The Andhra Agric. J 55(4):451-455, 2008

Cytoplasmic Heterosis of Yield and Yield Components in Rice Hybrids

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ABSTRACT

Thirty- two aF_1 and thirty- two bF_1 rice hybrids were evaluated in two seasons to study the effects of wild abortive and ARC sources of male sterile cytoplasms on cytoplasmic heterosis (%) of grain yield and yield components. Four aF_1 hybrids in kharif season and eleven aF_1 hybrids in rabi season were considered to be promising as they registered >20% yield increase than their fertile counterparts. Of them APMS1A x WGL3962, IR67683A x Vajram and IR62829A x IR46 were the top three hybrids registered consistent cytoplasmic heterosis for grain yield. The results inferred that both wild abortive and ARC cytoplasms were observed to be suitable for practical breeding if judicious selection of appropriate male parent and cytoplasm combination is identified to ensure the required heterotic effect on grain yield. Significant positive cytoplasmic heterosis of yield components viz., fertile spikelets per panicle, 1000- grain weight, panicle length, ear bearing tillers per plant, and harvest index contributed towards positive cytoplasmic heterosis of grain yield of aF_1 hybrids.

Key words : aF_1 and bF_1 hybrids, ARC Cytoplasm, Cytoplasmic heterosis, Wild abortive cytoplasm.

Most of the rice hybrids developed in China and other countries mainly developed from CMS lines of wild abortive cytoplasm only. The use of single source of male sterile cytoplasm narrows the genetic base of parental lines and lead to potential risk of becoming vulnerable to any strain of disease or pest. Hence, CMS lines of diverse cytoplasm sources are to be utilized for producing rice hybrids to over come the above difficulty. A critical prerequisite for the successful production of hybrid varieties is the availability of sufficient hybrid vigor (heterosis) through specific parental combinations, so that yields of hybrids would significantly exceed better parent and standard check variety and this difference is expressed in terms of heterobeltiosis and standard heterosis, respectively. The effect of sterile cytoplasm on yield and yield components is to be expressed in terms of cytoplasmic heterosis (%). The concepts of cytoplasmic heterosis (%) always help in determining the practical value of aF_1 hybrids when compared to bF_1 hybrids.

MATERIAL AND METHODS

The present investigation was carried out to determine the cytoplasmic heterosis of grain yield and yield components of rice hybrids. Thirty-two aF_1 hybrids were produced by crossing four CMS lines viz., IR62829A (CMS-WA), IR58025A (CMS-WA), IR67683A (CMS-WA), and APMS1A (CMS-ARC) and eight tester parents viz., Swarna, Vajram, Samba Mahsuri, IR64, Prabhath, Vijetha, IR46 and WGL3962 in line x tester fashion. Four maintainer lines (IR62829B, IR58025B, IR67683B, APMS1B and IR66707B) of the above CMS lines and eight tester parents were crossed to produce thirty-two bF_1 hybrids. A total of sixty-four hybrids (32 aF_1 and 32 bF_1 hybrids) were evaluated in randomized block design with three replications at Agricultural Research Station, Maruteru, Andhra Pradesh during kharif and rabi seasons of 2004. Each treatment was planted in a single row consisting of 25 plants with single seedling per hill. The observations were recorded on days to 50% flowering, plant height (cm), ear bearing tillers per plant (EBT- no.), panicle length (cm), fertile spikelets per panicle (no.), spikelet fertility percent, 1000- grain weight (g), harvest index and grain yield per plant (g) from five randomly selected plants of aF_1 and bF_1 hybrids. The mean values of various traits were utilized for statistical analysis to determine the cytoplasmic heterosis (%).

Cytoplasmic heterosis (%) was calculated as suggested by Sheng and Li (1986) in order to determine the genetic effects of sterile cytoplasms on yield and yield components.

$$\text{Cytoplasmic Heterosis, \%} = \frac{aF_1 - bF_1}{bF_1} \times 100$$

Where, aF_1 is the mean performance of aF_1 hybrid, bF_1 is the mean performance of bF_1 hybrid.

RESULTS AND DISCUSSION

The results pertaining to cytoplasmic heterosis (%) of yield and yield components are presented in Tables 1 and 1a. The results indicated that in general sterile cytoplasm exerted more negative effects on plant height and spikelet fertility per cent, while positive effects were predominant on the traits viz., panicle length, 1000 grain weight, and harvest index when 64 crosses were evaluated in kharif and rabi seasons. Cytoplasm showed both positive and negative effects on 50 per cent flowering, ear bearing tillers per plant, fertile spikelets per panicle and grain yield per plant.Sheng and Li (1986), Young and Virmani (1990), Thyagarajan and Subramanian (1990) and Wang *et al*. (1998) also observed similar results.

