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Study on Heterosis and Heterobeltiosis of Yield and Important Yield Attributes for Twenty One Crosses in Rice (*Oryza sativa* L.)

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ABSTRACT: *The heterosis study for grain yield and its attributes was carried out in rice (*Oryza sativa *L.) through Line x Tester mating design during* kharif *2012 and* rabi *2012-13. The variance due to line x tester interactions were significant for all the characters studied except for ear bearing tillers plant^{-1} indicating presence of considerable variability among the material studied and existence of overall heterosis for all the characters. The degree of heterosis and heterobeltiosis varied for all the cross combinations and for all the characters studied. In general, it is inferred that the magnitude of heterosis effect was high for grain yield plant^{-1}, grain number and 1000-grain weight. The crosses* viz.*, MTU 1071/MTU 1010, MTU 1075/MTU 1010, MTU 1075/MTU 3626, MTU 1081/MTU 3626, MTU 1121/TN1 and NRI 003/MTU 1010 exhibited the highest, significant and positive heterotic effect and mean performance for grain yield plant^{-1} and some of its important component traits. This could be exploited commercially for heterosis breeding in rice.*

Keywords: *Heterosis, heterobeltiosis, high density grain index, rice, yield traits, grain weight, grain number*

INTRODUCTION

Rice is a staple food crop for approximately 40% of the world's population. As the rice productivity continues to decline due to reducing acreage of rice cultivation and increasing urbanization, the only possible source of output growth is vertical yield improvement by improving yield related traits like grain number and grain weight. Population explosion demands the commercial exploitation of heterosis for genetic improvement of several crops especially rice which has received the top priority to enhance the productivity. The success of breeding programme depends upon the magnitude of heterosis which also helps in the identification of potential cross combination to be used in the conventional breeding programme to create wide array of variability in the segregating populations. Parental combination giving high heterosis to produce transgressive segregants along with higher magnitude of exploitable hybrid vigour is the prerequisite for making a breakthrough in yield. With this view the work was undertaken to investigate the heterosis and heterobeltiosis for quantifying the extent of hybrid vigour for grain yield and its component characters in rice.

MATERIAL AND METHODS

The experiment was conducted at APRRI & RARS (Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station), Maruteru, West Godavari district, Andhra Pradesh during *Kharif* 2012 *and rabi* 2012-13. The experimental material consisting 31 entries including 10 parents (7 females as lines and 3 males as testers) and resultant 21 crosses produced by line x tester mating design was raised in Randomised Complete Block Design with two replications. Crossing was done by employing clipping method and emasculation was carried out in evening hours and pollination in morning of next day. Each entry was grown in two rows with a row length of 2m with 20 x 20 cm spacing. Recommended agronomic practices and plant protection measures were adopted to raise healthy crop. The females used in the present study were MTU 1071, MTU 1075, MTU 1081, MTU 1121, NRI 003, MTU II-118-24-4-1 and

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MTU-PS-140-1 and the males included were MTU 1010, MTU 3626 and TN 1. The observations on days to 50% flowering, plant height (cm), number of ear bearing tillers plant^{-1}, panicle length (cm), number of fertile grains panicle^{-1}, spikelet fertility percentage, 1000-grain weight (g) and grain yield plant^{-1}(g) were recorded for five randomly selected plants in each entry and in each replication. The data were statistically analysed and heterosis over mid parent (H_1) and over better parent (H_2) were calculated as per standard procedure. Heterosis and heterobeltiosis were estimated from mean values according to Liang *et al.* (1971) and Mather and Jinks (1971).

Heterosis = $\frac{\overline{F_1} - \overline{M.P}}{\overline{M.P}} x100$ **Heterobeltiosis** = $\frac{\overline{F_1} - \overline{B.P}}{\overline{B.P}} x100$

RESULTS AND DISCUSSION

Mean of lines, testers and their hybrids (Table 1) indicated worth of genetic variability for the improvement of most of the traits studied. Results of ANOVA revealed that line x tester component was significant for all the traits except for ear bearing tillers plant^{-1}. The per cent heterosis over mid parent and better parent was calculated for all the eight characters pertaining to yield and yield attributes in 21 crosses based on mean values. The significance of the values for heterosis and heterobeltiosis were tested and furnished in Table 2. The data on estimates of heterosis (H_1) and heterobeltiosis (H_2) revealed that midparent heterosis for days to 50% flowering ranged from -9.09 % to 2.65% and that of high-parent heterosis was from -18.26% to -0.30%. The short duration varieties are of breeder's interest to fit them into multiple cropping systems. Hence, heterosis in negative direction is desirable for the trait days to 50% flowering, because this will help the hybrid to mature earlier. Nine crosses exhibited significant negative heterosis over mid parent, among which MTU 1075 / TN 1 showed highest negative value of -9.09% followed by MTU 1075 / MTU 1010 (-7.62%) and MTU 1081 / TN1 (-6.71%). Fifteen crosses exhibited negative and significant heterobeltiosis which is highly desirable. The cross, MTU 1075 / MTU 1010, expressed highest heterobeltiosis of -18.26% followed by MTU 1075 / TN 1 (-16.96%) and MTU-PS-140-1 / MTU 1010 (-14.86%). These crosses have showed significant heterosis values for the trait grain yield plant^{-1} also.

