Indian J. Applied & Pure Bio. Vol. 39(1), 613-623 (2024).
ISSN: 0970-2091
A Web of Science Journal

Heterosis studies for yield and its component traits in Hybrid Rice (*Oryza sativa* L.) under coastal saline condition

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Abstract

Salinity is a major abiotic constraint faced by farmers in most rice cultivating areas of the world and improving seed yield in rice is the most important breeding objective. In the current study, twenty four hybrids were developed by crossing six lines with four testers to determine the better parent and standard parent heterotic effects for yield and its component traits of rice crop under coastal-saline conditions.

The analysis of variance (line x tester) revealed significant differences among the genotypes for all the traits studied. Among the twenty four crosses, eight hybrids show superior performance for seed yield plant^{-1} over standard parent from those three hybrids exhibiting desirable high value of standard heterosis for seed yield plant^{-1} *viz.,* ADT 43x CSR 36, ADT 42x CSR 36 and ADT 37x CSR 36. These three hybrids also show high *per se* performance for the majority of the traits studied along with short stature plants and early flowering. So, these crosses were considered as superior crosses and further utilized in the breeding programme.

Key words : Rice, Heterosis, Hybrid, Yield component.

Rice (*Oryza sativa* L.) is a staple food for over half of the world's population and an essential crop for food security. Asia alone supplies more than 90 per cent of the world's rice and 20 per cent of global dietary energy[8]. According to the USDA, approximately 503.3 million metric tons of milled rice have been produced globally during the 2022-23 marketing year[25]. China is the largest rice producer, yielding 148.27 million tons of milled rice, followed by India (120.54 million tons)[10]. Similarly, in terms of consumption, China ranked highest, with 150.62 million tons of milled rice, trailed by India (104.17 million tons), and Bangladesh (36.10 million tons)[25].

Climate change is projected to increase global rice production and consumption by 18 per cent relative to 2010 and per capita land availability for rice cultivation is expected to decrease by 25 per cent by 2050 [2]. Ensuring food security for a growing global population requires a significant increase in rice yield potential[18]. However, limited resources and the impact of biotic and abiotic stresses pose considerable challenges in rice production[3].

These abiotic stresses cause significant problems by reducing crop growth and productivity of rice. Although active suppression of growth is a strategy helpful for maximizing plant survival in a stressed condition, it often negatively impacts crop productivity[27]. Increasing salinity is a major challenge for continuing rice production. Salinity affects all the developing stages of rice crop; it is highly sensitive at the early-seedling stage. Thus, the yield that ultimately depends on the number of seedlings withstands in saline water after transplantation, particularly in coastal farms[24].

One of the key challenges faced by plant breeders in improving high-yielding varieties is selecting suitable parents and crosses[16]. In crop breeding, out of different genetic component estimations, the analysis of combining ability is an effective method to overcome this problem[4]. For estimating genetic components, the line × tester method proposed by Kempthorne[5] in 1957 is useful for obtaining precise measurements of general combining ability (*gca*) and specific combining ability (*sca*) and selecting parents for the hybridization program. This will aid in the assessment of *gca* and *sca* variances in addition to their effects and thus help to deduce the nature of gene action responsible for the expression of economically important quantitative traits[19]. Both negative and positive heterosis play vital roles in plant breeding, depending on the breeding objectives. Positive heterosis is sought after for enhancing yield, while negative heterosis is valuable for promoting early maturity[11]. Breeding strategies centred around exploitation of heterosis, necessitate high levels of specific combining ability and heterosis in crosses.

