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Research Note

Heterosis for quality traits in rice (*Oryza sativa* L.)

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Abstract
Nine high yielding rice genotypes along with their twenty crosses which effected in line x tester fashion (5x4) were subjected to study the heterosis and heterobeltiosis for quality traits at Agricultural Research Station, Nellore. The estimates of heterosis were low for quality traits *viz.*, kernel length, kernel breadth, kernel L/B ratio, hulling%, milling% and amylose content whereas it was high for head rice recovery, water uptake, volume expansion ratio, kernel elongation ratio, gel consistency and alkali spreading value. The best genotypes with high heterosis were identified were, RNR 2456 x NLR 34449 for head rice recovery, water uptake and volume expansion ratio and RNR 2456 x IR 36 for alkali spreading value, kernel elongation ratio and gel consistency.

Key words
Heterosis, rice, quality traits, gel consistency.

Rice is one of the most important staple food crops of India. It contributes to total food grain and cereal production of the country to nearly 43% and 46% respectively (Bhati *et al*., 2014). The present world rice area, production and productivity is 161.6 mha, 480.7 mt and 2.97 t/ha. respectively. In India, it is being grown in an area of 44.00 mha with the production of 106.0 mt and productivity of 2.41 t/ha. It contributes 25% to agricultural GDP (USDA, Rice Outlook, 2014). Thus there is a need for continuous improvement of productivity in rice. Besides yield, quality co nsiderations have been attracting the attention of the breeders with increased quality consciousness of the consumers. This may be due to change in the income levels of the people. The major considerations in commercial exploitation of heterosis are whether it is possible to obtain sufficient heterosis for characters of economic importance and whether it is possible to fix such heterosis in pure breeding lines. Hence, detailed information about heterosis for quality characters by using the parental lines has direct relevance in breeding programmes.

The experimental materials used for the present investigation consisting of F_1 hybrids of 20 crosses developed by crossing 5 lines/genotypes of rice *viz*., BPT 5204, MTU 1010, WGL 48684, RNR 2465 and JGL 11118 with four testers *viz*., NLR 34449, NLR 145, IR 36 and IR 64 using line x tester mating design during kharif, 2014. The F_1's (20 hybrids along with parental lines (lines (5) + testers (4)) were evaluated in RBD with three replications at Agricultural Research Station, Nellore. In each replication, entries (F_1's and parents) were grown in four rows of 2 m length with spacing of 20 cm x 15 cm transplanted as single seedling/hill. The data was recorded from each cross/genotype in each replication for 12 quality traits which were recorded on individual plant basis *viz.* kernel length (mm), kernel breadth (mm), kernel L/B ratio, hulling (%), milling (%), head rice recovery (%), water uptake (ml), volume expansion ratio, kernel elongation ratio, gel consistency, alkali spreading value and amylose content. All the recommended agronomic and plant protection practices were uniformly applied throughout the crop growth period. The data were subjected to the statistical analysis for analysis of variance as per Panse and Sukhatme (1985) and line x tester analysis as per Kempthorne (1957).

For the ready acceptance by the consumers, the physical appearance of rice is a very important component in total quality improvement in- turn the market price of rice depends upon grain size and shape of the kernel. The range of heterosis for kernel length was from -18.01 (RNR 2465 x NLR 145) to 5.83 (BPT 5204 x NLR 34449) over mid parent and -24.65 (RNR 2465 x NLR 145) to 5.36 (BPT 5204 x NLR 34449) over better parent respectively. None of the crosses exhibited significant positive heterosis over mid and better parents for kernel length Krishnaveni *et al.* (2005), Raju *et al.* (2005) and Aditya *et al.* (2012) reported negative heterosis for the trait. Negative heterobeltiosis is considered to be the best for fine grain types for which 50% of the hybrid combinations were good suggesting the extent of heterosis present for lower kernal breadth in the material studied. The range of heterosis for kernel breadth was from -16.08 (RNR 2465 x NLR 145) to 14.8 (RNR 2465 x NLR 34449) over mid parent and -19.43 (RNR 2465 X NLR 145) to 14.41 (BPT 5204 x NLR 34449) over better parent. One parent which was in agreement with the results of Panwar and Mashiat Ali (2010).

