98	-3.25	-17.36 **	-20.20 **	28.9	31.20 **	16.87 *	18.15 **
Sumathi x I.P. Basmati	93	-16.67 **	-14.11 **	-8.20 **	23.55	14.87 **	6.08 **	4.53 *	30.1	82.59 **	34.03 **	22.89 **
Sumathi x Basmati 370	97	-7.15 **	-3.63 **	-4.26 **	23.85	8.50 **	7.42 **	5.84 **	27.3	15.65 **	10.27	11.47
I.P. Basmati x Basmati 370	94	-12.79 **	-6.60 **	-7.21 **	18.96	-6.51 **	-12.85 **	-15.85 **	30.1	70.94 **	21.75 **	23.08 **
	Kernel Length (mm)				**Kernel Breadth (mm)**				**Kernel L/B ratio**			
BPT 5204 x Akshyadhan	5.28	3.23	-2.94	-28.26 **	1.73	9.15 **	12.34 **	0.58	3.05	-5.27 *	-8.49 **	-28.66 **
BPT 5204 x NLR 145	4.97	-4.33 *	-11.25 **	-32.47 **	1.61	-3.30 *	4.55 *	-6.40**	3.09	-1.01	-1.38	-27.80 **
BPT 5204 x Pusa 1121	5.97	-1.73	-18.89 **	-18.89 **	1.81	11.04 **	17.53 **	5.23**	3.30	-10.78 **	-22.98 **	-22.98 **
BPT 5204 x RNR 2354	4.88	-6.78 **	-14.08 **	-33.70 **	1.50	-9.09 **	-2.60	-12.79**	3.25	2.63	0.72	-23.99 **
BPT 5204 x Sumathi	7.07	21.32 **	3.01	-3.99 *	1.73	9.84 **	12.34 **	0.58	4.08	10.76 **	-4.22 *	-4.60 *
BPT 5204 x I.P. Basmati	5.71	-1.72	-16.40 **	-22.42 **	1.67	6.71 **	8.44 **	-2.91	3.42	-7.69 **	-20.47 **	-20.09 **
BPT 5204 x Basmati 370	6.32	9.44 **	-6.51 **	-14.13 **	1.56	-7.42 **	1.30	-9.30**	4.05	18.92 **	9.35 **	-5.30 **
Akshyadhan x NLR 145	6.13	11.05 **	9.46 **	-16.71 **	1.67	-2.34	2.45	-2.91	3.67	13.45 **	9.99 **	-14.25 **
Akshyadhan x Pusa 1121	6.63	3.54 *	-9.96 **	-9.96 **	1.73	3.28 *	6.13 **	0.58	3.83	0.57	-10.51 **	-10.51 **
Akshyadhan x RNR 2354	6.29	13.07 **	10.68 **	-14.58 **	1.74	2.65	6.75 **	1.16	3.62	10.15 **	8.39 **	-15.50 **
Akshyadhan x Sumathi	6.76	9.92 **	-1.46	-8.15 **	1.79	10.49 **	11.18 **	4.07*	3.78	-0.61	-11.42 **	-11.76 **
Akshyadhan x I.P. Basmati	7.08	15.40 **	3.66 *	-3.80 *	1.62	0.62	1.89	-5.81**	4.37	14.54 **	1.71	2.18
Akshyadhan x Basmati 370	6.53	7.05 **	-3.40	-11.28 **	1.71	-1.16	4.91 **	-0.58	3.82	8.38 **	2.97	-10.83 **
NLR 145 x Pusa 1121	6.85	5.71 **	-6.93 **	-6.93 **	1.78	1.23	3.29 *	3.30*	3.86	4.14 *	-9.81 **	-9.81 **
NLR 145 x RNR 2354	5.96	5.67 **	4.93 *	-19.02 **	1.67	-5.92 **	-5.11 **	-2.91	3.57	12.10 **	10.42 **	-16.67 **
NLR 145 x Sumathi	6.45	3.53 *	-5.98 **	-12.36 **	1.62	-4.71 **	0.62	-5.81**	3.98	7.62 **	-6.65 **	-7.01 **
NLR 145 x I.P. Basmati	6.48	4.26 *	-5.12 **	-11.96 **	1.65	-2.37	3.77 *	-4.07*	3.93	5.65 **	-8.68 **	-8.26 **
NLR 145 x Basmati 370	6.71	8.58 **	-0.74	-8.83 **	1.61	-11.05 **	-10.06 **	-6.40**	4.17	21.83 **	12.41 **	-2.65
Pusa 1121 x RNR 2354	6.27	-3.89 *	-14.86 **	-14.86 **	1.66	-4.60 **	-3.49 *	-3.49*	3.78	0.67	-11.68 **	-11.68 **
Pusa 1121 x Sumathi	8.32	17.02 **	13.04 **	13.04 **	1.72	3.30 *	6.83 **	0.00	4.84	13.23 **	13.01 **	13.01 **
Pusa 1121 x I.P. Basmati	6.64	-6.46 **	-9.83 **	-9.83 **	1.61	-2.72	1.26	-6.40**	4.12	-3.96 *	-4.19 *	-3.74
Pusa 1121 x Basmati 370	6.70	-5.10 **	-8.97 **	-8.97 **	1.64	-7.79 **	-4.84 **	-4.84**	4.10	2.67	-4.21 *	-4.21 *
