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Combining ability analysis for quantitative traits in aerobic rice (*Oryza sativa* L.)

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Abstract
The present investigation was carried out in aerobic rice (*Oryza sativa* L.) with five 'lines' and six 'testers' crossed in a Line x Tester design to find out the best combination (s) in respect of their combining ability effects among the parents and hybrids. The results concluded that the parents ADT 47, Chithiraikar, N 22 and Poongar were the best general combiners and the crosses involving them would result in the identification of superior segregants with favourable genes for yield in aerobic condition. The hybrids *viz*., ADT 36 x Nootripathu, ADT 43 x PMK 4 and ADT 47 x PMK 4 was found to have superior mean and *SCA* effects for many of the traits. So these hybrids were identified as superior hybrids and can be effectively utilized for further breeding programme to release as a new variety.

Keywords: Line × tester, GCA, SCA, rice

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop of Asia and its ability to grow in a wide range of hydrological situations, soil types and climates. About 55 per cent of the rice area is irrigated and accounts for 75 per cent of total production. Rice is no longer a luxury food but has become the cereal that constitutes a major source of calories for the urban and rural poor. However, self-sufficiency in rice production is declining as demand increases. Hence there is need to increase and improve the production of rice in order to meet up with high demand. The need for expansion of rice cultivation depends not only on cultural practices but also on their inbuilt genetic variability. Hence, a successful breeding programme will depend on the genetic diversity of a crop for achieving the goals of improving the crop and producing high yielding varieties (Padulosi, 1993) [6]. Being a self-pollinated crop an attempt has been made to study the magnitude of selection parameters and the scope of selection for higher seed yield and related attributes in this cereal crop. Hence, the current program was undertaken to find out the best combination (s) in respect of their combining ability effects among the parents and hybrids

Materials and Methods

The present investigation was carried out at the research farm of Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai during 2009. The experimental materials used for line x tester analysis consisted of 11 genotypes of rice (*Oryza sativa* L.). The cultivars were received from different stations and used as parents for the present study. Among the parents five short duration high yielding cosmopolitan rice varieties (ADT 47, ADT 45, ADT 43, ASD 16, ADT 36) were used as 'lines' and six short duration local land races (Nootripathu, Chithiraikar, PMK 4, Poongar, N 22 and Moroberekan) were used as 'testers'. Crosses were effected in line x tester model following wet cloth method of emasculation and pollination, as suggested by Chaisang *et al*. (1967) [1]. The resultant 30 cross combinations (hybrids) along with 11 parents were evaluated in randomized block design with three replications, during Rabi 2009. Each treatment was accommodated in two rows of 1m length with a spacing of 30 x 30cm in each replication. A uniform population of 20 hills per treatment with single seedling was maintained in each replication. Normal agronomical practices and plant protection measures with external inputs such as supplementary irrigation and fertilizers were given at appropriate time. Observations were recorded for the traits *viz*., Days to 50 per cent flowering, Plant height, Productive tillers per plant, Panicle length, Grains per panicle, Spikelet fertility, Hundred grain weight, Root length, Root dry weight, Root: Shoot ratio, Chlorophyll stability index, Relative water content and Single plant yield. The standard procedures developed by Kempthorne (1957) [5] were followed to estimate the mean sum of squares (MSS) along with variances of SCA and GCA. Standard statistical tools (Singh and Choudhury, 1985) were used to analyze the combining ability effects.

Results and Discussions

The success of a plant breeding programme greatly depends on correct choice of parents for Hybridization. Among the different methods adopted, the Line x Tester analysis has been recommended for early evaluation of parents, because of the simplicity in both experimentation and analysis (Dhillion, 1975) [2]. The combining ability gives useful information on the choice of parents in terms of expected performance of the hybrids and the progenies.

Analysis of variance: The analysis of variance for different traits was presented in Table 1. The genotypes were found highly significant for all the traits which indicated that the treatments used in this study were significantly varied from each other. The mean sums of squares (MSS) of the treatments were further portioned into lines, testers and line x tester interaction. The results showed that all the parameters for lines, testers and line x tester interaction were found highly significant from each other.