Besides kernal length, kernel L/B ratio is the important trait to be considered in breeding quality rices for which positive heterosis found to be desirable. The range of heterosis for L/B ratio was -3.48 to 6.08 over mid parent and -3.77 to 4.44 over better parent. The hybrid JGL 11118 x NLR 34449 (MPH: 6.08, BPH: 4.44) recorded significant positive heterosis for kernel L/B ratio for both mid parent and better parent and it was found to be the best cross for this trait. Patil *et al.* (2011) and Venkanna *et al.* (2014) reported similar results for this trait. Significant positive heterosis is desirable for hulling %, in the present study it ranged from -5.27 (WGL 48684 x IR 64) to 6.82 (JGL 11118 x NLR 145) over mid parent and -9.36 to 3.58 over the better parent. Pandya and Tripathi *et al.* (2006) and Raju *et al.* (2006) reported both positive and negative heterosis for the trait hulling percent.

In the present study, the heterosis for milling% ranged from -13.95 (MTU 1010 X NLR 145) to 1.33 (WGL 48684 X IR 36) over mid parent and -18.60 (JGL 11118 x NLR 145) to 0.00 (WGL 48684 X IR 36) over better parent respectively. None of the crosses exhibited significant positive heterosis over mid and better parent. However, three hybrids recorded significant negative heterosis over mid parent and eleven hybrids over better parent. Negative heterosis for this trait was already reported by Rukminidevi *et al.* (2014). High head rice recovery is one of the objectives in quality rice breeding programmes and significant positive heterosis is desirable for this trait. The heterosis varied from -18.03 to 26.02 (RNR 2465 x NLR 34449) over mid parent and -22.24 to 11.91 (RNR 2465 x NLR 34449) over better parent. Seven crosses over mid parent and four crosses over better parent exhibited positive significant heterosis. Krishna *et al.* (2010) and Sarawagi *et al.* (2010) reported positive heterosis for the trait head rice recovery.

In rice, cooking quality traits include kernel length and breadth after cooking, volume expansion, linear elongation of kernels on cooking and water uptake. Lengthwise expansion after cooking without increase in breadth is considered to be one of the important features of quality rice. Water uptake is considered to be an important cooking character of rice, as it gives an indirect measure of volume expansion after cooking. Hence, positive heterosis is desirable. The range of heterosis for this trait was from -24.2 (RNR 2465 x NLR 145) to 75.1 (JGL 11118 x IR 36) over mid parent and -31.02 (WGL 48684 x NLR 145) to 70.21 (JGL 11118 x IR 36) over better parent respectively. Significant positive heterosis was exhibited by 12 hybrids each over mid parent and better parent respectively. Nayak *et al.* (2015) observed similar positive heterosis for this trait.

Volume expansion is the ability of the rice grain to expand upon cooking for which positive heterosis is desirable. Out of 20 crosses studied, positive significant heterosis was observed in seven crosses over mid parent and six crosses over better parent. The range of heterosis may vary from -43.75 to 107.79 over mid parent and -52.44 to 83.91 over better parent. The cross RNR 2465 x NLR 34449 (MPH: 107.79, BPH: 83.91) recorded high positive heterosis for both mid and better parents followed by JGL 11118 x IR 36 (MP: 66.67, BP: 30.08), RNR 2465 x IR 64 (MP: 44.74, BP: 29.41) and MTU 1010 x IR 36 (MP: 48.28, BP:22.86). Sahai *et al.* (1986) and Rukminidevi *et al.* (2014) reported positive values of heterosis for the trait volume expansion ratio.

Rice with good cooking quality is generally characterized by its length wise elongation upon cooking. The heterosis ranged for this trait was from -10.79 (WGL 48684 x IR 64) to 29.18 (RNR 2465 x IR 36) and -11.50 (JGL 11118 x NLR 34449) to 24.29 (RNR 2465 x IR 36) over mid parent and better parent respectively. Four hybrids each exhibited significant positive heterosis over mid parent and better parent. The crosses *viz.*, RNR 2465 x IR 36 (MP: 29.18, BP: 24.29), RNR 2465 x NLR 34449 (MP: 21.72, BP: 18.39), MTU 1010 x IR 36 (MP: 25.25, BP: 17.35) and BPT 5204 x IR 36 (MP:20.31, BP: 19.20) recorded significant positive heterosis over mid parent and better parent for and these were found to be the best crosses. Similar positive heterosis for this trait was already reported by Krishna *et al.* (2016).

Chemical quality characters include alkali spreading value, gel consistency and amylose content. Generally for chemical quality characters, intermediate values are desirable. Hence it is difficult to establish a definite trend for heterosis and much depends upon the parental material. In the present study most of the parents used were in desirable levels.

