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HETEROSIS STUDIES IN HYBRID RICE (*ORYZA SATIVA* L.) OVER LOCATIONS

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ABSTRACT

The present study was carried out to investigate the extent of standard heterosis and to identify promising hybrids with high magnitude of heterosis for yield and yield contributing traits. Fifty two hybrids were generated in line × tester mating fashion and evaluated in randomized block design along with parents and checks over locations. The assessment of heterosis showed significant results for all the traits. Eighteen hybrids exhibited significant standard heterosis for grain yield plant^{-1} and top among them were APMS 6A × MTU II-110-9-1-1-1-1, APMS 10A × MTU II-290-42-1 and APMS 9A × MTU II-143-26-2. These hybrids were also found significantly positive standard heterosis for yield components like number of panicle bearing tillers plant^{-1}, panicle length, number of filled grains panicle^{-1} and test weight. The above top performing hybrids may be used for commercial exploitation.

INTRODUCTION

Rice is one of the staple food crops in Asia and other parts of the world. In India, it is cultivated in an area of 43.97 million hectares with a production of 104.32 mt and an average productivity of 2372 kg/ha (http://agricop.nic.in/agristatics.html, 2011-12). Hybrid rice is one of the practically feasible and readily acceptable genetic options available to increase the rice production and have yield advantage of 20% over the conventional high yielding varieties (Virmani and Kumar 2004).

The success of hybrid rice programme depends upon the magnitude of heterosis which also helps in the identification of potential cross combinations to be used in the conventional breeding programme to create wide array of variability in the segregating generations (Krishna Veni and Sobha Rani, 2003). To know the potentiality of hybrids the magnitude and direction of heterosis are important (Singh *et al.,* 1995). However, for some practical importance, hybrid should be more profitable than the best available commercial variety to the farmers. Tiwari *et al.* (2011) studied the extent of heterosis in 60 hybrids generated from line x tester mating design and observed the range of standard heterosis for grain yield from 10.48% to 71.56%.

So, to increase the number of best heterotic hybrids the investigation was carried out to assess the extent of heterosis over locations in 52 hybrids developed by using CMS lines for yield and yield components.

MATERIALS AND METHODS

Four superior wild abortive based CMS lines were crossed with 13 elite indica/indica derivatives in a line x tester design (Kempthorne, 1957) during *kharif,* 2010 at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, Andhra Pradesh. The resultant 52 hybrids along with their parents and checks (*viz*., MTUHR 2089-hybrid check, MTU 1075 and MTU 1010-varietal checks) were evaluated in randomized block design with a spacing of 20 × 15 cm at four different agroclimatic zones of Andhra Pradesh *viz.,* Maruteru (Godavari zone), Warangal (Central Telangana agro-climatic zone), Jagtial (Northern Telangana agro-climatic zone) and Ragolu (North Coastal zone) locations during *rabi,* 2010-11. All the recommended practices were followed to raise and maintain healthy crop. Observations were recorded on ten randomly selected plants for days to 50% flowering, plant height, number of panicle bearing tillers plant^{-1}, panicle length, number of filled grains panicle^{-1}, spikelet fertility per cent, test weight and grain yield plant^{-1} at all locations. Data obtained from the four locations were subjected to pooled analysis of variance as per Kempthorne (1957) and standard heterosis over high yielding check MTU 1075 was computed as given by Liang *et al.* (1971) and expressed in percentage as follows:

$$\text{Standard heterosis (\%)} = \frac{\text{F1 - Mean of superior check}}{\text{Mean of superior check}} \times 100$$

RESULTS

The pooled analysis of variance over four locations revealed significant differences for environments, crosses, tester effect, line x tester effect, environment × crosses and environment × line × tester effect (Table 1). This indicated that the genotypes and environments had wide genetic diversity among themselves for all the traits. Variance of specific combining ability (*sca*) was higher than the general combining ability (*gca*) variance for yield and its contributing traits signify the predominance of non additive gene action in the inheritance of these traits. Pooled standard heterosis computed over best commercial variety MTU 1075 was presented in Table 2.

