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Combining ability analysis for grain yield and yield contributing characters in rice (*Oryza sativa* L.)

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ABSTRACT: Identification of heterotic parents is prerequisite in hybrid breeding. Combining ability analysis is useful in selecting the parents and desirable cross combinations to be used in any breeding programme to produce superior hybrid. Four identified maintainers (Kanchana, Jyothi, Aruna and Bharathy) and 11 restorers (Remya, Jayathi, Swarnaprabha, Manupriya, Annapoorna, Kanakom, Mattatriveni, Varsha, Aiswarya, Neeraja and Pavizham) were crossed in L × T fashion and combining ability of parental lines were carried out in F_1 generation. The GCA variances were significant for plant height, days to maturity, number of spikelet/panicle and number of grain/panicle indicating operation of additive gene action. On the other hand, SCA variances were highly significant for all characters except for total number of tillers, number of productive tillers and grain length/breadth ratio indicating the predominance of non-additive gene action. In order to assess heterosis in different combination of the identified maintainers and restorers an L × T analysis was done with maintainers as the lines and restorers as the testers. Perusal of findings indicated that line Jyothi is a good general combiner as it recorded a high over all GCA status. The hybrid Aruna × Varsha was the best specific combiner followed by, Jyothi × Pavizham and Kanchana × Mattatriveni. Three crosses *viz*; Aruna × Varsha, Jyothi × Pavizham and Bharathy × Annapoorna registered high significant heterosis for grain yield per plant over midparent, better parent and standard check Uma.

Keywords: GCA, CSA, Line, Tester, Hybrid.

INTRODUCTION

The concept of combining ability is a landmark in the hybridization programme. Knowledge on the nicking ability of genotypes in hybrid combination is of paramount importance, since the combining ability of parents and hybrids does not always depend on the *per* se performance. The Line × Tester analysis gives reliable information about the nature and magnitude of gene action and combining ability effects present in the genetic material. Combining ability analysis is useful in selecting the parents and desirable cross combinations to be used in any breeding programme to produce superior hybrid and also assist in formulation of a time bound breeding programme for genetic enhancement of yield and its contributing characters. It also gives an idea about the relative magnitude of additive and non-additive types of gene actions in the expression of a trait. The potentiality of a strain to be used as a parent in hybridization, or in a cross to be used as a commercial hybrid, may be judged by comparing the *per* se performance of the parents, the F_1 value (heterosis) and the combining ability effects (Venkateshwaralu and Singh 1982). Considering theses fact present investigation was therefore undertaken to study combining ability effects of 15 parent and their 44 crosses od rice for yield and its component traits.

MATERIALS AND METHODS

Present study includes 15 parents and their 44 crosses. All the parent and their crosses were raised in Randomized block design with three replications. Rice seeds were first raised in seedling nursery followed by 25 days old seedlings were transplant in the main field. Observation was recorded on 12 quantitative characters on five random plants in each replication. and replication were subjected to line × tester analysis as suggested by Kempthorne (1957) which is based on fixed effect model.

Table 1: List of parents and quantitative parameters.

Genotypes	Parameters
Kanchana, Aruna, Jyothi, Bhartahy, Remya, Jayathi, Swarnaprabha, Manupriya, Annapoorna, Kanakom, Varsha, Mattatriveni, Neeraja, Aishwarya, Pavizham.	Plant height, Total number of tillers/plants, Days to flowering, Number of productive tillers/plants, Panicle length, Pollen fertility %, Number of spikelet/panicles, Number of filled grain/panicle, Days to maturity, Length-breadth ratio, Number of grain/panicles, Grain yield/plant.

RESULT AND DISCUSSION

Analysis of variance (ANOVA)

The analysis of variance due to different sources for twelve characters studied *viz.*, plant height, days to flowering, total number of tillers, number of productive tillers, pollen fertility, days to maturity, number of spikelets/panicle, number of filled grains/panicle, number of grains/panicle, panicle length, length and breadth ratio and yield/plant.

The ANOVA indicated that, there is no significance difference among replications except for two characters viz; days to flowering and length and breadth ratio. The differences among the genotypes were highly significant for all the characters based on their mean sum of square values and the difference among the parents was highly significant for all the traits. Highly significant difference was found between Crosses, Tester and Line × Tester for all characters and significant difference was found between Lines except for Plant height. Highly significant difference also found among Parent vs Crosses for all characters.

General combining ability effects (*gca*)

gca effect was analyzed for all the 12 traits related to the yield among all the four lines and eleven testers revealed that most of the genotypes showed significant GCA effect for most of the traits. The results are presented in the Table 2.

Increased plant height is considered as having negative correlation with the high yielding trait in rice. Highest significant negative *gca* effect was recorded for Pavizham (-13.290) followed by the lines Neeraja (-8.249), jyothi (-4.372). However, high significant positive *gca* effect showed by the line Jayathi (14.932). Among the four lines evaluated, the line Kanchana (-3.515) exhibited highly significant *gca* effect in negative direction followed by Aruna (-0.484). While Bharathy (4.212) exhibited positive *gca* effect. In the testers, three testers exhibited highly significant negative GCA effects. Low *gca* effect for this trait is recorded by the testers Manupriya (-4.022) and Kanakom (-1.772). Four testers showed significant positive *gca* effect with Neeraja being highest with GCA effect (6.810) followed by Aiswarya (4.227), Pavizham (0.810) and Remya (0.5606).

Only two lines Jyothi (0.678) and Kanchana (0.137) expressed highly significant positive *gca* effect for the character total number of tillers and remaining two lines *viz;* Bharathy (-0.557) and Aruna (-0.258) showed significant negative *gca*. Among testers, Varsha (1.179), Swarnaprabha (1.047), Jayathi (0.926) and Neeraja (0.714) showed highly significant positive *gca* effect. Testers Mattatriveni (-1.431), Aiswarya (-1.366), Manupriya (-0.941), Annapoorna (-0.416) showed highly significant negative *gca* effect. Highly significant positive *gca* effect for number of productive tillers was expressed only by line Jyothi (1.664). While Bharathy (-1.145) and Kanchana (-0.389) showed negative *gca* effect. Among ten testers, only Neeraja (1.775), Swarnaprabha (1.6708), Jayathi (0.682), Pavizham (0.338) and Varsha (0.244) showed significant positive *gca* effect for this trait and remaining testers Aiswarya (-2.296), Manupriya (-1.296) and Mattatriveni (-0.980) showed significant negative *gca* effect.

Significant positive *gca* effect were observed for the line Kanchana (0.689) and Bharathy (0.416) where as significant negative effect for Aruna (-0.583) and Jyothi (-0.522) for the character pollen fertility. In the testers, five testers exhibited highly significant positive *gca* effect with Pavizham (2.113) being the highest followed by Annapoorna (1.863), Jayathi (0.947), Remya (0.863) and Neeraja (0.863). Three testers Mttatriveni (-3.219), Aiswarya (-2.303) and Kanakom (-1.63) showed significant negative *gca* effect. Remaining 3 testers showed non-significant *gca* effect for pollen fertility.

