Oryza Vol. 52 No.2, 2015 (100-104)

Effect of WA cytoplasm on yield and yield attributes of rice hybrids

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ABSTRACT

Twenty pairs of AF_1 (CMS line x restorer) and BF_1 (maintainer line x restorer) cross combinations were evaluated to assess the WA cytoplasmic influence on yield and yield traits of rice hybrids. The cytoplasmic influence for different traits was found to be cross-specific, depending on the nuclear background of CMS line and fertility restorer. Most of the traits were not significantly affected by the sterile cytoplasm in majority of the cross combinations. Only in some crosses, the cytoplasm has significant influence for the traits days to 50 per cent flowering, days to maturity, 100 grain weight and yield per plant. Male sterility inducing cytoplasm has no significant effect on plant height and effective tillers per plant.

Key words: *CMS line, maintainer, restorer, WA cytoplasm, yield traits, rice hybrids*

About half of the world's population and two third of Indians depend on rice for their survival. It is cultivated in 114 countries across the globe, but 90 percent of world's rice is grown in Asia. There is an urgent need to increase rice production to feed the ever growing population. Exploitation of heterosis in the form of hybrid rice technology has been contemplated as a potential strategy for yield enhancement in rice. The average yield of hybrid rice is at least 15-20 percent more than that of inbred rice and it has been anticipated that hybrid rice technology will play a key role in ensuring food security worldwide in the future decades (Sabar and Akhter, 2003).

Among the various approaches for hybrid breeding in rice, three-line system has become a practical option. In this system, male sterile cytoplasm has an essential role to play in hybrid development. But, it has been reported that majority of CMS sources have unfavourable effects on yield related traits and that the unfavourable effects vary among the sources of male sterility (Wang *et al.*, 1997 and Qin *et al.*, 2013). Young and Virmani (1990) observed that the male sterile cytoplasm of IR19661-283-3-2 has a significantly unfavourable effect on grain yield, while the male sterile cytoplasms of IR46828, IR46831, IR48483, IR54752, IR17492-18- 10-2-2-3, IR54753, IR19661-283-1-3-2, IR54758, and IR54756 have been found to show variable effects on the trait. Rani (2008) has reported both favourable and unfavourable effects of male sterile cytoplasm on grain yield in rice hybrids. The magnitude of effect varied, depending upon the type of sterile cytoplasm and parental combination. Moreover, among the various types of cytoplasmic male sterility, the WA system is widely used, accounting for about 90% of the rice hybrids produced in China and 100 % of the hybrids developed outside China (Sattari *et al.*, 2007). Therefore, the present investigation was carried out to study the effect of WA cytoplasm on yield and yield traits of rice hybrids.

MATERIALS AND METHODS

The present study was carried out over two seasons *viz.*, *kharif*-2012 and *kharif*-2013 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (UP). The site of study is situated at 25^0 18´ N latitude and 83^0 03´ E longitude at an elevation of 80.71 m above mean sea level.

Three cytoplasmic male sterile (or A) lines (IR-58025A, IR-68897A and Pusa 6A) having WA cytoplasm as a source of male sterility as well as their respective maintainer (or B) lines were used as female parents in crossing programme. Eight genotypes (Sanwal Basmati, Pusa Sugandh-2, Pusa Sugandh-3, Pusa Sugandh-5, Pusa 2517-2-51-1, HUR-JM-59221, Pusa-44 and Pusa Basmati-1121) identified as restorer (R) lines were used as male parents in the hybridization programme. All the genotypes (A, B and R lines) were obtained from 'All India Coordinated Rice Improvement Project (AICRIP)' at the Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.).

During *kharif*-2012, the three CMS lines were crossed with the eight identified restorers to generate the set of 20 rice hybrids. Six restorers (Sanwal Basmati, Pusa Sugandh-2, Pusa Sugandh-3, Pusa Sugandh-5, Pusa 2517-2-51-1 and HUR-JM-59221) were crossed with all the three CMS lines. Moreover, Pusa-44 and Pusa Basmati-1121 were crossed with IR-58025A and IR-68897A, respectively. Corresponding B x R crosses were produced in addition to A x R crosses. In *kharif*-2013, the seed of A x R and B x R hybrids generated during previous season were raised at a standard spacing of 20 x 15 cm in 5 m rows in randomized block design with three replications. Single seedling per hill was planted and recommended package of practices followed to raise a good crop. Data on yield and yield attributes for A x R (AF_1) and B x R (BF_1) hybrids was worked out. The cytoplasmic effect was calculated by the formula proposed by Sheng and Li (1988).

$$\text{Cytoplasmic Effect} = \frac{\overline{AF_1} - \overline{BF_1}}{\overline{BF_1}} \times 100$$

Where, $\overline{AF_1}$ and $\overline{BF_1}$ are the mean values of A x R and B x R, respectively. The statistical significance of deviation was calculated following 't' test for difference between two means from two independent samples.

$$t = \frac{\overline{X}_1 - \overline{X}_2}{[(S_1^2/r_1) + (S_2^2/r_2)]^{1/2}}$$

Where, S_1 and S_2 are the variances of mean values $\overline{X}_1$ and $\overline{X}_2$ over replications r_1 and r_2, respectively.

