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RECENT DEVELOPMENTS IN HYBRID RICE RESEARCH IN SRI LANKA

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ABSTRACT

Hybrid rice is one of the options to break the yield ceiling in rice by 15-20% over the best inbred varieties. The hybrid rice research and development activities in Sri Lanka are composed of three stages, namely; (1). testing of F_1 hybrids, evaluation of cytoplasmic Male Sterile (CMS) and restorer lines; (2). transfer of CMS character into promising local lines and (3). development of locally adapted package of management practices for seed production. One CMS line from India (PMS 11A) and 6 CMS lines from the International Rice Research Institute (IRRI) (IR58025A, IR62829A, IR69623A, IR64608A and IR68887A) found to be adaptable and stable under local conditions with out crossing rates of 28.4%, 37.0%, 40.0%, 40.5%, 41.0%, and 43.0%, respectively. Pollen sterility of these lines ranged from 88-100%. Some well-adapted varieties/lines were identified as maintainers or good restores for the wild abortive cytosterility system (CMS-WA). Some elite maintainers/ restores selected were H-4, At 95-6-8, Bg 95-328, Bg 97-3272, Bg 98-757, Bg 95-425, Bg 95-905, Bg 98-601 and Bg 98-919. Out of 1271 test crosses evaluated, 56 found to be highly sterile. Seventeen F_1 hybrid combinations developed at the Rice Research and Development Institute, Batalagoda were evaluated in yield trails in 4 locations during 1999 *yala* and 1999/2000 *maha* seasons. Six F_1 hybrids *viz.* BgHR1, BgHR2, BgHR3, BgHR4, BgHR5 and BgHR8 out yielded the standard check (Bg 357) by 27-45%. IRRI bred sixteen rice hybrids were tested under International Coordinated Hybrid Rice Yield Trail during 1999/2000 *maha* season in two locations. Some hybrids out yielded local and international checks by 1 t ha^{-1}. F_1 hybrids were produced through Isolation Free Method and Artificial Barrier Isolation method.

KEY WORDS: Cytoplasmic Male Sterility, Hybrid Rice, Maintainer, Restorer, Testcross

INTRODUCTION

Rice is the staple food of Sri Lankans and the most important food crop in the country. It is the livelihood of more than 1.8 million farm families. More than 30% of the total labour force in Sri Lanka is directly involved in rice or rice related activities. Sri Lanka has reached a stage where further expansion in rice area is not possible. With a per capita consumption of about 100 kg yr^{-1} and a limited annual cultivated rice land area of about 830,000 ha, Sri Lanka must raise its present average yield level of 3.5 t ha^{-1} to 4.1 t ha^{-1} by year 2005 to achieve self-sufficiency in rice (DOASL, 1995). The low and stagnating yields of semidwarf inbred varieties presently cultivated in Sri Lanka limit the scope for increasing production. Therefore, the Rice Research and Development Institute (RRDI) of the Department of Agriculture (DOA) has taken steps to carry out the hybrid rice research and development programme at RRDI in collaboration with International Rice Research Institute (IRRI) under the ADB funded project on "Development and Use of Hybrid Rice in Asia". Results of the preliminary work so far conducted on hybrid rice are encouraging and the DOA intends to widen

the scope of the programme. This paper reports the progress of hybrid rice research and development programme carried out during 1999 *yala* and 1999/2000 *maha* seasons at the RRDI, Batalagoda, Field Crop Research and Development Institute (FCRDI), Mahailluppallama, Agricultural Research Station (ARS), Girandirukotte and CIC Seed Farm, Thalawa.

MATERIALS AND METHODS

Experiment 1

During 1999 *yala* season and 99/2000 *maha* season, IRRI bred 26 (A/B) cytoplasmic male sterile (CMS) lines were evaluated at RRDI, Batalagoda based on the following practically and commercially usable characteristics;

(i) Pollen sterility - Ratio of the number of sterile pollen to the total number of pollen averaged over 3 microscopic fields. In each field two separate slides were prepared using ten plants each.