Highly significant negative *gca* effect was expressed by lines Kanchana (-2.891) and Jyothi (-0.917) for the character days to maturity. Remaining three lines showed significant positive effect. Among eleven, five testers *viz*; Manupriya (-3.742), Mattatriveni (-3.250), Annapoorrna (-2.977), Kanakom (0.780) and Swarnaprabha (-0.730) showed significant negative *gca* effect reamaing all testers showed significant positive effect.

With respect to number of spikelet's per panicle Jyothi (6.328) exhibited highest significant positive *gca* effect followed by Bharathy (4.886), whereas significant negative GCA effect was observed in Kanchana (-5.908) and Aruna (-5.307). Among the testers the highest significant positive *gca* effect was observed for Neeraja (19.367) followed by Swarnaprabha (13.742), Jayathi (11.309), Varsha (4.759), Pavizham (3.760), Annapoorna (3.600) and Remya (2.966), whereas significant negative *gca* effect were observed for Mattatriveni (-30.812) followed by Aiswarya (-14.364), Kanakom (-11.941) and Manupriya (-2.388).

Two lines Jyothi (5.061) and Bharathy (1.811) showed significant positive *gca* effect, whereas lines Kanchana (-6.298) and Aruna (-0.573) exhibited significant negative *gca* effect for number of filled grain per plant. In the testers, highest significant positive *gca* was reported for Neeraja (14.045) followed by Swarnaprabha (11.926), Jayathi (8.373), Varsha (4.639), Remya (3.656), Annapoorna (3.098) and Pavizham (1.800). While highest significant negative *gca* effect exhibited by Mattatriveni (-18.836) followed by Aiswarya (-17.834) and Varsha (-11.099). Tester Manupriya did not show any significant effect.

The line that produced highest positive *gca* effect for number of grains per panicle was Jyothi (17.270) followed by Bharathy (15.828). Line Kanchana (-19.412) produced the highest negative *gca* followed by Aruna (-13.687). Tester Mattatriveni (1.897) exhibit the highest positive *gca* effect followed by Pavizham (1.477), Jayathi (1.301) and Aiswarya (0.922). While tester Manupriya (-1.773) produced the highest significant negative *gca* effect followed by Neeraja (-1.603) and Swarnaprabha (-0.978). Tester Remya, Annapoorna, Kanakom and Varsha showed non-significant effect for this trait.

General combining ability effects for grain length and breadth ratio was highly significant in all the lines and testers. Lines Aruna (0.1745) and Bharathy (0.0172) produced positive significant effect whereas Kanchana

(-0.0870) and Jyothi (-0.1046) produced negative significant effect. Among eleven testers, Neeraja (0.553), Annapoorna (0.255), Remya (0.104), Swarnaprabha (0.092), Mattatrivei (0.059), Aiswarya (0.052) andManupriya (0.031) manifested positive significant effect. While Pavizham (-0.622), Kanakom (-0.247), Jayathi (-0.142) and Varsha (-0.137) manifested significant negative effect. Among all the line one line, Jyothi (1.910) showed highly significant positive *gca* effect, whereas significant negative *gca* effect was observed in Kanchana (-1.276) followed by Bharathy (-0.547) and Aruna (-0.086). Among the testers, Neeraja (2.668) manifested the highest positive significant *gca* effect followed by swarnaprabha (1.685), Annapoorna (1.142), Jayathi (0.817) and Varsha (0.372). While testers Aiswarya (-2.607), Mattatriveni (-2.562), Kanakom (-0.440), Manupriya and Remya (-0.148) showed significant negative *gca* effect.

Overall GCA status of parents

Yield is considered as a complex character dependent on interaction effect of a number of component traits. So, in order to achieve improvement in yield levels it is first necessary to bring improvement in the yield influencing traits. Therefore, it becomes very important to develop a system of working out pooled scores of GCA by utilizing the actual GCA values and also ensuring quantification of differences in GCA effects among parental genotypes. In the Simple pooled GCA method, parents with significant *gca* effect in desired direction is given score of +1 and –1 score to parents with significant GCA in undesirable direction (Arunachalam and Bandyopadhyay 1979). These values are added over different yield attributing traits to arrive at pooled score of *gca* effects.

The estimates of overall GCA status of parents (Table 3) revealed that, the testers Remya, Jayathi, Swarnaprabha, Annapoorna, Varsha, Neeraja and Pavizhamhad high overall GCA status. This result indicates that in general Remya, Jayathi, Swarnaprabha, Annapoorna, Varsha, Neeraja and Pavizham were good general combiners. Similarly, among lines Jyothi was identified as good combiner. The results implies that four lines and two testers studied were high combiners across all the traits, indicating their ability in transmitting additive genes in the desirable direction to their progenies. Further, these lines and testers may be further evaluated for the confirmation of their superiority as good parents for hybridization.

Specific Combining Ability Effect

Specific combining ability effect of a cross is the estimation and the understanding of the effect of non-additive gene action for a trait. Non-additive gene action of a trait is an indicator for successful hybrid breeding program. The results of *sca* effect of 44 hybrids of the present study are given in the Table 4.

The crosses Jyothi × Kanakom (-16.103), Kanchana × Pavizham (-12.947), Bharathy × Neeraja (-12.168) exhibited highly significant negative sca effects, while the hybrid combination Jyothi × Pavizham (12.415) and Jyothi × Varsha (10.571) exhibited highest significant positive *sca* effect for plant height. Among the 44 hybrids, the hybrid Kanchana × Mattatriveni (-4.651) had registered highly significant negative *sca* effect for days to flowering followed by Jyothi × Remya (-3.954), Jyothi × Pavizham (-3.871), Aruna × aiswarya (-3.681), Jyothi × Annapoorna (-3.204) and Aruna × Mattatriveni (-3.015). While, the hybrid Jyothi × Swarnaprabha (5.878) registered the higher significant positive *sca* effects followed by Kanchana × Annapoorna (5.431), Aruna × Pavizham (5.401) and Jyothi × Mattatriveni (4.378). The crosses Aruna × Varsha (2.860), Kanchana × Mattatriveni (2.742), Bharathy × Jayathi (1.812) and Jyothi × Pavizham (1.606) showed high significant positive *sca* effects for total number of tillers. Highest negative *sca* effect for this trait was observed in crosses Kanchana × Pavizham (-2.473), Arunam × Mattatriveni (-2.420) and Bharathy × Varsha (-2.172).