Negative heterosis is desirable for days to 50% flowering because this will make the hybrids to mature earlier as compared to parents. All hybrids recorded significant standard heterosis over standard check in desired direction and the magnitude of standard heterosis ranged from -19.22 (APMS 9A × MTU II-301-2-1) to -3.80 (APMS 10A × MTU II-290-42-1). For plant height also negative heterosis was desirable as the plant height negatively correlated with lodging resistance. The extent of heterosis over standard check for this trait was from -6.22 (APMS 6A × MTU II-301-2-1) to 24.64 (APMS 9A × MTU II-283-7-1-1) and three hybrids *viz.,* APMS 6A × MTU II-301-2-1, APMS 9A × MTU II-301-2-1 and IR 58025A × MTU II-301-2-1 exhibited significant negative standard heterosis for plant height.

The trait number of panicle bearing tillers plant^{-1} is believed to be closely associated with high grain yield plant^{-1} so, the hybrids with more number of panicle bearing tillers plant^{-1} to be identified. Significant positive standard heterosis for this trait was exhibited by fifteen hybrids and the observed range of heterosis was from -16.33 (APMS 10A × MTU II-124-41-1-1) to 30.15 (APMS 10A × MTU II-290-42-1). Superior crosses for number of panicle bearing tillers plant^{-1}were APMS 10A × MTU II-290-42-1 (30.15), APMS 6A × MTU II-110-9-1-1-1-1 (26.63) and APMS 10A × MTU 1071 (24.75).

Larger panicle length was related with high number of grains panicle^{-1} resulting in higher yield, therefore, hybrids with positive heterosis for panicle length was desirable. All the crosses showed significant positive standard heterosis for panicle length with a range from 7.01 (APMS 6A × MTU II 218-5-1) to 34.79 (APMS 10A × MTU 1071). The top performing hybrids were APMS 10A × MTU 1071 (34.79), IR 58025A × MTU II-143-26-2 (27.79) and APMS 9A × MTU II-283-7-1-1 (25.52).

Number of filled grains panicle^{-1} directly contributes to the seed yield and positive heterosis was highly desirable for this trait. In the present study, standard heterosis for this trait was from -41.45 (APMS 6A × MTU II-301-2-1) to 45.43 (APMS 9A × MTU II-283-7-1-1) and significant positive heterosis was exhibited by twenty four hybrids. The superior crosses identified among them were APMS 9A × MTU II-283-7-1-1 (45.43), APMS 9A × MTU II-110-11-1-1-1-6 (42.16) and IR 58025A × MTU II-190-1-1-1-1-1 (38.45). The extent of spikelet fertility ultimately results in increased grain yield. Most of the hybrids exhibited negative heterosis over locations and only one hybrid APMS 9A × MTU II -187-6-1-1 showed significant positive standard heterosis for spikelet fertility.

The extent of standard heterosis for the trait test weight was from -23.54 (APMS 9A x MTU II-110-11-1-1-1-6) to 13.73 (APMS 10A × MTU II-290-42-1) and only four hybrids showed significant positive heterosis. Highest standard heterosis for test weight was recorded by the hybrid APMS 10A × MTU II-290-42-1 (13.73). The grain yield plant^{-1} standard heterosis was observed from -65.92 (APMS 6A × MTU II-301-2-1) to 55.73 (APMS 6A × MTU II-110-9-1-1-1-1) and eighteen hybrids manifested significant positive standard heterosis for this trait. Superior heterotic combinations for grain yield plant^{-1} were APMS 6A × MTU II-110-9-1-1-1-1 (55.73), APMS 10A × MTU II-290-42-1 (50.26) and APMS 9A × MTU II-143-26-2 (48.88). All the superior crosses *viz.,* APMS 6A × MTU II-110-9-1-1-1-1, APMS 10A × MTU II-290-42-1 and APMS 9A × MTU II-143-26-2 expressed significant positive heterosis for number of panicle bearing tillers plant^{-1} and panicle length while APMS 6A × MTU II-110-9-1-1-1-1 and APMS 9A × MTU II-143-26-2 for filled grains panicle^{-1} and for test weight APMS 10A × MTU II-290-42-1 hybrid recorded significant positive standard heterosis.