(ii) Out crossing rate (OCR)% - Number of fertile spikelets/Total number of spikelets x 100.

(iii) Adaptability to local condition - Based on stable pollen sterility good phenotypic acceptability an out crossing score of 1-5.

Experiment 2

During 1999 *yala* and 1999/2000 *maha* seasons, 172 selected hybrid combinations were made. Days to 50% flowering, anther colour, pollen fertility and spikelet fertility performance in these lines were evaluated. The promising heterotic combinations were identified on the basis of their phenotypic acceptability.

Experiment 3

During 1999 *yala* season, 1271 test crosses were made using IRRI CMS/IRRI restorers and IRRI CMS/Sri Lankan restorers. These testcrosses were evaluated for their pollen sterility by the method described in Experiment 1.

Experiment 4

In 1999/2000 *maha* season, 16 hybrids developed at IRRI were compared with two international check varieties (IR 72 and PSBRc2) and two local inbred varieties (Bg 300 and Bg 357) in 5m x 4m in plots in a Randomised CB design

with three replications at the ARS, Girandurukotte and at CIC Seed Farm, Thalawa.

In 1999 /2000 *maha* season, locally developed 14 hybrid combinations derived from IRRI CMS/IRRI restores and IRRI CMS/Sri Lankan restores were compared with local inbred check Bg 357, (new improved 105d inbred variety) at RRDI, Batalagoda, and FCRDI, Mahailluppallama.

Experiment 5

Small scale seed production for various evaluation trails and CMS multiplication was undertaken during 1999 *yala* and 1999/2000 *maha* seasons by combining isolation free method and artificial barrier isolation method at RRDI, Batalagoda. All these experiments were conducted under transplanted condition where between and within row spacing was 20 cm x 15 cm with one plant per hill for hybrid rice and two plants per hill for inbred checks. All the experiments were fertilized according to the department recommendation. Experimental plots were kept free from pests, diseases and weeds. Data were analysed using Analysis of Variance (ANOVA) procedure whenever necessary.

RESULTS AND DISCUSSION

One CMS line from India (PMS 11A) and 5 CMS from IRRI (IR 58025A, IR 62829A, IR 69623A, IR 64608A and IR 68887A) were found to be adaptable and stable under local conditions. The out crossing rates of the CMS lines were 28.4%, 37.0%, 40.0%, 40.5%, 41.0% and 43.0% respectively. Pollen sterility of these lines ranged from 88-100% (table 1). All the IRRI developed CMS lines and PMS 11A, had the improved plant type and selected for hybrid rice breeding in Sri Lanka.

Of the 172 heterotic combinations derived from IRRI CMS/IRRI or Sri Lanka restores, 11 combinations were selected on the basis of their phenotypic acceptability (PA) (table 2). Since chances of obtaining good restorers in the system are low, hybrid combinations with desired characters cannot be easily obtained, which naturally result in a relatively low chance for developing elite hybrids.

Table 1. Performance of CMS lines from IRRI and India at RRDI, Batalagoda in 1999 *yala.*

CMS line	*Pollen Sterility[a] (%)*	*Out Crossing rate[b] (%)*	*Adaptability [c]*
IR58025A	100	37.0	not uniformbut adapted
IR62829A	98	40.0	Uniform and adapted
IR64608A	96	41.0	Uniform and adapted
IR68275A	100	7.0	Uniform and adapted
IR68280A	100	16.0	Uniform and adapted
IR68281A	100	34.0	Uniform and adapted
IR68887A	100	43.0	Uniform and adapted
IR68888A	100	4.5	Uniform and adapted
IR68890A	100	21.0	Uniform and adapted
IR68895A	93	39.0	Uniform and adapted
IR68897A	98	14.0	Uniform and adapted
IR68901A	100	9.0	Uniform and adapted
IR68902A	99	9.0	Uniform and adapted
IR69616A	97	28.8	not uniform but adapted
IR69623A	99	40.5	Uniform and adapted
IR69625A	100	40.0	Uniform and adapted
IR69628A	100	9.0	Uniform and adapted
IR68896A	97	13.0	Uniform and adapted
IR68899A	100	26.0	Uniform and adapted
IR69626A	100	11.0	Uniform and adapted
IR67684A	98	15.0	Uniform and adapted
IR66707A	100	20.0	Uniform and adapted
PMS4A	95	0.6	Uniform and adapted
PMS8A	100	7.0	Uniform and adapted
PMS10A	98	3.0	Uniform and adapted
PMS11A	88	28.4	Uniform and adapted