Number of productive tillers showed highest specific combining ability effect in the cross combination Aruna × Varsha (3.546) followed by the crosses Kanchana × Annapoorna (2.791) and Jyothi × Mattatriveni (2.311). However, highest significant negative *sca* effect was observed for the cross combination viz; Kanchana × Pavizham (-2.400), Kanchana × Varsha (-1.972) and Bharathy × Kanakom (-1.811).with respect to pollen fertility the cross combination Bharathy × Mattatriveni (4.583) and Aruna × Varsha (4.583) exhibited high significant positive *sca* effect for this trait followed by Bharathy × Jayathi (3.416), Kanchana × Annapoorna (2.893), Jyothi × Kanakom (2.272), Bharathy × Pavizham (2.416) and Jyothi × Swarnaprabha (2.022). Whereas, the crosses Aruna × Mattatriveni (-7.083), Kanchana × Varsha (-4.356), Kanchana × Aiswarya (-3.272), Jyothi × Jayathi (-3.643) and Bharathy × Kanakom (-3.000) expressed highly significant negative *sca* effect, whereas days to maturitywas found to have negatively significant scavalue for 16 cross combinations. Hybrid Bharathy × Kanakom (-3.555) had highest significant negative *sca* effect followed by Bharathy × Jayathi (-3.261), Jyothi × Varsha (-2.852), Jothi × Manupriya (-2.741), Aruna × Aiswarya (-2.675) and Bharathy × Manupriya (-2.636). Significant positive *sca* effect for this trait was observed in 19 hybrids.

The cross-combination Kanchana × Mattatriveni (27.834) exhibited high significant positive *sca* effect for no of filled garin followed by Aruna × Varsha (18.287), Jyothi × Kanakom (16.980), Bharathy × Kanakom (16.520) and Bharathy × Annapoorna (15.642). Highest significant negative *sca* effect was observed in cross combination Aruna × Kanakom (-47.461) followed by Jyothi × Mattatriveni (-43.245). Kanchana × Aiswarya (-30.221) and Bharathy × Varsha (-17.621). Almost all the cross combination showed significant *sca* effect for panicle length. The crosses Aruna × Varsha (4.162), Aruna × Swarnaprabha (2.798), Bharathy × Mattatriveni (2.538), Jyothi × Pavizham (2.442), Jyothi × Remya (2.344) and Bharathy × Manupriya (2.169) showed high positive significant *sca* effect. Highest significant negative effect was observed for cross Bharathy × Varsha (-2.883) followed by Kanchana × Pavizham (-2.695), Jyothi × Mattatriveni (-2.565), Aruna × Manupriya (-2.287) and Bharathy × Swarnaprabha (-2.037). in case

of grain length and breadth ratio, the hybrid Jyothi × Remya (0.356) exhibited high significant positive *sca* effect for this trait followed by Kanchana × Neeraja (0.263), Jyothi × Manupriya (0.203) and Jyothi × Aiswarya (0.202). Whereas significant negative *sca* effect was observed in Bharathy × Neeraja (-0.207), Jyothi × Jayathi (-0.196) and Aruna × Mattatriveni (-0.167). Highly Significant *sca* effects for grain were recorded by nineten hybrids out of 44 hybrids. The hybrid Aruna × Varsha (5.420) exhibited highly significant positive *sca* effect followed by Bharathy × Annapoorna (4.411), Jyothi × Pavizham (4.395), Kanchana × Mattatriveni (2.591) and Aruna × Swarnaprabha (2.570). However, significant negative *sca* effect was found for crosses Bharathy × Varsha (-3.295), Jyothi × Annapoorna (-3.132), Aruna × Jayathi (-2.861) and Aruna × Pavizham (-2.388).

Overall SCA status of parents

In the Simple pooled SCA method, hybrids with significant *sca* effect in desired direction is given score of +1 and –1 score to hybrids with significant *SCA* in undesirable direction (Arunachalam and Bandyopadhyay 1979). These values are added over different yield attributing traits to arrive at pooled score of *sca* effects. Out of 44 hybrids 26 had high (H) overall SCA status across the twelve traits and the remaining 18 had low (L) overall SCA (Table 5).

Table 2: General combining ability (*gca*) effect of parental lines for 12 characters.

PARENTS	PH (cm)	TTPP	DF	NPTP	PL	PF	NSPP	NFGP	DM	L:B	NGP	GYP
LINES												
Kanchana	2.240	-3.515**	0.137**	-0.38**	0.689**	-2.891**	-5.908**	-6.298**	-19.412**	-1.13**	-0.0870**	-1.276**
Aruna	2.513*	-0.484**	-0.25**	-0.128	-0.583**	0.835**	-5.307**	-0.573**	-13.687**	0.407**	0.1745 **	-0.086*
Jyothi	-4.372**	-0.212	0.678**	1.664**	-0.522**	-0.917**	6.328**	5.061**	17.270 **	0.83**	-0.104 **	1.910 **
Bharathy	-0.382	4.212**	-0.55**	-1.14**	0.416**	2.973**	4.886**	1.811**	15.828**	-0.10**	0.0172**	-0.547**
SEm	1.185	0.105	0.16	0.072	0.180	1.131	0.095	0.089	0.088	0.032	0.006	0.039
TESTERS												
Remya	0.868	0.5606**	-0.051	0.110	0.863**	3.017**	2.966 **	3.656**	-0.117	0.147*	0.104**	-0.148*
Jayathi	14.932**	-1.606**	0.926**	0.682**	0.947**	2.019**	11.309**	8.373**	1.301**	-0.117*	-0.142**	0.817**
Swarnaprabha	8.225 **	-0.939**	1.047**	1.670**	0.280	- 0.730**	13.742**	11.926**	-0.978**	1.301**	0.092**	1.685**
Manupriya	-0.739	-4.022**	-0.94**	-1.296**	0.113	- 3.742**	-2.388**	0.229	-1.773**	-0.97**	0.031**	-0.227**
Annapoorna	4.400**	-2.856**	-0.41**	-0.073	1.863**	- 2.977**	3.600**	3.098**	-0.102	-1.77**	0.255**	1.142**
Kanakom	2.658	-1.772**	-0.33**	-0.174	-1.63**	- 0.780**	-11.94**	-11.09**	0.147	-0.102	-0.247**	-0.440 **
Varsha	-2.103	-1.439**	1.179**	0.244*	0.113	1.231**	4.759**	4.639**	0.159	0.147**	-0.137**	0.372 **
Mattatriveni	-3.789	0.227	-1.43**	-0.980**	-3.219**	- 3.250**	-30.812**	-18.836**	1.897**	0.159**	0.059**	-2.562**
Neeraja	-8.249**	6.810**	0.714**	1.775**	0.863**	1.979**	19.367**	14.045**	-1.603**	1.897**	0.553**	2.668**
Aiswarya	-2.913	4.227**	-1.36**	-2.296**	-2.303**	1.419**	-14.364**	-17.834**	0.922**	-1.60**	0.052**	-2.607**
Pavizham	-13.290**	0.810**	0.674**	0.338**	2.113**	1.814**	3.760**	1.800**	1.477**	0.922**	-0.622**	-0.698**
SEm	3.92	0.36	0.536	0.240	0.598	4.17	0.316	0.298	0.293	0.102	0.020	0.129

PH- Plant height, TTPP- Total number of tillers/plant, DF- Days to flowering, NPTP- Number of productive tillers/plant, PL- Panicle length, PF%- Pollen fertility %, NSPP- Number of spikelet/panicle, NFGP- Number of filled grain/panicle, DM- Days to maturity, L:b- Length-breadth ratio, NGP- Number of grain/panicle, GYP- Grain yield/plant. * Significant at 0.05 level, ** Significant at 0.01 level.