The genetic effects of sterile cytoplasms vary with cytoplasmic source and cross combinations. Overall, wild abortive cytoplasm did not show much adverse effect on yield and yield components. Among 15 aF_1 hybrids with significant positive effects on grain yield per plant, majority of aF_1 hybrids in wet season (13) and dry season (14) were resulted from wild abortive cytoplasm only. In general ARC cytoplasm delayed flowering, induced tallness, reduced fertile spikelet number per panicle, harvest index and grain yield per plant of aF_1 hybrids. ARC cytoplasm however, showed positive effects on EBT per plant and 1000 grain weight. Only one hybrid, APMS1A x WGL3962 of ARC cytoplasm recorded the highest cytoplasmic heterosis for grain yield per plant in both wet and dry seasons. Cytoplasmic heterosis of grain yield per plant resulted because of positive heterosis of yield components viz., panicle length, fertile spikelets per panicle, 1000-grain weight and harvest index. This shows that the negative effect of sterile cytoplasm (CMS-ARC) was absent when the cross combination has high combining and restoring ability (WGL3962). This finding was in confirmation with the reports of Sheng and Li (1986) and Wang *et al*. (1998). The above-varied cytoplasmic effects might be resulted due to hereditary differences in cytoplasms and also due to differences in restoration ability of male parents with different CMS lines (Young and Virmani, 1990 and Wang *et al*., 1998).

The results further revealed that although three CMS lines viz., IR62829A, IR58025A and IR67683A originated from the same cytoplasmic source (CMS-WA), they exerted differential cytoplasmic heterosis (%) on various traits. Among three CMS lines, IR67683A was found to be promising as it showed significant positive cytoplasmic heterosis values for grain yield in a maximum of 13 aF_1 hybrids out of sixteen tested in both the seasons. The positive cytoplasmic heterosis of grain yield per plant resulted due to positive cytoplasmic heterosis of yield components viz., panicle length, fertile spikelets per panicle, 1000 grain weight and harvest index. The aF_1 hybrids of IR67683A flowered earlier than the respective bF_1 hybrids besides possessing high grain yield showing increase in productivity. IR62829A delayed flowering duration, while IR58025A induced early flowering when compared to bF_1 hybrids. These differences among CMS lines might be, because the nuclear genomes of female parents interacted differently with the same wild abortive cytoplasm.

Eleven aF_1 hybrids consistently showed positive cytoplasmic heterosis for grain yield per plant. Four aF_1 hybrids viz., IR62829A x IR46, IR67683A x Vajram, IR67683A x WGL3962 and APMS1A x WGL3962 in wet season and eleven aF_1 hybrids viz., IR62829A x Sambamahsuri, IR62829A x IR46, IR62829A x WGL3962, IR58025A x Sambamahsuri, IR58025A x IR64, IR58025A x Prabhath, IR67683A x Vajram, IR67683A x IR64, IR67683A x Prabhath, IR67683A x Vijetha and APMS1A x WGL3962 in dry season were found to be vigorous than their respective bF_1 hybrids as they recorded more than 20% grain yield per plant. Of the above mentioned hybrids, APMS1A x WGL3962, IR67683A x Vajram and IR62829A x IR46 were identified as the top three heterotic hybrids. The results inferred that both wild abortive and ARC cytoplasms were observed to be suitable for practical breeding if judicious selection of appropriate male parent and cytoplasm combinations are identified to ensure the required heterotic effect on grain yield as reported by Sheng and Li (1986), Zong *et al*. (1999) and Leon *et al*. (2001). Significant positive cytoplasmic heterosis of yield components viz., fertile spikelets per panicle, 1000 grain weight, panicle length, EBT per plant, and harvest index contributed towards the yield superiority in the above mentioned aF_1 hybrids as there are no separate genes for yield as it was an end product of the multiplicative interaction between the yield components.