[a] = Pollen Sterility (%) – $\frac{\text{sterile pollen}}{\text{total pollen}} \times 100$

Based on the count within a microscopic field, average on 6 counts per CMS line.

[b] = OCR%- number of fertile spiekelelets / total number of spikelets x 100 under natural condition.

[c] = Based on good rating for a, b and phenotypic characteristics.

Of the 1271 testcrosses evaluated, 56 were completely sterile (CS). The male parents of these CS test crosses were classified as suspected maintainers and were used as recurrent parents in order to develop locally adapted CMS lines. These potential CMS lines are presently in the back cross generation 1 (BC_1), 2 (BC_2) and 4 (BC_4). Some well adapted inbred lines identified as maintainers/restores are presented in table 3.

Table 2. Hybrid combinations selected on the basis of the phenotypic acceptability of the 172 combinations tested at RRDI, Batalagoda in 1999 *yala*.

Selected hybrid Combinations	*Days to 50% flowering*	*Anther colour*	*Pollen sterility/fertility*	*Spikelete+ fertility*	*Phenotypic acceptability**
IR68275A/IR5514-5-3-3-3	67	Yellow & plumpy	Fertile	Fertile	Excellent
IR58025A/97-3272	68	Yellow & plumpy	Fertile	Fertile	Excellent
IR68275A/98-757	70	Yellow & plumpy	Fertile	Fertile	Excellent
IR68902A/98-919	70	Yellow & plumpy	Fertile	Fertile	Excellen
IR68275A/97-905	71	Yellow & plumpy	Fertile	Fertile	Excellent
IR69616A/96-601	71	Yellow & plumpy	Fertile	Fertile	Excellent
PMS11A/96-601	72	Yellow & plumpy	Fertile	Fertile	Excellent
IR58025A/95-328	73	Yellow & plumpy	Fertile	Fertile	Excellent
IR68902A/95-425	73	Yellow & plumpy	Fertile	Fertile	Excellent
IR67684A/91-373XIRON126	73	Yellow & plumpy	Fertile	Fertile	Excellent
PMS10A/97-394	73	Yellow & plumpy	Fertile	Fertile	Excellent
Bg 300 (std)	64				
Bg 357(std)	75				

+ Spikelet fertility- Observe the open pollinated panicles of testcross F1 s for seed setting in comparison to the corresponding male parent

* Based on days to 50% Maturity, heterosis, anther colour, pollen fertility and spikelet fertility performances.

Table 3. Some suspected maintainers and restorers and their corresponding CMS lines identified on the basis of their pollen sterility of F_1s in the testcross nursery at RRDI, Batalagoda in 1999 *yala*.