Negative heterosis for plant height is desirable for breeding short statured varieties. Dwarf stature is preferable as it is less prone to lodging. Significant negative heterosis was found in negative direction for only one cross (NRI 003 / MTU 1010) with -16.67% and -19.09% of heterosis and heterobeltiosis respectively displaying additive type of gene action, because of the non significant values. Five crosses recorded significant negative heterobeltiosis which is more desirable. Majority of the crosses exhibited intermediate mean values between the parents for this trait except the crosses of MTU II-118-24-4-1 and MTU-PS-140-1. The crosses with intermediate mean values could be further utilized in future breeding progrmmes in order to reduce the plant height.

Among the yield components, number of ear bearing tillers plant^{-1} is considered as most important one and the strains with profuse tillering habit are selected to enhance grain yield. Out of 21 crosses, eight crosses showed significantly positive heterosis and five crosses showed significantly positive heterobeltiosis. The top five crosses for positive heterosis and heterobeltiosis were MTU II-118-24-4-1 / TN 1 (65.67%, 64.71%), MTU 1071 / MTU 1010 (64.38%, 53.85%), NRI 003 / TN 1 (46.79%, 41.18%), MTU 1071 / MTU 3626 (38.12%, 30.21%) and MTU 1121 / TN 1 (36.61%, 27.55%) respectively.

Panicle length in positive direction is desirable, as length of panicle is longer it can accommodate more number of grains. Spikelets attached to its primary and secondary rachis branches would increase proportionately with the enhancement of panicle length. Twelve hybrids showed significant positive heterosis for panicle length. Top three crosses for positive heterosis were MTU 1121 / TN 1 (24.97%), MTU II-118-24-4-1 / TN 1 (23.12%) and MTU 1081 / MTU 1010 (18.72%). Out of 21 crosses, nine crosses recorded heterobeltiosis in positive and significant direction. Top three crosses were MTU 1071 / MTU 1010 (17.52%) followed by MTU 1081 / MTU 1010 (17.29%) and MTU 1075 / MTU 1010 (16.34%).

The trait, number of fertile grains panicle^{-1} directly contributes to the grain yield, hence positive heterotic effect would be highly desirable. This trait is one of the most important components of yield and probably this character would be helpful in breaking the yield ceiling. All the hybrids exhibited significant positive heterosis except two crosses and range was from 2.85% to 66.52%. The top five crosses were MTU 1075 / MTU 1010 (66.52%) followed by MTU 1075 / MTU 3626 (56.43%), MTU-PS-140-1 / MTU 3626 (48.66%), MTU 1121 / TN 1 (46.09%) and MTU 1071 / MTU 1010 (45.77%). Heterobeltiosis ranged from -24.92% to 25.66% and only five crosses expressed significant positive heterobeltiosis. The top 3 heterotic crosses were MTU 1075 / MTU 1010 (25.66%) followed by

Table 1
Mean performance of parents and F_1 s for eight yield and yield attributes in rice (*Oryza sativa* L.)

