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Effect of nucleo-cytoplasmic interactions on the expression of quality characters in rice (*Oryza sativa* L.) hybrids

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Abstract

To study the effects of nucleo-cytoplasmic interactions on the expression of quality characteristics, critical comparisons were made between 11 CMS lines and their respective maintainers and between 30 A × R hybrids and 30 B × R hybrids for 14 quality traits. Since A and B lines are isogenic, the differences observed could be attributed to nucleo-cytoplasmic interactions. Hulling, milling and head rice recovery percentages were lower in A lines and A × R crosses as compared to their corresponding maintainers and B × R crosses. The negative effects of the male sterility inducing cytoplasm were also observed for kernel length, L/B ratio, kernel length after cooking and water uptake. Elongation ratio was found to be positively influenced by the sterility inducing cytoplasm. Nucleo-cytoplasmic effects for gelatinization temperature were cross specific. For gel consistency, the cytoplasmic effects were negligible. Most significant effect of the sterility inducing cytoplasm was the reduction in amylose content of A lines and A × R hybrids. The amylose content of those lines was 1-2 % less than their corresponding B lines and B × R hybrids. Male sterility inducing cytoplasm had no effects on aroma.

Key words: Rice hybrids, nucleo-cytoplasmic interactions, quality

Introduction

Grain and cooking quality characteristics of hybrids primarily determine their acceptance by the consumers. Efforts have been made by several workers to substitute the nuclear genomes into the background of different cytosterility sources to develop new CMS lines. Since CMS system is widely used for developing rice hybrids, the effects of nucleo-cytoplasmic interactions have become exceedingly important. Studies on the effect of sterility inducing cytoplasm on morphological and yield components have been limited in rice and far less in for quality characters. Cytoplasmic influence for different quantitative characters in rice has been reported by Katayama [1]. Viraktamath [2] reported that the cytoplasm of WA based CMS lines had positive effects on number of tillers per plant while negative effects were observed for upper most internode length, number of filled grains per panicle, 100-grain weight and spikelet fertility and reported that the impact of the sterility inducing cytoplasm on some traits was cross specific.

Grain characters appear to be influenced considerably by cytoplasmic factors, which is not unexpected considering the contribution of the female parent in grain development. Associated influence of sterility-inducing cytoplasm on grain quality traits can be studied either by comparing cytoplasmic male sterile lines with their corresponding maintainer lines or by comparing the A line hybrids (A×R) with those of B line hybrids (B×R), on the assumption that A and B are completely isogenic.

Materials and Methods

A set of 11 CMS lines and their corresponding maintainers were evaluated for 14 important quality traits *viz.* hulling percentage, milling percentage, head rice recovery (HRR) as given by Ghosh *et al.* [3]; kernel length (KL), kernel breadth (KB), L/B ratio following Ramaiah [4] classification; kernel length after cooking (KLAC), elongation ratio (ER), water uptake (WU) as given by Beachell and Stansel [5]; volume expansion ratio (VER) as per Juliano *et al.* [6] alkali spreading value (ASV) by following the method described by Little *et al.* [7]; gel consistency (GC) as given by Cagampange *et al.*, [8]; amylose content (AC) as per Juliano [9], and aroma. Similarly five CMS lines and their corresponding maintainers were crossed with the same set of six restorers during October 2000 to produce 30 A × R and 30 B × R hybrids and the produce was used for analyzing these quality traits to elucidate the effects of nucleo-cytoplasmic interactions on the expression of these traits. Since the restorers were common to both A and B lines, any differences observed were attributed to the nucleo-cytoplasmic interactions.

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Results and Discussion

The hulling and milling percentages of A lines was found to be lower than their corresponding B lines except for IR 58025A (80.90%), CRMS 31A (77.65%) and PMS 10A (79.15%) (Table 1).