RNR 2354 x Sumathi	6.23	-0.64	-9.18 **	-15.35 **	1.63	-3.26 *	1.24	-5.23**	3.82	1.96	-10.40 **	-10.75 **
RNR 2354 x I.P. Basmati	6.35	1.47	-7.08 **	-13.77 **	1.56	-6.87 **	-1.89	-9.30**	4.07	8.01 **	-5.43 **	-4.98 *
RNR 2354 x Basmati 370	5.87	-5.63 **	-13.17 **	-20.24 **	1.65	-8.08 **	-6.25 **	-4.07*	3.56	2.64	-3.96	-16.82 **
Sumathi x I.P. Basmati	6.21	-9.33 **	-9.52 **	-15.67 **	1.71	6.67 **	7.34 **	-0.77	3.64	-14.99 **	-15.35 **	-14.95 **
Sumathi x Basmati 370	5.84	-14.24 **	-14.87 **	-20.65 **	1.67	-3.10 *	3.52 *	-3.10	3.51	-11.92 **	-17.67 **	-17.99 **
I.P. Basmati x Basmati 370	6.37	-6.25 **	-6.73 **	-13.45 **	1.61	-5.85 **	1.26	-6.40**	3.96	-1.17	-7.98 **	-7.55 **
	Kernel Length After Cooking (mm)				**Kernel Elongation Ratio**				**Head rice recovery (%)**			
BPT 5204 x Akshyadhan	7.60	-13.64 **	-13.64 **	-25.49 **	1.44	-17.00 **	-22.16 **	3.75	58.58	-9.40 **	-12.31 **	37.38 **
BPT 5204 x NLR 145	10.10	10.99 **	7.45 **	-0.98	2.03	15.20 **	9.91 **	46.49	64.60	8.30 **	3.33	51.50 **
BPT 5204 x Pusa 1121	8.40	-11.58 **	-17.65 **	-17.65 **	1.41	-12.96 **	-23.78 **	1.59	46.72	-11.14 **	-25.27 **	9.57 *
BPT 5204 x RNR 2354	11.90	30.05 **	25.26 **	16.67 **	2.44	38.37 **	31.89 **	75.79	36.62	-36.50 **	-41.43 **	-14.12 **
BPT 5204 x Sumathi	9.40	-3.09	-11.32 **	-7.84 **	1.33	-21.49 **	-27.93 **	-3.94	46.62	-19.16 **	-25.43 **	9.33 *
BPT 5204 x I.P. Basmati	9.80	-14.04 **	-30.00 **	-3.92	1.72	-11.79 **	-16.10 **	23.92	38.72	-37.18 **	-38.07 **	-9.19 *
BPT 5204 x Basmati 370	9.40	-2.08	-9.62 **	-7.84 **	1.49	-12.09 **	-19.46 **	7.35	52.00	-19.53 **	-22.06 **	21.95 **
Akshyadhan x NLR 145	13.10	43.96 **	39.36 **	28.43 **	2.14	29.49 **	27.18 **	53.94	60.76	-1.67	-9.04 **	42.50 **
Akshyadhan x Pusa 1121	10.60	11.58 **	3.92	3.92	1.60	6.31	-1.23	15.27	48.90	-10.64 **	-26.80 **	14.68 **
Akshyadhan x RNR 2354	10.20	11.48 **	7.37 **	0.00	1.62	-1.52	-3.18	16.95	48.84	-18.34 **	-26.89 **	14.54 **
Akshyadhan x Sumathi	10.40	7.22 **	-1.89	1.96	1.54	-2.74	-4.94	10.95	56.72	-5.17 *	-15.09 **	33.02 **
Akshyadhan x I.P. Basmati	13.00	14.04 **	-7.14 **	27.45 **	1.84	0.09	-10.41 **	32.33	56.74	-11.04 **	-15.06 **	33.07 **
Akshyadhan x Basmati 370	13.80	43.75 **	32.69 **	35.29 **	2.11	33.76 **	30.45 **	52.26	50.86	-23.82 **	-23.86 **	19.28 **
NLR 145 x Pusa 1121	8.40	-14.29 **	-17.65 **	-17.65 **	1.23	-19.87 **	-26.79 **	-11.38	44.82	-9.84 **	-21.06 **	5.11
NLR 145 x RNR 2354	11.40	20.63 **	20.00 **	11.76 **	1.91	13.80 **	13.69 **	37.61	50.76	-7.37 **	-10.60 **	19.04 **
NLR 145 x Sumathi	9.60	-4.00 *	-9.43 **	-5.88 **	1.49	-7.64 *	-11.31 **	7.35	58.80	7.30 **	3.56	37.90 **
NLR 145 x I.P. Basmati	10.40	-11.11 **	-25.71 **	1.96	1.60	-14.03 **	-21.79 **	15.51	48.64	-17.24 **	-19.95 **	14.07 **
NLR 145 x Basmati 370	11.20	13.13 **	7.69 **	9.80 **	1.67	3.73	-0.60	20.32	48.78	-21.00 **	-26.89 **	14.40 **
Pusa 1121 x RNR 2354	10.60	7.61 **	3.92	3.92	1.69	10.43 **	0.99	22.00	50.88	6.60 *	-3.67	19.32 **

