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RESEARCH ARTICLE

Heterosis studies for yield and yield components in rice (*Oryza sativa* L.)

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SUMMARY

Heterosis in rice was studied for yield and its component traits in 25 F_1s involving 10 parents comprised of 5 lines and 5 testers. The high magnitude of heterosis for grain yield per plant is evident by significant superiority of crosses over mid parent and better parents in several crosses. The crosses *viz.*, ADT37/ Nona bokra, ADT 37 /Pokkali, ADT 37 / FL478, ADT 42 /Pokkali , ADT47/CSR36 showed high relative heterosis and heterobeltiosis for grain yield per plant. The crosses exhibiting good heterotic expression in F_1 may be further studied to isolate superior transgressive segregants in later generations. The development of pure lines from segregating population is very important for evolving high yielding varieties.

Key Words : Rice, Relative heterosis, Heterobeltiosis

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Rice (*Oryza sativa* L.) has been one of the world's most important food crops, feeding more than half of the world's population (Khush, 1997). In the Asia and Pacific region, rice is the main staple food. In the Indian scenario, it is estimated that rice demand in 2010 will be 100 million tonnes and in 2025, the demand will be 140 million tonnes (Mishra, 2004). This projected demand can only be met by maintaining steady increase in production over the years. 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. So there is a need to develop high yielding varieties. This aim may be achieved by heterosis breeding by using desired lines/varieties. Heterosis breeding an important tool which can facilitate yield enhancement and helps enrich many other desirable quantitative traits in rice (Venkanna *et al*., 2014).

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MATERIAL AND METHODS

The present investigation was carried out at the research farm of Department of Plant Breeding and Genetics, Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu, India. The breeding material comprised of 10 rice genotypes. Five high yielding popular varieties and susceptible to salinity *viz*., ADT 37, ADT 42, ADT 43, ADT(R)47, TNAU Rice ADT 49 were crossed with five salinity tolerant testers *viz.,* CSR 10, CSR 36, Nona Bokra, Pokkali, FL 478 and produced 25 hybrids by line × tester mating design. All the parents along with the 25 hybrids were raised in Randomized Block Design with two replications with spacing of 20 x 15 cm in field during *Kharif* 2015. Recommended package of practices were followed to establish the crop. Five plants were selected randomly from each entry in each replication to record data on ten physio-morphological traits *viz.,* days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility, thousand grain weight and single plant yield. Heterosis was estimated over mid parent and better parent and tested for significance as suggested by Snedecor and Cochran (1967).

The magnitude of heterosis is a prerequisite for development of any hybrid. Before selecting a cross on the basis of *per se* performance it would be worthwhile to evaluate them for hybrid vigour for various characters. Knowledge on the extent of heterosis would help in the choice of the best crosses for commercial exploitation.

RESULTS AND DISCUSSION

Mean of parents and crosses are given in the Table 1. The magnitude and range of heterosis showing significant heterosis over mid parent and better parent for all the characters are presented in Table 1. ADT 37 / FL478 was the most promising cross combination since it showed highly significant negative heterobeltiosis for days to 50 per cent flowering followed by ADT 42 / Nonabokra and ADT47/Nonabokra. Negative heterosis is a desirable feature for this character as it is useful for early maturity. Negative heterosis for this trait was reported by Hariramakrishnan *et al*. (2009); Selvaraj *et al.* (2011); Reddy *et al*. (2012); Latha *et al*. (2013) and Balakrishna and Satyanarayana (2015). The above mentioned heterotic cross showed good *per se* performance and among the parents, Nona bokra exhibited better *per se* performance.

Negative heterosis for plant height is a desirable feature as it is useful to develop dwarf types and resistance to lodging. The crosses ADT37/FL478, ADT37/CSR36, ADT42/ Nonabokra, ADT42/Pokkali, ADT42/CSR10,ADT43/Nonabokra, ADT43/Pokkali, ADT(R)47/Nona bokra, ADT(R)47/Pokkali, TNAUADT49/Nona bokra, showed high significant negative heterobeltiosis. Among these crosses the cross ADT(R)47/Pokkali, had shown highest significant negative heterobeltiosis. Similar results were also reported by Saravanan *et al*. (2006); Bagheri and Babaeian Jelodar (2010); Selvaraj *et al.* (2011) and Latha *et al*. (2013).

For number of productive tillers per plant most of the hybrids showed significant positive relative heterosis and heterobeltiosis. The cross ADT43/Pokkali exhibited the highest both significant positive relative heterosis and heterobeltiosis. The results of significant positive heterosis over mid parent and better parent for number of productive tillers per plant are in agreement with the results of Deo Raj *et al*. (2007); Selvaraj *et al.* (2011) and Latha *et al*. (2013). The *per se* performance of the above heterotic cross was high but the parents of the cross showed low *per se* performance. The heterotic performance of the cross may be due to good combining ability effect and high nicking ability of parents.

