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Research Note

Analysis of grain quality characters of best F_1 *indica* rice hybrids

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Abstract
Eighty F_1 hybrid combinations were developed using eight CMS lines and 10 elite genotypes for the development of rice hybrids with desirable grain qualities. Among the eighty hybrids, 20 top yielding hybrids were identified for the assessment of grain quality characters. Eight hybrids *viz.,* IR 72081 A x MDU 5 R, IR 72081 A x TP 1021 R, IR 75601 A x MDU 5 R, IR 80559 A x MDU 5 R, APMS 6 A x TP 1021 R and IR 72081 A x IR 62037 R, APMS 6 A x IR 62037 R, CRMS 32 A x IR 62037 R and seven parents *viz.*, IR 72081 A, IR 80559 A, APMS 6 A, CRMS 32 A, MDU5 R, IR 62037 R, TP 1021 R possessed hulling percentage, milling percentage, head rice recovery, linear elongation ratio, intermediate gel consistency, alkali spreading value and amylose content with medium slender grain type. These hybrids were found to be higher yield performers and coupled with good grain quality could be exploited commercially for grain yield and quality improvement.

Key words
Rice, grain quality, CMS lines, *indica* rice hybrids, amylose content

Rice quality is great importance for all people involved in producing, processing and consuming rice, because it affects the nutritional and commercial value of grains. Rice grain quality preference varies from country to country and region to region. Best quality type of one region may not be liked by another region. Hence, Breeding for better quality hybrids depending upon the local requirement assumes added significance. The most important quality components, common to all users, include appearance, milling, cooking, processing and nutritional quality. Further grain quality has become an important issue affecting domestic consumption and international trade of rice (Lodh, 2002). Head rice is a major determinant of price in the paddy markets of many countries, including the United States. Therefore, the value of rough rice is directly related to its milling quality and the prevailing market demands. Different cultivars of waxy and non-waxy rice are usually classified according to their grain dimensions, amylose content, amylograph consistency, gelatinisation properties of the extracted starches and the texture of cooked rice (Juliano, 1985). According to Khush *et al.* (1988) the cooking characteristics of hybrid bulk grains are intermediate between those of parents. Hence, to develop rice hybrids with acceptable grain quality both the parental lines with desirable grain quality should be selected. Keeping in this view, eight stable CMS lines and 10 elite testers with good grain qualities were selected for the development of rice hybrids with desirable grain qualities.

Eight diverse CGMS lines of rice *viz.,* IR 80559 A, APMS 6 A, IR 72081 A, IR 75601 A, IR 75596 A, IR 80154 A, CRMS 32 A, IR 75608 A were crossed with ten diverse elite restorer lines as testers *viz.*, IR 62037-93-1-3-1-1 (IR 62037 R), IR 72865-94-3-3-2 (IR 72865 R), IR 68427-8-3-3-2 (IR 68427 R), MDU 5 R, ACK 99017 R, TP 1021 R, RR 363-1 (RR 363 R), RR 347-1 (RR 347 R), RR 286-1 (RR 286 R) and ASD 06-8 R) through Line x Tester mating design. The resultant eighty hybrids along with their parents and checks *viz.* ,CORH 3, CO 48 were sown in raised beds and 25 days old seedlings were transplanted in main field under puddled condition under three environments in Tamil Nadu (E1: Coimbatore, E2: Bhavanisagar and E3: Aliyar Nagar) with two replications. For each genotype, single seedling per hill was planted at 20 x 20 cm spacing in two rows of 2.0 m length. Recommended fertilizer dose and cultural practices were adopted. In each entry, five plants were selected randomly from two replications and biometrical observations were recorded. Among eighty hybrids, 20 top yielding and stable hybrids (Table 1) in three environments were selected for analysis of grain quality characters. Grains of individual single plants of each hybrid along with their parents were hulled in rice husker. Observations were recorded on sixteen qualitative characters as per the Standard Evaluation System (SES, 1996) descriptors suggested by IRRI. The mean data for each character individually was subjected to statistical analysis. Genetic parameters like variability, GCV, PCV, heritability and genetic advance were calculated by Johnson *et al.* (1955).

