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Studies on Combining Ability Analysis of the Traits Related to Grain number and grain Weight for Yield Enhancement in Rice (*Oryza sativa* L.)

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ABSTRACT: *The present investigation was carried out with a view to study the combining ability and gene action for yield and yield attributing traits in rice (*Oryza sativa *L.) and special emphasis has been given for grain number and grain weight, where the parents with high grain number and low grain weight (females) and with high grain weight and low grain number (males) are used. A set of 31 genotypes, including ten parents (seven lines and three testers) and 21 crosses were grown at APRRI & RARS (Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station), Maruteru during* kharif *2012 and* rabi *2012-13. The hybrids were developed adopting line x tester mating design. Analysis of variance showed significant differences amongst parents and hybrids for most of the characters indicating presence of genetic variability. Combining ability analysis indicated that both additive and non additive gene effects were important in the inheritance of all the traits. The ratio of variance due to GCA to that of SCA was greater than one for days to 50% flowering indicating preponderance of additive effects in the inheritance of this character. On the other hand, ó² GCA : ó² SCA was less than unity for plant height, number of ear bearing tillers plant⁻¹, panicle length, number of fertile grains panicle⁻¹, spikelet fertility percentage, 1000-grain weight and grain yield plant⁻¹ indicating importance of dominance gene effects in the inheritance of these characters. In general, among ten parents the line, MTU 1075 and the tester, MTU 1010 found to be good general combiners for most of the yield and yield related traits. The cross combinations* viz., *MTU II-118-24-4-1 / MTU 3626, MTU 1075 / MTU 1010, MTU 1121 / TN 1 and NRI 003 / TN 1 registered significant and positive SCA effects for grain yield plant⁻¹.*

Key words: *rice, combining ability, gene action, L x T mating design and yield traits.*

INTRODUCTION

Rice is one of the most important crop plants in the world and is the main nutritional staple food for approximately 40% of the world's population. India is one of the world's largest producers of white rice and brown rice, accounting for 20% of world rice production. Rice is India's pre-eminent crop, and is the staple food of the people of the eastern and southern parts of the country and it is also important crop for Asia, Latin America, parts of Africa and the Middle East. Production of rice is increasing from time to time and population also increasing at an alarming rate in developing countries like India. The food grains increase in arithmetical progression while the population increases in geometrical progression Therefore the unmatching gap between production and food demand is existing even with the highest production of the crop. Given the fact that the area under rice is nearly stabilized at around 42 million ha, the only option left for achieving the future production targets is vertical yield improvement. Therefore for breaking the yield barrier level and make rice cultivation more attractive, it is more necessary to explore alternative approaches. Among the all possible alternatives, combining ability analysis is an important approach for increasing rice production by identifying good general combiners and specific cross combinations for yield traits. Hence the present investigation was carried out to study the general combining ability and specific combining ability effects for the traits pertaining to grain number and grain weight in rice by using L x T mating design, where lines (females) with high grain number and low grain weight and the testers (pollinators) with high grain weight and low grain number are used.

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MATERIAL AND METHODS

Plant Materials

The experimental material comprised of ten rice genotypes, seven genotypes (MTU 1071, MTU 1075, MTU 1081, MTU 1121, NRI 003, MTU II-118-24-4-1 and MTU-PS-140-1) were used as females (designated as lines) and three genotypes (MTU 1010, MTU 3626 and TN 1) designated as testers were used as males. These parents were crossed to produce 21 F_1 hybrids according to line x tester mating design (Kempthorne, 1957). Hybridization was done by employing clipping method and emasculation was carried out in afternoon and pollination in morning of next day. This study was conducted during *kharif* 2012 to produce 21 crosses and *rabi* 2012-13 to evaluate 10 parents and 21 cross combinations at APRRI & RARS (Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station), Maruteru. Single seedlings of each entry were transplanted at 20 x 20 cm spacing in a randomized complete block design with two replications. In this study twelve traits includes 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 evaluated. Data were recorded on ten randomly selected plants from parents and F_1s plant samples.

Statistical Analysis

Combining ability analysis was done using line x tester method (Kempthorne, 1957). The variances for general combining ability and specific combining ability were tested against their respective error variances derived from ANOVA reduced to mean level. Significance test for GCA and SCA effects were performed using t-test.