Gel consistency is a good index for assessing the texture of cooked rice. Varieties having the same amylose content may differ in tenderness may be attributed to the variation in the gel consistency. Therefore, the cooked rices need to be differentiated by gel consistency test. Generally the varieties with softer gel consistency are preferred in same amylose group. For gel consistency the range of heterosis varied from -59.28 (BPT 5204 x NLR 145) to 30.84 (RNR 2465 x IR 36) and -62.81 (BPT 5204 x NLR 145) to 14.77 (WGL 48684 x IR 64) over mid parent and better parent respectively. Eight hybrids over mid parent and 12 hybrids over better parent exerted negative significant heterosis for this trait. Similar trend of negative significant heterosis was already reported by Shivani *et al.* (2009).

Alkali spreading value is inversely related to gelatinization temperature (GT score). GT indicates the range of temperature within which the starch granules start swelling irreversibly in hot water and determines the time taken to cook the rice. In rice, the varieties with intermediate GT score were preferred. The range of heterosis for trait was -64.91 (RNR 2465 x NLR 34449) to 36.84 (RNR 2465 x IR 36) over mid parent and -66.67 (RNR 2465 x NLR 34449) to 30 (RNR 2465 x IR 36) over better parent respectively. Fifteen hybrids each over mid and better parents recorded significant negative heterosis for this trait. Only one hybrid RNR 2465 x IR 36 (MPH: 36.84, BPH: 30) exerted significant positive heterosis for alkali spreading value. Negative significant heterosis was already reported by Aditya Kumar *et al.* (2012).

Amylose is an important trait which determines the cooking quality of rice. Rice grains cook dry, less tender and become hard upon cooling, when amylose content is high (>25%), while rice grains cook moist and sticky when amylose is low (10-19%). Generally intermediate amylose content (20-25%) is preferred in most of the rice growing areas. All the 20 cross combinations studied recorded significant negative heterosis for the trait amylose content over both mid and better parent. It was ranged from -28.5 (WGL 48684 x NLR 34449) to -9.89 (BPT 5204 x NLR 145) over mid parent and -31.47 (WGL 48684 x NLR 34449) to -12.39 (BPT 5204 x NLR 145) over better parent respectively. The parents involved in these crosses showed medium amylose content but the cross combinations exhibited low values for this trait indicating all the parents that exhibited high mean values need not always produce heterotic hybrids. Shinde *et al.* (2013) reported negative heterosis for some of hybrids for amylose content.

The estimates of heterosis were low for quality traits *viz.*, kernel length, kernel breadth, kernel L/B ratio, hulling%, milling% and amylose content whereas it was high for head rice recovery, water uptake, volume expansion ratio, kernel elongation ratio, gel consistency and alkali spreading value. The best genotypes with high heterosis were identified were, RNR 2456 x NLR 34449 for head rice recovery, water uptake and volume expansion ratio and RNR 2456 x IR 36 for alkali spreading value, kernel elongation ratio and gel consistency.

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Table 1. Mean performance of parents and crosses for quality attributing characters

Genotype	KL	KB	L/B Ratio	H%	M%	HRR %	WU (ml)	VER	KER	GC(mm)	ASV	AC
Lines												
BPT 5204	5.60	1.90	2.95	74.80	68.90	52.25	239	4.10	1.62	50.00	5.00	23.00
MTU 1010	6.90	2.15	3.23	75.10	70.55	64.30	180	5.25	1.38	44.00	4.30	23.42
JGL 11118	6.15	1.75	3.52	72.10	64.30	52.80	178	6.15	1.40	51.50	3.50	25.45
RNR 2465	5.95	1.95	3.06	73.15	68.10	43.00	241	3.35	1.47	45.00	4.50	24.90
WGL 48684	5.90	1.85	3.20	72.75	66.90	57.05	218	3.55	1.54	43.50	4.25	23.75
Mean	**6.10**	**1.92**	**3.19**	**73.58**	**67.75**	**53.88**	**210.90**	**4.48**	**1.48**	**46.80**	**4.31**	**24.10**
Testers												
NLR 34449	5.55	1.90	2.93	74.40	67.40	55.40	230	4.35	1.55	56.00	4.05	25.90
NLR 145	7.10	2.15	3.32	75.55	68.45	57.25	274	4.15	1.57	60.50	4.10	21.72
IR 36	6.90	1.90	3.63	75.50	67.95	57.70	188	3.45	1.59	62.00	5.00	24.60
IR 64	7.10	2.20	3.26	77.10	71.60	59.75	248	4.25	1.57	44.00	4.10	24.60
Mean	**6.66**	**2.04**	**3.29**	**75.64**	**68.85**	**57.52**	**234.88**	**4.05**	**1.57**	**55.63**	**4.31**	**24.21**