Though hybrid rice has given a yield advantage, its acceptance by the consumers is primarily determined by cooking and sensory quality characters. The price which the farmers get for their produce is mostly determined by the quality traits. The seeds harvested from F_1 plants represent F_2 generation; hence segregation for quality traits is expected. Therefore, selection of parents with similar grain quality is essential to get hybrids with desirable grain quality. The hybrids IR 75601 A x RR 347 R, IR 80559 A x MDU 5 R, IR 75601 A x

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MDU 5 R, CRMS 32 A x RR 363 R and APMS 6 A x ACK 99017 R, APMS 6 A x IR 62037 R, APMS 6 A x TP 1021 R, IR 72081 A x TP 1021 R, IR 72081 A x MDU 5 R, IR 75596 A x MDU 5 R had higher milling per cent (> 65 %). Both the parents of these hybrids had high milling per cent and head rice recovery except the parent IR 62037 R. This is in accordance with the suggestion of Shobha Rani *et al.* (2002) to choose parents with high milling yield for producing hybrids with high milling quality and head rice recovery.

Ratio of length to breadth decides the shape of the kernel. All the parents are of medium slender kernel type (Table 2), but the cross between medium x medium slender kernel types resulted in the hybrids (13 hybrids) with long slender grain type, indicating the superiority of hybrids. Shobha Rani (2003) noted that medium-grain rice was more resistant to cracking than long-grain rice during milling, probably due to its more rounded and thicker grain shape compared to the slender-shaped grain of long-grain rice. High kernel breadth is a desirable trait in regions where consumers prefer bold grains for their daily consumption.

High kernel length after cooking (KLAC) is a desirable trait, as it decides the market acceptance and consumer preference. The hybrids *viz.,* IR 80559 A x RR 286 R, IR 72081 A x MDU 5 R, IR 75601 A x IR 72865 R, IR 75601 A x MDU 5 R, IR 75601 A x RR 347 R and IR 80154 A x IR 62037 R had high KLAC over the checks, which indicated their superiority for KLAC and also these hybrids were free from chalkiness. In general, minimum breadth wise expansion on cooking is preferred by the consumers. In this study, eight parents and 12 hybrids exhibited low kernel breadth expansion after cooking which may be due to the involvement of maternal parents with low breadth wise expansion. Lower breadth wise expansion ratio was found in all hybrids except IR 80559 A x RR 286 R, IR 72081 A x IR 68427 R, IR 80154 A x IR 62037 R and CRMS 32 A x RR 363-1 R over check variety. Length-wise expansion (grain elongation) upon cooking without increase in girth is a very desirable trait. Shobha Rani (2003) noted that medium-grain rice was more resistant to cracking than long-grain rice during milling, probably due to its more rounded and thicker grain shape compared to the slender-shaped grain of long-grain rice. Linear elongation ratio (LER), a special quality character of aromatic and other long slender grains decides the market value of the hybrid. This character has positive association with KLAC. Greater LER, less VE and less water absorption have been associated with high quality rice varieties (Ge *et al.*, 2005). In the present study, the hybrids *viz.,* APMS 6 A x IR 62037 R, APMS 6 A x TP 1021 R, IR 72081 A x MDU 5 R, IR 75601 A x IR 72865 R, IR 75601 A x RR 347 R, IR 75601 A x RR 286 R, IR 75596 A x MDU 5 R, IR 75596 A x ASD 06-8 R, IR 80154 A x IR 62037 R and CRMS 32 A x IR 62037 R showed high LER than the hybrid check CORH 3. Minimum breadth wise expansion on cooking is generally preferred by the consumers. Eight parents and 12 hybrids exhibited low kernel breadth expansion after cooking which may be due to the involvement of maternal parents with low breadth wise expansion.