Parent /Cross	*Days to 50% flowering*	*Plant height (cm)*	*Ear bearing tillers plant^{-1}*	*Panicle length (cm)*	*Number of fertile grains panicle^{-1}*	*Spikelet fertility (%)*	*1000 grain weight (g)*	*Grain yield plant^{1} (g)*
LINES								
1. MTU 1071	117.50	113.5	8.5	23.77	293.00	89.5	16.7	24.72
2 MTU 1075	115.00	106.45	10.5	24.36	270.03	83.9	21.96	27.7
3 MTU 1081	100.00	95.71	8.75	22.97	212.05	85.95	16.87	27.5
4 MTU 1121	100.90	106.30	9.8	26.19	239.90	93.4	21.80	34.02
5 NRI 003	99.00	97.0	7.85	24.62	284.35	80.97	13.88	24.03
6 MTU II-118-24-4-1	101.50	139.67	8.6	26.03	302.35	85.70	14.00	28.75
7 MTU -PS-140-1	111.00	144.83	8.8	26.73	312.45	84.98	15.93	28.18
Average	106.41	114.78	8.97	24.95	273.45	86.34	17.31	27.84
TESTERS								
1 MTU 1010	88.50	103.00	9.75	23.53	137.5	89.07	24.6	28.06
2 MTU 3626	96.10	93.75	9.6	23.34	136.3	86.83	27.65	27.09
3 TN 1	95.10	110.43	8.5	20.93	166.5	91.03	26.10	19.61
Average	93.23	102.39	9.28	22.60	146.77	88.98	26.12	24.92
1.MTU 1071/MTU 1010	105.5	121.67	15.0	27.93	313.78	93.54	24.47	43.56
2.MTU 1071/MTU 3626	105.0	111.93	12.5	24.66	283.51	91.37	19.83	44.95
3.MTU 1071/TNI	102.0	120.16	8.5	21.83	283.96	92.24	21.31	29.88
4.MTU 1075/MTU 1010	94.0	105.00	11.5	28.34	339.31	93.07	23.87	44.82
5.MTU 1075/MTU 3626	100.1	106.02	12.10	26.98	317.81	91.86	30.99	34.49
6.MTU 1075/TNI	95.5	121.7	10.75	26.57	247.14	91.31	25.14	33.05
7.MTU 1081/MTU 1010	89.5	105.06	12.00	26.60	222.4	92.22	20.04	29.66
8.MTU 1081/MTU 3626	92.0	88.83	11.00	23.46	224.52	93.29	32.61	42.12
9.MTU 1081/TNI	91.0	116.66	10.9	21.75	241.83	92.32	27.42	36.10
10.MTU 1121/MTU 1010	95.0	113.15	10.75	28.5	268.3	95.25	26.22	42.13
11.MTU 1121/MTU 3626	99.5	113.35	10.56	26.97	258.81	92.08	25.21	38.38
12.MTU 1121/TNI	100.6	113.45	12.5	29.44	296.85	91.45	29.92	43.64
13. NRI 003/MTU 1010	95.0	83.3	10.0	25.71	278.16	89.43	23.68	44.29
14. NRI 003/MTU 3626	96.0	101.5	9.66	23.46	229.72	91.00	20.62	33.10
15. NRI 003/TNI	96.0	105.0	12.00	24.33	282.78	86.05	22.52	41.91
16. MTU II-118-24-4-1 / MTU 1010	90.5	129.5	11.5	28.84	291.3	93.5	27.33	33.46
17. MTU II-118-24-4-1/MTU 3626	96.5	119.5	8.83	26.49	226.99	84.82	20.38	44.49
18. MTU II-118-24-4-1/TNI	94.5	143.33	14.16	28.90	241.11	88.4	29.25	28.85
19. MTU-PS-140-1/ MTU 1010	94.5	119.61	9.5	29.46	270.70	90.6	21.44	34.67
20. MTU-PS-140-1/ MTU 3626	100.0	137.33	9.15	27.88	334.00	87.89	29.03	39.01
21. MTU-PS-140-1/ TNI	98.5	128.66	10.75	23.15	284.93	91.59	26.48	30.16
Average	96.72	114.51	11.12	26.25	273.23	91.11	25.13	37.75

MTU 1121 / TN 1 (23.74%) and MTU 1075 / MTU 3626 (17.69%).

The extent of spikelet fertility directly influences the grain yield. Eleven hybrids showed significantly positive heterosis and five hybrids showed significantly positive heterbeltiosis out of 21 hybrids. The top three crosses for positive heterosis were NRI 003 / MTU 3626 (8.46%), MTU 1081 / MTU 3626 (7.99%) and MTU 1075 / MTU 1010 (7.62%). While, the top crosses for heterbeltiosis were MTU 1081 / MTU 3626 (7.44%) followed by MTU 1075 / MTU 3626 (5.79%) and MTU 1071 / MTU 1010 (4.51%) exhibited positive values.