The calculated 't' value was compared with 't' tabulated at 0.05 and 0.01 levels of significance and appropriate degrees of freedom. The significant deviation was attributed to sterility inducing WA cytoplasm. Accordingly, the cytoplasmic effect was determined as significant or non significant for the different traits studied.

RESULTS AND DISCUSSION

The performance of AF_1 (CMS line x restorer line) hybrid is expected to be equivalent to that of cross generated by the pollination of respective maintainer line with the same restorer (BF_1). If the performance of AF_1 differs significantly from that of BF_1, it may be attributed to the sterile cytoplasm derived from the CMS line as the latter does not involve this. The mean values recorded for different yield parameters in WA based AF_1 and the respective BF_1 hybrids have been presented in Table 1, whereas the cytoplasmic influence estimated has been presented in Table 2.

For days to 50 per cent flowering, positive values of cytoplasmic effect were observed in all the 20 cross combinations; but in only six crosses, the cytoplasmic effects were found to be significant. The highest significant positive influence was noticed in IR-58025A x Pusa Sugandh-2. Four and two crosses were observed to show the significant positive effect among the cross combinations based on CMS lines IR-58025A and IR-68897A, respectively. For all the crosses based on Pusa 6A, cytoplasmic influence was observed to be non-significant. The days to maturity was observed to reveal positive estimate of cytoplasmic effect for all the cross combinations. However, 12 crosses exhibited the significant cytoplasmic influence with IR-58025A x Pusa Sugandh-2 recording the highest significant estimate. Five crosses from each of the two CMS lines IR-58025A and IR-68897A were found to show significant cytoplasmic effects, but only two hybrids from Pusa 6A based cross combinations recorded the significant value of cytoplasmic influence. Kadoo *et al.* (2002) also reported that WA cytoplasm enhanced the duration of crop in different cross combinations studied.

The negative values of cytoplasmic effect on plant height were recorded in all the 20 cross combinations. However, the cytoplasm was observed to show no significant influence on the trait in any of the crosses studied. Although, the cytoplasm was found to reveal positive influence for mean number of effective tillers per plant, the differences between AF_1

Table 1. Mean values of AF_1 (CMS line x restorer) and BF_1 (Maintainer line x restorer) for yield and yield traits