RESULTS AND DISCUSSION

Mean of lines, testers and their hybrids (Table 1) indicated worth of genetic variability for the improvement of all the eight traits studied which are important in enhancement of rice yield. The mean performance of parents showed that all the lines are contributing the genes for high grain number and the testers for high grain weight. The range of mean values for the trait grain number among lines varied from 212.05 to 312.45 and for the trait 1000 grain weight among testers was from 24.6g to 27.65g. Analysis of variance of combining ability revealed significant differences among genotypes, crosses, lines, testers and line x tester interactions (Table 2). Variance due to parents was significant for all the traits studied except for ear bearing tillers plant^{-1}, indicating good amount of genetic differences among the parents. The results also revealed the existence of variability among different cross combinations (line x tester effect) for all the characters. The mean sum of squares of crosses was partitioned into lines, testers and line x tester effects. The significance of the mean of sum of squares due to lines and testers indicated a prevalence of additive variance. However, significant differences due to interactions of line x tester for the characters, indicating the importance of both additive and non- additive variance.

Variances of SCA (s^2SCA) were higher than the GCA (s^2GCA) variances which indicated preponderance of non-additive gene action in the inheritance of all the characters except for days to 50% flowering (Table 2). Gnanasekaran *et al.* (2006), Muhammad Rashid *et al.* (2007) and Dalvi and Patel (2009) reported predominance of additive gene action in the inheritance of days to 50% flowering through their studies. Hasan *et al.* (2013), Satheeshkumar and Saravanan (2013), Utharasu and Anandakumar (2013) reported non- additive gene action for the traits plant height, ear bearing tillers plant^{-1} and panicle length. Inheritance of number of fertile grains panicle^{-1} and spikelet fertility percentage by non- additive gene action was reported by Sanghera and Hussain (2012) and Shyam Chandra *et al.* (2012) and for the traits, 1000 grain weight and grain yield plant^{-1} by Hasan *et al.* (2013). It suggested greater importance of non-additive gene action in its expression and indicated very good prospect for the exploitation of non-additive genetic variation for these traits through hybrid breeding. The trait, days to 50% flowering, which had shown additive gene action can be improved by pedigree breeding. The presence of non-additive genetic variance is the primary justification for initiating the hybridization programme (Pradhan *et al.*, 2006).

The proportional contribution of lines, testers and their interactions to total variances was presented in Table 2. The proportion of testers (males) in total variance was less than proportions of lines (females) as well as line x tester. This result revealed that the female parent and line x tester component were responsible of a great proportion of the variation in all the traits. Therefore, the extent of cytoplasmic influence on the expression of most of the traits was very high. The contribution of maternal and paternal interactions (line x tester) were found vital for ear

Table 1
Mean performance of parents and F_1 s for eight quantitative traits 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
			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
			CROSSES					
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

bearing tillers plant^{-1}, 1000 grain weight and grain yield plant^{-1}. Maternal lines contributed more towards days to 50% flowering, plant height, panicle length, number of fertile grains panicle^{-1} and spikelet fertility percentage.

There were significant differences among the genotypes for characters, which lead to the combining ability analysis. Thus were partitioned genetic effects between genotypes into General Combining Ability and Specific Combining Ability. Regarding to the significance of gi in two directions in traits, it can be declared that parents have potential of transfer of high and low values for each trait. Hence, in cases which increasing and decreasing the value of traits are desired, positive and negative values of gi, should be considered respectively. Therefore, for plant height and days to 50% flowering negative GCA and SCA effects were desirable, while in case of other characters positive GCA and SCA effects were desirable.

The studies on general combining ability of parents revealed that none of the lines or tester parents were found to possess high GCA effects for all the traits studied (Table 3). Among them, the line MTU 1075, was found to be a good general combiner for plant height, panicle length, number of fertile grains panicle^{-1} and 1000 grain weight. The other promising lines identified were MTU 1121 and MTU 1071 for most of the characters studied. Among the testers, MTU 1010, was found to be good general combiner for days to 50 % flowering, plant height, panicle length, number of fertile grains panicle^{-1} and grain yield plant^{-1}. Hence these good general combiners of males and females may be extensively used in future for rice breeding programme.

The knowledge of combining ability coupled with *per se* performance of parents would be of great value in selecting suitable parents for hybridization programme. Generally, the primary criterion for the choice of desirable parents should be on the basis of performance for their high expression of mean and GCA for various traits. The lack of correspondence between GCA effects of these parents and their *per se* performance indicated that in these parents the particular trait was probably under the influence of non additive gene action. These parents can be used for recombination breeding.