Pusa 1121 x Sumathi	13.20	26.92 **	24.53 **	29.41 **	1.59	8.29 *	2.80	14.55	49.00	2.66	-7.23 *	14.92 **
Pusa 1121 x I.P. Basmati	10.80	-10.74 **	-22.86 **	5.88 **	1.63	-5.23	-20.49 **	17.44	47.00	-9.09 **	-22.65 **	10.23 *
Pusa 1121 x Basmati 370	10.90	5.83 **	4.81 *	6.86 **	1.63	11.26 **	5.84	17.44	49.00	-10.39 **	-26.56 **	14.92 **
RNR 2354 x Sumathi	11.10	10.45 **	4.72 *	8.82 **	1.78	10.44 **	6.16	28.24	55.00	4.13	4.13	28.99 **
RNR 2354 x I.P. Basmati	11.20	-4.68 **	-20.00 **	9.80 **	1.77	-5.19	-13.82 **	27.28	47.00	-17.24 **	-22.65 **	10.23 *
RNR 2354 x Basmati 370	11.10	11.56 **	6.73 **	8.82 **	1.89	17.51 **	12.72 **	36.17	40.66	-31.97 **	-39.06 **	-4.64
Sumathi x I.P. Basmati	12.00	-2.44	-14.29 **	17.65 **	1.93	7.51 **	-5.69 *	39.29	38.88	-31.54 **	-36.01 **	-8.82 *
Sumathi x Basmati 370	12.70	20.95 **	19.81 **	24.51 **	2.17	40.82 **	40.52 **	56.58	48.78	-18.39 **	-26.89 **	14.40 **
I.P. Basmati x Basmati 370	10.50	-13.93 **	-25.00 **	2.94	1.65	-8.08 **	-19.51 **	18.88	46.72	-26.70 **	-29.98 **	9.57 *