Table 3: Pooled GCA score for yield and yield attributing traits in rice.

Parents	PH (cm)	TTPP	DF	NPTP	PL	PF	NSPP	NFGP	DM	L:B	NGP	GYP	Total	GCA status
LINES														
Kanchana	0	1	1	-1	1	1	-1	-1	-1	-1	-1	-1	-3	L
Aruna	-1	1	-1	0	-1	-1	-1	-1	-1	1	1	-1	-5	L
Jyothi	1	0	1	1	-1	1	1	1	1	1	-1	1	7	H
Bharathy	0	-1	-1	-1	1	-1	1	1	1	-1	1	-1	-2	L
TESTERS														
Remya	0	-1	0	0	1	-1	1	1	0	1	1	0	3	H
Jayathi	-1	1	1	1	1	-1	1	1	1	-1	-1	1	4	H
Swarnaprabha	-1	1	1	1	0	1	1	1	-1	1	1	1	7	H
Manupriya	0	1	-1	-1	0	1	-1	0	-1	-1	1	-1	-3	L
Annapoorna	-1	1	-1	0	1	1	1	1	0	-1	1	1	4	H
Kanakom	0	1	-1	0	-1	1	-1	-1	0	0	-1	-1	-4	L
Varsha	0	1	1	1	0	-1	1	1	0	1	-1	1	5	H
Mattatriveni	0	0	-1	-1	-1	1	-1	-1	1	1	1	-1	-2	L
Neeraja	1	-1	1	1	1	-1	1	1	-1	1	1	1	6	H
Aiswarya	0	-1	-1	-1	-1	-1	-1	-1	1	-1	1	-1	-7	L
Pavizham	1	-1	1	1	1	-1	1	1	1	1	-1	-1	4	H

PH- Plant height, TTPP- Total number of tillers/plant, DF- Days to flowering, NPTP- Number of productive tillers/plant, PL- Panicle length, PF%- Pollen fertility %, NSPP- Number of spikelet/panicle, NFGP- Number of filled grain/panicle, DM- Days to maturity, L:b- Length-breadth ratio, NGP- Number of grain/panicle, GYP- Grain yield/plant. H- High, L- Low

Table 4: Specific combining ability (*sca*) effects in crosses for yield and yield contributing characters.

Crosses	PH (cm)	TTPP	DF	NPTP	PL	PF	NSPP	NFGP	DM	L:B	NGP	GYP
Kanchana x Remya	4.966	-0.318	0.096	0.581*	-0.439	1.219**	7.975**	7.974**	9.446**	0.367**	0.069**	1.308**
Kanchana1 x Jayathi	-0.897	1.181**	-0.568**	0.522*	-0.522	-2.146**	6.632**	8.301**	7.048**	1.597**	-0.017	2.072**
Kanchana1 x Swarnaprabha	-3.357	-1.484**	0.384**	-0.509*	-1.856**	-2.064**	2.865**	4.271**	4.377 **	0.103	0.137**	0.793**
Kanchana1 x Manupriya	3.337	1.931**	0.475**	1.458**	1.977**	1.092**	9.483 **	7.768**	8.697**	1.315**	0.019	0.297*
Kanchana1 x Annapoorna	3.158	5.431**	0.183	2.791**	2.893**	0.183	-17.768**	-19.767**	-16.921**	0.360**	-0.028	-2.219**
Kanchana1 x Kanakom	6.190	2.348**	0.067	-0.201	0.393	0.986**	13.550**	13.960**	13.478**	0.329**	-0.115**	0.169
Kanchana1 x Varsha	-5.411	0.348	0.298**	-1.972**	-4.356**	-2.138**	-10.640**	-7.274**	-6.325**	-1.600**	-0.108**	-2.192**
Kanchana1 x Mattatriveni	-7.585	**-4.651****	2.742**	0.699**	1.977**	-0.034	**37.530****	**27.834****	**28.715****	1.391**	-0.012	2.591**
Kanchana1 x Neeraja	8.035*	-2.234**	-0.280**	-0.427**	1.893**	3.504**	2.350**	3.008**	0.761**	0.350**	0.263**	0.254*
Kanchana1 x Aiswarya	4.511	-2.318**	-0.923**	-0.541**	-3.272**	0.231	-38.137**	-30.221**	-33.746**	-0.817**	-0.042*	-0.962**
Kanchana1 x Pavizham	-12.947**	-0.234	-2.473**	-2.400**	1.310*	-0.832**	-13.841**	-15.856**	-15.532**	-2.695**	-0.167**	-2.112**
Aruna x Remya	-0.989	2.984**	-0.086	-0.319	1.500*	-1.536**	2.557**	-1.950**	-0.478	-1.328**	0.151**	-1.118**
Aruna x Jayathi	0.006	1.484**	-1.217**	-1.628**	0.750	-1.365**	-9.925**	-12.45**	-13.709**	-1.835**	0.014	-2.861**
Aruna x Swarnaprabha	0.279	-1.848**	0.882**	1.383**	0.083	1.877**	13.484**	8.023**	8.129 **	2.798**	-0.010	2.570**
Aruna x Manupriya	-7.382	-0.765*	-0.620**	-1.082**	-1.750**	-0.334	-8.874**	-5.640**	-4.710**	-2.287**	-0.088***	-1.566**
Aruna x Annapoorna	0.508	-0.598	-0.145	-1.249**	-2.166**	-1.876**	18.740**	8.351**	11.197**	-0.542**	-0.039	0.940**
Aruna x Kanakom	5.250	-0.015	-1.602**	-1.368**	0.333	1.073**	**-50.661****	**-47.461****	-47.942**	-0.460**	0.123 **	-1.753**
Aruna x Varsha	1.228	2.984**	**2.860****	**3.546****	**4.583****	5.583**	25.691**	18.287**	19.236**	**4.162****	0.146**	**5.420****
Aruna x Mattatriveni	3.697	-3.015**	-2.420**	-1.561**	**-7.083****	0.730**	-22.957**	7.166**	8.047**	-1.364**	-0.167**	-2.135**
Aruna x Neeraja	-4.084	-2.931**	0.478**	1.411**	0.166	1.002**	8.749**	6.437**	4.189**	1.341**	-0.164**	2.301**
Aruna x Aiswarya	3.692	-3.681**	0.339**	0.750**	1.666**	-2.675**	11.448**	10.693**	7.168**	0.244*	-0.093**	0.590**
Aruna x Pavizham	-2.207	5.401**	1.532**	0.118	1.916**	-0.334	11.747**	8.548**	8.872**	-0.731**	0.128**	-2.388**
Jyothi x Remya	0.569	-3.954**	0.711**	0.930**	0.439	0.967**	11.844**	9.534**	12.626**	2.344**	**0.356 ****	2.361**
Jyothi x Jayathi	-2.317	0.212	-0.026	0.315	-3.643**	3.448**	3.238**	3.321**	4.922**	0.774**	-0.196**	0.945**
Jyothi x Swarnaprabha	4.455	5.878**	-0.657**	-0.229	2.022**	-1.843**	0.225	-0.455	2.147**	-0.864**	-0.101**	-0.789**
Jyothi x Manupriya	-4.546	-1.704**	-0.243*	-1.309**	0.189	-2.791**	-6.897**	-9.062**	-8.585**	-1.198**	0.203**	-0.452**
Jyothi x Annapoorna	-8.718*	-3.204**	-0.291**	-1.422**	-0.560	-1.322**	-16.005**	-4.227**	-12.657**	0.211*	0.089**	-3.132**
Jyothi x Kanakom	**-16.103****	-1.954**	0.262**	-0.241	2.272**	0.111	23.313**	16.980 **	21.989**	0.036	-0.007	0.716**
Jyothi x Varsha	10.571**	-0.621	-0.986**	-0.136	0.522	-2.852**	9.132**	6.608 **	10.201**	0.321**	-0.024	0.067
Jyothi x Mattatriveni	-5.039	4.378**	-0.023	2.311**	0.522	-1.870**	-39.542**	-43.245**	**-50.637****	-2.565**	0.095**	-1.228**

