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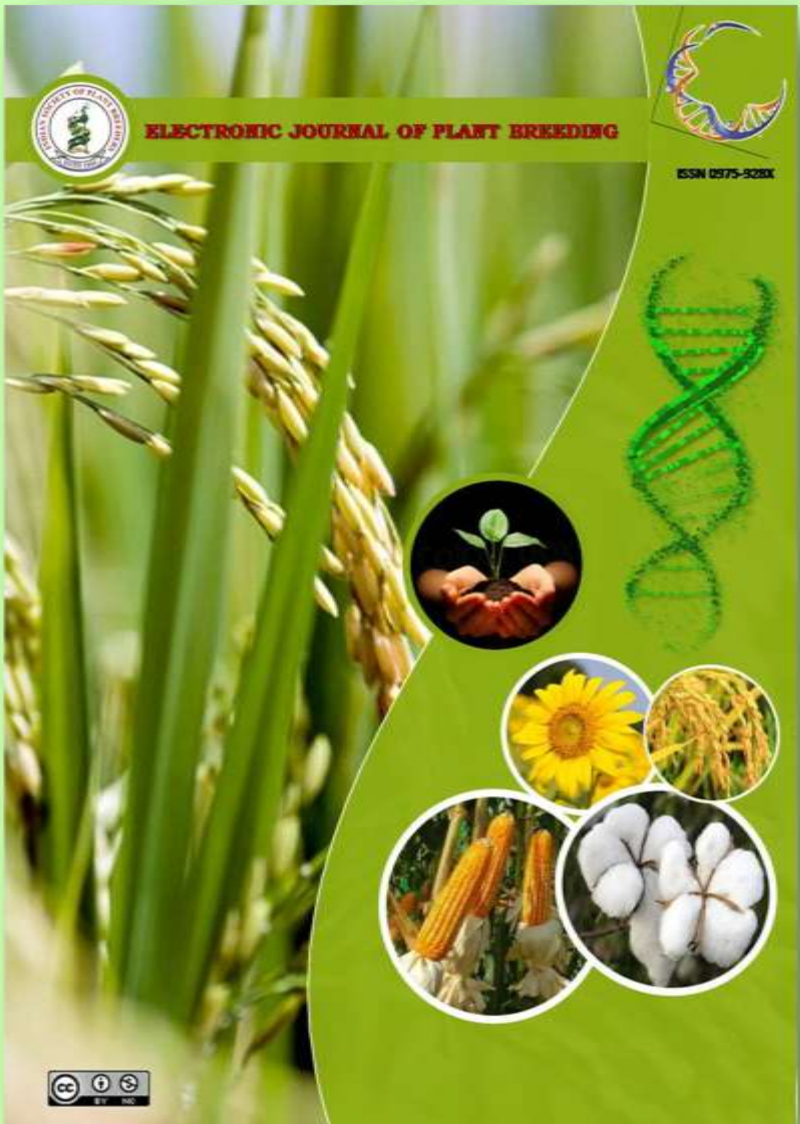

ISSN: 0975-928X

Volume: 10

Number:2

EJPB (2019) 10(2):440-445

DOI:10.5958/0975-928X.2019.00056.5

Electronic Journal of Plant Breeding, 10 (2): 440-445 (Jun 2019) DOI: 10.5958/0975-928X.2019.00056.5
ISSN 0975-928X

Research Article

Combining ability analysis for yield and yield contributing traits in rice (*Oryza sativa* L.)

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(Received: 10 May 2019; Revised: 14 Jun 2019; Accepted: 15 Jun 2019)

Abstract
Combining ability analysis was conducted in Line × Tester mating design using 10 parents and 21 hybrids for the yield and yield contributing traits. The ratio of additive genetic variance to dominance genetic variance was nearing unity which showed the prevalence of non additive gene action for the traits *viz.*, days to 50 % flowering**,** plant height, panicle length, number of productive tillers per plant, number of filled grains per panicle, hundred grain weight and single plant yield. Hence, selection for these characters may be postponed to later generation for improvement. Among the lines, CO 51, Improved White Ponni and Improved Samba Mahsuri expressed significant *per se* and *gca* effects for grain yield traits. In testers, ADT 41 was adjudged as the excellent general combiner for yield related traits. Considering *per se* performance and *sca* effects, the hybrids CO 51/Jeeragasamba, CO 51/ADT 41 and ADT 37/VGD 1 were the superior combiners for single plant yield, number of productive tillers per plant and hundred grain weight. These crosses deserve the due attention for further utilization in subsequent breeding programmes.