Table 1: Analysis of variance of combining ability for different traits

Source of variation	d.f.	Mean squares												
		DFL	PH	PT	PL	GP	SF	HW	RL	RDW	R: S	CSI	RWC	YLD
Replication	2	1.73	21.07	1.42	2.28	12.12	8.20	0.00	0.58	0.01	0.0005	1.50	0.26	0.12
Lines	4	21.92**	199.24**	24.19**	55.87**	434.88**	476.13**	0.73**	24.01**	8.49**	0.0028**	635.63**	58.02**	10.32**
Testers	5	25.65**	754.31**	23.25**	13.84**	383.98**	378.12**	2.84**	11.38**	1.93**	0.0004**	391.97**	32.69**	22.11**
Line x Tester interaction	20	78.61**	252.27**	32.57**	17.57**	600.93**	616.18**	0.53**	15.91**	2.83**	0.0014**	259.68**	16.83**	55.35**
Error	58	5.03	17.53	1.98	0.91	13.64	13.42	0.00	0.82	0.04	0.0003	13.63	1.73	1.37

** Significant at 1% level

DFL: Days to 50 per cent flowering RL: Root length
PH: Plant height RDW: Root dry weight
PT: Productive tillers per plant RS Root: Shoot ratio
PL: Panicle length CSI: Chlorophyll stability index
GP: Grains per panicle RWC: Relative water content
SF: Spikelet fertility YLD: Single plant yield
HW: Hundred grain weight

General combining ability (*GCA*) effects: The *GCA* effects of parents for different traits were presented in Table 2. The general combining ability is defined as the average performance of a strain in a series of cross combinations. Dhillon (1975) opined that combining ability provides useful information on the choice of parents in terms of expected performance of the hybrids and progenies. Singh and Harisingh (1985) [12] and Tiwari *et al*. (1993) [16] had also suggested that parents having high *GCA* effects could produce transgressive segregants in F_2 or later generations. Among the lines, ADT 47 was the best general combiner for seven traits namely panicle length, grains per panicle, spikelet fertility, root length, root dry weight, chlorophyll stability index and single plant yield and ADT 36 recorded significant *GCA* effects for the four traits *viz*., days to 50 per cent flowering, panicle length, root: shoot ratio and relative water content. Among the testers Chithiraikar had highly significant *gca* effects for six traits namely, days to 50 per cent flowering, plant height, panicle length, spikelet fertility, root dry weight and relative water content, whereas N 22 recorded significant *GCA* effects for six traits *viz*., grains per panicle, spikelet fertility, 100 grain weight, root length, chlorophyll stability index and relative water content and Poongar also recorded significant *GCA* effects for the above traits with productive tillers per plant except grains per panicle and spikelet fertility. The results were in agreement with the findings of Hossain *et al.* (2009) [4], Rashid *et al.* (2007) [7] and Singh and Kumar (2004) [14]. From the above discussion, it may be concluded that the parents ADT 47, Chithiraikar, N 22 and Poongar were the best general combiners and the crosses involving them would result in the identification of superior segregants with favourable genes for yield in aerobic condition.

Table 2: General combining ability effects of parents for different traits under aerobic condition