Jyothi x Neeraja	8.218*	1.462**	-0.678**	-1.778**	-1.227**	1.743**	-5.876**	-4.521**	-2.801**	-1.430**	0.108**	-2.181**
Jyothi x Aiswarya	0.494	3.378**	0.323**	0.024	0.272	4.084**	6.288 **	10.342**	6.233**	-0.070	0.202**	-0.702**
Jyothi x Pavizham	12.415**	-3.871**	1.606**	1.535**	-0.810	-0.008	14.278**	14.723**	16.560**	2.442**	-0.012	4.395**
Bharathy x Remya	-4.546	1.287**	-0.721**	-1.193**	-1.500**	2.544**	-22.376**	-15.559**	-21.594**	-1.383**	0.135**	-2.551**
Bharathy x Jayathi	3.208	-2.878**	1.812**	0.791**	3.416**	**-3.261****	0.054	0.834**	1.737**	-0.536**	0.198**	-0.156
Bharathy x Swarnaprabha	-1.377	-2.545**	-0.609**	-0.643**	-0.250	1.085**	-16.576**	-11.839**	-14.653**	-2.037**	-0.026	-2.575**
Bharathy x Manupriya	8.590*	0.537	0.388**	0.933**	-0.416	4.483**	6.288 **	6.934**	4.599**	2.169**	-0.134**	1.721**
Bharathy x Annapoorna	5.051	-1.628**	0.253**	-0.119	-0.166	1.409**	15.033**	15.642**	18.381**	0.030	-0.022	4.411**
Bharathy x Kanakom	4.663	-0.378	1.273**	1.811**	-3.000**	**-3.555****	13.798**	16.520**	12.474**	0.095	-0.066**	0.867**
Bharathy x Varsha	-6.388	-2.712**	-2.172**	-1.437**	-0.750	2.156**	-24.182**	-17.621**	-23.113**	**-2.883****	-0.013	-3.295**
Bharathy x Mattatriveni	8.927*	3.287**	-0.298**	-1.448**	**4.583****	-2.636**	24.969**	8.244**	13.874**	2.538**	0.083**	0.772**
Bharathy x Neeraja	-12.168**	3.704**	0.480**	0.794**	-0.833	0.701*	-5.224**	-4.924**	-2.149**	0.440**	**-0.207****	-0.374*
Bharathy x Aiswarya	-8.698*	2.621**	0.261**	-0.233	1.333*	2.918**	20.400**	9.185**	20.345**	0.643**	-0.066**	1.074**
Bharathy x Pavizham	2.738	1.295**	-0.666**	0.745**	2.416**	-0.008	-12.183**	-7.416**	-9.900**	0.985**	0.052**	0.105
SEm	**3.920**	**0.367**	**0.098**	**0.240**	**0.598**	**0.284**	**0.316**	**0.298**	**0.293**	**0.102**	**0.020**	**0.129**

PH- Plant height, TTPP- Total number of tillers/plant, DF- Days to flowering, NPTP- Number of productive tillers/plant, PL- Panicle length, PF%- Pollen fertility %, NSPP- Number of spikelet/panicle, NFGP- Number of filled grain/panicle, DM- Days to maturity, L:b- Length-breadth ratio, NGP- Number of grain/panicle, GYP- Grain yield/plant. * Significant at 0.05 level, ** Significant at 0.01 level

Table 5: SCA score for yield and yield attributing traits with GCA status of parents in hybrids.

Crosses	PH (cm)	TTPP	DF	NPTP	PL	PF	NSPP	NFGP	DM	L:B	NGP	GYP	**Total**	SCA **status**	**GCA status of crosses**
Kanchana x Remya	0	0	0	1	0	-1	1	1	1	1	1	1	6	H	L X H
Kanchana x Jayathi	0	-1	-1	1	0	1	1	1	1	1	0	1	5	H	L X H
Kanchana x Swarnaprabha	0	1	1	-1	-1	1	1	1	1	0	1	1	6	H	L X H
Kanchana x Manupriya	0	-1	1	1	1	-1	1	1	1	1	0	1	6	H	L X L
Kanchana x Annapoorna	0	-1	0	1	1	0	-1	-1	-1	1	0	-1	-2	L	L X H
Kanchana x Kanakom	0	-1	0	0	0	-1	1	1	1	1	-1	0	1	H	L X L
Kanchana x Varsha	0	0	1	-1	-1	1	-1	-1	-1	-1	-1	-1	-6	L	L X H
Kanchana x Mattatriveni	0	1	1	1	1	1	**1**	**1**	**1**	1	0	1	10	H	L X L
Kanchana x Neeraja	-1	1	-1	-1	-1	-1	1	1	1	1	1	1	2	H	L X H
Kanchana x Aiswarya	0	1	-1	-1	1	0	-1	-1	-1	-1	-1	-1	-6	L	L X L
Kanchana x Pavizham	1	0	-1	-1	1	1	-1	-1	-1	-1	-1	-1	-5	L	L X H
Aruna x Remya	0	-1	0	0	1	1	1	-1	0	-1	1	1	2	H	L X H
Aruna x Jayathi	0	-1	-1	-1	0	1	-1	-1	-1	-1	0	-1	-7	L	L X H