* Significant at 5 % level, ** Significant at 1 % level

Table 4. Comparative study of top six crosses exhibited relative heterosis and desirable heterosis for other traits

Cross	Grain yield per plant (Mean)	Relative Heterosis	Desirable heterosis for other traits
RNR 2354 x Improved Pusa Basmati	27.7	85.65	DFF, TW, DFF, KL, KB and L/B ratio
NLR 145 x Sumathi	28.5	46.43	DFF, TW, DFF, KL, KB, L/B ratio and HRR
Akshyadhan x Pusa 1121	27.9	37.50	DFF, TW, DFF, KL and KLAC
BPT 5204 x Basmati 370	28.0	35.48	DFF, DFF, KL, KB and L/B ratio
RNR 2354 x Basmati 370	28.9	31.20	DFF, DFF, KB, L/B ratio, KLAC and KER
BPT 5204 x Sumathi	29.7	52.19	DFF, TW, DFF, KL and L/B ratio

DFF: Days to 50 % flowering, TW: Test weight, GY: Grain yield, KL: Kernel length, KB: Kernel breadth, L/B ratio: Kernel length/breadth ratio, KLAC: Kernel length after cooking, KER: Kernel elongation ratio and HRR: Head rice recovery

The parents with lower values were considered as better parents for the estimation of heterosis for days to 50 per cent flowering and kernel breadth and negative heterosis as desirable when the objective is for evolving early and fine grain varieties. For the other characters, parents with higher estimates were considered as better parents.

High amount of heterosis registered in desirable direction for days to 50% flowering with all the crosses exhibiting significant negative heterosis except the cross BPT 5204 x RNR 2354 and 19 crosses showed significant negative heterobeltiosis, while only two crosses (BPT 5204 x Basmati 370 and BPT 5204 x RNR 2354) showed positive heterobeltiosis. Higher magnitudes of negative heterosis for earliness was reported by Palaniraja *et al.* (2010) and Tiwari *et al.* (2011) and in the case of present study, indicating dominance nature of minus genes for earliness. For test weight crosses, NLR 145 x Sumathi, Sumathi x Improved Pusa Basmati and Sumathi x Basmati 370 exhibited significant positive value of relative heterosis, heterobeltiosis and standard heterosis and also the mean value within the range of 20-26 g. Out of 28 crosses, nineteen crosses exhibited significant positive heterosis over mid parent and eleven over better parents for grain yield per plant. The range of heterosis over mid parent ranged from -29.93 (NLR 145 x Pusa 1121) to 130.52 per cent (BPT 5204 x Pusa 1121), over better parent it varied between -42.40 (Pusa 1121 x Sumathi) and 97.92 per cent (BPT 5204 x Pusa 1121) and range of standard heterosis varied from -59.33 to 74.93 per cent over the yield check. Out of 28 hybrids, 8 expressed significant positive values for relative heterosis, heterobeltiosis and standard heterosis. Head rice recovery is an important character from the miller and consumer point of view. Twenty three crosses registered significantly positive heterosis over the check Pusa 1121, while three crosses recorded significantly negative values. BPT 5204 x NLR 145 (51.50 %) recorded highest value of standard heterosis followed by Akshyadhan x NLR 145 (42.50 %), NLR 145 x Sumathi (37.90 %) and BPT 5204 x Akshyadhan (37.38 %). The hybrid BPT 5204 x NLR 145 recorded highest positive and significant heterosis over both mid parent (8.30 per cent) and standard check (51.50 per cent). For kernel length, the relative heterosis was significant and positive in 14 out of 28 crosses but only five crosses viz., Pusa 1121 x Sumathi, Akshyadhan x RNR 2354, Akshyadhan x NLR 145, NLR 145 x RNR 2354 and Akshyadhan x Improved Pusa Basmati recorded significant and positive heterosis over better parent. For standard heterosis, all the crosses exhibited significant negative standard heterosis over the check Pusa 1121 except the cross Pusa 1121 x Sumathi. Under this situation, selecting for short grained aromatic genotypes suiting the local demand would be an easy task. The magnitude of heterosis realized for this trait indicated presence of quantum of variability for this trait to obtain segregants with desirable kernel lengths.