Heterosis for panicle length was most important factor in deciding grain yield. In the present study sixteen crosses exhibited significant positive heterosis over mid parent, while fifteen crosses showed significant positive heterosis over better parent. The crosses, ADT(R)47/CSR36 followed by ADT43/CSR36 showed the highest positive heterosis over both mid and better parents. Similar results were earlier reported by Krishnaveni *et al*. (2005), Bagheri and Jelodar (2010), Selvaraj *et al.* (2011) and Latha *et al*. (2013). Both the heterotic crosses above mentioned recorded high *per se* performance while the parents involved in the above crosses recorded low *per se* performance. This indicated that the high heterosis may be due to good combining ability and high nicking ability of parents.

The cross ADT(R)47/ CSR36 showed highest significant positive relative heterosis where as the cross TNAU ADT49/CSR36 showed both high significant positive relative heterosis and heterobeltiosis for thousand grain weight. These results are in accordance with the results of Deo Raj *et al*. (2007); Selvaraj *et al.* (2011); Latha *et al*. (2013) and Jarwar *et al*. (2013).

The cross ADT(R)47/CSR36 showed highest significant positive relative heterosis, where as the cross ADT37/CSR36 showed both high significant positive relative heterosis and heterobeltiosis for number of filled grains per panicle. For spikelet fertility per cent the hybrids ADT37/CSR36 showed high significant positive relative heterosis. The cross ADT43/Pokkali exhibited the highest both significant positive relative heterosis and heterobeltiosis.

For grain yield per plant thirteen crosses showed significant positive relative heterosis while four crosses exhibited significant positive heterobeltiosis. The cross, ADT37/Pokkali recorded the highest positive heterosis over mid parent and better parent followed by ADT37/ Nona bokra and ADT37/FL478. Similar findings were also reported by Deo Raj *et al*. (2007), Bagheri and Jelodar (2010), Selvaraj *et al*. (2011), Reddy *et al*. (2012); Latha *et al*. (2013); Jarwar *et al*. (2013) and Venkanna *et al*. (2014). These superior heterotic crosses

Table 1 : *Per se* performance of parents and hybrids for different characters of rice

Parents/hybrids	DFF	PH	NPT	PL	TGW	NFG	SFP	SPY
ADT37	74.50	107.85	15.65	24.89	2.26	79.4	82.07	16.42
ADT42	82.95	102.90	17.32	26.16	2.21	150.8	91.65	19.02
ADT43	81.01	76.18	14.50	21.18	1.53	87.1	88.36	19.08
ADT(R)47	88.72	81.80	15.35	20.73	1.38	130.4	87.20	16.35
TNAU Rice ADT49	94.85	94.20	21.00	23.11	1.50	147.4	89.31	24.53
Nonabokra	101.13	134.40	14.75	21.32	2.59	126.6	88.26	18.52
Pokkali	114.10	140.50	13.05	25.85	2.49	122.6	85.95	19.23
FL478	83.30	88.80	17.15	23.43	2.34	152.7	88.73	22.25
CSR10	87.15	92.40	14.55	20.93	1.74	136.3	88.62	16.52
CSR36	95.50	76.70	17.40	16.24	1.30	94.1	83.51	17.74
ADT 37 / Nonabokra	91.6	133.89	22.5	27.05	2.47	121.8	85.62	28.09
ADT37/Pokkali	100.35	149.75	18.58	29.39	2.44	144.4	86.63	33.00
ADT37 / FL478	64.68	99.95	16	23.1	2.28	147.8	86.89	33.05
ADT37 / CSR10	82.32	104.29	21	23.97	1.26	121.3	85.97	19.44
ADT37 / CSR36	83.2	99.37	13.9	24.16	2.18	127	86.24	22.63
ADT42 / Nonabokra	84.68	109.27	23.2	26.96	1.44	107.52	83.19	24.55
ADT42 / Pokkali	105.55	103.63	20.6	26.93	1.65	133.8	88.35	29.06
ADT42 / FL478	72.32	98.18	15.9	25.96	2.24	117.2	86.5	26.59
ADT42 / CSR10	85.32	93.81	19.85	27.33	2.06	141.9	85.77	28.03
ADT42 / CSR36	82.35	121.82	21	29.46	2.22	115.8	86.57	20.52
ADT43 / Nonabokra	107.2	119.6	18.95	24.7	2.06	144.2	88.19	27.42
ADT43/Pokkali	109.5	132.36	23.95	25.14	2.23	128.2	91.43	23.48
ADT43/FL478	77	105.35	18.75	25.65	2.36	142.9	92.06	28.15
ADT43/CSR10	89.1	121.35	21	23.71	2.05	127.4	85.17	21.38
ADT43/CSR36	80.62	106.5	17.75	27.08	1.72	123.4	89.28	20.8
ADT(R)47 /Nonabokra	115.55	106.28	20.95	26.05	1.39	123.3	84.35	22.76
ADT(R)47/Pokkali	104.2	86.45	21	26.02	1.41	136.2	88.88	17.26
ADT(R)47/FL478	89.25	105.56	22.75	29.58	1.95	170	88.36	44.44
ADT(R)47/CSR10	91.25	104.35	21	26.75	1.54	157.3	87.13	24.37
ADT(R)47/CSR36	91.35	102.97	19.37	27.01	1.77	165.8	88.48	26.97
TNAU Rice DT49/Nonabokra	103.65	105.01	20.9	29.53	1.38	158.6	85.74	27.18
TNAU Rice ADT49/Pokkali	103.1	148.37	15.85	26.97	2.16	140.8	85.23	23.33
TNAU Rice ADT49/FL478	85.7	118.2	16.85	26.6	2.31	148.4	90.01	30.36
TNAU Rice ADT49/CSR10	91.57	119.25	14.05	26.54	1.51	137.4	84.88	15.65
TNAU Rice ADT49/CSR36	100.7	117.9	16.4	26.01	2.06	139.4	86.31	17.59