CMS Line	*Maintainer*	*Restorer*
IR 58025A	At95-27-18, Bg 2039, Bg 98-328	Bg 98-919, At 354 IR 29-341-41-1R IR 55-14-5-3-3-3R
IR 62829A	Bg 98-328, Ld 97-420	Bg 92-979, Bg 98-601 IR 60-821-34-1-2R
IR 68281A	Bg 357	IR 68281B x Bg 95-390
IR 68887A	--	Bg 94-45-16, Bg 98-1102
IR 69623A	--	Bg 95-3-28, Bg 95-905 IR 62037-12-1-2-2-2R
IR 69625A	Bg 403	Bg 97-32-72
IR 68899A	Bg 2426-2	--
IR 68890	At 95-15-20	IR 68890B x Bg 450
IR 68275	At 95-15-20	IR 68275B x Bg 95-622
IR 68902	Bg 300	--
IR 68280	Bg 2039	--
IR 66707	Bg 92-36-77	--
IR 68896	Bg 97-915	--
IR 68901	Bg 97-32-72	--
IR 69616	Bg 98-11-53 Ld 355	H4, Bg 98-757; At 95-6-8; IR 60-819-4-2-1R; IR 48-749-5-3-2-2-1R; Bg 1528 x IR 13540-56-3
IR 68901	Ld 355	--
IR 62275	--	Bg 92-36-72
IR 64608	--	IR 57-287-32-3-2R
IR 62281	--	BKN 6986-108-2R
PMS 11	Bg 12-1///Bg 379-2 Bg 12-1//Bg 450	H4
PMS 8	Bg 12-1//Bg 450	--

Based on F_1 sterility

Of the sixteen hybrids tested, four hybrids *viz.* APHR-2, IR 72073H, IR 69690H and IR 69676H out yielded the local and the international check varieties in the International Co-ordinated Hybrid Rice Yield Trial in 1999/2000 *maha* season at CIC Seed Farm, Thalawa. These four hybrids showed a standard heterosis ranging from 22.0% to 23.6% (table 4). IR 69690H out yielded the local and international check varieties at the ARS, Girandurukotte. Furthermore, four hybrids *viz.* KRH –2, NSD-2, IR 72073H, and IR 69690H showed a standard heterosis of 70%, 74%, 75% and 84% respectively, at Girandurukotte. Some hybrids especially those with short maturity duration showed comparatively a location specific adaptation. This is in agreement with the results of previous observation (Abeysekera *et al.*, 1998). The five RRDI developed hybrids BgHR1 (IR 69616A/H4), BgHR3 (PMS 11A/HRSP 674), BgHR2 (PMS 11A/HRSP 668), BgHR4 (PMS 11A/H4). BgHR5 (PMS 8A/At 95-6-8) and BgHR7 (PMS 8A/H4) showed a significantly higher standard heterosis (23.8 to 45.7%) over Bg 357 at FCRDI, Mahailluppallama (table 5). Out of eight hybrids, BgHR8 (IR 62829A/HRSP 757) showed a significantly higher standard heterosis (41.7%) over Bg 357 at RRDI, Batalagoda. Thus, the performance of hybrids is generally location specific so that it is necessary to conduct multilocational yield trails to identify hybrids those having wide adaptability and those with specific adaptability to certain locations (Virmani *et al.*, 1997). Genotype by environment interaction analysis of hybrids and inbreds showed that both groups of cultivars were affected similarly and the hybrids were more widely adapted than inbred rice (Bartolome *et al.*, 1996).

Factors responsible for high yield are accounted for the increased yield obtained in hybrid rice was due to increased dry matter production resulting from higher leaf area index, crop growth index, crop growth rate, chlorophyll content, grain per panicle and per m^2, and grain weight (Ponnuthurai *et al.*, 1984, Kim 1985, Yamauchi *et al.*, 1985). Therefore, crop management in hybrid rice need to be revised especially with respect to the seedbed management and N application as compared to the crop management in inbred varieties (Yan, 1988).