Lesser dimensions of kernel breadth (mm) are always desirable, since slenderness enhances the length/breadth ratio and kernel length after cooking and fetch high premium in market. In contrast, bold kernels with higher breadth are often discriminated against because they break in milling (Jennings *et al.* 1979). Thus, heterosis in negative direction is desirable for this trait accordingly significant negative heterosis was recorded in thirteen hybrids with a rage of -3.10 percent in (Sumathi x Basmati 370) to -11.05 per cent in (NLR 145 x Basmati 370). Similarly, five hybrids registered significantly negative heterobeltiosis and the range was from -6.25 percent in (RNR 2354 x Basmati 370) to -10.06 percent (NLR 145 x Basmati 370). Fourteen hybrids recorded significantly negative standard heterosis over the check Pusa 1121 from -3.49 (Pusa 1121 x RNR 2354) to -12.79 per cent (BPT 5204 x RNR 2354). Crosses with lesser L/B ratios indicated the possibility of obtaining segregants with short slender grains with aroma. However, Standard heterosis over the check Pusa 1121 was significantly negative in all crosses except Pusa 1121 x Sumathi and Akshyadhan x Improved Pusa Basmati. The cross Pusa 1121 x Sumathi registered highest positive and significant heterosis over both better parent and standard check. Earlier researchers Kumar Babu *et al.* (2010) reported positive heterosis for Length/Breadth ratio and Saravanan *et al.* (2006) for negative heterosis. Lengthwise expansion of kernel after cooking is a highly desirable feature and manifestation of heterosis for this trait is useful. Sixteen crosses had shown heterosis to kernel length after cooking in desirable direction and maximum percentage of 43.96 was associated with Akshyadhan x NLR 145 and minimum was observed in Pusa 1121 X Basmati 370 (5.83 per cent). Twelve crosses recorded significant positive heterobeltiosis and fourteen hybrids exhibited significant positive standard heterosis. A total of ten crosses recorded positive and significant heterosis, heterobeltiosis and standard heterosis.

Among the hybrids studied, twelve hybrids were significantly superior over the mid parental value and seven hybrids recorded significant positive heterobeltiosis for kernel elongation ratio. Standard heterosis ranged from -11.38 to 75.79 per cent over the best check Pusa 1121. The best cross was BPT 5204 x RNR 2354 which registered significant and positive standard heterosis. Krishna Veni *et al.* (2005) and Roy *et al.* (2009) also reported good manifestation of heterosis for kernel length after cooking and kernel elongation ratio, in several combinations emphasizing usage of both additive and non-additive types of genetic variation.

Conclusion

Significant heterosis over mid and better parents in desired direction was observed in many crosses for various traits under study. The cross RNR 2354 x Improved Pusa Basmati exhibited highly significant heterosis and heterobeltiosis for yield and its important component characters, also was found to be early. The crosses NLR 145 x Sumathi, RNR 2354 x Basmati 370 and Akshyadhan x Pusa 1121 exhibited significant positive heterosis for yield and one or more grain quality traits (Table 4), so these promising aromatic cross combinations can be further used in rice breeding programme.

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