Table 1. Cytoplasmic heterosis (%) of yield and yield components of rice hybrids

Cross	Days of 50% flowering		Plant height (cm)		EBT plant^{-1}		Panicle Length (cm)		Fertile spikelets panicle	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
IR62829A x Swarna	2.03**	1.49*	-11.53**	-12.27**	-20.83**	-17.81**	-7.38**	6.30**	-16.77**	-20.70**
IR62829A x Vajram	9.47**	6.15**	-4.97**	-8.20**	-18.33**	14.41**	-3.94	21.09**	-12.95**	38.31**
IR62829A x Sambamahsuri	5.95**	-0.39	5.03**	5.95**	-7.29	-22.19**	11.95**	15.77**	6.84**	39.16**
IR62829A x IR64	-3.61**	-2.93**	3.10**	2.72**	4.92	26.08**	-1.93	7.25**	8.75**	20.59**
IR62829A x Prabhath	1.65**	0.70	4.06**	3.69**	-13.73**	17.12**	-10.10**	1.10	-46.03**	-55.68**
IR62829A x Vijetha	3.53**	4.88**	-2.94**	-3.69**	-26.36**	-22.62**	11.55**	-1.85	-16.30**	-11.31**
IR62829A x IR46	5.94**	14.78**	-0.44	-1.08	4.23	12.00**	14.47**	5.49*	16.10**	43.11**
IR62829A x WGL3962	6.26**	10.42**	-1.49**	-4.50**	20.31**	-1.08	19.02**	5.71**	14.18**	45.25**
IR58025A x Swarna	-5.40**	2.37**	8.84**	9.41**	4.38	-16.07**	11.73**	12.21**	13.90**	30.57**
IR58025A x Vajram	1.11**	8.81**	4.23**	4.90**	16.67**	-26.84**	4.84*	-4.49*	11.78**	39.63**
IR58025A x Sambamahsuri	-1.82**	2.55**	-7.07**	-6.60**	0.00	4.92	3.27	-0.46	-7.30**	7.88**
IR58025A x IR64	-2.40**	-0.77	12.64**	13.95**	-14.06**	-6.39	-1.67	6.22**	-6.05**	27.11**
IR58025A x Prabhath	-5.71**	-8.51**	5.45**	5.68**	-10.79*	-30.30**	-0.75	2.72	-8.37**	14.06**
IR58025A x Vijetha	1.08	0.20	11.20**	14.61**	-4.53	-29.62**	3.12	-2.08	-5.90**	12.71**
IR58025A x IR46	-9.50**	-4.84**	-5.59**	-4.52**	-5.82	-22.65**	18.89**	-3.28	6.41**	28.82**
IR58025A x WGL3962	-6.97**	3.31**	-4.11**	-3.99**	-9.95*	-26.48**	-0.30	-11.55**	-14.26**	-7.20**
IR67683A x Swarna	-10.87**	-4.54**	6.43**	9.32**	6.09	-19.43**	17.06**	1.65	6.84**	-6.81**
IR67683A x Vajram	0.97	-2.20**	10.62**	12.46**	6.19	9.71*	12.39**	-0.34	9.40**	-3.38*
IR67683A x Sambamahsuri	-4.14**	-4.72**	6.38**	6.56**	5.14	11.77**	12.26**	-1.50	-1.30	-10.38*
IR67683A x IR64	3.76**	0.77	-10.61**	-10.91**	-27.84**	33.15**	13.35**	12.23**	9.25**	8.10**
IR67683A x Prabhath	-10.33**	-10.68**	-5.80**	-5.55**	-8.31	23.02**	-0.77	-4.40*	-14.84**	-28.31**
IR67683A x Vijetha	-2.78**	-0.98	7.19**	6.19**	-22.95**	-27.59**	7.56**	7.77**	5.19**	30.88**
IR67683A x IR46	1.60*	1.15	-6.50**	-6.19**	10.18*	-46.31**	-1.50	8.58**	-6.90**	-1.34
IR67683A x WGL3962	-6.12**	-3.31**	-6.12**	-4.71**	7.36	-7.20*	24.14**	6.24**	6.55**	11.11**
APMS1A x Swarna	-0.98	4.95**	-4.11**	-5.55**	21.51**	-8.21*	-15.72**	9.42**	-31.06**	-39.85**
APMS1A x Vajram	-0.23	1.61*	4.74**	2.35**	16.64**	7.90*	-10.45**	21.95**	-25.09**	-6.79*
APMS1A x Sambamahsuri	-2.04**	-1.55*	-5.15**	-4.44**	7.41*	-14.85**	15.38**	-1.57	11.45**	1.64
APMS1A x IR 64	4.69**	2.03*	-5.73**	-6.85**	44.39**	7.89**	-17.49**	-7.17**	-64.38**	-66.57**
APMS1 Ax Prabhath	-0.03	-0.82	-9.39**	-7.78**	43.31**	16.52**	-18.05**	-14.28**	-59.20**	-72.19**
APMS1A x Vijetha	-5.34**	-6.58**	-3.46**	-4.61**	25.38**	-4.08	-13.43**	11.77**	-18.21**	-21.84**
APMS1A x IR46	1.29*	3.09**	-4.06**	-3.35**	3.00	1.82	7.11**	6.33**	2.23	6.00*
APMS1A x WGL3962	5.14**	6.73**	-0.47	0.37	12.20**	-15.60**	11.78**	18.98**	66.55**	87.50**
Lsd 0.05	1.17	0.94	1.00	1.45	0.81	0.75	0.97	0.93	4.18	5.42
Lsd 0.01	1.54	1.24	1.33	1.91	1.07	0.99	1.29	1.22	5.52	7.16

Table 1a. Cytoplasmic heterosis (%) of yield and yield components of rice hybrids