KL: Kernal Length, **KB: Kernal Breadth,** **L/B ratio: Kernal length/Breadth ratio**

H%: Hulling % **M%:Milling %** **HRR%: Head Rice Recovery%**

WU: Water Uptake **VER: Volume Expansion Ratio** **KER: Kernal Elongation Ratio**

GC: Gel Consistancy **ASV: Alkali Spreading Value** **AC: Amylose Content**

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Table 2. Estimates of mid parent Heterosis (MP), Heterobeltiosis (BH) for grain quality attributes in rice hybrids

		Kernal length (mm)		Kernal breadth (mm)		Kernal L/B ratio		Hulling%		Milling%		Head Rice Recovery (%)	
S.No	Cross	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
1	BPT 5204 x NLR 34449	5.83	5.36	14.80*	14.41*	-0.80	-1.07	-1.32	-2.39	-7.89	-7.89	9.89**	6.77*
2	BPT 5204 x NLR 145	-8.66**	-18.31**	0.00	-5.57	3.76*	3.24	0.91	0.58	-8.64	-13.95*	-4.57	-8.73*
3	BPT 5204 x IR 36	-15.20**	-23.19**	-7.90	-16.53**	0.20	-0.26	3.84	3.12	-7.89	-7.89	12.69**	7.37*
4	BPT 5204 x IR 64	-4.72	-14.79**	5.23	0.15	2.30	0.78	-3.91	-5.73*	-9.76*	-15.91**	-8.48**	-14.23**
5	MTU 1010 x NLR 34449	-3.61	-13.04**	2.60	-2.17	3.41*	2.93	4.10	1.77	-6.17	-11.63*	3.26	-3.89
6	MTU 1010 x NLR 145	-5.71*	-7.04*	9.01	7.53	-3.48*	-3.77*	-1.01	-2.48	-13.95**	-13.95*	-9.17**	-14.15**
7	MTU 1010 x IR 36	-2.90	-2.90	2.92	-2.75	1.66	1.39	-4.12	-5.88*	-6.17	-11.63*	-18.03**	-22.24**
8	MTU 1010 x IR 64	-7.14**	-8.45**	5.31	4.75	3.15*	1.82	-1.86	-2.58	-10.80*	-11.82*	-12.62**	-15.71**
9	JGL 11118 x NLR 34449	2.56	-2.44	6.51	-2.41	6.08**	4.44*	4.87	2.46	-4.11	-7.89	12.03**	9.40**
10	JGL 11118 x NLR 145	-6.42*	-12.68**	3.65	0.71	3.62*	1.26	6.82*	3.58	-10.26*	-18.60**	3.32	-0.70
11	JGL 11118 x IR 36	-6.51*	-11.59**	-2.52	-3.99	5.28**	2.91	2.91	0.15	-4.11	-7.89	5.61	1.13
12	JGL 11118 x IR 64	-0.38	-7.04*	5.23	1.42	1.27	-2.01	-4.49	-9.36**	-6.33	-15.91**	-2.62	-8.28*
13	RNR 2465 x NLR 34449	-0.87	-4.20	-2.26	-4.26	1.59	0.74	-0.66	-1.17	1.30	0.00	26.02**	11.91**
14	RNR 2465 x NLR 145	-18.01**	-24.65**	-16.08**	-19.43**	1.14	-0.46	-0.70	-0.95	-2.44	-6.98	18.70**	3.93
15	RNR 2465 x IR 36	-9.73**	-15.94**	-6.21	-13.64*	0.37	-1.19	-3.27	-3.38	-3.90	-5.13	13.31**	-1.13
16	RNR 2465 x IR 64	-3.45	-11.27**	2.22	-1.07	3.23*	0.58	-4.65	-6.98*	-6.02	-11.36*	21.46**	4.44
17	WGL 4868 x NLR 34449	-5.68	-8.47*	7.10	2.66	2.75	1.61	-0.07	-0.45	-12.00*	-13.16*	-11.96**	-13.23**
18	WGL 48684xNLR 145	-6.92*	-14.79**	0.54	-1.36	-1.21	-3.04	0.63	-0.51	-7.50	-13.95*	-17.59**	-17.73**
19	WGL 48684xIR 36	-6.25*	-13.04**	-7.40	-12.95*	3.07*	1.19	-4.78	-5.52	1.33	0.00	2.48	1.91
20	WGL 48684xIR 64	-6.15*	-14.08**	-7.89	-8.88	-0.50	-3.31*	-5.27*	-8.38**	1.23	-6.82	3.34	1.00