Key words
Combining ability, yield, dominance and Line × Tester mating design

Introduction

Rice (*Oryza sativa* L.) is one of the most vital staple food crop cultivated in most of the countries. With the growing population, the need for rice production gets increased and almost all the developed and developing countries fulfill their consumption needs. Improving the grain yield and quality traits is the key point to be considered for increasing the national income. Rice is grown in an area of 158 million hectares globally, with the annual production of about 700 million tones (Anonymous, 2016). In Asia, nearly 640 million tons of rice has been produced. India holds the maximum rice acreage of 44 million hectares with a production of 108.8 million tonnes and productivity of 2.47 tonnes per hectare (Anonymous, 2016). Among the quality aspects, aroma is the one which plays a vital role in increasing a country’s foreign exchange and high rated items are made with aromatic rices (Bindusree *et al.*, 2017). Basmati constitutes the major group of aromatic rice with long slender grains ; but fails to be a good combiner (Kour *et al.*, 2019). Several Indian landraces which are aromatic possess short slender grain type with unique fragrance. Hence, major focus is given on the development of aromatic short slender rice varieties using these indigenous varieties. Therefore, breeding efforts are necessary to investigate the best combiners to be effectively utilized in crossing programme. The current investigation on rice involves combining ability analysis which is helpful to explicate the gene action for the particular trait by using line × tester analysis (Kempthorne, 1957) intended for identification of good combiners for yield and yield contributing traits.

Materials and Methods

The experiment was carried out using seven lines *viz.*, Improved White Ponni, Improved Samba Mahsuri, RNR 15048, ADT 37, WGL 20471 (Erramallelu), MDU 6 and CO 51 and three testers *viz.*, Jeeragasamba, ADT 41 and VGD 1. Hybridization block was raised at the Research farm of Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai during *kharif*, 2018 with three staggered sowing at a gap of 10 days to synchronize the line and tester flowering time. The F_1s and their parents were grown during *rabi*, 2018-19 with three replications in a randomized block design. Four week old seedlings were planted in the main field with the spacing of 20 × 15 cm in two rows of 2 m length. All the regular cultural practices and timely plant protection measures were followed. At right time observations for seven quantitative traits *viz.*, days to 50 % flowering**,** plant height, panicle length, number of productive tillers per plant, number of filled grains per panicle, hundred grain weight and single plant yield were recorded. Line × tester design was adopted as suggested by Kempthorne (1957). This mating design gives the estimates various gene effects, general combining ability effects of parents and specific combining ability effects of hybrids.

Results and Discussion

Analysis of Variance showed that significant differences exist among the parents utilized in crossing programme for the entire yield characters studied (Table 1). The preponderance of non additive gene action for the yield traits *viz.,* days to 50 % flowering, plant height, panicle length, number of productive tillers per plant, number of grains per panicle, hundred grain weight and single plant yield is evident from the ratio of additive to dominance genetic variance being less then unity. This was on par with Savita *et al.* (2015), Satheeshkumar *et al.* (2016) and Sudeepthi *et al.* (2018). In these circumstances, following simple pedigree selection procedure will be ineffective and better segregating progenies has to be selected in later generations of selection cycle.

Among the lines based on *per se* performance, ADT 37 and CO 51 were early flowering and WGL 20471 and Improved Samba Mahsuri were with short stature. The line RNR 15048 was found to be better for the characters *viz.,* number of productive tillers per plant (21), number of grains per panicle (216.67) and single plant yield (29.50 g) and MDU 6 recorded the highest hundred grain weight (2.19 g). The highest mean among the lines for grain yield was observed in WGL 20471 (32.47 g). Among the parents based on *per se* performance, Improved Samba Mahsuri and VGD 1 had desirable hundred grain weight and ADT 41 recorded high single plant yield (30.13 g) and VGD 1 had high panicle length (21.50 cm) and number of grains per panicle (168.67) (Table 2).