DFF-Days to 50% flowering, PH- Plant height, NPT-Number of productive tillers per plant, PL-Panicle length, NFG-Number of filled grains per panicle, SFP-Spikelet fertility , TGW- Thousand grain weight, SPY-.Single plant yield

Table 2 : Estimates of heterosis over mid parent (MP) and better parent (BP) in per cent for different characters in rice

Hybrids	DFF		PH		NPT		PL		TGW		NFG		SFP		SPY	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
ADT 37 / Nonabokra	4.31**	-9.42**	10.54**	-0.38NS	48.03**	43.77**	17.07**	8.68**	1.86NS	-4.63**	18.25**	-3.79NS	0.53NS	-3.00**	60.76**	51.65**
ADT37/Pokkali	6.42**	-12.05**	20.60**	6.58**	29.48**	18.72*	15.84**	13.70**	2.85*	-1.81NS	42.97**	17.78**	3.12**	0.80NS	85.13**	71.61**
ADT37 / FL478	-18.02**	-22.35**	1.66NS	-7.32**	-2.44NS	-6.71NS	-4.38NS	-7.19**	-0.87NS	-2.56NS	27.36**	-3.21NS	1.75**	-2.07**	70.93**	48.54**
ADT37 / CSR10	1.84NS	-5.55**	4.16NS	-3.30NS	39.07**	34.19**	4.62NS	-3.70NS	-37.00**	-44.25**	12.47**	-11.01**	0.72NS	-3.00**	18.06NS	17.71NS
ADT37 / CSR36	-2.12NS	-12.88**	7.69**	-7.86**	-15.89**	-20.11**	17.46**	-2.95NS	22.19**	-3.76*	46.40**	34.96**	4.16**	3.26**	32.49**	27.56*
ADT42 / Nonabokra	-8.00**	-16.27**	-7.91**	-18.70**	44.71**	33.99**	13.56**	3.06NS	-39.94**	-44.40**	-22.48**	-28.70**	-7.52**	-9.23**	30.77**	29.05*
ADT42 / Pokkali	7.13**	-7.49**	-14.85**	-26.25**	35.68**	18.97**	3.57NS	2.94NS	-29.64**	-33.60**	-2.12NS	-11.27**	-0.51NS	-3.61**	51.95**	51.12**
ADT42 / FL478	-12.99**	-13.18**	2.41NS	-4.58NS	-7.73NS	-8.17NS	4.71*	-0.76NS	-1.65NS	-4.19**	-22.77**	-23.25**	-4.09**	-5.62**	28.86**	19.51NS
ADT42 / CSR10	0.32NS	-2.10NS	-3.93NS	-8.83**	24.59**	14.64*	16.06**	4.47NS	4.44*	-6.58**	-1.15NS	-5.90*	-4.85**	-6.42**	57.77**	47.40**
ADT42 / CSR36	-7.71**	-13.77**	35.66**	18.39**	20.99**	20.69**	38.96**	12.61**	26.68**	0.68NS	-5.43NS	-23.21**	-1.15*	-5.54**	11.62NS	7.86NS
ADT43 / Nonabokra	17.71**	6.01**	13.59**	-11.01**	29.57**	28.47**	16.24**	15.85**	-0.12NS	-20.46**	34.96**	13.90**	-0.13NS	-0.19NS	45.85**	43.71**
ADT43/Pokkali	12.24**	-4.03**	22.17**	-5.79**	73.87**	65.17**	6.92**	-2.73NS	10.95**	-10.26**	22.27**	4.57NS	4.91**	3.48**	22.58*	22.10NS
ADT43/FL478	-6.27**	-7.56**	27.72**	18.64**	18.48**	9.33NS	15.01**	9.50**	21.70**	0.77NS	19.18**	-6.42*	3.97**	3.75**	36.22**	26.52*
ADT43/CSR10	5.97**	2.24NS	43.97**	31.33**	44.58**	44.33**	12.60**	11.95**	25.50**	18.10**	14.06**	-6.53*	-3.76**	-3.90**	20.11NS	12.05NS