The present investigation was conducted during *Thaladi* (October 2020) at the Experimental Farm, Department of Genetics and Plant Breeding, Annamalai University, Chidambaram, Tamil Nadu, India. The material for this study consists of six lines (ADT 37, ADT 43, ADT 38, ADT 46, ADT 42, ADT 45) and four testers (CSR 10, CSR 36, FL 478 and POKKALI) as testers. Utilizing ten parents, twenty four crosses were developed through Line x Tester analysis. Thirty four genotypes along with twenty four crosses and ten parents were raised in a randomized block design with three replications. True F_{1s} were identified based on the morphological traits. Observations were recorded for 11 biometric traits viz., days to 50 per cent flowering, plant height at maturity, number of tillers plant^{-1}, number of productive tillers plant^{-1}, panicle length, number of filled seeds panicle^{-1}, thousand seed weight, seed length, seed L/B ratio and seed yield plant^{-1} on ten randomly chosen plants from each replication, leaving the border plants. These data were subjected to analysis of variance for mean performance by Panse and Sukahatme[14] and the relative heterosis (di) based on mid-parental value, heterobeltiosis (dii) based on better parental value and standard heterosis using a standard check (ADT-45) were estimated.

The analysis of variance revealed significant differences among the studied characters in twenty four hybrids, indicating a wide range of variability (Table-1). The observed heterosis range were presented in Table-2 for 11 characters of rice. For plant height at maturity and days to 50 per cent flowering negative heterosis is desirable but for the rest of the characters, positive heterosis is desirable. Eight hybrids (ADT 37x CSR 36, ADT 43x CSR 36, ADT 38x CSR 36, ADT 46x CSR 10, ADT 42x CSR 10, ADT 42x CSR 36, ADT 45x CSR 10, ADT 45x CSR 36) from twenty four crosses exhibited significant and positive standard heterosis for seed yield plant^{-1}. Negative heterosis for days to 50 per cent flowering is desirable for breeding early maturing hybrids and varieties. Ten hybrids exhibited negative significant values for heterobeltiosis. Negative significant values ranged from -26.12 to 25.47 per cent. The maximum significant and negative value was recorded in cross ADT 42x CSR 36 (-26.12) followed by ADT 43x CSR 36 (-17.45). The standard heterosis for days to fifty per cent flowering ranged from -28.51 to 10.74 per cent and the cross ADT 46 x CSR 36 showed the highest negative significant value of -28.51 for days to 50 per cent flowering followed by ADT 42 x CSR 36 (-25.21). The significant heterosis was also recorded by Padmavathi *et al.,*[12].

Negative heterosis was desirable for plant height at maturity for breeding short-statured hybrids and varieties. Ten hybrids show significant negative better parent heterosis for plant height at maturity which ranges from -20.99 to 36.59. The cross ADT 43x CSR 36 (-20.99) recorded the highest negative significant value followed by ADT 37x CSR 36 (-19.92). Five crosses were recorded negative and significant standard heterosis which range from -7.52 to 87.22. The cross ADT 46x CSR 10 (-7.52) showed the highest negative significant value followed by ADT 43 x CSR 36 (-7.50). The present findings are in accordance with the earlier findings of Tiwari *et al.,*[23].

Nine cross-recorded positive hetero-beltiosis for number of tillers plant^{-1} ranged from -55.87 to 31.28. The cross ADT 46x CSR 10 (31.28) shows the maximum value followed by the cross ADT 46x FL 478 (27.90). Only five crosses showed positive standard heterosis for the number of tillers plant^{-1} ranging from -60.18 to 19.48. The cross ADT 45x CSR 10 (19.48) was observed for maximum value followed by ADT 37x CSR 36 (19.12).

The number of productive tillers plant^{-1} is one of the important components of yield thus the hybrids with positive heterosis were desirable. For this trait, it was observed that only eight crosses showed significant positive heterobeltiosis. The cross ADT 46x CSR 10 (40.93) showed the highest positive value followed by ADT 45x CSR 10 (29.05). Seven hybrid shows positive standard heterosis. The maximum positive standard heterosis was recorded by ADT 43x CSR 36 (41.67) followed by ADT 37x CSR 36 (40.42). These results are similar to the findings of Rao *et al.,*[17] and Sarker *et al.,*[22].