For the trait 1000 grain weight, twelve crosses exhibited heterosis over mid parent in significantly positive direction. Among them top crosses were MTU 1081 / MTU 3626 (46.50%) followed by MTU II-118-24-4-1 / TN 1 (45.91%), MTU II-118-24-4-1 / MTU 1010 (41.61%), MTU-PS-140-1 / MTU 3626 (33.23%) and MTU 1081 / TN 1 (27.62%). For heterobeltiosis MTU 1081 / MTU 3626 (17.94%) followed by MTU 1121 / TN 1 (14.66%), MTU II-118-24-4-1 / TN 1 (12.09%), MTU 1075 / MTU 3626 (12.06%) and MTU II-118-24-4-1 / MTU 1010 (11.10%) were positive and significant. Lowest value recorded for heterosis and heterobeltiosis was -10.59% and -28.30% in the cross MTU 1071 / MTU 3626, this cross combination could be exploited to develop fine grain varieties. The highest value recorded was 46.50% and 17.94% in the cross MTU 1081 / MTU 3626 respectively.

For the trait grain yield plant^{-1} all the 21 crosses exhibited positive heterosis and heterobeltiosis except

Table 2
Estimates of heterosis (H_1) and heterobeltiosis (H_2) for yield and yield attributes in rice (*Oryza sativa* L.)

Cross combination	*Days to 50% flowering*		*Plant height (cm)*		*Ear bearing tillers plant⁻¹*		*Panicle length (cm)*		*Number of fertile grains panicle⁻¹*		*Spikelet fertility (%)*		*1000 grain weight (g)*		*Grain yield plant⁻¹(g)*	
	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
1. MTU 1071/MTU 1010	2.43	-10.21**	12.40**	7.20	64.38**	53.85**	18.11**	17.52**	45.77**	7.09	4.77*	4.51*	18.52**	-0.51	65.05**	55.21**
2. MTU 1071/MTU 3626	-1.69	-10.64**	8.02*	-1.38	38.12**	30.21*	4.71	3.77	32.08**	-3.24	3.63*	2.09	-10.59*	-28.30**	73.54**	65.95**
3. MTU 1071/TNI	-4.05	-13.19**	7.32*	5.87	0.00	0.00	-2.29	-8.14	23.60**	-3.09	2.19	1.33	-0.40	-18.33**	34.79**	20.87*
4. MTU 1075/MTU 1010	-7.62**	-18.26**	0.26	-1.36	13.58	9.52	18.34**	16.34**	66.52**	25.66**	7.62**	4.50*	2.56	-2.95	60.75**	59.70**
5. MTU 1075/MTU 3626	-5.16*	-12.96**	5.92	-0.40	20.40	15.24	13.13**	10.76*	56.43**	17.69**	7.61**	5.79**	24.92**	12.06**	25.90**	24.51**
6. MTU 1075/TNI	-9.09**	-16.96**	12.23**	10.21*	13.16	2.38	17.35**	9.07	13.23**	-8.48*	4.40*	0.31	4.64	-3.66	39.70**	19.31*
7. MTU 1081/MTU 1010	-5.04*	-10.50**	5.75	2.00	29.73*	23.08	18.72**	17.29**	27.25**	4.88	5.38**	3.54	-3.35	-18.54**	6.76	5.68
8. MTU 1081/MTU 3626	-6.17*	-8.00**	-6.23	-7.19	19.89	14.58	1.34	0.54	28.90**	5.88	7.99**	7.44**	46.50**	17.94**	54.31**	53.16**
9. MTU 1081/TNI	-6.71**	-9.00**	13.19**	5.65	26.38*	24.57	-0.90	-5.31	27.77**	14.04*	4.33*	1.42	27.62**	5.06	53.24**	31.27**
10. MTU 1121/MTU 1010	0.32	-5.85*	8.12*	6.44	9.97	9.69	14.63**	8.82*	42.18**	11.84**	4.40	1.98	13.02**	6.59	35.72**	23.84**
11. MTU 1121/MTU 3626	1.02	-1.39	13.30**	6.61	8.92	7.81	8.91*	2.98	37.59**	7.88	2.18	-1.41	1.97	-8.82*	25.61**	12.82*
12. MTU 1121/TNI	2.65	-0.30	4.69	2.74	36.61**	27.55*	24.97**	12.41**	46.09**	23.74**	-0.82	-2.08	24.95**	14.66**	62.75**	28.29**
13. NRI 003/MTU 1010	1.33	-4.04	-16.67**	-19.09**	13.64	2.56	6.80	4.45	31.88**	-2.18	5.19*	0.41	23.10**	-3.72	70.05**	57.83**
14. NRI 003/MTU 3626	-1.59	-3.03	6.42	4.64	10.77	0.68	-2.15	-4.69	9.22*	-19.21**	8.46**	4.80	-0.69	-25.42**	29.52**	22.20**
15. NRI 003/TNI	-1.08	-3.03	1.24	-4.92	46.79**	41.18*	6.84	-1.18	25.45**	-0.55	0.06	-5.47*	12.68**	-13.70**	92.05**	74.41**
16. MTU II-118-24-4-1 / MTU 1010	-4.74*	-10.84**	6.73*	-7.28*	25.34*	17.95	16.39**	10.81*	32.45**	-3.65	6.99**	4.97*	41.61**	11.10*	17.79*	16.38*
17. MTU II-118-24-4-1/MTU 3626	-2.33	-4.93	2.39	-14.44**	-2.97	-8.02	7.33	1.79	3.50	-24.92**	-1.67	-2.31	-2.15	-26.31**	59.35**	54.75**
18. MTU II-118-24-4-1/TNI	-3.87	-6.90*	14.62**	2.62	65.67**	64.71**	23.12**	11.04*	2.85	-20.25**	0.04	-2.89	45.91**	12.09**	19.30*	0.35
19. MTU-PS-140-1/ MTU 1010	-5.26*	-14.86**	-3.47	-17.41**	2.43	-2.56	17.24**	10.23*	20.33**	-13.36**	4.11	1.72	5.82	-12.83**	23.30**	23.05**
20. MTU-PS-140-1/ MTU 3626	-3.43	-9.91**	15.13**	-5.18	-0.54	-4.69	11.39**	4.32	48.66**	-6.90**	2.31	1.21	33.23**	4.99	41.16**	38.43**
21. MTU-PS-140-1/ TNI	-4.42*	-11.26**	0.81	-11.16**	24.28	22.16	-2.82	-13.37**	18.98**	-8.81**	4.07	0.62	26.03**	1.48	26.23**	7.04
SE±	2.137	2.468	3.544	4.092	1.084	1.251	0.949	1.096	9.22	10.647	1.77	2.04	0.899	1.039	1.657	1.913