Aruna x Swarnaprabha	0	1	1	1	0	-1	1	1	1	1	0	1	7	H	L X H
Aruna x Manupriya	0	1	-1	-1	-1	0	-1	-1	-1	-1	-1	-1	-8	L	L X H
Aruna x Annapoorna	0	0	0	-1	-1	1	1	1	1	-1	0	1	2	H	L X L
Aruna x Kanakom	0	0	-1	-1	0	-1	**-1**	**-1**	-1	-1	1	-1	-7	L	L X H
Aruna x Varsha	0	-1	**1**	**1**	**1**	1	1	1	1	**1**	1	**1**	9	H	L X L
Aruna x Mattatriveni	0	1	-1	-1	**-1**	-1	-1	1	1	-1	-1	-1	-5	L	L X H
Aruna x Neeraja	0	1	1	1	0	1	1	1	1	1	-1	1	8	H	L X L
Aruna x Aiswarya	0	1	1	1	1	1	1	1	1	1	-1	-1	7	H	L X H
Aruna x Pavizham	0	1	1	0	1	0	1	1	1	-1	1	-1	5	H	L X L
Jyothi x Remya	0	1	1	1	0	-1	1	1	1	1	**1**	1	8	H	L X H
Jyothi x Jayathi	0	0	0	0	-1	-1	1	1	1	1	-1	1	2	H	H X H
Jyothi x Swarnaprabha	0	-1	-1	0	1	1	0	0	1	-1	-1	-1	-2	L	H X H
Jyothi x Manupriya	0	1	-1	-1	0	1	-1	-1	-1	-1	1	-1	-4	L	H X H
Jyothi x Annapoorna	1	1	-1	-1	0	1	-1	-1	-1	1	1	-1	-1	L	H X L
Jyothi x Kanakom	**1**	1	1	0	1	0	1	1	1	0	0	1	8	H	H X H
Jyothi x Varsha	-1	0	-1	0	0	1	1	1	1	1	0	0	3	H	H X L
Jyothi x Mattatriveni	0	-1	0	1	0	1	-1	-1	**-1**	-1	1	-1	-3	L	H X H
Jyothi x Neeraja	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	-1	-10	L	H X L
Jyothi x Aiswarya	0	-1	1	0	0	-1	1	1	1	0	1	-1	2	H	H X H
Jyothi x Pavizham	-1	1	1	1	0	0	1	1	1	1	0	1	7	H	H X L
Bharathy x Remya	0	-1	-1	-1	-1	-1	-1	-1	1	-1	1	-1	-7	L	L X H
Bharathy x Jayathi	0	1	1	1	1	**1**	0	1	1	-1	1	0	7	H	L X H
Bharathy x Swarnaprabha	0	1	-1	-1	0	-1	-1	-1	-1	-1	0	-1	-7	L	L X H
Bharathy x Manupriya	-1	0	1	1	0	-1	1	1	1	1	-1	1	4	H	L X L
Bharathy x Annapoorna	0	1	1	0	0	-1	1	1	1	0	0	1	5	H	L X H
Bharathy x Kanakom	0	0	1	1	-1	**1**	1	1	1	0	-1	1	5	H	L X L
Bharathy x Varsha	0	1	-1	-1	0	-1	-1	-1	-1	**-1**	0	-1	-7	L	L X H
Bharathy x Mattatriveni	-1	-1	-1	-1	**1**	1	1	1	1	1	1	1	4	H	L X L
Bharathy x Neeraja	1	-1	1	1	0	-1	-1	-1	-1	1	**-1**	-1	-3	L	L X H
Bharathy x Aiswarya	1	-1	1	0	1	-1	1	1	1	1	-1	1	5	H	L X L
Bharathy x Pavizham	0	-1	-1	1	1	0	-1	-1	-1	1	1	0	-1	L	L X H

PH- Plant height, TTPP- Tillers no of tillers/plant, DF- Days to flowering, NPTP- Number of productive tillers/plant, PL- Panicle length, PF%- Pollen fertility %, NSPP- Number of spikelet/panicle, NFGP- Number of filled grain/panicle, DM- Days to maturity, L:b- Length-breadth ratio, NGP- Number of grain/panicle, GYP- Grain yield/plant, H- High, L- Low.

Proportional contribution of lines, testers and line × tester interaction on the performance of hybrids

The proportional contribution of lines, testers and line × tester interaction for twelve traits is presented in Table 7. The results revealed that the per cent contribution of lines was higher for number of grain per Panicle (41.207), days to maturity (35.78), days to flowering (31.463), number of productive tillers (25.827) and panicle length (12.942) and yield per plant (11.274). Whereas the per cent contribution of tester was high for most of the traits *viz*; yield per plant (73.722), plant height (52.136), total number of tillers (37.149), days to flowering (37.019), spikelet per panicle (33.868), pollen fertility (32.748), productive tillers (32.158), days to maturity (31.57) and number of filled grain (31.334). However, the per cent contribution of lines × testers was more for grain length and breadth ratio (69.440), number of filled grain (63.928), pollen fertility (63.301), spikelet per panicle (60.374), panicle length (58.882) and total no of tillers (53.562).

Table 6: Components of variance for 12 traits in rice.

Sr. No.	Characters	σ^2GCA	σ^2SCA	σ^2GCA/ σ^2SCA	σ^2A	σ^2D
1	Plant Height (cm)	2.01	45.15	0.04	3.44	488.20
2	Days to Flowering	0.61	11.02	0.05	0.61	11.02
3	Total no of Tillers	0.21	1.79	0.12	0.43	1.79
4	Number of productive tillers	0.07	2.47	0.03	0.07	2.47
5	Pollen Fertility%	0.03	7.05	0.004	0.03	7.05
6	Days to Maturity	5.18	7	0.74	5.18	17.37
7	Number of spikelet per Panicle	3.44	488.20	0.007	3.44	591.82
8	Number of Filled grain	1.41	340.89	0.004	1.41	340.89
9	Number of grain per Panicle	12.32	418.80	0.02	12.32	418.80
10	Panicle Length (cm)	0.39	3.58	0.10	0.78	3.58
11	Grain length and breadth ratio	0.004	0.02	0.17	0.004	0.02
12	Yield per plant (g)	0.08	6.290	0.01	0.08	6.29

Table 7: Proportional contribution (%) of lines, testers and line × tester interaction to total variance in the rice hybrids.

Sr. No.	Characters	Lines	Testers	Line x Tester
1	Plant Height (cm)	7.458	52.316	40.225
2	Days to Flowering	31.463	37.019	31.516
3	Total number of Tillers	9.289	37.149	53.562
4	Number of productive tillers	25.827	32.158	42.014
5	Pollen Fertility%	3.950	32.748	63.301
6	Days to Maturity	35.78	31.51	32.71
7	Number of Spikelet per Panicle	5.757	33.868	60.374
8	Number of Filled grain	4.736	31.334	63.928
9	Number of grain per Panicle	41.207	16.495	42.296
10	Panicle Length (cm)	12.942	28.175	58.882
11	Grain length and breadth ratio	7.356	23.203	69.440
12	Yield per plant (g)	11.274	73.722	15.003

DISCUSSION

General Combining ability

The potentiality of a strain to be used as a parent in hybridization may be judged by comparing the *per se* performance of the parents, the F_1 value (heterosis) and the combining ability effects. However, most of the time *per se* performance of a parent alone is not always a true indicator of its potentiality in hybrid combination. Therefore, general combining ability, which is also the breeding value of the parent, has proved as a useful tool for choosing the parents for hybridization. Among the parents with significant *gca* effects, the ones with higher magnitude of *gca* effects were considered as superior to those with lower magnitude.