Amylose content, gelatinization temperature and gel consistency are the important starch properties which influence cooking and eating characteristics. Gel consistency (GC) determines the softness or hardness of the cooked rice. GC of *indica* rice varies hard through medium and soft. Medium and soft gel consistency types of rice varieties/ hybrids are generally preferred. Among the 20 hybrids, only one hybrid IR 80154 A x IR 62037 (99.00) showed soft and eight hybrids (40.00 - 60.00 mm) showed medium gel consistency (Table 2). The hybrids with soft GC resulted from the crossing of either medium x soft or soft x medium or soft x soft GC types indicating the dominance of soft over medium (Dong *et al*., 1998). The highest GC was recorded in 'Ghansal' and lowest in 'Pusa Basmati-1'. Kernel length after cooking (KLAC) ranged from 2.31-5.88 mm and the amylose content, starch, gel consistency and non-reducing sugar content decrease with elevated temperature (Shilpa, 2010).

The hybrids *viz.,* IR 80559 A x RR 286 R, APMS 6 A x IR 62037 R, APMS 6 A x RR 347 R, IR 72081 A x IR 62037 R, IR 72081 A x IR 68427 R, IR 72081 A x TP 1021 R and IR 75601 A x IR 72865 R had intermediate amylose content as that of the checks. The results indicated that the parents with intermediate amylose content produced hybrids with intermediate amylose. The amylose content might be influenced by maternal parent cytoplasm, whereas other studies (Xu *et al.,* 1995) indicated that it was mainly controlled by triploid endosperm without any cytoplasmic effect and rice hybrids with intermediate amylose content were reported by Shobha Rani *et al.* (2008). Cooking parameters like volume expansion and water uptake are also important cooking parameter of consumer preference. The hybrids *viz.,*IR 80559 A x ACK 99017 R, IR 80559 A x RR 286 R, APMS 6 A x ACK 99017 R, APMS 6 A x RR 347 R, IR 72081 A x IR 62037 R, IR 72081 A x TP 1021 R, IR 75601 A x IR 72865 R, IR 75596 A x ASD 06-8 R and CRMS 32 A x IR 62037 R higher increse in volume after cooking and it was intermedite or nearer to the better parent. Banumathy *et al.* (2011) reported that volume expansion is highly dependent on amylose content.

Higher magnitude of genotypic variability in terms of GCV of more than 20 per cent was recorded for gel consistency, gelatinization temperature and amylose content. All the quality characters studied revealed generally higher heritability estimates in broad sense exceeding 60 per cent except volume expansion ratio and amylose content (Table 3). Mishra and Verma (2002) observed high heritable values for kernel length after cooking, kernel breadth after cooking, and kernel elongation. High heritability coupled with high genetic advance observed for water uptake, gel consistency and gelatinization temperature indicates the predominance of additive gene action in the inheritance of these characters and suggests their amenability for effective phenotypic selection. On the contrary high heritability and high genetic advance was reported by Hussain *et al.* (1987) for amylose content.

Combining all superior quality traits in a single hybrid combination is very difficult. In the present study, different hybrids were found superior for various quality traits. Among the 20 hybrids studied, 12 hybrids possessed one or more quality traits over the hybrid check CORH 3. The hybrid IR 75601 A x RR 347 R was identified as the best hybrid since it recorded the highest total quality score (49) followed by CRMS 32 A x IR 62037 R, IR 75601 A x MDU 5 R, IR 72081 A x MDU 5 R, IR 75601 A x IR 72865 R, IR 80559 A x MDU 5 R and APMS 6 A x ACK 99017 R (Table 4). The hybrids had good scores for milling per cent, head rice recovery, volume expansion, intermediate gelatinization temperature, soft gel consistency and amylose content. The parents of these hybrids also had higher total quality score. These hybrids were found to be higher yield performers and coupled with good grain quality could be exploited commercially for grain yield and quality improvement.