In the present study, among 21 crosses studied, nine crosses showed significant SCA effects in positive direction for grain yield plant^{-1} and they were MTU II-118-24-4-1 / MTU 3626, MTU 1075 / MTU 1010, MTU 1121 / TN 1, NRI 003 / TN 1, MTU 1081 / MTU 3626, MTU 1071 / MTU 3626, NRI 003 / MTU 1010, MTU 1081 / TN 1 and MTU 1071 / MTU 1010. Majority of these hybrids involved at least one parent with positive GCA effect. Seven crosses *viz*., MTU-PS-140-1 / MTU 3626, MTU II-118-24-4-1 / MTU 1010, MTU 1075 / MTU 1010, MTU 1121 / TN 1, NRI 003 / TN 1, MTU 1075 / MTU 3626 and MTU 1081 / TN 1 showed significant SCA effects in positive direction for the trait number of fertile grains panicle^{-1}. Out of 21 crosses evaluated, eight cross combinations *viz*., MTU 1081 / MTU 3626, MTU 1075 / MTU 3626, MTU 1071 / MTU 1010, MTU-PS-140-1 / MTU 3626, MTU II-118-24-4-1 / MTU 1010, MTU II-118-24-4-1 / TN 1, NRI 003 / MTU 1010 and MTU 1121 / TN 1 recorded significant positive SCA effects for the trait 1000 grain weight.

It is evident that cross combinations, which expressed high SCA effects for grain yield have invariably exhibited positive SCA effects for one or more yield related traits also. While selecting the best specific combination for yield, it would be important

Table 2
Analysis of variance for combining ability for eight quantitative traits in rice (Oryza sativa L.)

Source of variation	*d.f.*	*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)*
Replication	1	0.06	0.28	0.30	0.10	337.96	13.93	1.53	21.23
Crosses	20	39.32**	412.11**	5.37*	12.35**	2497.40**	12.92**	29.46**	66.52**
Line effect	6	103.19**	928.64**	3.14	18.02*	4164.00	19.36	28.06	37.97
Tester effect	2	45.23**	481.29	3.57	33.53*	1090.51	20.86	17.69	92.49
Line x Tester effect	12	6.40	142.32**	6.78**	5.99**	1898.59**	8.37**	32.12**	76.47**
Error	20	7.58	20.50	2.08	1.66	152.70	2.56	1.43	4.44
s^2GCA		6.78**	56.26**	-0.34	1.98**	72.86	1.173*	-0.92	-1.123
s^2SCA		0.15	62.78**	2.61**	2.40**	892.60**	2.097	15.52**	36.407**
s^2GCA/ s^2SCA		45.2	0.89	-0.13	0.82	0.08	0.56	-0.06	-0.03
Contribution of									
Line %		78.72	67.60	17.56	43.75	50.02	44.96	28.57	17.12
Tester %		11.50	11.68	6.66	27.14	4.37	16.14	6.00	13.90
Line x Tester %		9.77	20.72	75.78	29.11	45.61	38.90	65.42	68.97

Table 3
Estimates of General combining ability effects for eight quantitative traits in rice (*Oryza sativa* L.)

Parent	*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					
MTU 1071	7.443**	3.410	0.875	-1.489**	20.515**	1.274	-3.261**	1.715*
MTU 1075	-0.190	-3.604*	0.325	0.996*	28.188**	0.972	1.535**	-0.297
MTU 1081	-5.890**	-10.993**	0.175	-2.027**	-43.652**	1.502	1.557**	-1.790*
MTU 1121	1.643	-1.202	0.147	2.003**	1.420	1.819*	1.985**	3.635**
NRI 003	-1.057	-17.902**	-0.570	-1.797**	-9.680*	-2.281*	-2.856**	2.020*
MTU II-118-24-4-1	-2.890*	16.265**	0.373	1.781**	-20.100**	-2.203*	0.520	-2.150*
MTU-PS-140-1	0.943	14.025**	-1.325*	0.534	23.310**	-1.083	0.520	-3.133**
SE±	1.42	2.36	0.72	0.63	6.14	1.18	0.6	1.104
			TESTERS					
MTU 1010	-1.867*	-3.465**	0.339	1.757**	10.188**	1.407*	-1.268**	1.193*
MTU 3626	1.719*	-3.304**	-0.581	-0.597	-5.325	-0.779	0.392	1.757**
TN 1	0.148	6.770**	0.241	-1.160**	-4.863	-0.628	0.875**	-2.950**
SE±	0.93	1.55	0.47	0.41	4.02	0.77	0.4	0.723

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

Table 4
Estimates of specific combining ability effects for eight quantitative traits in rice (*Oryza sativa* L.)