Nine hybrids show positive significant heterobeltiosis for panicle length. The cross ADT 46x CSR 10 (31.55) showed the highest

Table-1. ANOVA for combining ability analysis in rice (*Oryza sativa* L.) for eleven characters

Source of variation	df	Mean Sum of Square			
		Days to 50 per cent flowering	Plant height at maturity	Number of tillers plant^{-1}	Number of productive tillers plant^{-1}
Replication	2	0.89	0.10	0.06	0.05
Hybrid	23	331.24**	2086.89**	91.99**	82.99**
Line	5	195.36**	131.18**	12.01**	10.80**
Tester	3	2006.48**	14522.21**	535.38**	462.98**
LxT	23	41.48**	251.73**	29.97**	31.06**
Error	66	0.32	0.10	0.04	0.02

Table 1. Continued

Panicle length	Number of filled seeds panicle^{-1}	Thousand seed weight	Seed length	Seed breadth	Seed L/B ratio	Seed yield plant^{-1}
0.0079	3.09	0.01	0.0002	0.0003	0.0004	0.15
43.64**	3197.00**	16.69**	1.3494**	0.0845**	0.3340**	567.61**
8.38**	172.74**	26.68**	0.2520**	0.1562**	0.1906**	31.89**
134.49**	17861.31**	64.77**	5.9038**	0.0899**	1.1475**	3427.00**
37.22**	1272.22**	3.74**	0.8044**	0.0595**	0.2190**	174.30**
0.02	3.53	0.01	0.0003	0.0003	0.0005	0.27

*,** Significant at 5 and 1 per cent respectively

positive value followed by ADT 38_x CSR 36 (16.70). Fourteen hybrids show positive standard heterosis. The maximum positive Standard heterosis was recorded by ADT 43 x CSR 36 (19.05) followed by ADT 43 x Pokkali (17.83). These results are similar to the findings of Pandey *et al.,*[13].

For the number of filled seeds per panicle^{-1}, a total of seven hybrids exhibited positively significant values for heterobeltiosis ranging from -40.69 to 29.16. The cross ADT 43 x CSR 36 (29.16) showed positive maximum value followed by ADT 38 x CSR 36 (26.73). Seven hybrids recorded positive significant values in standard heterosis for the number of filled seeds panicle^{-1}. The cross ADT 43 x CSR 36 (28.86) registered the highest positive value for the number of filled seeds panicle^{-1} followed by ADT 37 x CSR 36 (23.56). These results are similar to the findings of Ammar Gholizadeh Ghara *et al.,*[1].

For the trait thousand seed weight, the heterobeltiosis was significantly positive for only three crosses. The maximum significant and positive heterobeltiosis was observed in ADT 38 x CSR 36 (4.05) followed by ADT 45 x CSR 10 (3.47). Standard heterosis was observed to be significant and positive in twenty two crosses which ranged from -4.52 to 43.84. The maximum positive and significant value was noticed in the cross ADT 46 x CSR 36 (43.84) followed by ADT 46 x FL 478 (40.04). The present observation is in close conformity with the findings of Maurya and Singh[9].

Only one hybrid ADT 37 x CSR 10 (2.85) shows positive significant heterobeltiosis for seed length. Six hybrids show positive and significant standard heterosis values. The maximum value was recorded in the cross ADT 42 x FL 478 (11.65) followed by ADT 38 x FL 478 (10.94). Vivekanandan and Giridharan[26] reported negative as well as positive heterobeltiosis for seed length in rice. Reddy *et al*.[20] and Priyanka *et al.,*[15] reported positive estimates of standard heterosis for seed length.

Four hybrids show positive significant heterobeltiosis for seed breadth. The maximum seed breadth was observed in the cross ADT 43 x CSR 10 (27.45) followed by ADT 43 x CSR 36 (12.16). Only two crosses show positive and significant standard heterosis for seed breadth. The maximum value was observed in ADT 46 x POKKALI (12.54). Both positive and negative heterotic values for seed breadth were also reported by Rahimi *et al*.[16] and Sanghera and Hussain[21].

