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Heterosis and Combining Ability Studies for Yield and Yield Component Traits in Rice (*Oryza sativa* L.)

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ABSTRACT

The present investigation was carried during *Kharif* 2015-16 at Agricultural College Farm, Bapatla to estimate the combining ability and to determine the nature and magnitude of heterosis for yield and yield component traits in rice. The experimental material consisted of 21 hybrids produced by crossing three cytoplasmic male sterile lines with seven elite testers in Line x Tester design. The magnitude of combining ability revealed both additive and non-additive gene action were found to control the expression of the traits under study, however non-additive genetic variance was higher than the additive variance for all the studied traits except for test weight. Among parents, CMS line IR 58025A and testers NLR 33654, NLR 3083 were found to be promising good general combiners for grain yield plant^{-1} and other traits. Three crosses were found to be desirable for grain yield plant^{-1} where in the cross IR 58025A x NLR 33057 recorded significant *sca* effects for majority of the characters *viz.*, days to 50% flowering, days to maturity, plant height, number of productive tillers plant^{-1}, number of filled grains panicle^{-1} and grain yield plant^{-1}.None of the hybrids recorded significant *sca* effects for all the eight characters.

Introduction

Rice has been one of the world's most important food crops, feeding more than half of the world's population (Khush, 1997). In Asia and Pacific region, rice is the main staple food and the most important source of employment and income for rural people.

The rice productivity has reached a plateau so it is thus imperative to find alternative means for increasing the yield potential of rice cultivars in a sustainable manner. Of the various approaches contemplated to break the existing yield barriers in rice, hybrid rice technology offers an opportunity to boost the yield of rice under fragile conditions as hybrid rice varieties have a yield advantage of 15-20% over the conventional high yielding varieties (Virmani *et al.*, 1996). Breeding strategies for developing hybrids with high yield potential and better grain quality require the expected level of heterosis and combining ability. Knowledge of combining ability and heterosis helps in the selection of appropriate parents for a hybridization programme for evolving elite segregants with high grain yield in the segregating generations. Heterosis breeding is an important tool which can facilitate yield enhancement and helps enrich many other desirable quantitative traits in rice In order to exploit maximum heterosis using the CMS system in a hybrid programme, one must know the combining ability of different male sterile lines and testers. The knowledge of combining ability allows the assessment of nicking ability among genotypes and understanding the nature and magnitude of gene actions involved. Its role is important to decide parents, crosses and appropriate breeding procedures to be followed to select desirable segregants.

Materials and Methods

A field experiment was conducted at Agricultural College Farm, Bapatla during *Kharif* 2015-16 with 21 hybrids generated from crossing three lines (IR 58025A, IR 68888A and IR 68897A) and seven testers (NLR 40065, NLR 33564, NLR 33057, NLR 3083, NLR 3042, NLR 3449 and WGL 44) in L x T fashion along with ten parents and two checks DRRH 2 (hybrid) and MTU 1010 (varietal check) in a randomized block design with two replications. One month old seedlings were transplanted in thoroughly puddled main field with a spacing of 20 x 15 cm. All necessary precautions were taken to maintain uniform plant population in each treatment per replication. Observations were recorded on 10 randomly selected plants from each cross for eight metric traits *viz.*, plant height (cm), number of productive tillers per plant, panicle length (cm), number of filled grains panicle^{-1}, test weight (g), grain yield plant^{-1} (g) in each replication. Days to 50% flowering and days to maturity were recorded on plot basis. Heterosis was estimated over better parent and standard check and tested for significance as suggested by Snedecor and Cochran (1967) and combining ability analysis was computed using Line x Tester design according to Kempthorne (1957).

Results and Discussion

The analysis of variance for combining ability revealed highly significant differences among the crosses with respect to all the characters studied (Table 1). The ratio of GCA and SCA variance was less than unity for all the characters except for test weight indicated preponderance of non-additive gene action for majority of characters. These results are in concordance with Savita *et al.,* (2015) for Days to 50% flowering, Sateeshkumar and Sarvanan (2013) for Days to Maturity, Sathya and Jebaraj (2015) for plant height, Savita *et al.,* (2015) for number of productive tillers plant^{-1}, Kishor *et al.,* (2017) for panicle length, Ali *et al.,* (2014) for number of filled grains panicle^{-1}, Devi *et al.,* (2017) for grain yield plant^{-1}. Additive gene action for test weight had been reported by Ali *et al.,* (2014). The presence of greater magnitude of non-additive gene action offers scope for exploiting hybrid vigour through heterosis breeding.

The estimates of *gca* effects of parents showed that IR 58025A and testers NLR 33654, NLR 3083 were found to be promising good general combiners for grain yield plant^{-1} and other yield component traits. The line IR 58025A recorded significant *gca* effects in desirable direction for grain yield plant^{-1} and line IR 68897A recorded significant *gca* effects in desirable direction for characters like days to 50% flowering, days to maturity, number of productive tillers plant^{-1} and test weight while the tester NLR 33654 recorded significant *gca* effects in desirable direction for majority of the characters *viz.*, days to maturity, plant height, productive tillers plant^{-1}, panicle length, filled grains panicle^{-1} and grain yield plant^{-1}.