DISCUSSION

In the present study, the pooled analysis of variance revealed significant differences for environments, crosses, tester effect,

Table 1: Analysis of variance for yield and yield contributing characters pooled over four locations in rice (*Oryza sativa* L.)

Source of variation	d.f.	Days to 50% flowering	Plant height	No. of panicle bearing tillers plant^{-1}	Panicle length	No. of filled grains panicle^{-1}	Spikelet fertility	Test weight	Grain yield plant^{-1}
Replicates	1	0.24	0.94	0.05	0.01	70.95	15.92	0.08	12.85
Environments	3	3294.71**	7412.65**	48.09**	138.29**	295301.50**	1757.91**	28.75**	7602.03**
Rep × Env.	3	0.99	1.75	0.33	0.48	167.00	2.06	0.17	0.93
Crosses	51	212.28**	492.35**	10.57**	11.47**	15921.38**	633.43**	22.70**	460.77**
Line effect (L)	3	600.71**	39.97	12.02	58.84**	23032.20*	1530.68**	149.29**	365.62
Tester effect (T)	12	540.48**	1619.58**	25.89**	20.12**	44777.81**	1803.56**	36.09**	1191.86**
Line × Tester effect	36	70.51**	154.30**	5.34**	4.64**	5710.00**	168.62**	7.69**	225.00**
Env × Crosses	153	17.72**	58.10**	1.55**	1.15**	1858.64**	31.36**	1.12**	45.83**
Env × Line effect	9	18.44	198.72**	1.99	2.62**	3557.75*	36.83	4.00**	30.61
Env × Tester effect	36	19.03	48.57	1.59	1.22	1897.54	17.72	0.97	48.07
Env × L × T effect	108	17.23**	49.56**	1.50**	1.01**	1704.08**	35.46**	0.93**	46.35**
σ^2GCA		6.66	8.84	0.19	0.45	399.58	22.16	0.85	22.33
σ^2SCA		7.33	13.09	0.48	0.50	500.74	16.65	1.23	54.85
Error	204	2.09	11.19	0.70	0.54	452.33	10.66	0.38	13.87
Total	415	57.47	141.03	2.56	3.10	5000.28	107.41	3.60	135.33

σ^2GCA = Variance of general combining ability, σ^2SCA = Variance of specific combining ability, **significant at 1% level,
* significant at 5% level, Env = environment

Table 2: Standard heterosis of hybrids for yield and yield component characters over locations (pooled) in rice (*Oryza sativa* L.)

