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Heterosis breeding in aromatic rice (*Oryza sativa* L.) for yield and quality characters

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Abstract

Pollen and spikelet fertility of 75 F_1's were counted, total 41 potential restorers and 11 effective maintainers were identified for different CMS lines, these effective maintainers can be used to develop new aromatic CMS lines through repeated back crossing. Forty one hybrids were evaluated for yield and quality characters with Pusa Basmati-1 and Basmati-370, respectively. Based on quality characters, three hybrids *viz.*, IR 58025 A × PB-6-12-55-5, IR 68888A × Patloon Tahni and IR 68888A × Gopal Bhog were identified superior which also exhibited higher yield heterosis. Hybrid, IR 68888A × Patloon Tahni was early in maturity and also showed high outcrossing. These hybrids can be exploited successfully in hybrid rice breeding programme.

Key words : Hybrid rice, heterosis, yield and quality characters

Introduction

Quality rices have important place in local and international markets due to their superfine grains, pleasant aroma, soft texture, extra elongation and excellent cooking quality, and earn more foreign currency for the country. Therefore intensive efforts are needed to develop high yielding varieties with good grain quality. Now-a-days hybrid technology is the best approach to develop basmati rice hybrids and this is also a major part of the Indian hybrid rice programme. Hybrid breeding is mainly depends on effective restorers and higher heterosis and outcrossing potential of CMS lines, High outcrossing would help to produce huge quantity of hybrid seed with minimum cost. Hence, in the present study attempts have been made to identify effective restorers, estimate the extent of heterosis and assess the outcrossing potential of CMS lines.

Materials and methods

Three CMS lines, IR 68888A, IR 68891A and IR 58025A were crossed with 25 diverse aromatic varieties/mutants in a line × tester fashion, and resultants 75 F_1s were evaluated in a randomized block design with three replications for pollen and spikelet fertility at the Agricultural Research Farm of the Banaras Hindu University, Varanasi. Each entry per replication was planted in a single row of 3 m length with the spacing of 20 × 15 cm at one seedling per hill. Five randomly selected plants from each replication were used to record observations on pollen and spikelet fertility. For pollen fertility, one each spikelet was collected from top, middle and bottom portion of panicle before anthesis, and pollen grains were stained with 1% iodine-potassium iodide (IKI) solution. Total 200 pollen grains were observed for pollen fertility and round shaped pollen grains considered as fertile. Spikelet fertility was estimated by counting of filled and unfilled grains of bagged panicles taken from five randomly selected plants from each replication. On the basis of pollen and spikelet fertility, varieties were classified as potential restorers (>80% fertility), partial restorers (21-79% fertility), partial maintainers (1-20% fertility) and effective maintainers (<1% fertility) as suggested by Virmani [1].

Forty one hybrids along with their parents and checks were evaluated in a randomized block design with three replications at the same research farm with the same spacing. Pusa Basmati-1 was used as a control for comparison of yield characters, whereas quality parameters compared with Basmati-370. The observations *viz.*, days to maturity, plant height, number of panicles plant^{-1}, grains panicle^{-1},100-grain weight and grain yield plant^{-1} were recorded on ten randomly selected plants from each replication, whereas composite seed samples of ten randomly selected plants from each replication were used to record quality characters like head rice recovery, kernel length, kernel breadth, 1/B ratio, kernel elongation and amylose content. The head rice recovery was recorded as per Ghosh *et al.*, [2]. The kernel length and breadth were measured from milled kernels by using dial micrometer (Mitutoya), and L/B ratio derived from individual kernel length and breadth. Kernel elongation was measured from cooked milled kernels with the help of graph paper, and aroma detected from leaves as well as kernels by technique

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of Nagaraju *et al.* [3] The cooking quality characters, like alkali digestion value and amylose content were measured by standard procedures [4 and 5], respectively. The standard heterosis was estimated as percent increase or decrease of F_1 values over standard check. The outcrossing potential was assessed by planting of CMS lines and their restorers in a crossing block with the ratio of 4:2. (A:R line). The border rows of purple puttu were raised around the crossing block as well as between each combination to check foreign pollens. All the plants of every CMS line were used to count spikelet fertility. The outcrossing percentage were computed as proportion of fully developed grains to the total number of spikelets.