Selection of good general combiners within the parents is a crucial step in breeding programme. Parents with high *gca* would produce better segregants in the subsequent generations as stated by Singh and Singh (1985). WGL 20471, CO 51, MDU 6 and VGD 1 showed negative significant *gca* effects for days to 50 % flowering (Table 3). For plant height ADT 37, WGL 20471 and RNR 15048 were found desirable with negative significant *gca*. Kour *et al.* (2019) and Savita *et al.* (2015) reported several parents which possessed desirable *gca* effects. For the character panicle length, RNR 15048 and ADT 41 expressed significant positive effects. ADT 37, Improved White Ponni, Jeeragasamba and ADT 41 recorded significant and positive *gca* effects for number of productive tillers per plant. For grains per panicle, Improved Samba Mahsuri, Improved White Ponni and ADT 41 were found to have highly positive and significant *gca* effects. Kumar *et al.* (2018), Savita *et al.* (2015) and Suvathipriya and Kalaimagal (2018) also adjudged several parents with positive *gca* for the above mentioned trait. ADT 37, MDU 6, CO 51 and ADT 41 showed desirable *gca* effects for hundred grain weight and for single plant yield. CO 51, Improved White Ponni and Jeeragasamba showed highly significant and positive *gca* effects. Utilizing the good general combiners from the present study superior genotypes could be developed. Based on *per se* and *gca* effects, Improved White Ponni, Improved Samba Mahsuri and CO 51, were found to be the promising combiners for many of the yield related traits among the lines. Among the testers ADT 41 was the best combiner. The result is in accordance with Gnanamalar and Vivekanandan (2013).

The mean performance of hybrids for the yield traits was given in Table 4. For days to 50 % flowering lower mean value was observed in the cross CO 51/ADT 41 and RNR 15048/ VGD 1. Similarly for plant height desirable mean performance was noticed in Improved Samba Mahsuri/VGD 1, MDU 6/VGD 1 as the parent VGD 1 showed negative significance for height**.** Among the hybrids, for panicle length RNR 15048/ADT 41 had significant and high *per se* value (24.77 cm). The cross CO 51/Jeeragasamba had high number of productive tillers per plant (21.33), high hundred grain weight (2.25), single plant yield of 38.67 g while the hybrid Improved Samba Mahsuri /ADT 41 had desirable number of grains per panicle (218.17). For hundred grain weight, the cross MDU 6/ADT 41 had high and significant *per se* value (2.31 g). Single plant yield is a significant trait as it contributes to the total yield and the hybrid CO 51/ADT 41 (44.97 g) recorded the highest significant value.

Regarding specific combining ability effects for grain yield related traits (Table 5) the hybrid Improved White Ponni/Jeeragasamba had desirable negatively significant *sca* effect for plant height. The cross CO 51/ADT 41 was earlier than other hybrids as they had negative significance and recorded highly significant effect for plant yield. MDU 6/VGD 1 had desirable positive combining ability effects for panicle length. The hybrid CO 51/Jeeragasamba showed desirable *sca* effect for number of productive tillers per plant and the highest significant *sca* value for hundred grain weight was observed in the cross MDU 6/ADT 41. The results were on par with Suvathipriya *et al.*

(2018) and Gahtyari *et al.* (2017). Based on *per se* performance and *sca* effects, CO 51/ADT 41 was adjudged as the best hybrid for earliness and single plant yield. The hybrid CO 51/Jeeragasamba had positive *sca* effect and high *per se* values for the traits *viz.,* number of productive tillers per plant, hundred grain weight and single plant yield. ADT 37/VGD 1 was also found to be a good specific combiner for number of productive tillers per plant and hundred grain weight.

Among the parents studied, CO 51, Improved Samba Mahsuri, Improved White Ponni and ADT 41 were identified as the best based on *per se* performance and *gca* effects. The high *per se* performance may be due to interaction between positive alleles. A good cross combination is one with high *sca* effect and with both the parents having high *gca* effect. Among the hybrids CO51/ADT 41 and CO51/Jeeragasamba were identified as the best specific combiners. From the above discussion, it was observed that the gene action governing the characters taken for study was non additive and non fixable. Hence, selection for improvement of these characters may be postponed to later generation.

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Table 1. Analysis of variance for combining ability for grain yield and yield attributing traits

Source of variation	Mean squares							
	df	DFF	PH	PL	NPT	GPP	HGW	SPY
Crosses	20	31.88**	639.96**	2.23**	20.78**	1586.66**	0.21**	47.50**
Lines	6	75.61**	1593.14**	0.69	13.49	3404.72**	0.46**	51.65
Testers	2	5.35	450.74	7.38*	48.77	904.17	0.08	53.56
L×T interaction	12	14.44**	194.9**	2.13**	19.75**	791.38**	0.10**	44.41**
Error	40	1.30	13.78	0.25	1.01	13.50	0.002	0.27

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

DFF - Days to 50% flowering, PH - Plant height, PL - Panicle length,
NPT - Number of productive tillers per plant, GPP - Number of filled grains per panicle,
HGW - Hundred grain weight, SPY - Single plant yield