For the trait seed L/B ratio, three hybrid shows positive and significant heterobeltiosis. The maximum value was observed in the cross ADT 37x POKKALI (15.57) followed by ADT 37x CSR 10 (2.36). Ten hybrid shows positive and significant standard heterosis. The maximum value was observed in ADT 38x FL 478 (26.61) followed by ADT 42x FL 478 (23.09). Both high and low value for seed L/B ratio over the standard checks has been reported by Sanghera and Hussain[21] in rice. However, studies of Vivekanandan and Giridharan[26], and Reddy *et al*.,[20] have evinced lower values for kernel length/breadth ratio than the check varieties in most of the cross combinations studied in this crop.

Six hybrids show significant and positive heterobeltiosis for seed yield plant^{-1}. The maximum value was recorded by ADT 46x CSR 10 (50.31) followed by ADT 43x CSR 36 (37.61). Eight hybrids show positive and significant standard heterosis. The maximum value was registered by ADT 43x CSR 36 (50.54) followed by ADT 42x CSR 36 (44.21). A high magnitude of standard heterosis for seed yield plant^{-1} in rice was observed in the present study and has also been reported by Kumar *et al.,*[6], (2010), Rahimi *et al.,*[16] and Reddy *et al*.,[20].

To summarise the present findings, desirable performance for all yield and yield contributing traits was not expressed in a single hybrid combination. The relative magnitude of superiority differed from character to character and cross to cross. Latha *et al.,*[7] also reported that the magnitude of heterosis in rice varied from trait to trait and cross to cross and none of the cross combinations recorded significant heterosis for all the traits studied.

Table 2. Estimation of heterosis over standard checks (SH) and better parent heterosis (BPH)

S. No	Cross	Days to fifty per cent flowering		Plant height at maturity	
		BPH	SH	BPH	SH
1	ADT 37 x CSR 10	2.79**	-8.68**	23.78**	17.72**
2	ADT 37 x CSR 36	-13.95**	-23.55**	-19.92**	-6.25**
3	ADT 37 x FL 478	5.68**	0.00	36.59**	29.90**
4	ADT 37 x POKKALI	19.07**	5.79**	-3.86**	76.25**
5	ADT 43 x CSR 10	6.81**	3.72**	21.22**	33.00**
6	ADT 43 x CSR 36	-17.45**	-19.83**	-20.99**	-7.50**
7	ADT 43 x FL 478	8.94**	5.79**	6.78**	17.15**
8	ADT 43 x POKKALI	14.04**	10.74**	0.13	83.58**
9	ADT 38 x CSR 10	5.66**	-7.44**	4.68**	9.59**
10	ADT 38 x CSR 36	-12.74**	-23.55**	-15.51**	-1.08**
11	ADT 38 x FL 478	10.48**	4.55**	14.08**	19.44**
12	ADT 38 x POKKALI	25.47**	9.92**	-3.30**	77.29**
13	ADT 46 x CSR 10	-11.71**	-25.21**	-15.82**	-7.52**
14	ADT 46 x CSR 36	-13.07**	-28.51**	-3.78**	12.65**
15	ADT 46 x FL 478	-3.49**	-8.68**	7.75**	18.37**
16	ADT 46 x POKKALI	17.92**	3.31**	-7.33**	69.90**
17	ADT 42 x CSR 10	-17.14**	-16.12**	-2.19**	8.45**
18	ADT 42 x CSR 36	-26.12**	-25.21**	-16.62**	-2.38**
19	ADT 42 x FL 478	0.00	1.24*	9.14**	21.01**
20	ADT 42 x POKKALI	8.57**	9.92**	2.08**	87.14**
21	ADT 45 x CSR 10	-11.57**	-11.57**	6.05**	6.05**
22	ADT 45 x CSR 36	-12.40**	-12.40**	9.54**	28.25**
23	ADT 45 x FL 478	4.96**	4.96**	18.50**	18.50**
24	ADT 45 x POKKALI	3.72**	3.72**	2.12**	87.22**