**Significant at 1% * Significant at 5%

Table 2(Continued). **Estimates of mid parent Heterosis (MP), Heterobeltiosis (BH) for grain quality attributes in rice**

		Water uptake (ml)		Volume expansion ratio		Kernal elongation ratio		Gel consistency (mm)		Alkali spreading value		Amylose content	
S.No	**Cross**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**
1	BPT 5204 x NLR 34449	11.73**	9.62*	-10.06	-12.64*		-8.98	-5.66	-10.71	-55.80**	-60.00**	-20.04**	-24.52**
2	BPT 5204 x NLR 145	-23.20**	-28.10**	-20.00**	-20.48**	-7.86	-9.29	-59.28**	-62.81**	-56.04**	-60.00**	-9.89*	-12.39*
3	BPT 5204 x IR 36	66.74**	48.95**	19.21**	9.76	20.31**	19.20*	-30.36**	-37.10**	-40.00**	-40.00**	-18.91**	-21.54**
4	BPT 5204 x IR 64	21.27**	19.19**	-7.78	-9.41	11.64	9.91	-8.51	-14.00	-23.08*	-30.00**	-19.54**	-22.15**
5	MTU 1010 x NLR 34449	67.77**	49.35**	7.29	-1.90	10.73	4.84	-20.00	-28.57*	-52.10**	-53.49**	-24.78**	-28.38**
6	MTU 1010 x NLR 145	-13.34**	-28.28**	-14.89**	-23.81**	10.85	4.47	-21.53	-32.23**	-28.57*	-30.23*	-13.84**	-16.97**
7	MTU 1010 x IR 36	55.65**	52.13**	48.28**	22.86**	25.25**	17.35*	-27.36*	-37.90**	-35.48**	-40.00**	-25.04**	-26.83**
8	MTU 1010 x IR 64	63.23**	40.81**	-18.95**	-26.67**	17.29*	10.54	-11.36	-11.36	-52.38**	-53.49**	-27.12**	-28.86**
9	JGL 11118 x NLR 34449	35.71**	20.22**	-28.57**	-39.02**	-5.08	-9.68	-19.07	-22.32	-33.77**	-38.27**	-23.47**	-24.13**
10	JGL 11118 x NLR 145	49.94**	23.54**	12.62**	-5.69	8.60	2.88	-24.11*	-29.75*	-34.21**	-39.02**	-21.78**	-27.50**
11	JGL 11118 x IR 36	75.10**	70.21**	66.67**	30.08**	9.55	3.15	-13.66	-20.97	5.88	-10.00	-25.47**	-26.72**
12	JGL 11118 x IR 64	6.59	-8.48*	-43.75**	-52.44**	10.29	4.47	-23.56	-29.13*	-47.37**	-51.22**	-20.68**	-22.00**
13	RNR 2465 x NLR 34449	30.92**	28.07**	107.79**	83.91**	21.72**	18.39*	-26.73*	-33.93*	-64.91**	-66.67**	-22.64**	-24.13**
14	RNR 2465 x NLR 145	-24.20**	-28.83**	28.00**	15.66*	-5.94	-8.95	-14.69	-25.62*	-18.60	-22.22	-11.85*	-17.47**
15	RNR 2465 x IR 36	30.92**	16.63**	17.65*	15.94*	29.18**	24.29**	30.84*	12.90	36.84**	30.00**	-25.05**	-25.50**
16	RNR 2465 x IR 64	21.93**	20.20**	44.74**	29.41**	11.88	8.31	-19.10	-20.00	4.65	0.00	-20.4**	-20.88**
17	WGL 4868 x NLR 34449	-10.04**	-12.39**	3.80	-5.75	3.88	3.55	-53.77**	-58.93**	-51.81**	-52.94**	-28.5**	-31.47**
18	WGL 48684xNLR 145	-23.17**	-31.02**	-22.08**	-27.71**	5.31	4.47	-43.27**	-51.24**	-40.12**	-41.18**	-23.91**	-27.16**
19	WGL 48684xIR 36	0.25	-6.65	4.29	2.82	-3.36	-4.73	-26.07*	-37.10**	-45.95**	-50.00**	-21.61**	-22.97**
20	WGL 48684xIR 64	-17.29**	22.22**	-1.28	-9.41	-10.79	-11.50	15.43	14.77	-4.19	-5.88	-24.3**	-25.61**

** Significant at 1% * Significant at 5%

MP= Mid parent, BP: Better Parent