Table 1. Comparison between CMS lines and their corresponding maintainers for various quality traits

Genotypes	Hulling (%)	Milling (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	ER	WU (ml)	VER	ASV	GC (mm)	AC (%)	Aroma
IR 58025A	80.90	68.90	55.30	6.20	1.73	3.57	9.0	1.44	230	4.75	6.50	86.5	17.40	SS
IR 58025B	78.75	70.20	58.35	6.73	1.84	3.65	11.3	1.67	310	5.16	6.00	84.0	18.75	SS
Difference	+2.15	-1.30	-3.05	-0.53	-0.11**	-0.08	-2.3**	-0.23**	-80**	-0.41	-0.50	+2.5	-1.35**	
IR 62829A	76.80	69.05	40.25	5.69	1.97	2.89	9.4	1.64	220	5.50	2.00	68.5	22.65	NS
IR 62829B	77.95	72.50	68.70	5.94	1.85	3.22	8.7	1.46	260	6.34	2.00	94.0	24.00	NS
Difference	-1.15	-3.45**	-28.44**	-0.25	+0.12**	-0.38**	+0.07	+0.18**	-40*	-0.84	0.00	-25.5**	-1.35**	
IR 68886A	74.10	66.00	41.50	6.03	1.89	3.13	11.7	1.93	180	4.95	2.00	86.0	25.45	NS
IR 68886B	78.70	71.45	46.15	6.31	1.79	3.54	11.3	1.78	165	5.93	2.00	73.5	27.10	NS
Difference	-4.60**	-5.45**	-4.65	-0.28	+0.10**	-0.41**	+0.04	+0.15*	+15	-0.08	0.00	+112.5	-1.65**	
IR 68888A	76.20	66.30	28.70	5.85	1.89	3.07	9.0	1.53	230	4.86	5.30	76.5	24.00	NS
IR 68888B	79.00	70.95	61.80	5.71	1.84	3.10	10.9	1.90	275	5.50	4.50	68.5	26.60	NS
Difference	-2.80*	-4.65**	-33.10**	+0.14	+0.05	-0.03	-1.9	-0.37**	-45*	-0.84	+0.80	+8.0	-2.60**	
IR 68897A	76.70	64.95	36.05	6.28	1.92	3.26	11.0	1.75	270	4.93	5.50	78.0	25.35	MS
IR 68897B	79.05	70.80	76.80	6.80	1.99	3.41	11.4	1.67	310	5.84	5.65	81.0	26.35	MS
Difference	-2.35*	-5.85**	-40.75**	-0.52	-0.07*	-0.15	-0.4	+0.08	-40*	-0.91	-0.15	-3.0	-1.00**	
IR 69628A	75.30	63.55	37.55	5.81	1.96	2.97	10.8	1.86	225	6.20	4.60	37.5	14.85	SS
IR 69628B	79.00	71.60	66.35	6.19	1.94	3.18	10.5	1.69	240	6.10	5.50	80.0	15.25	SS
Difference	-3.70**	-8.05**	-28.80**	-0.38	-0.02	-0.21*	+0.3	+0.17**	-15	+0.10	-0.90	-42.5**	-0.40	
DRR 2A	77.65	67.25	43.15	5.93	1.89	3.13	9.5	1.60	220	5.33	5.50	26.0	25.25	NS
DRR 2B	79.15	73.65	68.50	5.81	1.94	2.98	9.5	1.63	265	5.40	6.50	71.5	27.70	NS
Difference	-1.50	-6.40**	-25.35**	-0.12	-0.05	+0.15	0.0	-0.03	-45*	-0.07	-1.00*	-45.5**	-2.45**	
CRMS 31A	77.65	70.30	56.40	5.90	1.88	3.13	10.0	1.69	220	6.09	6.00	35.0	24.80	NS
CRMS 31B	77.20	70.75	64.85	5.89	1.81	3.25	10.4	1.76	275	5.34	7.00	83.5	23.90	NS
Difference	+0.45	-0.45	-8.45	-0.01	+0.07*	-0.12	-0.4	-0.07	-55**	+0.75	-1.00*	-48.5**	+0.90*	
PMS 10A	79.15	70.70	49.50	6.07	1.82	3.33	9.6	1.58	220	6.04	5.50	28.0	24.40	MS
PMS 10B	78.20	71.05	68.95	6.52	2.15	3.03	9.6	1.47	265	4.84	6.17	95.0	29.15	MS
Difference	+0.95	-0.35	-19.45**	-0.45	-0.33**	+0.30**	0.0	+0.11	-45*	+1.20	-0.67	-67.0**	-4.75**	
PMS 12A	78.90	70.35	62.90	6.27	1.88	3.32	10.6	1.69	235	5.49	5.00	28.5	26.40	NS
PMS 12B	82.60	73.75	70.00	6.57	1.95	3.36	10.9	1.65	340	5.58	5.75	36.0	29.55	NS
Difference	-3.70**	-3.40**	-7.10	-0.30	-0.07*	-0.04	-0.3	+0.04	-105**	-0.09	-0.75	-7.5	-3.15**	
Pusa 5A	72.65	63.75	46.05	6.20	1.93	3.20	11.3	1.82	195	5.66	7.00	43.5	17.50	MS
Pusa 5B	77.40	71.85	65.45	7.05	1.96	3.59	11.9	1.68	230	4.28	6.00	72.5	18.85	MS
Difference	-4.75**	-8.10**	-19.40**	-0.85	-0.03	-0.39**	-0.6*	+0.14*	-35	+1.38	+1.00*	-29.0**	-1.35**	
Mean diff.	-1.90	-4.31	-19.86	-0.29	-0.002	-0.11	-0.37	0.01	-44.50	-0.04	-0.28	-22.30	-1.74	
S.Em.	0.78	0.71	3.17	0.64	0.02	0.05	0.2	0.04	12.00	0.51	0.27	4.5	0.32	
C.D.(0.05)	2.28	2.08	9.32	1.89	0.07	0.16	0.6	0.13	36.00	1.51	0.81	13.35	0.94	
C.D.(0.01)	3.10	2.83	12.69	2.57	0.09	0.22	0.9	0.17	49.00	2.05	1.10	18.17	1.27	