Cross combination	DTF		DTM		PH		ET/P	1	00 GW		Y/P	
	AF_1	BF_1	AF_1	BF_1	AF_1	BF_1	AF_1	BF_1	AF_1	BF_1	AF_1	BF_1
IR-58025A&B x Sanwal Basmati	95.67	92.67	123.33	120.67	119.33	120.91	10.93	10.13	2.10	2.20	26.63	28.56
IR-58025A&B x Pusa Sugandh-2	90.33	85.00	120.33	114.33	103.00	105.22	10.77	10.56	2.46	2.58	25.95	26.84
IR-58025A&B x Pusa Sugandh-3	91.67	87.67	119.00	114.67	102.32	103.58	9.13	8.80	2.43	2.49	27.90	28.27
IR-58025A&B x Pusa Sugandh-5	92.33	88.67	120.00	117.33	103.99	105.57	9.75	9.45	2.44	2.47	28.95	29.28
IR-58025A&B x Pusa 2517-2-51-1	90.67	88.33	120.33	117.33	107.67	109.89	10.28	9.83	2.51	2.60	28.34	28.89
IR-58025A&B x HUR-JM-59221	105.00	102.67	134.00	132.67	104.33	105.56	9.32	8.78	2.32	2.39	29.06	29.66
IR-58025A&B x Pusa-44	96.33	92.00	125.67	121.67	91.35	94.21	10.40	10.14	2.04	2.11	26.67	28.83
IR-68897A&B x Sanwal Basmati	95.33	93.00	124.67	123.00	116.64	118.25	12.92	12.24	2.29	2.39	28.10	29.86
IR-68897A&B x Pusa Sugandh-2	90.67	86.67	118.67	115.00	91.70	94.56	12.68	11.82	2.37	2.46	22.48	24.36
IR-68897A&B x Pusa Sugandh-3	86.33	83.67	114.00	111.67	96.17	98.77	14.36	14.21	2.42	2.50	29.48	30.06
IR-68897A&B x Pusa Sugandh-5	85.00	82.33	112.67	109.67	96.35	98.22	12.11	11.56	2.38	2.47	23.30	24.72
IR-68897A&B x Pusa 2517-2-51-1	85.33	82.00	113.00	109.67	94.34	97.56	10.92	10.41	2.41	2.48	22.74	24.44
IR-68897A&B x HUR-JM-59221	97.33	94.33	126.33	123.33	106.08	107.86	10.84	10.71	2.48	2.56	28.50	30.48
IR-68897A&B x Pusa-1121	99.33	93.67	127.67	122.00	100.04	101.80	12.37	11.83	2.38	2.48	25.54	26.93
Pusa 6A&B x Sanwal Basmati	94.00	91.33	123.00	120.67	122.00	124.56	11.39	11.25	2.06	2.15	25.42	27.50
Pusa 6A&B x Pusa Sugandh-2	90.33	87.33	120.00	117.33	102.03	104.23	9.93	9.35	2.45	2.51	28.27	29.96
Pusa 6A&B x Pusa Sugandh-3	88.00	86.67	117.67	116.33	105.33	107.89	9.30	9.16	2.55	2.61	28.14	28.55
Pusa 6A&B x Pusa Sugandh-5	92.00	89.00	120.33	117.33	100.66	102.90	11.59	11.27	2.40	2.47	21.13	22.09
Pusa 6A&B x Pusa 2517-2-51-1	91.00	88.33	120.00	117.67	103.32	107.58	11.10	10.59	2.60	2.70	28.69	29.26
Pusa 6A&B x HUR-JM-59221	101.67	98.00	129.00	126.33	117.32	120.23	9.49	9.36	2.37	2.44	24.08	25.81

[DTF= Days to 50% flowering, DTM= Days to maturity, PH= Plant height (cm), ET/P= Number of effective tillers per plant, 100 GW= 100 grain weight (g) and Y/P= Yield per plant (g)]

Table 2. Cytoplasmic effect (%) for yield and yield traits

Cross Combination	DTF	DTM	PH	ET/P	100 GW	Y/P
IR-58025A&B x Sanwal Basmati	3.24	2.21*	-1.31	7.89	-4.84	-6.76
IR-58025A&B x Pusa Sugandh-2	6.27**	5.25**	-2.11	1.96	-4.65**	-3.34
IR-58025A&B x Pusa Sugandh-3	4.56*	3.78**	-1.21	3.83	-2.28*	-1.31
IR-58025A&B x Pusa Sugandh-5	4.14*	2.27	-1.49	3.21	-1.35	-1.12
IR-58025A&B x Pusa 2517-2-51-1	2.64	2.56**	-2.02	4.65	-3.21	-1.90
IR-58025A&B x HUR-JM-59221	2.27	1.01	-1.17	6.23	-2.92	-2.00
IR-58025A&B x Pusa-44	4.71**	3.29**	-3.03	2.60	-3.31	-7.50
IR-68897A&B x Sanwal Basmati	2.51	1.36	-1.36	5.58	-4.18*	-5.91
IR-68897A&B x Pusa Sugandh-2	4.62*	3.19**	-3.02	7.25	-3.79	-7.74*
IR-68897A&B x Pusa Sugandh-3	3.19	2.09*	-2.64	1.08	-3.33*	-1.94
IR-68897A&B x Pusa Sugandh-5	3.24	2.74*	-1.91	4.76	-3.77	-5.72
IR-68897A&B x Pusa 2517-2-51-1	4.07	3.04	-3.29	4.87	-2.69	-6.97
IR-68897A&B x HUR-JM-59221	3.18	2.43**	-1.65	1.21	-2.99	-6.47
IR-68897A&B x Pusa-1121	6.05**	4.64**	-1.73	4.54	-4.16*	-5.16
Pusa 6A&B x Sanwal Basmati	2.92	1.93	-2.06	1.24	-4.19	-7.58
Pusa 6A&B x Pusa Sugandh-2	3.44	2.27*	-2.11	6.20	-2.26	-5.66
Pusa 6A&B x Pusa Sugandh-3	1.54	1.15*	-2.37	1.56	-2.17	-1.44
Pusa 6A&B x Pusa Sugandh-5	3.37	2.56	-2.17	2.84	-2.96**	-4.36
Pusa 6A&B x Pusa 2517-2-51-1	3.02	1.98	-3.96	4.82	-3.58**	-1.97
Pusa 6A&B x HUR-JM-59221	3.74	2.11	-2.42	1.32	-2.60*	-6.70