Table 4. Performance of experimental rice hybrids and local and International inbred check varieties at CIC Seed Farm, Thalawa and Agriculture Research Station, Girandurukotte in 1999/2000 *maha* season

	Malwanagama		*Girandurukotte*	
Rice Hybrid/ Inbred	*Yield ($t ha^{-1}$) Over*	*Standard Heterosis Bg 357(%)*	*Yield (t/ha^{-1}) Over*	*Standard Heterosis Bg 357(%)*
IR 69689H	6.27 abc	18.30	4.95bcd	61.76
PSD-1	5.79 abcde	9.25	4.73 bcde	54.58
APHR-2	6.55 a	23.58	4.42 def	44.44
IR 72064H	5.85 abcd	10.37	4.89 bcd	59.80
IR 68284H	5.96 abcd	12.45	5.06 abcd	65.35
IR 76901H	5.73 abcd	8.11	4.92 bcd	60.78
IR 69676H	6.46 ab	22.08	5.02 abc	64.05
IR 64618H	5.51 bcde	3.96	4.10 efg	33.98
IR 72073H	6.53 ab	23.21	5.35 ab	74.83
IR 76900H	4.53 ef	-17.92	3.73 g	22.22
IR 69690H	6.47 ab	22.08	5.63 a	83.98
IR 67265H	5.53 cde	4.34	4.04 fg	32.02
IR 65487H	6.05 abcd	14.15	4.58 cdef	50.00
KRH-2	6.14 abc	15.84	5.20 abc	69.93
NSD-2	5.69 abcd	7.36	5.32 ab	73.85
COHR-2	5.41 abcde	2.08	5.01 abcd	63.73
PSBRc2	4.83 ef	-	4.11 efg	-
IR 72 (check)	5.72 abcde	-	4.39 def	-
Bg 357 (check)	5.30 bcde	-	3.06 h	-
Bg 300 (check)	3.92 f	-	3.54 gh	-
cv%	9.10			7.67

* Means in a column with the same letter are not statistically significantly different

Table 5. Performance of promising experimental rice hybrids at RRDI, Batalagoda and FCRDI, Mahailluppallama 1999/2000 *maha* season

Rice Hybrid/Inbred	*Batalagoda*		*Mahailluppallama*	
	Yield ($t ha^{-1}$)	*Standard Heterosis Over Bg 357(%)*	*Yield ($t ha^{-1}$)*	*Standard Heterosis Over Bg 357(%)*
BgHR1 (IR 69616A/H4)	*	-	6.37 a	45.77
BgHR2 (PMS 11A/IR32809-26-3-3R)	*	-	5.78 ab	32.36
BgHR3 (PMS11A/IR49615-11-3-1-1-3R)	3.36 cd	-7.87	5.96 ab	36.61
BgHR4 (PMS11A/H4)	*	-	5.58 ab	27.69
BgHR5 (PMS 8A/At 95-6-8)	*	-	5.58 ab	27.69
BgHR7 (PMS 8A/H4)	*	-	5.40 b	23.8
BgHR8 (IR 62829A/IR33507-26-2-2R)	5.13 a	41.71	*	-

Table 5. Continued				
BgHR10 (IR58025A/IR21567-18-3R)	4.14 b	14.36	*	-
BgHR11 (IR62829A/IR65515-56-1-3-19R)	4.04 b	11.60	5.18 b	18.54
BgHR12 (PMS10A/IR29341-41-1R)	4.03 b	11.33	4.36 c	-0.23
BgHR13 (IR62829A/IR46R)	3.23 de	-10.77	*	-
BgHR15 IR62829A/IR29723-143-3-2-1R)	3.04 ed	-16.02	*	-
BgHR16 (PMS 11A/At-95-6-8)	*	-	2.81 d	-35.7
Scp2/95-3350	2.85 f	-20.99	*	-
Bg357(inbred check)	3.26 c	-	4.37 c	-
cv%	4.23		8.31	

Means in a colum followed by the same letter are not significantly different
* Did not plant due to shortage of seeds

Hybrid rice seed production

Hybrid rice seed production for yield trails and multilocational trails showed a seasonal variation in seed yield from 0.75 t ha^{-1} to 1 t ha^{-1} with 25 locally adapted male sterile lines during 1999 *yala* and 99/2000 *maha* seasons at RRDI, Batalagoda. Attempts are being made to produce nuclear seeds of CMS lines by isolation free method and barrier isolation method (table 6).