SS: Strong scent; MS: Mild scent; NS: No scent

Similarly the A × R crosses had lower values for these traits than their counterparts, though the differences were not significant for all the crosses. Even for head rice recovery also, similar trend was observed for male sterile lines and their maintainers. With the exception of IR 68888 B (5.71mm), DRR 2B (5.81 mm) and CRMS 31B (5.89 mm) all the maintainers possessed longer kernels as compared to their A lines, though the differences were not significant. However, similar trend was not observed for A × R and B × R crosses for this trait. With the exception of DRR 2A (3.13) and PMS 10A (3.33), the L/B ratio of A lines was greater than their B lines. Elongation ratio was found to be positively influenced by male sterile cytoplasm though the differences were not significant.

For cooking quality characters like water uptake, negative influence of male sterility inducing cytoplasm was observed while for volume expansion ratio, the effect was statistically non-significant though IR 69628A (6.20), CRMS 31A (6.09), PMS 10A (6.04) and Pusa

5A (5.66) had higher estimates for this trait. For physico-chemical traits like gelatinization temperature and gel consistency, no influence of nucleo-cytoplasmic interactions was observed. Though the average gel lengths between A lines and their maintainers and also between A × R and B × R crosses varied, they fall within the same category of gel consistency.

The most interesting among the nucleo-cytoplasmic interactions is the reduction in amylose content of A lines and A × R hybrids as compared to their corresponding maintainers and their hybrids (Table 2). The amylose content of A lines was found to be 1-2 % less than that of their maintainers. Significant negative influence of male sterile cytoplasm on amylose content was also reported by Yi and Chen [10], Mo [11], Xu and Zhang *et al.* [12], Li *et al.* [13] and Liao *et al.* [14] while Shu *et al.* [15] reported no significant differences between the apparent amylose content and starch viscosity of CMS lines and their maintainers indicating that male sterile cytoplasm had no effect on these traits. A profound significant negative effect of the sterility inducing cytoplasm on amylose content has important implications in hybrid rice breeding. There is no influence of nucleo-cytoplasmic interactions on the aroma of CMS lines and their maintainers.