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Table 1. List of hybrids used for grain quality analysis

Sl. No.	Hybrids	Sl. No.	Hybrids
1	IR 80559 A x MDU 5 R	11	IR 72081 A x TP 1021 R
2	IR 80559 A x ACK 99017 R	12	IR 75601 A x IR 72865 R
3	IR 80559 A x RR 286 R	13	IR 75601 A x MDU 5 R
4	APMS 6 A x IR 62037 R	14	IR 75601 A x RR 347 R
5	APMS 6 A x ACK 99017 R	15	IR 75601 A x RR 286 R
6	APMS 6 A x TP 1021 R	16	IR 75596 A x MDU 5 R
7	APMS 6 A x RR 347 R	17	IR 75596 A x ASD 06-8 R
8	IR 72081 A x IR 62037 R	18	IR 80154 A x IR 62037 R
9	IR 72081 A x IR 68427 R	19	CRMS 32 A x IR 62037 R
10	IR 72081 A x MDU 5 R	20	CRMS 32 A x RR 363 R

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Table 2. Mean performance of selected hybrids for milling, physical and cooking quality traits

Sl. No.	Hybrids	H %	M %	HRR %	KL	KB	L/B	KLAC	KBAC	L/BAC	LER	BWER	VER	GT	GC	WU	AC%	Clk	G.Type
1	IR 80559 A x MDU 5 R	76.71	70.47	45.34	7.05	1.85	3.81	9.50	2.45	3.88	1.35	1.33	3.50	3.50	22.50	4.01	40.50	0	L.S
2	IR 80559 A x ACK 99017 R	73.27	63.57	49.20	7.20	1.85	3.90	9.45	2.40	3.94	1.32	1.30	4.00	2.50	42.50	4.27	31.10	0	L.S
3	IR 80559 A x RR 286 R	74.59	58.15	49.31	7.30	1.95	3.75	9.85	3.00	3.29	1.35	1.54	4.30	4.00	25.00	3.71	24.30	0	L.S
4	APMS 6 A x IR 62037 R	76.88	66.53	49.95	6.45	2.15	3.00	9.10	2.80	3.25	1.42	1.30	3.49	2.50	30.00	4.56	23.60	1	M.S
5	APMS 6 A x ACK 99017 R	72.96	67.32	46.82	6.45	1.95	3.15	8.05	2.30	4.03	1.25	1.18	4.12	2.00	30.00	4.32	44.00	1	M.S
6	APMS 6 A x TP 1021 R	74.61	64.61	45.00	6.75	2.00	3.38	9.70	2.75	3.60	1.44	1.38	3.92	2.50	20.00	3.51	30.70	1	L.S
7	APMS 6 A x RR 347 R	75.70	60.12	47.90	6.45	2.10	3.07	8.70	2.75	3.17	1.35	1.31	4.31	2.00	41.00	4.40	23.40	0	M.S
8	IR 72081 A x IR 62037 R	70.83	61.68	47.45	6.80	2.05	3.32	8.50	2.45	3.47	1.25	1.20	4.49	5.50	59.00	3.62	24.40	1	L.S
9	IR 72081 A x IR 68427 R	74.68	61.50	58.81	6.95	1.80	3.86	9.10	2.75	3.31	1.31	1.53	3.10	4.50	26.50	4.05	18.20	1	L.S
10	IR 72081 A x MDU 5 R	73.78	67.12	40.78	6.65	2.00	3.33	10.55	2.55	4.14	1.59	1.28	3.10	6.00	20.00	4.19	39.00	0	M.S
11	IR 72081 A x TP 1021 R	73.80	66.64	46.23	7.15	2.00	3.58	8.90	2.65	3.36	1.25	1.33	4.32	3.00	42.50	4.19	24.03	1	L.S
12	IR 75601 A x IR 72865 R	75.79	62.03	52.50	7.25	2.00	3.63	10.50	2.55	4.12	1.45	1.28	4.24	3.50	32.50	3.20	24.40	1	L.S
13	IR 75601 A x MDU 5 R	74.57	70.05	47.29	6.95	2.00	3.48	10.30	2.70	4.04	1.49	1.35	3.05	4.50	48.50	4.57	42.50	1	L.S
14	IR 75601 A x RR 347 R	77.35	71.48	57.99	7.00	1.85	3.79	10.55	2.55	4.14	1.51	1.38	3.78	3.00	47.50	3.66	29.20	1	L.S
15	IR 75601 A x RR 286 R	65.43	60.37	45.38	6.50	1.95	3.34	9.70	2.55	3.81	1.50	1.31	2.59	4.00	32.50	4.41	45.50	1	M.S