Cross	Spikelet fertility (%)		1000-grain weight (g)		Harvest index		Grain yield plant^{-1} (g)	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
IR62829A x Swarna	-11.45**	-12.50**	-5.77**	-3.15**	-7.82**	-2.07	-30.78**	-41.62**
IR62829A x Vajram	-8.83**	-6.21**	16.14**	15.76**	-0.50	11.84**	-15.69**	-12.98**
IR62829A x Sambamahsuri	0.75	-0.60	11.95**	8.83**	14.02**	27.48**	9.50**	33.75**
IR62829A x IR64	-6.84**	-7.36**	-17.89**	-15.92**	0.12	16.82**	1.65	17.27**
IR62829A x Prabhath	-39.74**	-45.50**	-2.93*	-0.16	-15.13**	-16.53**	-43.77**	-26.42**
IR62829A x Vijetha	-0.41	-3.97**	-1.30	-1.99*	1.42	13.10**	-10.63**	-17.25**
IR62829A x IR46	1.47	4.68**	0.45	-1.33	3.21*	17.50**	22.43**	56.74**
IR62829A x WGL3962	-2.27	0.10	11.61**	6.39**	2.61	12.67**	14.18**	22.67**
IR58025A x Swarna	-10.06**	-12.35**	2.36	-0.93	-1.47	-0.71	18.37**	1.43
IR58025A x Vajram	-7.72**	-15.13**	4.88**	4.76**	-4.55**	6.48**	10.94**	17.20**
IR58025A x Sambamahsuri	-8.97**	-11.42**	28.19**	30.91**	-0.76	19.46**	7.70**	33.05**
IR58025A x IR64	-4.44**	-10.30**	5.50**	4.48**	-3.18*	17.95**	-24.72**	28.24**
IR58025A x Prabhath	-8.34**	-11.06**	7.60**	7.37**	-5.47**	8.78**	-15.17**	21.29**
IR58025A x Vijetha	5.48**	5.19**	10.54**	10.54**	-1.06	-1.08	-4.60**	4.69
IR58025A x IR46	4.15**	6.10**	8.06**	9.74**	4.89**	4.66**	2.45	3.88
IR58025A x WGL3962	-7.78**	-11.26**	5.01**	6.07**	-5.88**	-2.07	-4.79*	-10.31**
IR67683A x Swarna	-9.89**	-10.67**	-11.49**	-10.33**	5.23**	14.23**	11.42**	3.40
IR67683A x Vajram	2.05	1.34	-13.54**	-13.03**	9.61**	5.07**	54.26**	39.76**
IR67683A x Sambamahsuri	2.61*	2.23	2.13	0.72	4.94**	9.44**	16.24**	5.84**
IR67683A x IR64	-15.26**	-19.13**	2.44	1.64*	6.31**	2.45	8.95**	22.99**
IR67683A x Prabhath	-17.51**	-18.15**	22.06**	19.93**	5.00**	5.79**	-0.21	29.47**
IR67683A x Vijetha	-8.78**	-3.85**	2.50	1.58	9.51**	20.68**	5.71*	43.85**
IR67683A x IR46	-0.92	-2.89*	2.91*	-5.99**	-3.00*	9.01**	6.44**	4.97
IR67683A x WGL3962	-2.70*	-4.96**	14.63**	11.56**	9.78**	14.43**	49.22**	9.55**
APMS1A x Swarna	-42.52**	-39.64**	13.66**	6.17**	-15.98**	-39.95**	-30.26**	-55.95**
APMS1A x Vajram	-20.71**	-8.30**	5.54**	2.89**	-20.65**	-14.43**	-39.64**	-49.73**
APMS1A x Sambamahsuri	-10.00**	-9.00**	5.20**	2.77**	1.05	-4.38**	13.69**	-7.66**
APMS1A x IR 64	-40.23**	-48.38**	2.48*	4.40**	-21.85**	-46.04**	-54.76**	-63.76**
APMS1 Ax Prabhath	-47.05**	-47.14**	1.59	-1.20	-21.70**	-32.39**	-45.59**	-62.98**
APMS1A x Vijetha	-15.01**	-13.83**	-2.66*	-4.34**	-22.35**	-18.50**	-45.97**	-59.44**
APMS1A x IR46	-6.43**	-12.83**	-7.43**	-5.19**	-5.05**	-4.29**	-0.77	-16.67**
APMS1A x WGL3962	3.52**	-5.35**	4.51**	3.80**	20.07**	33.82**	62.12**	62.22**
Lsd 0.05	2.24	2.38	0.64	0.41	1.47	1.14	0.8	0.94
Lsd 0.01	2.95	3.14	0.85	0.54	1.95	1.5	1.06	1.24

* Significant at 5% level; ** Significant at 1% level.

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(Received on 01.02.2008 and revised on 05.07.2008)