Table 2. Mean performance of parents for grain yield and yield attributing trait

Parents	DFF(%)	PH(cm)	PL(cm)	NPT	GPP	HGW(g)	SPY(g)
			Lines				
RNR 15048	80.33	97.00	20.13	21.00**	216.67**	1.62	29.50
ADT 37	70.00**	93.33*	19.77	14.33	138.67	1.74	28.17*
WGL 20471	72.67**	86.00**	19.17	16.33	137.33	1.60	32.47**
MDU 6	75.33**	98.37	19.43	19.00**	120.67	2.19**	28.37
CO 51	70.33**	88.27**	19.57	18.00	126.33	1.67	29.00
I. Samba Mahsuri	92.67	87.67**	19.23	17.67	215.33**	1.53	28.47
I. White Ponni	95.00	140.67	20.00	16.00	162.33	1.61	29.50
Mean	79.48	98.76	20.13	17.48	159.62	1.71	29.35
SEd	0.44	2.23	0.19	0.39	1.41	0.02	0.20
CD (0.05)	0.89	4.57	0.38	0.79	2.85	0.04	0.40
CD (0.01)	1.19	6.11	0.51	1.05	3.81	0.05	0.54
			Testers				
J.samba	94	108.00	20.20	19.33**	168.00**	1.55	29.33
ADT 41	71**	97.07**	21.13	17.33	128.67	2.14**	30.13**
VGD 1	95.67	124.33	21.50**	19.00	168.67**	1.41	29.43
Mean	86.89	109.80	20.94	18.56	155.11	1.70	29.63
SEd	0.29	1.46	0.13	0.25	0.93	0.01	0.13
CD (0.05)	0.59	2.99	0.26	0.51	1.88	0.02	0.26
CD (0.01)	0.78	4.00	0.35	0.68	2.51	0.03	0.35

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

I. Samba Mahsuri - Improved Samba Mahsuri, I. White Ponni - Improved White Ponni,
J. samba - Jeeragasamba

Table 3.General combining ability effects of parents for grain yield and yield attributing traits

Parents	DFF	PH	PL	NPT	GPP	HGW	SPY
Lines							
RNR 15048	-0.87	-1.52**	0.42**	-0.10	-1.71	-0.10**	0.93**
ADT 37	-0.43	-0.16**	-0.11	1.24**	-5.36**	0.24**	-0.27
WGL 20471	-2.21**	-3.16**	-0.34*	-0.54*	-2.86**	-0.09**	-3.50**
MDU 6	-1.65*	-8.82	-0.24	-1.21**	-26.58**	0.13**	-2.75**
CO 51	-2.21**	-7.24	0.08	-0.65*	-4.81**	0.31**	3.1**
I. Samba Mahsuri	1.46*	-8.28	-0.11	-0.87**	38.64**	-0.24**	0.56**
I. White Ponni	5.90**	29.17	0.29*	2.13**	2.69*	-0.26**	1.93**
SE	0.68	1.57	0.14	0.27	1.00	0.01	0.14
Testers							
J.samba	0.46*	4.31	0.17	1.06**	-1.59*	0.01	1.73**
ADT 41	0.08	-4.90	0.49**	0.68**	7.21**	0.06**	-1.42**
VGD 1	-0.54*	0.59**	-0.66**	-1.75**	-5.62**	-0.07**	-0.32**
SE	0.20	1.03	0.09	0.18	0.65	0.01	0.09

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

Table 4. Mean performance of hybrids for grain yield and yield attributing traits