Parents	Days to 50 per cent flowering	Plant height	Productive tillers per plant	Panicle length	Grains per panicle	Spikelet fertility	Hundred grain weight	Root length	Root dry weight	Root: Shoot ratio	Chlorophyll stability index	Relative water content	Single plant yield
Lines													
L_1	-0.38	1.86	-0.67 *	1.98**	6.14**	6.35**	-0.19**	1.6 **	1.02**	-0.01 *	8.37 **	-2.06**	1.28**
L_2	-0.04	-5.89**	-0.23	-1.85**	0.28	1.88 *	0.29 **	-0.25	-0.76**	-0.01 *	-3.79 **	-1.70**	-0.40
L_3	0.12	1.23	1.65**	-1.88**	-6.42**	-7.03**	0.13**	0.22	0.25**	0.00	-2.71 **	0.46	0.05
L_4	1.68**	1.99 *	0.59	0.95**	2.98**	1.84 *	-0.13**	-0.09	-0.46**	0.02**	-5.82 **	1.45**	-0.64 *
L_5	-1.38 *	0.81	-1.34**	0.80**	-2.97**	-3.03**	-0.10**	-1.55**	-0.05	0.00	3.96 **	1.85**	-0.29
SE	0.52	0.98	0.33	0.22	0.87	0.86	0.02	0.21	0.05	0.00	0.87	0.31	0.27
Testers													
T_1	-1.07	1.11	-1.08**	1.44**	-0.38	0.68	-0.35 **	0.28	0.54**	-0.01	4.65 **	-0.06	0.66 *
T_2	-1.60**	-4.59**	-1.68**	0.10	4.27**	4.50**	-0.08**	-0.79**	0.30**	-0.00	-8.00 **	0.72 *	-1.26**
T_3	0.33	-10.25**	0.45	-1.51**	5.65**	4.61**	-0.57**	-0.15	-0.44**	0.00	-4.65 **	-2.78**	1.82**
T_4	-0.33	-1.33	0.98**	-0.29	-6.08**	-6.08**	0.29**	0.94**	-0.06	-0.00	3.59 **	1.13**	-0.26
T_5	0.60	9.67**	-0.27	0.15	2.45 *	2.64**	0.63**	0.89**	-0.21**	0.00	2.83 **	1.16**	0.38
T_6	2.07 **	5.38**	1.59**	0.40	-5.90**	-6.34**	0.09**	-1.18**	-0.13 *	0.01	1.60	-0.18	-1.35**
SE	0.57	1.08	0.36	0.24	0.95	0.94	0.02	0.23	0.05	0.00	0.95	0.33	0.30

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

***Per se* performance and general combining ability (*GCA*) effects:** Combination of *per se* performance and *GCA* effects will result in the selection of parents with good reservoir of superior genes. According to Sharma and Chauhan (1985) [11], the *per se* performance and *GCA* effects of the parents were directly related to each other. The comparison of *per se* and *GCA* effects revealed that most of the parents with high *per se* also have high *GCA* effects indicating that *per se* is an indicator for *GCA* effects (Reddy, 2002 and Sharma *et al*., 2005) [8, 16]. Parents with desirable mean performance and *GCA* effects are presented in Table 3. In the present investigation, ADT 43 was the best parent based on both *per se* and *GCA* effects for the following three traits *viz.*, productive tillers per plant, grains per panicle and root dry weight followed by N 22 showed significant effect based on both *per se* and *GCA* effects for two characters namely 100 grain weight and chlorophyll stability index. Thus, it can be concluded that crosses involving ADT 43 and N 22 would result in the identification of superior segregants with favourable genes for yield and drought condition.

Table 3: Parents choosen based on mean and *GCA* effects under aerobic condition

S. No.	Characters	Mean	*GCA* effects	Overall performance in mean and *GCA* effects
1.	Days to 50 per cent flowering	ADT 47, Nootripathu, Chithiraikar	ADT 36, Chithiraikar	Chithiraikar
2.	Plant height	ADT 43, Nootripathu	ADT 45, Chithiraikar, PMK 4	-
3.	Productive tillers per plant	ADT 43, Poongar	ADT 43, Poongar, Moroberekan	ADT 43, Poongar
4.	Panicle length	ASD 16, Moroberekan	ADT 47, ASD 16, ADT 36	ASD 16
5.	Grains per panicle	ADT 43, ADT 36, Poongar	ADT 47, ADT 45, ADT 43, Chithiraikar, PMK 4, N 22	ADT 43
6.	Spikelet fertility	ADT 43, Poongar	ADT 47, ADT 45, ASD 16, Chithiraikar, N 22	-
7.	Hundred grain weight	ASD 16, Chithiraikar, N 22, Moroberekan	ADT 45, ADT 43, Poongar, N 22, Moroberekan	N 22
8.	Root length	Chithiraikar	ADT 47, Poongar, N 22	-
9.	Root dry weight	ADT 43, N 22, Moroberekan	ADT 47, ADT 43, Nootripathu, Chithiraikar	ADT 43
10.	Root: Shoot ratio	ADT 36	ASD 16	-
11.	Chlorophyll stability index	ADT 47, N 22, Moroberekan	ADT 47, ADT 36, Nootripathu, Poongar, N 22	ADT 47, N 22
12.	Relative water content	-	ASD 16, ADT 36, Chithiraikar, Poongar, N 22	-
13.	Single plant yield	ADT 43, ADT 36, PMK 4, Poongar	ADT 47, Nootripathu, PMK 4	PMK 4
Overall effects		ADT 43, Moroberekan, Poongar, ADT 36, N 22, Chithiraikar	ADT 47, Chithiraikar, Poongar, N 22, ADT 36	ADT 43, N 22