[DTF= Days to 50% flowering, DTM= Days to maturity, PH= Plant height, ET/P= Number of effective tillers per plant, 100 GW= 100 grain weight and Y/P= Yield per plant; *, ** = Significant at 0.05 and 0.01 levels, respectively]

and BF_1 were not statistically significant in any of the cross combinations. Contrary to the present findings, Kadoo *et al.* (2002) reported that WA cytoplasm has negative influence on plant height, while enhancing the number of productive tillers. Sun *et al.* (2006) observed significant negative effect of male sterile cytoplasm on plant height with insignificant effect on panicle number per plant.

Negative values of cytoplasmic effect for 100 grain weight were observed in all the 20 cross combinations, but significant effect was found for only eight crosses. The highest significant negative influence was recorded in IR-58025A x Pusa Sugandh-2. Two crosses were observed to show significant effect from IR-58025A based hybrids. Three crosses from each of CMS lines IR-58025A and IR-68897A were observed to reveal significant negative effect for the trait. For yield per plant, the negative estimate of cytoplasmic influence was observed in all the 20 hybrids; while the significant negative effect was recorded in only one cross combination (IR-68897A x Pusa Sugandh-2). Kadoo *et al.* (2002) also observed that WA cytoplasm has negative influence on test grain weight and grain yield per plant. Sun *et al.* (2006) observed insignificant effect of male sterile cytoplasm on 1000 grain weight, while the effect on grain yield per plant was reported to be significantly negative. Qin *et al.* (2013) observed that cytoplasm exerts less effect on 1000 grain weight, but showed a significant positive effect on grain yield.

To summarise the findings of present investigation, the WA cytoplasmic influence in present study for different traits was found to be cross-specific, depending on the nuclear background of CMS line and fertility restorer. Majority of the traits were not significantly affected by the sterile cytoplasm in most of the cross combinations. The cytoplasm has significant positive influence on days to 50 per cent flowering and days to maturity in some of the cross combinations. Highest average value of cytoplasmic effect for both the traits was revealed by IR-58025A, followed by IR-68897A and Pusa 6A. The traits, 100 grain weight and yield per plant were found to be negatively influenced by the sterility inducing cytoplasm. For 100 grain weight, the highest negative value of mean cytoplasmic effect was exhibited by IR-68897A, followed by IR-58025A and Pusa 6A. For yield per plant, the negative cytoplasmic effect was revealed by IR-68897A. The traits, plant height and effective tillers per plant were not significantly influenced by male sterile cytoplasm.

Both favourable and unfavourable influence of male sterile cytoplasm has been reported by various workers. The nature and magnitude of cytoplasmic effect vary with sterile cytoplasm, parental combination and trait under study. Young and Virmani (1990) reported that different male sterile cytoplasms have different effects on grain yield. It could be feasible to reduce or overcome the unfavourable effects of cytosterility by choosing appropriate parental lines (Kadoo *et al.*, 2002). Among the various types of cytoplasms, the WA and Kalinga I has been reported to show the minimum instances of unfavourable influence (Hariprasanna *et al.*, 2006). Sun *et al.* (2006) investigated the genetic effects of male sterile cytoplasms on major characters of rice hybrids and reported that effects of different sterile cytoplasms were different on different traits.

The cytoplasmic influence might be the result of specific nucleo-cytoplasmic interactions. Several rice researchers have opined for the existence of possible interaction between nuclear genome and male sterile cytoplasm for different agronomic traits. Virmani (1996) proposed that cytoplasm as well as nucleo-cytoplasmic interactions influence the heterosis for yield, yield attributes and other agronomic traits. Faiz *et al.* (2007) reported that inconsistent behaviour of the F_1 hybrids was the result of nucleo-cytoplasmic interactions rather than the negative effect of the male sterile cytoplasm itself. The development of CMS lines possessing different sources of male sterility in the same nuclear background (alloplasmic CMS lines) and crossing these with a single pollen parent will help in better evaluation of cytoplasmic as well as nucleo-cytoplasmic interaction effects.

To minimise the cytoplasmic effects, each cross combination irrespective of the cytosterile source should be evaluated and only those crosses selected where cytoplasmic influences are absent or less predominant. Thus, studies on the effect of male sterile cytoplasm in rice hybrids provide practical information for breeding CMS lines and their appropriate selection to mate with specific restorers for improvement of various traits of economic importance.

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