16	IR 75596 A x MDU 5 R	67.29	65.44	44.29	6.45	2.45	2.64	9.70	2.95	3.29	1.51	1.21	3.73	3.00	30.00	3.97	31.10	5	M.S
17	IR 75596 A x ASD 06-8 R	74.45	64.21	33.28	6.75	2.00	3.38	9.70	2.80	3.47	1.44	1.40	4.07	3.50	30.00	3.78	30.60	1	L.S
18	IR 80154 A x IR 62037 R	74.43	58.24	58.41	7.05	1.80	3.92	9.85	2.75	3.59	1.40	1.53	3.52	2.00	99.00	3.00	28.50	1	L.S
19	CRMS 32 A x IR 62037 R	74.89	60.70	48.47	6.45	2.00	3.23	9.30	2.45	3.88	1.45	1.23	4.54	3.00	42.50	4.46	31.60	1	M.S
20	CRMS 32 A x RR 363 R	71.31	69.13	52.61	6.75	1.95	3.47	8.90	3.10	2.88	1.32	1.59	3.45	3.50	52.50	4.49	27.60	1	L.S
	Mean	**73.66**	**64.47**	**48.35**	**6.82**	**1.99**	**3.45**	**9.50**	**2.66**	**3.63**	**1.39**	**1.35**	**3.78**	**3.40**	**38.70**	**4.02**	**30.71**		-
Checks	CORH 3	71.61	64.85	47.94	6.30	2.10	3.01	8.75	2.35	3.73	1.39	1.12	4.03	3.50	51.00	3.93	21.45	1	M.S
	CO (R) 48	73.79	63.85	43.19	6.35	1.80	3.53	9.90	2.65	3.74	1.56	1.47	3.63	3.00	57.50	4.40	20.70	0	M.S
	SD	**1.56**	**2.28**	**3.71**	**0.07**	**0.05**	**0.09**	**0.09**	**0.08**	**0.07**	**0.02**	**0.05**	**0.38**	**0.51**	**5.38**	**0.12**	**5.69**		-
	CD	**3.24**	**4.74**	**7.70**	**0.16**	**0.11**	**0.18**	**0.21**	**0.17**	**0.15**	**0.05**	**0.11**	**0.79**	**1.06**	**11.19**	**0.24**	**11.84**		-

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Table 3. Variance and coefficient of variation for different quality characters in hybrid rice

Sl. No.	Characters	Mean	PV	GV	PCV (%)	GCV (%)	Heritability (%)	GA (%) of mean
1	Hulling per cent (H %)	73.66	9.55	7.12	4.20	3.63	74.59	6.45
2	Milling per cent (M %)	64.47	17.63	12.44	6.51	5.47	70.57	9.47
3	Head rice recovery per cent (HRR %)	48.35	40.56	26.83	13.24	10.77	66.16	18.05
4	Kernel length (KL)	6.82	0.10	0.09	4.75	4.62	94.64	9.26
5	Kernel breadth (KB)	1.99	0.02	0.02	7.51	7.05	88.07	13.63
6	L/B ratio	3.45	0.12	0.11	9.95	9.62	93.48	19.16
7	Kernel length after cooking (KLAC)	9.50	0.47	0.46	7.24	7.16	97.90	14.60
8	Kernel breadth after cooking (KBAC)	2.66	0.05	0.04	8.26	7.69	86.77	14.76
9	L/B ratio after cooking	3.63	0.13	0.12	10.05	9.84	95.98	19.86
10	Linear elongation ratio (LER)	1.39	0.01	0.01	7.15	6.97	95.18	14.02
11	Breadth wise expansion ratio (BWE)	1.35	0.02	0.01	9.87	9.06	84.22	17.12
12	Volume expansion ratio (VE)	3.78	0.35	0.19	15.52	11.77	57.53	18.39
13	Gelatinization temperature (GT)	4.02	1.25	0.99	32.99	29.34	79.10	53.75
14	Gel consistency (GC)	38.70	328.73	299.79	45.20	43.16	91.20	84.91
15	Water uptake (WU)	3.40	0.20	0.19	11.15	10.78	93.38	21.45
16	Amylose content % (AC)	30.71	78.69	46.26	29.73	22.80	58.78	36.00