Specific combining ability (*SCA*) effects: The *SCA* effects of hybrids for different traits were presented in Table 4. The specific combining ability is defined as the average performance of specific cross combination expressed as deviation from the population mean. According to Sprague and Tatum (1942) [15], the specific combining ability is controlled by non-additive gene action. Usually, positive and significant *SCA* effects were taken however, in the case of days to 50 per cent flowering and plant height significant negative *SCA* effects is favourable as it indicates earliness and non-lodging. The hybrids with significant *SCA* effects in the present study are discussed hereunder. In the present investigation, the hybrid ADT 36 x Nootripathu recorded high *SCA* effects for eight traits *viz.*, days to 50 per cent flowering, panicle length, grains per panicle, spikelet fertility, root dry weight, chlorophyll stability index, relative water content and single plant yield. and the hybrid ADT 47 x PMK 4 also showed significantly superior *SCA* effect for eight traits *viz.*, plant height, panicle length, grains per panicle, spikelet fertility, root length, chlorophyll stability index, relative water content and single plant yield. The other hybrids ADT 47 x Nootripathu, ADT 43 x Chithiraikar, ADT 43 x PMK 4 and ASD 16 x Chithiraikar showed significant *SCA* effect for seven traits each. The results were confirmed with the findings of Ganesen and Rangaswamy (1997), Roy and Mondal (2001) [9], Singh and Kumar (2004) and Rashid *et al.* (2007) [7]. These hybrids were identified as superior hybrids and can be effectively utilized for further breeding programme.

Table 4: Specific combining ability effects of hybrids for different traits under aerobic condition

Hybrids	Days to 50 per cent flowering	Plant height	Productive tillers per plant	Panicle length	Grains per panicle	Spikelet fertility	Hundred grain weight	Root length	Root dry weight	Root: Shoot ratio	Chlorophyll stability index	Relative Water content	Single Plant yield
L_1 x T_1	-1.82	-6.28 *	1.83 *	-1.61**	4.86 *	2.67	-0.14**	0.68	0.46**	0.02 *	4.29 *	1.92 *	1.08
L_1 x T_2	-5.96**	-2.75	5.10**	-1.41 *	-17.12**	-18.35**	0.06	-1.42**	-0.36**	-0.01	-4.63 *	-1.82 *	2.17**
L_1 x T_3	5.44**	-8.12**	-1.47	2.23**	12.40**	13.27**	-0.14**	1.78**	-0.60**	-0.02	11.36**	2.04**	4.89**
L_1 x T_4	-0.22	9.70**	-1.93 *	-0.95	6.00**	7.53**	0.72**	-1.08 *	0.04	-0.00	3.65	-1.33	-1.03
L_1 x T_5	-1.49	-1.70	-3.58**	-0.39	-9.26**	-9.02**	-0.3 **	-1.50**	1.41**	-0.01	-4.19	-1.96 *	-5.11**
L_1 x T_6	4.04**	9.15**	0.03	2.13**	3.12	3.89	-0.1**	1.54**	-0.95**	0.01	-10.49**	1.14	-2.01**
L_2 x T_1	6.84**	1.70	0.07	0.98	-10.61**	-11.86**	0.44**	-1.46**	-0.95**	-0.03 *	2.52	0.36	4.00**
L_2 x T_2	7.71**	-3.63	0.00	-1.71**	-16.23**	-16.18**	-0.56**	-1.52**	-0.29 *	0.01	1.00	-0.69	-1.41 *
L_2 x T_3	-7.56**	7.06**	-1.00	0.03	-10.47**	-8.49**	-0.42**	-2.13**	0.79**	0.03**	13.52**	0.68	-4.59**
L_2 x T_4	2.44	-4.65	6.54**	-0.05	14.12**	15.37**	0.10 *	4.45**	-0.67**	-0.01	-6.79 **	-0.06	4.95**
L_2 x T_5	-0.82	-11.22**	-4.15**	-0.35	18.46**	15.28**	0.56**	3.10**	-0.26 *	-0.01	-1.70	-2.03**	-1.59 *
L_2 x T_6	-8.62**	10.74**	-1.47	1.09 *	4.74 *	5.89**	-0.12 *	-2.43**	1.38**	0.00	-8.54 **	1.74 *	-1.36 *
L_3 x T_1	3.68**	-7.35**	-0.99	-1.79**	-0.58	-0.42	0.2**	0.53	0.44**	-0.01	-1.80	-4.20**	-2.83**
L_3 x T_2	-0.46	-11.65**	-1.82 *	-0.28	5.74**	4.60 *	0.31**	0.27	1.60**	-0.03**	2.18	1.72 *	2.00**
L_3 x T_3	-6.72**	6.75**	4.31**	0.36	14.96**	14.45**	0.22**	1.90**	-0.23	0.01	-10.36**	-0.31	2.65**
L_3 x T_4	0.94	2.43	-0.01	-1.10 *	-5.78**	-6.19**	0.22**	-2.33**	0.20	0.03**	-0.90	-0.78	0.19
L_3 x T_5	1.34	8.13 **	1.30	0.80	-8.27**	-4.84 *	-0.17**	0.76	-1.14**	0.02 *	7.86**	2.68**	-0.18
L_3 x T_6	1.21	1.69	-2.79**	2.02**	-6.06**	-7.60**	-0.30**	-1.14 *	-0.87**	-0.02	3.02	0.89	-1.85**