Evaluation of hybrids based on *sca* effects

The second important criterion for the evaluation of hybrids is the specific combining ability effects which could be related with hybrid vigour. The *sca* effects signify the role of non-additive gene action in trait expression. According to Ping and Virmani (1990), *sca* effects are the index to determine the usefulness of a particular cross combination for exploitation of heterosis. Out of 21 crosses the cross IR 58025A x NLR 33057 recorded significant *sca* effects for majority of the characters *viz.*, days to 50% flowering, days to maturity, plant height, number of productive tillers plant^{-1}, number of filled grains panicle^{-1} and grain yield plant^{-1}.Ranking of parents with respect to general combining ability effects for grain yield and yield component characters in addition to number of hybrids exhibiting significant and desirable *sca* effects for the different traits shown in Table 2. The negative estimates of *sca* effects are desirable for earliness and medium dwarf plant height. Five hybrids *viz.*IR 58025A x NLR 40065(3.29**), IR 68888A x NLR 33654 (3.34**), IR 68897A x NLR 33654 (5.90**), IR 58025A x NLR 33057 (7.51**) and IR 58025A x NLR 3042 (4.68**) showed significant *sca* effects for grain yield plant^{-1}. Similarly 8 hybrids for Days to 50% flowering, 5 hybrids for days to maturity, 4 hybrids for number of productive tillers plant$^{-1,}$ 6 hybrids each for traits filled grains plant^{-1} and test weight and single hybrid each for traits plant height IR 58025A x NLR 33057(-6.08**) and panicle length IR 68897A x NLR 3042 (0.99*) showed significant *sca* effects in desirable direction. Predominance of non-additive gene action for grain yield and its components was also reported by Dalvi and Patel (2009), Saidaiah *et al.,* (2011) and Tiwari *et al.*, (2011).

A hybrid is commercially valuable only when it exhibits significantly high standard heterosis over the best locally adopted variety or hybrid. Biju *et al.,* (2006), reported the presence of exploitable level of heterosis is yet another pre - requisite for the success of hybrid breeding and is recognized as the genetic tool in yield ceiling areas where yields have already approached their potential. In the present study, the hybrids were evaluated based on the two types of heterosis *i.e.* Heterobeltiosis (over better parent) and Standard heterosis (Over hybrid check DRRH2). The range of heterosis, number of desirable heterotic hybrids and best hybrid combination for each trait were depicted in Table 3.

No desirable heterotichybrid was found for the trait panicle length for both heterobeltiosis and standard heterosis. Similar result reported by Krishna *et al.*, (2011) and Singh *et al.*, (2015) respectively. For the trait grain yield plant^{-1} 3 hybrids were found to be desirable for standard heterosis showing a range of -77.27 to 59.44. None of the hybrid was found to be desirable for trait grain yield per plant for heterobeltiosis.

High *sca* effects alone may not be the appropriate choice for heterosis exploitation because hybrids with low mean values may also possess high *sca* effects. Further, heterosis value alone may also mislead the identity of superior hybrids. Exploitation of hybrids for heterosis breeding is best judged by *per se*, *sca* effects and magnitude of heterosis, characteristics of parents with regards to *gca* effects for grain yield plant^{-1} and component characters (Table 4). Based on these criteria the hybrids IR 68897A x NLR 33654, IR 58025A x NLR 33057, IR 68888A x NLR 33654 and IR 68897A x NLR 3083 were found to be suitable for heterosis breeding.

Considering the hybrid IR 68897A x NLR 3083 showing non-significant *sca* effect with favourable *gca* effects of parents is suitable for recombination breeding to get desirable segregants in early segregating generations for yield attributes. These results are in support with findings of Sheeba *et al.,* (2010) and Sathya and Jebaraj (2015).

Table.1 Analysis of variance for combining ability for yield and yield component traits in rice hybrids (*Oryza sativa* L.)

Source of variation	d.f	Days to 50% Flowering	Days to maturity	Plant Height (cm)	Number of Productive tillers plant^{-1}	Panicle length (cm)	Number of Filled grains panicle^{-1} (g)	Test weight (g)	Grain yield plant^{-1} (g)
Replication	1	0.095	1.52	0.02	0.30	0.10	1.30	0.09	0.16
Treatments	30	92.84**	50.86**	156.13**	7.20**	3.86**	1355.95**	12.71**	79.00**
Parents	9	84.13**	76.71**	316.09**	8.75**	9.44**	1943.85**	21.16**	139.21**
Parents *vs*Crosses	1	320.88**	196.37**	1023.55**	0.66	2.72*	14.61	6.89**	34.61**
Crosses	20	85.36**	31.95**	40.78**	6.84**	1.40**	1158.46**	9.19**	54.13**
Lines	2	77.16**	70.16**	156.68**	4.58*	2.54**	157.12*	11.23**	0.06
Testers	6	33.11**	35.28**	320.34**	10.25**	13.31**	2738.68**	23.00**	31.35**
Lines *vs*testers	1	404.15**	338.40**	609.46**	8.12*	0.03	748.26**	30.01**	1064.66**
Error	30	1.09	1.02	4.19	0.58	0.25	5.67	0.11	1.36
σ^2 GCA		12.06	4.59	4.93	0.83	0.10	81.23	1.85	3.42
σ^2SCA		36.89	10.78	7.53	2.85	0.33	543.09	1.55	28.26
σ^2 GCA/SCA		0.32	0.42	0.65	0.29	0.30	0.14	1.19	0.12