Hybrid	Days to 50% flowering	Plant height	No. of panicle bearing tillers $plant^{-1}$	Panicle length	No. of filled grains	Spikelet fertility $panicle^{-1}$	Test weight	Grain yield $plant^{-1}$
APMS 6A × MTU 1071	-7.83**	12.00**	5.53	17.05**	7.91	-15.41**	-10.12**	-1.22
APMS 6A × MTU II 218-5-1	-19.10**	-1.57	-12.69**	7.01**	0.06	-8.68**	-11.54**	-21.32**
APMS 6A × MTU II-110-9-1-1-1-1	-8.29**	17.32**	26.63**	19.38**	25.59**	-5.74**	-16.53**	55.73**
APMS 6A × MTU II-110-11-1-1-1-6	-11.97**	7.32**	-10.55*	9.23**	21.81**	-4.85*	-9.61**	-1.10
APMS 6A × MTU II -187-6-1-1	-8.40**	10.06**	10.55*	12.66**	-9.50*	-2.25	-3.89*	36.16**
APMS 6A × MTU II-190-1-1-1-1-1	-12.89**	8.87**	-0.50	14.28**	33.29**	-8.36**	-17.67**	-6.40
APMS 6A × MTU II-143-26-2	-16.92**	15.86**	10.30 *	14.70**	8.44	-8.06**	-13.41**	36.49**
APMS 6A × MTU II-124-41-1-1	-17.03**	6.60**	-4.02	11.66**	17.61**	-3.81*	-7.82**	0.20
APMS 6A × MTU II-178-28-1-1-1	-18.07**	7.80**	-1.88	11.51**	1.19	-11.54**	-11.02**	2.57
APMS 6A × MTU II-290-42-1	-6.56**	12.03**	6.53	10.86**	9.98*	-10.95**	-19.09**	1.51
APMS 6A × MTU II-301-2-1	-17.49**	-6.22**	-2.01	11.12**	-41.45**	-56.09**	-12.59**	-65.92**
APMS 6A × MTU II-283-7-1-1	-12.31**	22.04**	5.53	17.05**	26.24**	-6.53**	-6.97**	24.91**
APMS 6A × WGL 285	-18.64**	-0.93	-13.07**	8.77**	-20.68**	-11.66**	-12.38**	0.20
APMS 9A × MTU 1071	-6.79**	7.83**	7.79	24.45**	2.85	-3.98*	-9.40**	27.27**
APMS 9A × MTU II 218-5-1	-17.38**	-1.13	-4.27	12.33**	12.55**	-2.00	-12.56**	3.63
APMS 9A × MTU II-110-9-1-1-1-1	-4.37**	11.95**	6.91	15.67**	19.22**	-3.82*	-19.40**	37.18**
APMS 9A × MTU II-110-11-1-1-1-6	-4.60**	13.23**	8.42*	19.14**	42.16**	-2.53	-23.54**	27.19**
APMS 9A × MTU II -187-6-1-1	-3.91**	8.96**	8.92*	16.93**	18.36**	4.40*	-2.89	36.69**
APMS 9A × MTU II-190-1-1-1-1-1	-4.60**	18.63**	18.84**	15.80**	18.84**	-4.12*	-21.98**	1.43
APMS 9A × MTU II-143-26-2	-7.13**	22.06**	20.35**	19.60**	19.70**	0.72	-12.74**	48.88**
APMS 9A × MTU II-124-41-1-1	-17.84**	-0.90	-4.27	9.58**	-3.95	-10.31**	-13.99**	-10.31
APMS 9A × MTU II-178-28-1-1-1	-12.66**	3.99*	-9.30*	16.74**	5.00	-8.12**	-6.81**	-0.61
APMS 9A × MTU II-290-42-1	-5.29**	12.26**	7.29	15.26**	21.41**	-1.48	-1.73	1.10
APMS 9A × MTU II-301-2-1	-19.22**	-4.53**	-3.27	11.92**	-5.21	-18.04**	-20.04**	-17.24**
APMS 9A × MTU II-283-7-1-1	-7.13**	24.64**	7.29	25.52**	45.43**	3.21	-14.91**	36.16**