Table 6. Seed yield of 17 experimental rice hybrids at RRDI 1999 yala and 1999/2000 maha seasons

Hybrid rice combination	*Seed yield kg/plot*		
	Average	*1999 yala*	*1999/2000 maha*
1. PMS 11A/IR49615-11-3-1-1-3	1.2	1.4	1.3
2. PMS 11A/96-601	1.0	1.5	1.2
3. IR 58025A/97-3272	1.1	1.3	1.2
4. PMS 8A/At 95-6-8	1.0	1.0	1.0
5. PMS 8A/H4	1.2	1.2	1.2
6. IR 62829A/IR33509-26-2-2R	1.0	1.6	1.3
7. IR 58025A/95-328	1.0	1.2	1.1
8. IR 62829A/IR29723-143-3-2-1R	1.2	1.3	1.2
9. PMS 10A/IR29341-41-1R	1.0	1.2	1.1
10. IR 62829A/Ajaya R	1.3	1.4	1.3
11. IR 62829A/IR46R	1.2	1.2	1.2
12. IR 58025A/IR55838-B2-2-3-2-3R	1.0	1.4	1.2
13. IR 62829A/IR65515-56-1-3-19R	1.4	1.3	1.3
14. IR 58025A/IR62036-222-3-3-1-2R	1.3	1.2	1.2
15. IR 58025A/IR 65515-47-2-1-1-9R	1.2	1.6	1.3
16. IR 58025A/BR 827-35-2-1-1-1R	1.3	1.4	1.3
17. IR 58025A/IR 34686-179-1-2-1R	1.4	1.2	1.3

CONCLUSION

Five hybrids developed at RRDI gave significantly high yielded over the standard inbred variety Bg 357. These hybrids had 21-48% higher standard heterosis. The hybrid seed production done under Barrier Isolation Method gave 1-0.75 t ha^{-1} yield. The results indicated a positive adoption rate for hybrid rice in Sri Lanka.

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REFERENCES

Abeysekera, S.W. M.P., Dhanapala, D.S.de Z. Abeysiriwardena. 1998. Research and Development for hybrid rice technology in Sri Lanka. In S.S.Virmani, E. A. Siddiq, and K. Muralidharan. Advances in Hybrid Rice Technology. Proceeding of the 3rd International Symposium on Hybrid Rice held in Hyderabad, India. 14-16 Nov. 1996; International Rice Research Institute. Manila, Philippines. 395-402

Bartolome, V.I., G.G. McLaren, M.A. Ynalvez, S.S.Virmani, and R.C. Chaudhary. 1996. Comparison of variability and G x E interaction in hybrid and inbred rices. Paper presented at the FCSSP, Davao City, Philippines. 13-17 May 1996;

DOASL (Department of Agriculture, Sri Lanka) 1995. Work plan for the development of rice sector in Sri Lanka.): DOASL. 19 p

Kim C.H. 1985. Studies on heterosis in F_1 rice hybrids using cytoplasmic genetic male sterile lines of hybrid rice *(Oryza sativa L.)* Crop Improve. 12(1-2): 55-59

Ponnuthurai, S., S.S.Virmani, and B.S. Vergara. 1984. Comparative studies on the growth and grain yield of some F_1 rice *(Oryza sativa L.)* hybrids. Philipp. J. Crop. Sci. 9(3): 183-193

Virmani, S. S., B.C.Viraktamath, C.L. Casal, R.S.Toledo, M.T. Lopez and J.O. Manalo. 1997. Evaluation of Experimental rice hybrids. Hybrid rice breeding manual: International Rice Research Institute. 74-72

Yamauchi, M., S. Yoshida, and S.S.Virmani. 1985. Improved leaf development of hybrid rice. Int. Rice Comm. Newsl. 34(1): 44-47

Yan. Z.D. 1998. Agronomic Management of rice hybrids compared with conventional varieties in hybrid rice. Manila, (Philippines): International Rice Research Institute. 217-223