Table.2 Ranking of parents with respect to general combining ability effects for grain yield and yield components characters in addition to number of hybrids exhibiting significant and desirable *sca* effects for the different traits in rice

S No	TRAITS	IR 58025A	IR 68888A	IR 68897A	NLR 40065	NLR 33654	NLR 33057	NLR30 83	NLR34 49	NLR 3042	WGL 44	No. of hybrids with significant *sca* effects
1	DFF	Low	Low	High	Low	Low	High	Low	High	High	High	8
2	DM	Low	Low	High	Low	Low	High	Low	Low	High	High	5
3	PH	Low	Low	Low	Low	Low	Low	Low	High	High	High	1
4	EBT	Low	Low	High	Low	High	Low	High	Low	Low	High	5
5	PL	Low	Low	Low	Low	High	High	Low	Low	Low	Low	1
6	FGP	Low	Low	Low	Low	High	Low	Low	High	Low	Low	6
7	TW	Low	Low	High	Low	Low	High	High	Low	Low	High	5
8	GYP	High	Low	Low	Low	High	Low	High	Low	Low	Low	5

DFF= Days to 50% flowering, DM= Days to maturity, Plant Height, EBT= Number of Productive tillers per plant, PL= Panicle length, FGP= Number of Filled grains per panicle, TW= Test weight, GYP= Grain Yield Plant^{-1}

Table.3 Heterobeltiosis and Standard heterosis for grain yield and yield component characters in Rice

S No.	Character	Heterobeltiosis			Standard heterosis		
		Range	No. of desirable heterotic hybrids	Best hybrid combination	Range	No. of desirable heterotic hybrids	Best hybrid combination
1	DFF	-18.36 to 6.81	18	IR 68897A x NLR 3083	-11.05 to 12.71	17	IR 68888A x NLR 33057
2	DM	-11.15 to -2.3	18	IR 68897A x NLR 3083	-10.71 to-4.37	17	IR 68897A x NLR 3042
3	PH	-27.95 to 6.46	18	IR 58025A x NLR 33057	-23.10 to -6.81	21	IR 68888A x NLR 3449
4	EBT	-31.46 to 19.75	4	IR 58025A x NLR 33057	-25 to 23.91	4	IR 68897A x NLR 33654
5	PL	-14.44 to-5.93	0	0	-13.81 to -6.5	0	-
6	FGP	-40.80 to 54.71	6	IR 68897A x NLR 33654	-24.83 to 69.03	15	IR 68897A x NLR 33654
7	TW	-29.96 to 10.28	1	IR 68888A x NLR 3083	-20.30 to 21.95	8	IR 68897A x WGL 44
8	GYP	-81.53 to -11.14	0	0	-77.27 to 59.44	3	IR 68897A x NLR 33654

DFF= Days to 50% flowering, DM= Days to maturity, Plant Height, EBT= Number of Productive tillers per plant, PL= Panicle length, FGP= Number of Filled grains per panicle, TW= Test weight, GYP= Grain Yield Plant^{-1}

Table.4 Details of the promising hybrids identified for grain yield per plant in rice

Cross combination	*Per se* performance	Heterobeltiosis	Standard heterosis (DRRH2)	*sca* effect	Characteristics of parents with regards to *gca* effects	Desirable *per se* heterosis and *sca* effects for yield component characters
IR 68897A x NLR 33654	22.80	3.64	59.44**	5.90**	L x H	Number of Productive tillers plant^{-1}, Number of filled grains panicle^{-1}
IR 58025A x NLR 33057	20.80	3.48	45.45**	7.51**	H x L	Days to 50% flowering, Days to maturity, Plant Height, Number of filled grains panicle^{-1}
IR 68888A x NLR 33654	19.55	-11.14*	36.71**	3.34**	L x H	Days to 50% flowering, Days to maturity
IR 68897A x NLR 3083	17.50	-17.84**	22.38**	2.73	L x H	Days to 50% flowering, Days to maturity

In the crosses showing high SCA effects due to high × low general combiners, simple pedigree breeding would not be effective to improve the characters. Population improvement *i.e.* mass selection with concurrent random mating in early segregating generations could be a perspective breeding procedure for yield improvement in rice.

The GCA and SCA results indicated importance of both additive and dominance genetic components in the inheritance. The lines IR 58025A and IR 68897A and tester NLR 33654 recorded significant *gca* effects in desirable direction for majority of the characters. Therefore these genotypes can be utilized in improvement of the respective traits in any breeding programme. Due to good combining ability these genotypes can also be utilized straightaway as parents for production of good hybrids by crossing with other divergent lines.

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