The summary of general combining ability effects of the parents revealed that none of the parent was found to be good general combiner for all the characters. Among the lines, Jyothi had significant *gca* effects in desired direction for nine traits, plant height, total number of tillers, productive tillers, days to maturity, number of spikelet/panicle, number of filled grain, number of grains/panicle, panicle length and yield/plant. The line Kanchana was a good source of favorable genes for days to flowering, total no of tillers, pollen fertility and days to maturity whereas the line Aruna was found to be good combiner for days to flowering, panicle length and grain length/breadth ratio in desirable direction. The line Bharathy was a good combiner for pollen fertility, number of spikelet/panicle, no of filled grain, no of grain/panicle and L/B ratio.

Among the eleven testers, Swarnaprabha was found to be a good general combiner for days to flowering, total number of tillers, number of productive tillers, days to maturity, number of spikelets/panicle, number of filled grains/panicle, panicle length, length/breadth ratio and yield/plant and tester Neeraja for plant height, total number of tillers, number of productive trillers, pollen fertility, number of spikelet/panicle, number of filled grains/panicle, panicle length, grain length and breadth ratio and yield/plant. Tester Jayathi was found to be

good general combiner for days to flowering, total number of tillers, productive tillers, pollen fertility, number of spikelet/panicle, number of filled grain, number of grain/panicle and yield/plant, whereas Annapoorna was found to be good general combiner for days to flowering, pollen fertility, days to maturity, number of spikelet/panicle, no of filled grain/panicle, length and breadth ratio and yield/plant. The tester Varsha was a good combiner for days to flowering, total number of tillers, productive tillers, spikelet/panicle, number of filled grains/panicle, panicle length, length and breadth ratio and yield/plant. While tester Pavizham was found to be good general combiner for plant height, total no of tillers, productive tillers, pollen fertility, number of spikelet/panicle, no of filled grain, no of grain/panicle, length and breadth ratio and panicle length. The tester Remya was found to be good general combiner for pollen fertility, number of spikelets/panicle, number of filled grain, panicle length and grain length-breadth ratio. High overall good general combiners suggesting their ability to transmit additive genes in the desirable direction for the traits under study. Superiority of female and male parents based on *gca* effects was also reported by Swamy *et al*. (2003), Panwar (2005), Sao and Motiramani (2006), Rashid *et al*. (2007), Chakraborty *et al.* (2009), Kumar and Reddy (2011) and Patil *et al*. (2011).

Perusal of findings indicated that lines Jyothi was observed good general combiner for yield and yield contributing traits. Barrathy was observed as good general combiner for pollen fertility, number of spikelet/panicle, number of filled grains/panicle and number of grains/panicle. Among testers Swarnaprabha, Neeraja, Annapoorna, Varsha and Jayathi, were good general combiners for yield and yield contributing characters. They could be considered as the best combining parents of the present study in yield attributes and hence could be utilized in the future breeding programme.

Specific Combining Ability Effects

Grain yield is a complex character dependent upon the contribution of various component characters affecting directly or indirectly. The existence of total genetic variability and magnitude as well as nature of gene effects in the population under improvement to a large extent would dictate the choice of breeding methodology. The range of *sca* effects for grain yield per plant varied from- 0.067 (Jyothi × Varsha) to 5.420 (Aruna × Varsha).

In case of specific combing ability effects, none of the hybrids exhibited favorable *sca* effect for all the characters. Yield/plant is ultimate goal of rice breeding and hybrid development programme. For grain yield/plant eighteen hybrids showed significant *sca* effects for seed yield per plant, of which the best ten hybrid combination were Aruna × Varsha followed by Jyothi × Pavizham, Bharathy × Annapoorna, Kanchana × Mattatriveni, Aruna × Swarnaprabha, Jyothi × Remya, Kanchana × Jayathi, Aruna × Neeraja, Bharathy × Manupriya and Kanchana × Remya and these were good specific combiners based on high and significant *sca* effects.

The cross combination Aruna × Varsha was the best specific combination for acceptable and significant *sca* effects for yield/plant and other desireable characters like total number of tillers, productive tillers, pollen fertility, number of spikelets/panicle, number of filled grains/panicle, number of grains/panicle, panicle length and grain length/breadth ratio. Kanchana × Mattatriveni was another best specific combination for acceptable and significant SCA for grain yield/plant and other desireable characters like days to flowering, total number of tillers, productive tillers, pollen fertility, number of spikelet/panicle, number of filled grain/panicle, no of grain/panicle and panicle length. Some other cross combination for acceptable and significant SCA effects for grain yield/plant and other desirable characters areJyothi × Kanakom, Jyothi × Remya, Kanchana x Jayathi, Aruna × Swarnaprabha, Aruna × Neeraja, Bharathy × Manupriya and Bharathy × Annapoorna.

High *sca* effect results mostly from dominance and interaction effects existing between the hybridizing parents. High *sca* effects for grain yield using line × tester analysis have earlier been reported by Roy and Mandal (2001), Singh and Kumar (2004), Rashid *et al*., (2007), Thakare *et al*. (2010). Saidaiah *et al., (*2010) reported high SCA effect for grain yield also and most of the remaining traits over environments. Similar kind of results was reported by Mirarab *et al*. (2011).

Out of forty four crosses the top three crosses exhibiting high *sca* effects selected for each character and GCA status of parents of such hybrids are presented as either low or high in Total 5 hybrids had significant negative effect for Plant height. Out of 5 hybrids Jyothi × Kanakom, Kanchana × Pavizham and Bharathy × Neeraja were the superior hybrids and Kanchana × Pavizham (L × H) had both desirable *sca* effects and high *per se* performance. Among top three crosses, Kanchana × Mattatriveni (L × L) also had both higher *sca* effect and *per se* performance in desirable direction for days to flowering. Totally nineteen crosses exhibited desirable positive significant *sca* effect for total number of tillers/plant and among them Aruna × Varsha (L × H) had both desirable SCA and high per see performance followed by Bharathy × J ayathi (L × H) and Kanchana x Mattatriveni (L × L). A total of fifteen crosses were found to be significant for productive tillers/plant. Among them three crosses having highest significant SCA were Aruna × Varsha, Kanchana × Annapoorna, and Jyothi × Mattatriveni. Hybrid Aruna × Varsha (L × H) had both high *sca* effect as well as per see performance.