APMS 9A × WGL 285	-13.58**	4.91**	-12.81**	16.70**	-10.64*	-18.85**	-18.24**	-31.23**
APMS 10A × MTU 1071	-4.83**	21.83**	24.75**	34.79**	26.30**	-12.04**	-16.14**	19.69**
APMS 10A × MTU II 218-5-1	-10.36**	-1.84	11.18**	16.16**	-21.21**	-21.81**	-0.73	-1.02
APMS 10A × MTU II-110-9-1-1-1-1	-4.60**	9.01**	16.71**	23.67**	5.65	-11.70**	-7.22**	-0.61
APMS 10A × MTU II-110-11-1-1-1-6	-5.98**	10.81**	4.94	17.11**	-1.53	-13.96**	0.73	-0.20
APMS 10A × MTU II -187-6-1-1	-5.06**	9.98**	0.00	18.62**	-5.06	-13.24**	11.09**	17.90**
APMS 10A × MTU II-190-1-1-1-1-1	-5.18**	20.11**	13.32**	23.15**	11.55**	-9.62**	-8.92**	19.32**
APMS 10A × MTU II-143-26-2	-9.90**	16.71**	19.85**	18.36**	11.31**	-10.45**	0.18	34.37**
APMS 10A × MTU II-124-41-1-1	-16.11**	2.64	-16.33**	12.42**	-0.30	-14.44**	7.26**	-18.47**
APMS 10A × MTU II-178-28-1-1-1	-12.08**	10.21**	-4.52	13.96**	-2.89	-15.84**	1.78	4.44
APMS 10A × MTU II-290-42-1	-3.80**	11.44**	30.15**	19.77**	3.74	-12.02**	13.73**	50.26**
APMS 10A × MTU II-301-2-1	-14.38**	-3.25	-5.53	12.93**	-31.87**	-41.45**	2.38	-37.14**
APMS 10A × MTU II-283-7-1-1	-8.98**	18.60**	7.54	19.76**	11.27**	-6.99**	-0.39	28.37**
APMS 10A × WGL 285	-7.83**	2.25	-11.56**	15.39**	-12.27**	-21.33**	-4.32**	-19.61**
IR 58025A × MTU 1071	-10.59**	10.50**	-5.78	19.11**	14.03**	-8.56**	-12.39**	-0.69
IR 58025A × MTU II 218-5-1	-7.36**	9.93**	-10.55*	15.35**	1.17	-5.96**	-2.59	-34.69**
IR 58025A × MTU II-110-9-1-1-1-1	-8.29**	2.28	17.84**	24.10**	20.48**	-10.72**	-17.50**	30.53**
IR 58025A × MTU II-110-11-1-1-1-6	-6.79**	14.89**	-8.79*	23.05**	19.52**	-6.82**	-8.20**	2.77
IR 58025A × MTU II -187-6-1-1	-7.59**	8.29**	-10.55*	20.60**	2.92	-8.11**	7.88**	-2.32
IR 58025A × MTU II-190-1-1-1-1-1	-8.52**	19.81**	8.17	22.56**	38.45**	-6.65**	-15.52**	34.04**
IR 58025A × MTU II-143-26-2	-11.6 **	21.32**	0.25	27.79**	17.43**	-10.45**	-4.01*	-2.61
IR 58025A × MTU II-124-41-1-1	-17.2 **	-0.97	-14.57**	17.09**	7.89	-5.73**	-4.28**	-11.09
IR 58025A × MTU II-178-28-1-1-1	-8.86**	11.72**	0.50	19.43**	14.03**	-0.37	-5.08**	-3.63
IR 58025A × MTU II-290-42-1	-10.93**	0.56	12.31**	15.51**	-0.16	-7.64**	1.23	-6.40
IR 58025A × MTU II-301-2-1	-14.04**	-4.61**	-12.06**	16.32**	-38.40**	-35.42**	-5.71**	-33.35**
IR 58025A × MTU II-283-7-1-1	-7.94**	13.69**	5.03	20.53**	6.84	-5.26**	-13.10**	-1.35
IR 58025A × WGL 285	-7.13**	4.84**	4.65	22.66**	-4.38	-17.49**	-16.64**	-1.43