L_4 x T_1	-3.21 *	14.25**	-2.09 *	-0.11	-7.71**	-6.25**	-0.05	0.68	-0.32 *	0.03**	-13.05**	-0.06	-6.18**
L_4 x T_2	2.66 *	3.25	-2.60**	5.73**	17.48**	19.00**	0.1 **	-0.32	-0.80**	0.02 *	12.86**	1.06	1.76 *
L_4 x T_3	4.7 **	-2.79	-1.95 *	-2.73**	-4.47 *	-5.32 *	0.39**	-2.96**	-0.11	-0.01	-14.82**	0.43	0.54
L_4 x T_4	-3.61**	-3.40	-0.25	0.09	-19.58**	-21.49**	-0.70**	2.02**	-0.73**	-0.03 *	5.64**	3.75**	-1.18
L_4 x T_5	-1.21	2.87	5.20**	1.95**	18.13**	16.89**	-0.40**	-0.76	0.55**	-0.02	-0.53	-0.45	7.41**
L_4 x T_6	0.66	-14.18**	1.68 *	-4.74**	-3.86	-2.84	0.63**	1.34 *	1.42**	-0.00	9.90**	-4.74**	-2.36**
L_5 x T_1	-5.4 **	-2.33	1.17	2.53**	14.04**	15.85**	0.04	-0.43	0.36**	-0.02	8.04**	1.97 *	3.92**
L_5 x T_2	-3.9 **	14.77**	-0.69	-2.33**	10.13**	10.93**	0.06	2.98**	-0.15	0.00	-11.42**	-0.27	-4.52**
L_5 x T_3	4.1 **	-2.90	0.11	0.11	-12.42**	-13.92**	-0.05	1.41**	0.15	-0.01	0.30	-2.84**	-3.50**
L_5 x T_4	0.44	-4.08	-4.35**	2.19**	5.24 *	4.78 *	-0.35**	-3.05**	1.16**	0.01	-1.60	-1.58 *	-2.93**
L_5 x T_5	2.18	1.92	1.23	-2.01**	-19.05**	-18.31**	0.31**	-1.60**	-0.56**	0.02	-1.44	1.75 *	-0.53
L_5 x T_6	2.71 *	-7.39**	2.54**	-0.50	2.06	0.66	-0.01	0.70	-0.97**	0.00	6.12**	0.96	7.57**
SE	1.29	2.41	0.81	0.55	2.13	2.11	0.04	0.52	0.12	0.010	2.13	0.76	0.67

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