→ Table 2. Continued

Number of tillers plant^{-1}		Number of productive tillers plant^{-1}		Panicle length		Number of filled seeds plant^{-1}	
BPH	SH	BPH	SH	BPH	SH	BPH	SH
-19.22**	-22.61**	-6.69**	-17.44**	-4.38**	-0.70	7.70**	10.25**
16.39**	19.12**	20.97**	40.42**	12.24**	16.56**	20.70**	23.56**
-36.89**	-39.54**	-30.58**	-38.58**	-23.45**	-20.50**	-30.24**	-28.59**
-23.65**	-26.85**	-24.06**	-32.81**	-6.71**	10.81**	-32.68**	-31.08**
-18.27**	-15.08**	-9.37**	-11.39**	-4.56**	1.05*	-5.54**	-5.76**
13.15**	17.56**	22.05**	41.67**	12.44**	19.05**	29.16**	28.86**
-30.00**	-27.27**	-20.02**	-21.81**	-33.79**	-29.90**	-40.69**	-40.82**
-38.30**	-35.89**	-25.60**	-27.26**	-0.79**	17.83**	-24.24**	-24.42**
15.43**	-16.76**	0.18	-15.16**	-19.84**	-25.09**	-20.48**	-23.99**
1.77**	4.15**	5.93**	22.96**	16.70**	15.99**	26.73**	21.13**
-21.92**	-43.70**	-28.72**	-39.63**	-14.40**	-20.01**	-19.35**	-22.91**
-33.41**	-51.98**	-33.87**	-44.00**	-3.31**	14.84**	-22.77**	-26.18**
31.28**	-10.19**	40.93**	11.53**	31.55**	4.44**	15.56**	13.69**
-6.41**	-4.22**	-18.92**	-5.88**	-24.61**	-25.07**	-11.41**	-12.84**
27.90**	-31.32**	28.50**	-23.17**	10.84**	-12.00**	-17.68**	-19.01**
0.12	-43.70**	-1.29	-33.70**	-1.75**	16.70**	-15.67**	-17.04**
4.75**	-5.48**	17.20**	20.44**	1.51**	4.26**	-8.78**	-0.69
8.63**	11.17**	16.62**	35.37**	14.67**	17.78**	7.98**	17.54**
-29.40**	-36.30**	-22.43**	-20.29**	-19.57**	-17.39**	-38.07**	-32.58**
-55.87**	-60.18**	-62.80**	-61.77**	-1.67**	16.78**	-40.69**	-35.43**
19.48**	19.48**	29.05**	29.05**	2.91**	2.91**	13.09**	13.09**
-20.43**	-18.57**	-18.82**	-5.76**	-3.32**	-3.32**	0.58	0.58
-35.40**	-35.40**	-34.35**	-34.35**	9.39**	9.39**	-30.89**	-30.89**
-46.53**	-46.53**	-53.70**	-53.70**	-23.36**	-8.97**	-21.14**	-21.14**