ADT43/CSR36	-8.66**	-15.59**	39.33**	38.85**	11.29NS	2.01NS	44.74**	27.86**	20.99**	11.73**	36.20**	31.14**	3.90**	1.05*	13.01NS	9.04NS
ADT(R)47/Nonabokra	21.73**	14.26**	-1.68NS	-20.92**	39.20**	36.48**	23.90**	22.19**	-29.97**	-46.33**	-4.05NS	-5.44NS	-3.86**	-4.44**	30.54*	22.89NS
ADT(R)47/Pokkali	2.75*	-8.68**	-22.22**	-38.47**	47.89**	36.81**	11.73**	0.68NS	-27.04**	-43.26**	7.67**	4.45NS	2.67**	1.93**	-2.95NS	-10.22NS
ADT(R)47/FL478	3.77*	0.60NS	23.75**	18.87**	40.00**	32.65**	33.98**	26.28**	4.84**	-16.67**	20.10**	11.33**	0.46NS	-0.41NS	30.23**	29.71**
ADT(R)47/CSR10	3.77*	2.86NS	19.80**	12.93**	40.47**	36.81**	28.41**	27.78**	-1.28NS	-11.49**	17.96**	15.41**	-0.89NS	-1.69**	48.28**	47.52**
ADT(R)47/CSR36	-0.82NS	-4.35*	29.93**	25.88**	18.29**	11.32NS	46.12**	30.29**	32.09**	28.26**	47.71**	27.15**	3.66**	1.47**	58.26**	52.06**
TNAU Rice ADT49/Nonabokra	5.78**	2.50NS	-8.13**	-21.87**	16.92**	-0.48NS	32.91**	27.75**	-32.27**	-46.53**	15.77**	7.60**	-3.42**	-3.98**	26.21**	10.71NS
TNAU Rice T49/Pokkali	-1.32NS	-9.64**	26.43**	5.60**	-6.90NS	-24.52**	10.17**	4.35NS	8.41**	-13.08**	4.30NS	-4.48NS	-2.73**	-4.56**	6.58NS	-4.97NS
TNAU Rice ADT49/FL478	-3.79*	-9.65**	29.18**	25.48**	-11.66*	-19.76**	14.31**	13.55**	20.57**	-1.07NS	-1.10NS	-2.82NS	1.12*	0.80NS	29.76**	23.69*
TNAU Rice ADT49/CSR10	0.63NS	-3.46*	27.81**	26.59**	-20.96**	-33.10**	20.50**	14.82**	-6.79**	-13.22**	-3.14NS	-6.78*	-4.59**	-4.96**	-23.81*	-36.27**
TNAU Rice ADT49/CSR36	5.81**	5.45**	37.98**	25.16**	-14.58**	-21.90**	32.18**	12.52**	47.14**	37.33**	15.45**	-5.43*	-0.10NS	-3.34**	-16.81NS	-28.35**

* and ** indicate significance of values at P=0.05 and 0.01, respectively NS=Non-significant MP-Mid parent BP-Better parent

exhibited high *per se* performance for yield.

The heterosis showed variation from trait to trait. The traits number of productive tillers per plant and number of filled grains per panicle showed high heterobeltiosis. Mid parent heterosis for yield ranged from -23.95 per cent to 85.19 per cent. Better parent heterosis for yield ranged between -36.27 per cent and 71.61 per cent.

Conclusion :

In conclusion based on the overall performance (*per se* performance and high significant positive relative heterosis and heterobeltiosis) the crosses ADT 37/ FL478 and ADT47/CSR36 were identified as the most promising cross. These crosses may be further advanced to isolate superior transgressive segregants for yield and yield contributing traits.

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