**significant at 1% level *significant at 5% level

line × tester effect, environment x crosses and environment × lines × tester effect indicating wide genetic diversity among the genotypes. A comparison of the magnitude of variance components due to general combining ability (*gca*) and specific combining ability (*sca*) combined the nature of gene action in controlling the expression of the traits. Variances due *gca* and *sca* showed the importance of *sca* variance and were higher than the *gca* variance for all the traits indicating the predominance of non additive gene action for yield and its components. Similar results were also reported by Dalvi and Patel (2009), Jayasudhan and Deepaksharma (2009), Bagheri and Babaeian (2010), Kumarbabu et *al*. (2010), Saidaiah et *al*. (2011) and Bhadru et *al*. (2012) . Presence of non-additive genetic variation offers a scope of exploitation of heterosis breeding for these traits.

Heterosis refers to the increase (or) decrease in F_1 over the mean parental value. From the view point of plant breeding, increased yield of F_1 over the better (or) best commercial variety is more relevant (Virmani *et al.,* 1981). A higher yield over high yielding check varieties and wider adaptability has been instrumental in rapid spread of hybrid rice in India. The hybrids which are likely to be released for commercial scale should surpass the yield level of locally cultivated superior variety/ hybrid (Swaminathan *et al.,* 1972). Hence, in practical breeding programme standard heterosis would alone be taken into consideration for selection of hybrids. In the present investigation, considerable heterosis over standard check was observed both in positive and negative direction and the degree of heterosis varied from cross to cross and from character to character (Chaitali Sen and Singh, 2011 and Gulzar Sanghera and Waseem Hussain 2012).

Negative heterosis was desirable for the traits *viz.,* days to 50% flowering and plant height as early flowering contributed to high heterosis for grain yield. All hybrids recorded significant negative heterosis over standard check for days to 50% flowering and three hybrids *viz.,* APMS 6A × MTU II-301-2-1, APMS 9A × MTU II-301-2-1 and IR 58025A × MTU II-301-2-1 exhibited significant negative standard heterosis for plant height. Heterosis for earliness has been reported by Young Virmani (1990) and Mishra and Pandey (1998). Significant negative standard heterosis for days to 50% flowering and plant height was also indicated by Pandya and Tripati (2006), Chaudry *et al.,* (2007), Rosamma and Vijayakumar (2007), Chandirakala *et al.,* (2010), Gouri Shankar *et al.* (2010), Kumar Babu *et al.* (2010) and Tiwari *et al.* (2011).

Positive heterosis was enviable for rest of the traits *viz.,* number of panicle bearing tillers plant^{-1}, panicle length, number of filled grains panicle^{-1}, spikelet fertility per cent, test weight and grain yield plant^{-1}. Both positive and negative heterosis was recorded for all these traits and panicle length was positive for all hybrids in the study. These findings were in close agreement with the earlier findings of Rosamma and Vijayakumar (2007), Chandirakala *et al.,* (2010), Gouri Shankar *et al.* (2010), Kumar Babu *et al.* (2010), Chaitali Sen and Singh (2011) and Tiwari *et al.* (2011).

Out of 52 hybrids, 18 hybrids showed significant positive standard heterosis for grain yield plant^{-1} and the superior among them were APMS 6A × MTU II-110-9-1-1-1-1, APMS 10A × MTU II-290-42-1 and APMS 9A × MTU II-143-26-2. Yield traits *viz.,* number of panicle bearing tillers plant^{-1}, panicle length, number of filled grains panicle^{-1} exhibited significant and positive heterosis in the crosses *viz.,* APMS 6A × MTU II-110-9-1-1-1-1, APMS 10A × MTU II-290-42-1 and APMS 9A × MTU II-143-26-2 which directly contributed towards yield improvement.

Increased number of panicle length and number of filled grains panicle^{-1} were responsible for yield improvement in the crosses *viz.,* APMS 9A × MTU II-110-9-1-1-1-1 and APMS 9A × MTU II-190-1-1-1-1-1 and the cross combination APMS 9A × MTU II-190-1-1-1-1-1 also exhibited significant and positive heterosis for spikelet fertility. Hybrids are generally characterized by having larger panicle which enhances its efficiency in partitioning of assimilates to reproductive parts. This is one of the attributes of higher yields in hybrids.

Similar results of high yields of hybrids mainly due to increased yield contributing traits *viz.,* number of panicle bearing tillers plant^{-1}, panicle length, number of filled grains panicle^{-1} and spikelet fertility were reported by of Rosamma and Vijayakumar (2007), Chandirakala *et al.,* (2010), Gouri Shankar *et al.* (2010), Kumar Babu *et al.* (2010) and Tiwari *et al.* (2011).

Thus, the yield contributing characters helped the hybrids to get higher heterosis for grain yield. The promising hybrids identified *viz.,* APMS 6A × MTU II-110-9-1-1-1-1, APMS 10A × MTU II-290-42-1 and APMS 9A × MTU II-143-26-2 might be used for commercial cultivation under coastal irrigated ecosystem.

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