Results and discussion

The various restorers and maintainers for different CMS lines are presented in Table 1. The total 41 potential restorers and 11 effective maintainers were screened from 75 crosses. Several restorers and maintainers were also identified by others [6]. The present study showed that there was no strict association between pollen and spikelet fertility, because some hybrids showed low pollen fertility whereas their spikelet fertility was high indicating that pollen sensisterility would not affect to spikelet fertility. Similarly few genotypes acted as restorers for one CMS line whereas maintainers for other CMS line. It may be due to cytoplasmic-genomic interaction involve complex genetic phenomenon like complementations, inhibition, epistasis and accumulation. Similar results were also reported by earlier workers [7].

Table 1. Restorers and maintainers for different CMS lines, *viz.*, IR 68888 A, IR 68891 A and IR 58025 A

Variety/mutant	IR 68888A	IR 68891 A	IR 58025 A
Hawm Kikwai	R	R	R
Patloon Tahni	R	PR	PR
KCN 80152	R	M	R
Gopal Bhog	R	R	R
Seeta Sail	R	M	R
Pakistani Basmati	PR	PR	R
Khao Dawk Mali 105	M	PM	R
Basmati 134	R	PR	PR
Basmati 397	R	PM	R
AC 25419	R	M	PM
Pusa Basmati 1	R	PM	R
Basmati Sathi	R	M	R
PB-6-12-55-5	R	PR	R
PB-3-17-58-2	M	PR	R
PB-8-48-59-2	R	R	R
PB-3-17-57-1	R	M	PM
PB-7-21-64-2	R	PR	PR
PB-6-12-24-4	R	R	M
PB-7-16-57-3	R	PM	M
PB-17-4-5-63-3	R	PR	R
PB-6-1-60-9	R	R	PR
PB-5-14-50-1	R	R	PM
PB-3-17-32-2	M	R	PR
PB-6-4-60-7	PM	R	M
PB-4-18-57-6	PR	PM	R

R = Potential restorer, PR = Partial restorer, PM = Partial maintainer, M = Effective maintainer

The range of standard heterosis and number of hybrids showing significant heterosis are presented in Table 2. Earliness is desirable character helps to develop early varieties. The significant negative standard heterosis for days to maturity was observed in 15 hybrids. Dwarf plant stature is desirable to develop semi-dwarf high yielding varieties which will be lodging resistant and fertilizer responsive. Two hybrids exhibited significant negative standard heterosis for plant height. These findings are in conformity with Vishwa Karma *et al.*, [8]. Number of panicles plant^{-1} is important yield component and significant positive standard heterosis was observed in 17 hybrids. Similar results were also reported by earlier workers [9]. Number of grains panicle^{-1} is also important yield attributing character and 3 hybrids showed significant positive standard heterosis for this character. These results are in conformity with Janardhanan *et al.*, [9]. For test weight, 26 hybrids exhibited significant positive standard heterosis. These findings are in accordance with earliers [10]. Thirty two hybrids exhibited significant positive standard heterosis for grain yield plant^{-1}. Jannardhanam *et al.* [9] also reported high standard heterosis for grain yield plant^{-1}. The higher head rice recovery is desirable from commercial point of view and much preferred by consumers and traders. The significant positive standard

Table 2. Range of standard heterosis for various yield and quality characters and number of hybrids showing significant heterosis