Cross combination	*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 (%)*	*1000 grain weight (g)*	*Grain yield plant^{-1}(g)*
1.MTU 1071/MTU 1010	3.200	7.212	2.661**	1.366	9.842	-0.252	3.869**	2.902*
2.MTU 1071/MTU 3626	-0.886	-2.684	1.081	0.450	-4.915	-0.236	-2.436**	3.733*
3.MTU 1071/TNI	-2.314	-4.528	-3.741**	-1.817*	-4.927	0.488	-1.434	-6.635**
4.MTU 1075/MTU 1010	-0.667	-2.444	-0.289	-0.714	27.704**	-0.415	-1.527	6.174**
6.MTU 1075/TNI	-1.181	4.021	-0.941	0.433	-49.420**	-0.141	-2.400**	-1.453
7.MTU 1081/MTU 1010	0.533	5.010	0.361	1.575	-17.371*	-1.800	-5.384**	-7.493**
8.MTU 1081/MTU 3626	-0.552	-11.386**	0.281	-0.211	0.261	1.461	5.531**	4.403**
9.MTU 1081/TNI	0.019	6.375**	-0.641	-1.363	17.110*	0.339	-0.147	3.090*
10.MTU 1121/MTU 1010	-1.500	3.304	-0.861	-1.560	-16.543*	0.913	0.368	-0.448
11.MTU 1121/MTU 3626	-0.586	3.328	-0.126	-0.736	-10.515	-0.066	-2.297	-4.762**
12.MTU 1121/TNI	2.086	-6.631**	0.987	2.297**	27.058**	-0.847	1.930*	5.210**
13. NRI 003/MTU 1010	1.200	-9.811**	-0.894	-0.545	4.417	-0.802	2.674**	3.332*
14. NRI 003/MTU 3626	-1.386	8.193*	-0.309	-0.441	-28.510**	2.949	-2.046*	-8.422**
15. NRI 003/TNI	0.186	1.619	1.204	0.987	24.093*	-2.147	-0.629	5.090**
16. MTU II-118-24-4-1 / MTU 1010	-1.467	2.187	-0.338	-0.994	27.977**	3.185*	2.943**	-3.333*
17. MTU II-118-24-4-1/ MTU 3626	0.948	-7.974*	-2.088*	-0.990	-20.815**	-3.304*	-5.667**	7.133**
18. MTU II-118-24-4-1/TNI	0.519	5.787	2.425*	1.983*	-7.162	0.119	2.725**	-3.800*
19. MTU-PS-140-1/ MTU 1010	-1.300	-5.458	-0.639	0.873	-36.028**	-0.830	-2.942**	-1.135
20. MTU-PS-140-1/ MTU 3626	0.614	12.101**	-0.069	1.647*	42.780**	-1.359	2.988**	2.636
21. MTU-PS-140-1/ TNI	0.686	-6.643*	0.709	-2.520**	-6.752	2.189	-0.045	-1.502
SE±	2.47	4.09	1.25	2.4	10.65	2.04	1.03	1.91

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

to give due weight age to yield related traits. Grafius (1959) had already suggested that there is no separate gene for yield, but yield is an end product of multiplicative interaction among various yield components. The present study revealed that, the cross combination MTU 1075 / MTU 1010 which had high SCA effect for grain yield also possessed high SCA effects for number of fertile grains panicle^{-1} and the cross, MTU 1071 / MTU 1010 for number of ear bearing tillers plant^{-1}, 1000 grain weight and the cross, MTU 1121 / TN 1 for plant height, panicle length and number of filled grains panicle^{-1}. These crosses should be inter mated using biparental mating system and desirable recombinants can be identified from later segregating generations. Generally, high x high, low x high and high x low general combiner parents produced good specific cross combinations. In these crosses additive x additive, dominance x additive and additive x dominance type of gene action was found. In cases, where high x high general combiner parents produced inferior cross combinations, indicated epistatic type of gene action for these traits. The hybrids *viz.*, MTU 1075 / MTU 1010 , MTU 1071 / MTU 1010, MTU 1121 / TN 1 and NRI 003 / TN 1 showing positive and significant SCA effects will be further tested in observational yield/multi-location yield trials to exploit its heterotic potential and fertility.

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