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Table 4. Performance of selected hybrids for milling and cooking quality traits

Sl. No.	Hybrids	H %	M %	HRR	KL	KB	L/B	KLAC	KBAC	LER	BWER	VER	WU	GC	GT	AC	Score
1	IR 80559 A x MDU 5 R	5	5	1	3	4	4	2	3	1	2	3	1	1	2	5	42
2	IR 80559 A x ACK 99017 R	4	3	1	3	4	4	2	3	1	2	3	3	3	1	5	42
3	IR 80559 A x RR 286 R	4	2	1	3	4	4	2	1	1	1	4	2	1	2	4	36
4	APMS 6 A x IR 62037 R	5	4	1	2	3	3	2	2	2	2	3	4	1	1	4	39
5	APMS 6 A x ACK 99017 R	4	4	1	2	4	4	1	4	1	3	4	3	1	1	5	42
6	APMS 6 A x TP 1021 R	4	3	1	3	4	4	2	2	2	2	3	2	1	1	5	39
7	APMS 6 A x RR 347 R	5	4	1	2	3	3	1	2	1	2	4	3	3	1	4	39
8	IR 72081 A x IR 62037 R	4	3	1	3	4	4	1	3	1	3	4	2	3	3	4	43
9	IR 72081 A x IR 68427 R	4	3	3	3	4	4	2	2	1	1	2	3	1	2	3	38
10	IR 72081 A x MDU 5 R	4	4	1	3	4	4	3	3	2	3	2	3	2	3	5	46
11	IR 72081 A x TP 1021 R	5	4	1	3	4	4	1	2	1	2	4	3	3	2	4	43
12	IR 75601 A x IR 72865 R	4	3	2	3	4	4	3	3	2	3	4	1	1	2	4	43
13	IR 75601 A x MDU 5 R	4	4	1	3	4	4	3	2	2	2	2	4	3	2	5	45
14	**IR 75601 A x RR 347 R**	**5**	**5**	**3**	**3**	**4**	**4**	**3**	**3**	**2**	**2**	**3**	**3**	**3**	**2**	**4**	**49**
15	IR 75601 A x RR 286 R	2	3	1	2	4	4	2	3	2	2	1	3	1	2	5	37
16	IR 75596 A x MDU 5 R	3	4	1	2	1	3	2	1	2	3	3	2	1	2	5	35
17	IR 75596 A x ASD 06-8 R	4	3	1	3	4	4	2	2	2	2	4	2	1	2	5	41
18	IR 80154 A x IR 62037 R	4	2	3	3	4	4	2	2	2	1	3	1	2	1	5	39
19	CRMS 32 A x IR 62037 R	4	3	1	2	4	4	2	3	2	3	5	3	3	2	5	46
20	CRMS 32 A x RR 363 R	4	4	2	3	4	4	1	1	1	1	2	3	3	2	5	40
Check	**CORH 3**	**4**	**3**	**1**	**2**	**3**	**3**	**1**	**4**	**1**	**3**	**4**	**2**	**3**	**2**	**4**	**40**