Character	Range	SE(±)	No. of hybrids showing desirable significant heterosis
Days to maturity	–15.87 to –10.5	5.72	15
Plant height	–19.18 to 32.75	7.58	02
No. of panicles plant^{-1}	–29.68 to 60.0	0.88	17
Grains panicle^{-1}	9.32 to 51.46	14.21	33
Test weight	–1.51 to 38.38	0.16	26
Grain yield plant^{-1}	8.93 to 136.62	2.48	32
Head rice recovery	–4.92 to 39.41	2.66	29
Kernel length	–9.03 to 12.63	0.31	06
Kernel breadth	–1.66 to 38.88	0.08	00
L/B ratio	–20.55 to 8.02	0.14	04
Kernel elongation	6.47 to 16.47	0.11	27
Alkali digestion value	15.6 to 123.4	0.18	40
Amylose content	5.36 to 39.62	1.47	27

heterosis for this character was observed in 29 hybrids. Long grains rice increases market acceptability, and six hybrids showed significant positive standard heterosis for kernel length. These results are in conformity with findings of earlier workers [11]. None of the hybrid exhibited significant negative standard heterosis for kernel breadth. The L/B ratio and kernel elongation are important grain quality characters, and four hybrids for L/B ratio and 27 hybrids for kernel elongation showed significant positive standard heterosis. Alkali digestion value and amylose content are important cooking quality characters. The significant positive standard heterosis for alkali digestion value was observed in 40 hybrids. These results are in accordance with results obtained by Kaw and Dela Cruz [12]. Twenty seven hybrids showed significant positive standard heterosis for amylose content. Similar findings were also reported earlier [13]. The promising hybrids for various yield and

Table 3. Promising heterotic combinations for different yield and quality characters

Characters	Cross combination
Days to maturity	IR 68888 A × PB-7-16-57-3, IR 68888 A × PB-17-4-5-63-3, IR 68891 A × PB-6-12-24-4, IR 68888 A × PB-8-48-59-2
Plant height	IR 68888 A × PB-17-4-5-63-3, IR 68888 A × PB-5-14-50-1
No. of panicles plant^{-1}	IR 68891 A × PB-5-14-50-1, IR 68888 A × Hawm Kikwai, IR 68888 A × Seeta Sail, IR 68888 A × PB-6-12-24-4
No. of grains panicle^{-1}	IR 58025 A × Khao Dawk Mali 105, IR 58025 A × Pakistani Basmati, IR 68891 A × PB-6-4-60-6
Grain yield plant^{-1}	IR 68888 A × Patloon Tahni, IR 68888 A × Seeta Sail, IR 58025 A × Khao Dawk Mali 105, IR 68888 A × PB-6-12-24-4
Head rice recovery	IR 68888 A × PB-5-14-50-1, IR 68888 A × Seeta Sail, IR 68891 A × Gopal Bhog, IR 58025 A × Basmati Sathi
Kernel length	IR 58025 A × PB-6-12-55-5, IR 68888 A × Hawm Kikwai, IR 58025 A × Hawm Kikwai, IR 58025 A × Khao Dawk Mali-105
L/B ratio	IR 58025 A × PB-6-12-55-5, IR 68888 A × Gopal Bhog, IR 68888 A × Patloon Tahni, IR 68888 A × Basmati 397
Kernel elongation	IR 68888 A × AC 25419, IR 68888 A × Gopal Bhog, IR 68888 A × PB-3-17-57-1, IR 68891 A × PB-6-4-60-7
Alkali digestion value	IR 68888 A × Basmati 134, IR 58025 A × Gopal Bhog, IR 68888 A × Patloon Tahni, IR 68888 A × AC 25419
Amylose content	IR 68888 A × PB-6-12-24-4, IR 68888 A × PB-3-17-57-1, IR 68891 A × Hawm Kikwai, IR 68891 A × PB-6-4-60-7
Outcrossing (%)	IR 68888 A × PB-8-48-59-2, IR 68888 A × Patloon Tahni, IR 68888 A × AC25419, IR 68891 A × Gopal Bhog