Table 2. Continued

S. No	Cross	Thousand seed weight		Seed length	
		BPH	SH	BPH	SH
1	ADT 37 x CSR 10	-7.25**	12.92**	2.85**	-12.90**
2	ADT 37 x CSR 36	1.68**	31.85**	-18.55**	-12.35**
3	ADT 37 x FL 478	-22.20**	7.94**	-11.22**	6.95**
4	ADT 37 x POKKALI	-10.23**	4.17**	-7.66**	-6.20**
5	ADT 43 x CSR 10	-21.08**	-3.91**	-14.01**	-13.98**
6	ADT 43 x CSR 36	-2.44**	26.51**	-0.43*	7.15**
7	ADT 43 x FL 478	-22.04**	8.16**	-27.04**	-12.10**
8	ADT 43 x POKKALI	-11.82**	-4.52**	-9.42**	-7.99**
9	ADT 38 x CSR 10	-18.16**	7.45**	-19.65**	-9.53**
10	ADT 38 x CSR 36	4.05**	36.61**	-20.72**	-10.73**
11	ADT 38 x FL 478	-13.03**	20.66**	-7.91**	10.94**
12	ADT 38 x POKKALI	-18.67**	6.78**	-16.11**	-5.53**
13	ADT 46 x CSR 10	-10.43**	30.74**	-22.23**	-11.94**
14	ADT 46 x CSR 36	-1.46**	43.84**	-13.52**	-2.08**
15	ADT 46 x FL 478	-4.06**	40.04**	-13.78**	3.87**
16	ADT 46 x POKKALI	-20.53**	16.00**	-14.77**	-3.49**
17	ADT 42 x CSR 10	-18.83**	15.05**	-21.42**	-10.86**
18	ADT 42 x CSR 36	-2.82**	37.75**	-16.54**	-5.32**
19	ADT 42 x FL 478	-12.82**	23.57**	-7.32**	11.65**
20	ADT 42 x POKKALI	-21.77**	10.89**	-17.09**	-5.95**
21	ADT 45 x CSR 10	3.47**	25.98**	-16.22**	-16.22**
22	ADT 45 x CSR 36	-7.40**	20.07**	-11.02**	-4.24**
23	ADT 45 x FL 478	-21.60**	8.77**	-11.71**	6.36**
24	ADT 45 x POKKALI	-6.57**	1.17**	-13.43**	-12.06**

→ Table 2. Continued

Seed breadth		Seed L/B ratio		Seed yield plant^{-1}	
BPH	SH	BPH	SH	BPH	SH
-4.97**	-4.97**	2.36**	-8.32**	-7.83**	-7.17**
-2.96**	-2.96**	-33.82**	-9.61**	29.51**	41.68**
-8.17**	-8.17**	-5.51**	16.53**	-38.46**	-38.02**
-20.10**	-5.44**	15.57**	-0.82	-43.84**	-43.44**
27.45**	-1.66**	-33.78**	-12.43**	-7.62**	-7.19**
12.16**	-11.60**	-11.16**	21.34**	37.61**	50.54**
-6.55**	-8.76**	-27.13**	-3.63**	-45.62**	-45.36**
-17.4**	-2.25**	-28.81**	-5.86**	-48.03**	-47.79**
-6.83**	-17.63**	-13.71**	9.96**	-25.79**	-30.87**
2.41**	-9.47**	-27.81**	-1.41*	23.42**	35.01**
-10.18**	-12.31**	-0.64	26.61**	-27.99**	-32.93**
-23.1**	-8.99**	-18.49**	3.87**	-37.35**	-41.64**
-2.10**	-6.04**	-20.66**	-6.33**	50.31**	19.01**
-0.62	-4.62**	-24.72**	2.81**	-14.14**	-6.07**
-2.06**	-4.38**	-11.88**	8.68**	0.21	-20.65**
-4.9**	12.54**	-27.31**	-14.19**	-12.71**	-30.88**
-10.78**	-10.89**	-11.88**	0.00	-4.12**	4.90**
1.18*	1.07*	-31.42**	-6.33**	31.81**	44.21**
-9.12**	-9.23**	-0.19	23.09**	-31.82**	-25.40**
-20.30**	-5.68**	-12.09**	-0.23	-65.43**	-62.18**
-10.18**	-10.18**	-6.68**	-6.68**	10.64**	10.64**
-5.44**	-5.44**	-25.84**	1.29	-6.60**	2.17*
-12.31**	-12.31**	-1.52**	21.45**	-30.28**	-30.28**
-27.00**	-13.61**	1.88**	1.88**	-57.28**	-57.28**

Among the twenty four crosses, eight hybrids show superior performance over standard parent for seed yield plant^{-1} from those three hybrids exhibiting desirable high value of standard heterosis *viz.,* ADT 43 x CSR 36, ADT 42 x CSR 36 and ADT 37 x CSR 36. These three hybrids also show high *per se* performance for the majority of the traits studied along with short stature plants and early flowering. Hence, these superior crosses were further utilized in crop improvement programme.

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