Table 2. Comparison between A × R and B × R hybrids for various quality traits

Crosses	Hulling (%)	Milling (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	ER	WU (ml)	VER	ASV	GC (mm)	AC (%)
IR 58025 based A×R	76.84	69.01	5.10	6.00	1.93	3.12	9.25	1.52	231.6	4.99	5.98	36.4	20.9
IR 58025 based B×R	78.84	70.84	62.75	6.06	2.07	2.92	9.61	1.57	238.8	5.16	6.48	38.4	23.8
Difference	-2.00	-1.83	-6.65	-0.06	-0.14	+0.20	-0.36	-0.05	-7.2	-0.17	-0.5	-2.0	-2.9
IR 62829 based A×R	76.01	68.01	54.40	5.45	1.99	2.73	8.28	1.51	221.6	5.02	4.68	52.2	24.1
IR 62829 based B×R	70.84	70.68	64.85	6.07	2.12	2.67	8.58	1.52	228.3	5.07	4.30	51.3	25.5
Difference	-5.17	-2.67	-10.45	-1.62	-0.13	+0.06	-0.30	-0.01	-6.7	-0.05	+0.38	+0.9	-1.4
IR 69628 based A×R	76.68	67.35	54.00	5.96	2.04	2.92	9.05	1.49	230.0	5.45	6.71	45.4	21.7
IR 69628 based B×R	79.45	70.07	60.77	6.00	2.02	2.96	8.93	1.48	219.1	5.27	6.46	43.9	25.5
Difference	-2.77	-2.72	-6.77	+0.04	+0.02	-0.04	+0.12	+0.01	+10.9	+0.18	+0.25	+1.5	-3.8
IR 68886 based A×R	75.67	68.84	52.31	5.88	1.99	2.93	9.26	1.56	193.0	5.09	5.83	36.5	24.7
IR 68886 based B×R	77.95	70.97	58.80	5.95	2.06	2.88	9.33	1.56	210.0	5.23	5.83	37.2	26.8
Difference	-2.28	-2.13	-6.49	-0.07	-0.07	+0.05	-0.07	0.0	-17.0	-0.14	0.0	-0.7	-2.1
IR 68888 based A×R	75.87	67.90	50.25	5.66	2.05	2.76	8.78	1.54	223.3	4.88	4.73	31.4	25.0
IR 68888 based B×R	79.31	71.08	62.74	5.69	2.09	2.71	8.75	1.52	228.3	4.90	4.85	33.5	27.8
Difference	-3.44	-3.18	-12.49	-0.03	-0.04	+0.05	+0.03	+0.02	-5.0	-0.18	-0.12	-2.1	-2.8
Mean difference	-3.13	-2.50	-8.57	-0.34	-0.07	+0.06	-0.11	-0.006	-5.0	-0.07	+0.002	-0.48	-2.6

Negative nucleo-cytoplasmic effects for brown rice, milled rice head rice recovery and kernel dimensions obtained in the present study are in conformity with the findings of several authors. This finding has a significant bearing on the development of CMS lines and hybrids. The negative influence of male sterility inducing cytoplasm on kernel dimensions may be counteracted by its positive influence on elongation ratio. The negative influence on water uptake is desirable from the point of view of cooking quality when lower water uptake up to certain limit during cooking is desirable. The absence of nucleo-cytoplasmic interactions for gelatinization temperature and gel consistency is a welcome trend as it could be easy to develop hybrids without jeopardizing the quality fabric of hybrids. The information obtained on the influence of nucleo-cytoplasmic interactions on amylose content suggests that for developing CMS lines with intermediate amylose content, the maintainers should have little higher amylose content than the intermediate range so that the resultant hybrids will have intermediate amylose content which is desirable.

The new information generated through this investigation on specific effects of sterility inducing cytoplasm on various quality traits, which was hitherto lacking, has significant bearing on the hybrid rice breeding aimed towards the improvement of quality traits. The results will guide the breeders as regards the choice of maintainers for developing CMS lines and also for developing hybrids with acceptable quality characteristics, which will go a long way in helping the breeders to develop hybrids with acceptable grain and cooking characteristics.

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