* Significant at 5% level ** Significant at 1% level

MTU II-118-24-4-1 / TN 1 and MTU-PS-140-1 / TN 1 over better parent and MTU 1081 / MTU 1010 over mid parent and better parent. The heterosis values ranged from 6.76% (MTU 1081 / MTU 1010) to 92.05% (NRI 003 / TN 1) over mid parent and 0.35% (MTU II-118-24-4-1 / TN 1) to 74.41 % (NRI 003 / TN 1) over better parent. The top three crosses recorded highest values over mid parent were NRI 003 / TN 1 (92.05%), MTU 1071 / MTU 3626 (73.54%) and NRI 003 / MTU 1010 (70.05%) and the top three crosses over better parent were NRI 003 / TN 1 (74.41%), MTU 1071 / MTU 3626 (65.95%) and MTU 1075 / MTU 1010 (59.70). From the present study it can be concluded that heterosis in yield was primarily due to increased number of spikelets panicle^{-1} followed by 1000 grain weight and spikelet fertility. Grain yield is a complex trait and it is the end product of several basic yield components.

In general, the crosses with significant heterosis and non significant heterobeltiosis for a particular trait narrated that the trait was under the control of partial dominant type of gene action, significant values for both the genetic phenomena i.e., heterosis and heterobeltiosis indicated the role of dominant gene action and non significant values for heterosis over mid parent and better parent confirmed the major role of additive gene action in governing the trait under consideration.

Both positive and negative heterosis for the traits *viz*., days to 50% flowering, number of ear bearing tillers plant^{-1}, panicle length and 1000 grain weight was reported by Latha *et al*. (2013). For the trait plant height, positive and negative heterosis was reported by Deoraj *et al.* (2007), for the trait number of fertile grains panicle^{-1} by Montazeri *et al.* (2014) and for the trait spikelet fertility percentage by Muhammad *et al*. (2012). Rajendra Reddy *et al.* (2012) and Latha *et al*. (2013) reported highest heterosis for grain yield plant^{-1}.

The present study revealed that the degree of heterosis varied from cross to cross and from character to character. In an ideal situation, cross combinations with high tiller number, semi dwarf plant type, short days to 50% flowering, high panicle length, high spikelets per panicle, high panicle fertility, high grain weight and grain yield are preferable. As this situation hardly exists, compromises will have to be made among morphological traits while selecting superior genotypes. Keeping in view mean performance and heterosis estimates, eight cross combinations viz., MTU 1071/MTU 1010, MTU 1075/MTU 1010, MTU 1075/MTU 3626, MTU 1081/MTU 3626, MTU 1121/ TN1, NRI 003/MTU 1010, MTU II-118-24-4-1/MTU 3626 and MTU-PS-140-1/MTU 3626 having better mean performance for many of the yield attributes are recommended for future breeding programmes.

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