Sixteen hybrids had positively significant *sca* effect for pollen fertility. 3 hybrids which showed highest *sca* effect were Aruna × Varsha (L × H), Bharathy × Mattatriveni (L × L) and Bharathy × Jayathi (L × H). For Days to maturity total sixteen hybrids showed negative sca effect. Among them Bharathy × Kanakom (L × L) had highest *sca* effect (-3.55). The cross combination *viz*; Kanchana × Mattatriveni, Aruna × Varsha and Bharathy × Mattatriveni recorded highest significant positive *sca* effect. Among them hybrid Aruna × Varsha had both higher sca

effect and higher per see performance. Among three best crosses Aruna × Varsha (L × L) had both higher SCA and per see performance, where as two other crosses had higher *sca* effect but moderate per se performance. All three best hybrids Kanchana × Mattatriveni, Jyothi × Kanakom and Bharathy × Aiswaryahad high *sca* effect and moderate per se performance for total grain/panicle. Among them Kanchana × Mattatriveni (L × L) had highest *sca* effect (28.71). For Panicle length among the three best hybrids Aruna × Varsha (L × L) had both highest *sca* effect and highest per see performance. Among top three crosses Kanchana × Neeraja (L × H) had higher *sca* effect and highest per se performance for grain Length/Breadth ratio. With respect to grain yield, top three crosses for high *sca* effect exhibited highest to moderate grain yield. Hybrid Aruna × Varsha (L × L) had highest sca effect as well as per see performance.

Based on the *sca* effects of the hybrids, 26 out of 44 hybrids had high (H) overall SCA status across the twelve traits. Hence, these crosses could be utilized for exploitation of heterosis and the remaining 18 had low (L) overall *sca* status. The high (H) performing hybrids belonged to H × H, H × L, L × H and also L × L type of parental combinations suggesting the action of additive, non additive gene action and also overdominance and epistasis, respectively. Several workers including Swamy *et al.,* (2003), Jagadeesan and Ganesan (2006), Rahimi *etal.,* (2010), Saidaiah*et al.* (2010) and Tiwary *et al*., (2011) identified good specific combiners for different yield attributing traits based on high *sca* effects in desirable direction.

Three hybrids (Jyothi × Jayathi, Jyothi × Aiswarya and Jyothi × Kanakom) out of 26 had expressed high overall SCA status involving H × H type of general combiners. This interaction between positive and positive alleles in high × high combiners can be fi x ed in subsequent generations if no repulsion phase linkages are involved. Similar conclusion was reported by Shivani *et al.,* (2009) in their study on combining ability for grain quality characters in indica/indica hybrids of rice. Eleven crosses had both the parents with low overall GCA status (Low × Low), which has been attributed to over dominance and epistasis interaction as suggested by Swamy *et al*., (2003), Singh *et al.,* (2005) and Dalvi and Patel (2009). In remaining crosses high *SCA* was mainly either due to high × low (12) or low × high (17) combining parents, which further substantiate the operation of non-additive gene action (additive × dominance and dominance × dominance epistatic interaction).

Proportional contribution of parents

Testers appeared to contribute to the bulk of the variation observed in hybrids which was higher for yield/plant, plant height, total number of tillers/plant, days to flowering, number of spikelets/panicle, pollen fertility, productive tillers and number of filled grains. Per cent contribution of the line × tester interaction effect to the variation observed in hybrids was higher for grain length and breadth ratio, number of filled grain/panicle, pollen fertility, number of spikelet/panicle and panicle length. Whereas the lines contributed less towards the variation in the hybrids compared to testers and line × tester interaction.

The contribution of Line × Tester towards the total variance was found higher than lines and Testers. The greater contributions of lines × testers interaction for all the characters than testers except days to maturity indicates higher estimates of specific combining ability variance effects These results are in agreement with the findings of Rashid *et al*., (2007). Greater contribution of Line × tester interactions than that of lines and testers except for number of spikelets per panicle was also reported by Ghara, *et al*., (2012).). Greater contribution of testers than lines × tester's interaction and thus higher estimates of variance due to *gca* effects was reported by Faiz *et al*., (2006) and Saleem *et al*., (2010

In this study the lines chosen are varieties which are identified as maintainers for the CGMS system. The testers are the varieties identified as restorers for the CGMS system. The line in the best hybrid can be used for the development of male sterile line by repeated backcrossing. So that the hybrid can be released as hybrid rice with provision for easy commercial hybrid seed production using CGMS system.

SUMMARY

Four identified maintainers (Kanchana, Jyothi, Aruna and Bharathy) and 11 restorers (Remya, Jayathi, Swarnaprabha, Manupriya, Annapoorna, Kanakom, Mattatriveni, Varsha, Aiswarya, Neeraja and Pavizham) were crossed in L × T fashion and combining ability of parental lines were carried out in F_1 generation. The GCA variances were significant for plant height, days to maturity, number of spikelet/panicle and no of grain/panicle indicating operation of additive gene action. On the other hand, SCA variances were highly significant for all characters except for total number of tillers, number of productive tillers and grain length/breadth ratio indicating the predominance of non-additive gene action. Perusal of findings indicated that line Jyothi was observed good general combiner for yield and yield contributing traits. Barrathy was observed as good general combiner for pollen fertility, number of spikelets/panicle, number of filled grains/panicle and number of grain/panicle. Among testers Swarnaprabha, Neeraja, Annapoorna, Varsha and Jayathi, were good general combiners for yield and yield contributing characters. So, these lines could be considered as the best combining parents of the present study in yield attributes and hence could be utilized in the future breeding programme.

In case of specific combining ability effects, none of the hybrids exhibited favorable *sca* effect for all the characters. The cross combination Aruna × Varsha was the best specific combination for acceptable and significant *sca* effects for yield/plant and other desireable characters like total number of tillers, number of productive tillers, pollen fertility, number of spikelet/panicle, number of filled grain/panicle, number of grain/panicle, panicle length and grain length/breadth ratio.

Based on the *sca* effects of the hybrids, 26 out of 44 hybrids had high (H) overall SCA status across the twelve traits. Hence, these crosses could be utilized for exploitation of heterosis and the remaining 18 had low (L) overall SCA status. The high (H) performing hybrids belonged to H × H, H × L, L × H and also L × L type of parental combinations suggesting the action of additive, non additive gene action and also overdominance and epistasis, respectively. Three best hybrids Aruna × Varsha (L × L), Jyothi × Pavizham (H × H) and Kanchana × Mattatriveni (L × L) were identified based on SCA effect for yield as well as other yield contributing characters and mean performance.

CONCLUSIONS

In order to assess heterosis in different combination of the identified maintainers and restorers an L × T analysis was done with maintainers as the lines and restorers as the testers. Perusal of findings indicated that line Jyothi is a good general combiner as it recorded a high over all GCA status. The hybrid Aruna × Varsha was the best specific combiner followed by, Jyothi × Pavizham and Kanchana × Mattatriveni. Three crosses *viz*; Aruna × Varsha, Jyothi × Pavizham and Bharathy × Annapoorna registered high significant heterosis for grain yield per plant over mid parent, better parent and standard check Uma.

Conflict of Interest. There is no conflict of interest regarding the manuscript among the authors.

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