Table 4. Standard heterosis of top ten heterotic combinations based on quality characteristics

Crosses	DM	PH	NPP	GPP	TW	GYP	HRR	KL	KB	L/B	KE	ALKD	AC	OC(%)
IR 58025 A × PB-6-12-55-5	–5.26	–13.21	27.6*	25.54**	14.64*	81.18**	20.98**	12.63*	2.77	9.77*	14.11**	108.88**	30.31**	16.70
IR 58025 A × Khao Dawk Mali 105	–9.35*	29.25**	20.93**	51.46**	15.15*	110.75**	19.66**	7.22*	15.55**	–7.01	11.17*	110.00**	2.73	37.82
IR 58025A × KCN 80152	–5.97	32.75**	–18.02	36.01*	16.66*	26.94**	2.08	7.22*	6.11	1.25	14.7**	46.40**	25.63**	31.68
IR 58025 A × Hawm Kikwai	–4.78	6.93	–3.33	23.62**	15.65**	37.29**	18.72*	7.63**	10.0	–2.0	13.52**	64.4*	19.78*	14.65
IR 68888A × Patloon Tahni	–11.21*	2.33	41.04**	34.35**	28.78**	136.62**	24.46**	1.38	10.0	7.76*	12.94**	12.64**	29.0**	43.63
IR 68888A × Basmati-397	–11.21*	29.03**	22.18**	28.35*	19.29**	97.17**	21.85**	1.80	10.55	7.76*	9.41	80.0**	23.84**	39.87
IR 68888A × PB-8-48-59-2	–11.64*	–7.22	39.58**	27.45*	14.14	98.11**	28.05**	5.13	7.77	–2.25	13.52**	28.8**	19.31*	44.67
IR 68888A × PB-3-17-57-1	15.51*	–11.02	2.50	33.97**	11.11	52.15**	22.94**	9.30*	6.11	–3.50	15.88**	118.4**	39.05**	34.45
IR 68888A × Gopal Bhog	8.35	19.4*	1.97	18.64*	21.21**	44.75**	14.53*	6.25	15.55**	8.02*	15.88**	114.4**	29.57**	29.75
IR 68888A × Hawm Kikwai	–4.30	15.07	60.0**	18.64*	–1.51	85.88**	23.0**	10.41*	5.00	5.26	11.17	82.0**	16.57*	26.45

* and ** significant at P = 0.05 and 0.01, respectively; Yield and quality components compared with PB-1 and Basmati - 370, respectively; DM = Days to maturity, PH = Plant height, NPP = Number of panicles plant^{-1}, GPP = Grains panicle^{-1}, TW = Test weight, GYP = Grain yield plant^{-1}, HRR = Head rice recovery, KL = Kernel length, KB = Kernel breadth, L/B = Length breadth ratio, KE = Kernel elongation, ALKD = Alkali digestion value, AC = Amylose content. OC = Outcrossing potential.

quality characters are presented in Table 3. None of the hybrid was found aromatic during testing aroma in leaves as well as in kernels. However, F_2 seeds will segregate in aromatic and non-aromatic ones. Therefore, aroma should be further confirmed in individual F_2 seeds for testing aroma.

The outcrossing potential of CMS lines with their various restorers ranged from 14.65 to 44.6%. The higher outcrossing (>40%) was recorded in hybrids, which can be used to produce huge quantity of hybrid seed with minimum cost The effective maintainers of CMS lines can be useful to develop new aromatic CMS lines through repeated backcrossing. On the basis of quality, traits, three hybrids, IR 58025 A × PB-6-12-55-5, IR 68888 A × Patloon Tahni and IR 68888 A × Gopal Bhog were identified superior among them and also exhibited higher yield heterosis. Out of these one hybrid, IR 68888 A × Patloon Tahni was early in maturity and also showed high outcrossing potential. Hence, these hybrids can be exploited successfully in hybrid rice breeding programme.

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