Hybrids	DFF(%)	PH(cm)	PL(cm)	NPT	GPP	HGW(g)	SPY(g)
RNR 15048 × J .samba	90.00	110.50	23.93*	16.00	144.67	1.64	38.46**
RNR 15048 × ADT 41	93.67	90.70**	24.77**	20.33**	152.73	1.91**	35.45
RNR 15048 × VGD 1	87.33**	107.23	22.30	15.33	164.73**	1.64	39.11**
ADT 37× J. samba	91.00	116.33	23.17	15.67	137.33	1.88	43.07**
ADT 37 × ADT 41	91.33	99.00	24.00*	19.67**	165.17**	2.05**	30.25
ADT 37 × VGD 1	90.00	97.17	22.27	20.33**	148.67	2.27**	36.11
WGL 20471 × J. samba	88.33**	98.00	22.53	17.67	144.00	1.89*	35.26
WGL 20471 × ADT 41	90.67	92.50**	24.07*	18.33	142.33	1.69	29.26
WGL 20471 × VGD 1	88.00**	113.00	22.13	14.33	172.33**	1.63	35.20
MDU 6 × J. samba	90.00	99.57	22.13	19.00*	134.67	2.02**	39.11**
MDU 6 × ADT 41	88.00**	96.47*	23.00	14.33	132.50	2.31**	30.20
MDU 6 × VGD 1	90.67	90.50**	23.90	15.00	120.33	1.55	32.67
CO 51 × J. samba	91.00	100.40	24.40**	21.33**	152.83	2.25**	38.67**
CO 51 × ADT 41	85.00**	95.53**	23.33	15.00	163.00**	2.06**	44.97**
CO 51 × VGD 1	91.00	95.33**	22.27	13.67	137.00	2.09**	35.90
I. Samba Mahsuri × J. samba	94.67	107.00	24.33**	18.67**	206.33**	1.66	38.60**
I. Samba Mahsuri × ADT 41	92.33	93.47**	23.00	18.33	218.17**	1.54	36.27
I. Samba Mahsuri × VGD 1	91.00	87.67**	22.10	12.33	158.67	1.56	37.03
I. White Ponni × J. samba	96.67	128.67	23.47	20.33**	159.33	1.53	36.17
I. White Ponni × ADT 41	98.00	128.33	24.00	20.00**	166.83**	1.62	40.90**
I. White Ponni × VGD 1	96.67	143.50	23.17	18.00	149.17	1.56	38.97**
Mean	91.21	104.33	23.25	17.32	155.75	1.83	36.74
SEd	0.76	3.86	0.33	0.66	2.45	0.03	0.34
CD (0.05)	1.54	7.80	0.67	1.33	4.95	0.06	0.69
CD (0.01)	2.06	10.43	0.89	1.78	6.62	0.08	0.92

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

Table 5. Specific combining ability effects of hybrids for grain yield and yield attributing traits

Hybrids	DFF	PH	PL	NPT	GPP	HGW	SPY
RNR 15048 × J .samba	-0.79	3.38	0.09	-2.29**	-7.79**	-0.10**	-0.94**
RNR 15048 × ADT 41	3.25**	-7.21*	0.61*	2.43**	-8.52**	0.12**	-0.81**
RNR 15048 × VGD 1	-2.46**	3.84	-0.71**	-0.14	16.31**	-0.02	1.75**
ADT 37 × J. samba	-0.24	7.86**	-0.15	-3.95**	-11.47**	-0.20**	4.86**
ADT 37 × ADT 41	0.48	-0.27	0.37	0.43	7.57**	-0.07**	-4.81**
ADT 37 × VGD 1	-0.24	-7.59**	-0.22	3.52**	3.90*	0.27**	-0.05
WGL 20471 × J. samba	-1.13*	-7.48**	-0.55*	-0.17	-7.30**	0.14**	0.28
WGL 20471 × ADT 41	1.59**	-3.77	0.67**	0.87	-17.77**	-0.11**	-2.56**
WGL 20471 × VGD 1	-0.46	11.25**	-0.12	-0.70	25.07**	-0.03	2.28**
MDU 6 × J. samba	-0.02	-0.26	-1.05**	1.83**	7.09**	0.05**	3.39**
MDU 6 × ADT 41	-1.63**	5.85*	-0.50*	-2.46**	-3.88*	0.29**	-2.38**
MDU 6 × VGD 1	1.65**	-5.60*	1.55**	0.63	-3.21	-0.34**	-1.01**
CO 51 × J. samba	1.54**	-1.00	0.89**	3.60**	3.47	0.10**	-2.91**
CO 51 × ADT 41	-4.08**	3.34	-0.49*	-2.35**	4.85**	-0.13**	6.54**
CO 51 × VGD 1	2.54**	-2.34	-0.41	-1.25	-8.32**	0.02	-3.63**
I. Samba Mahsuri × J. samba	1.54**	6.64*	1.02**	1.16	13.53**	0.06**	-0.43
I. Samba Mahsuri × ADT 41	-0.41	2.32	-0.63*	1.21	16.57**	-0.11**	0.38
I. Samba Mahsuri × VGD 1	-1.13*	-8.97**	-0.38	-2.37**	-30.10**	0.05**	0.05
I. White Ponni × J. samba	-0.90	-9.14**	-0.25	-0.17	2.47	-0.05**	-4.24**
I. White Ponni × ADT 41	0.81	-0.27	-0.03	-0.13	1.18	-0.01	3.64**
I. White Ponni × VGD 1	0.10	9.41**	0.28	0.30	-3.65*	0.06**	0.61*
SE	0.54	2.73	0.24	0.47	1.73	0.02	0.24

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