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Evaluation of F1 hybrid for the assessment of combining ability for yield and its attributes in rice (*Oryza sativa* L.)

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Abstract
The present investigation entitled "Evaluation of F_1 hybrid for the assessment of combining ability for yield and its attributes in rice (*Oryza sativa* L.)" was undertaken with a view to determine general combining ability of parents and specific combining ability of different crosses. The experimental material consisting of 39 genotypes including 28 crosses and 11 parents were evaluated during *kharif* 2018 in Randomized Block Design (RBD) with 3 replications at Main Rice Research Centre, Navsari Agricultural University, Navsari. Combining ability analysis revealed that both gca and sca variances were important for inheritance of most of the characters under study. However, the magnitude of sca variance was higher than gca variance for most of the characters, which indicated the predominance of non-additive gene action in the expression of most of the characters. The estimates of gca effects of parents indicated that the line NVSR-398 was good general combiner for yield contributing characters, whereas testers GNR-3 and NAUR-1 were good general combiners for yield contributing characters. The best specific crosses involved the combinations of either good x good, good x poor, average x good, average x average and poor x good general combining parents.

Keywords: Combining ability, line x tester, gca, sca

Introduction

Rice (*Oryza sativa* L.) belongs to the genus *Oryza*, family Poaceae, was domesticated probably in north-eastern India and southern China about 8000 years ago and is the staple food for more than 50% of the world's population (Gowda *et al.*, 2003) [13]. It accounts for over 20% of global calorie intake. Over 90% of the world's rice is produced and consumed in the Asian region with 6 countries (China, India, Indonesia, Bangladesh, Vietnam and Japan) accounted for 80% in the world's production and consumption (Abdullah *et al*., 2015) [1]. The world's population is projected to reach 9.7 billion by year 2050. If rice remains a staple and land resources are limited, a large increase in rice production will be needed (Anonymous, 2015) [3]. Global production of rough rice is 758.9 million tonnes from 163.2 million hectares area and its productivity 4650 kg/ha (FAO, 2017) [11]. Rice being most important food crop more than 2 billion people in Asia provides 27% of dietary energy and 20% of overall dietary protein (Bashir *et al.*, 2007) [5]. Asia is considered as 'Rice Bowl' of the world, and its produces and consumes more than 90% of world rice. While in India, a newly born state Chhattisgarh is known as 'Rice Bowl' of India. India is the largest rice growing country, while China is the largest producer of rice. In India, rice is cultivated in 43.99 million ha along with production of 109.70 million tonnes and productivity 2494 kg/ha during year 2016-17 (Anonymous, 2017) [4]. In Gujarat, rice accounts for 0.84 million ha along with production of 1.93 million tonnes and productivity 2305 kg/ha during year 2016-17 (Anonymous, 2017) [4].

Materials and method

The present investigation was carried out to elicit information on combing ability of parents and hybrids. The experiment was conducted during *kharif* 2018 at Main Rice Research Centre, Navsari Agricultural University, Navsari. The experimental materials for present investigation consisted of 11 parents namely NVSR-391, NVSR-395, NVSR-396, NVSR-397, NVSR-398, NVSR-2394 and NVSR-2475 as lines, whereas NAUR-1, GNR-3, GNR-6 and GR-4 as testers and their 28 crosses. The crossing programme was carried out by hand emasculation and pollination at Main Rice Research Centre, NAU, Navsari during summer 2018.

Total 28 crosses were obtained through line x tester mating design. All the hybrid seeds and selfed parental seeds were harvested, cleaned and handled properly in seed bag for sowing in the next season *i.e*., *kharif* 2018. The experiment was laid out in a randomized complete block design with three replications. Each entry was planted in a single row consisting of ten plants in each row with a spacing of 20 cm x 15 cm. The standard agronomical practices were followed to raise the good experimental crop. Five competitive plants excluding border plant were randomly selected to record the observation on eight characters*viz*., days to 50% flowering, plant height, panicles/plant, panicle length, grains/panicle, grain yield/plant, L/B ratio and test weight and mean values over five plants were subjected to statistical analysis.

Results and discussion

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) [10]. 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 nature and magnitude of estimates of genetic variance provide an idea about the relative role of fixable and non-fixable gene effects in the inheritance of character. This in turn helps in identifying suitable parents for hybridization as well as breeding method to be employed. The variation present in the hybrids was partitioned into portions attributable to lines, testers and line x tester sources. Analysis of variance for combining ability revealed that mean squares due to females were significant or non-significant for various characters in rice.

The estimation of general combining ability (gca) variances for lines (σ^2_l) were significant for all the characters except plant height and panicle length. In contrast, general combining ability (gca) variances for testers (σ^2t) were significant for 4 different characters, *viz*., panicle length, grain yield/plant, L/B ratio and test weight. On the other hand, specific combining ability (sca) variances for line x tester interactions were highly significant for all characters except panicle length. The magnitude of the gca variances was lower than sca variances for various characters except panicle length, grain yield/plant and test weight which indicates thepredominance of non-additive gene action for most of the characters. This was further supported by low magnitude of σ^2gca/ σ^2sca ratios. General combining ability effects of females (g_i) and of males (g_j) as well as specific combining ability effects of crosses (s_{ij}) for all the characters were also estimated. Preponderance of non-additive variance in the expression of different traits in rice has been reported by Milan *et al*. (2010) [18], Rahimi *et al.* (2010) [23], Salim *et al.* (2010) [25], Thakare *et al.* (2010) [33], Patil *et al.* (2011) [21], Shanthi *et al*. (2011) [29], Varpe *et al*. (2011) [35], Bhadru *et al*. (2012) [7], Padmavathi *et al.* (2012) [19], Patil *et al.* (2012) [22], Shanghera and Hussain (2012) [26], Hasan *et al*. (2013) [14], Latha *et al.* (2013) [16], Singh *et al*. (2013) [30], Utharasu and Anandakumar (2013) [34], Adilakshmi and Upendra (2014) [2], Bedi and Sharma (2014) [6], Dar *et al.* (2014) [9], Mallikarjuna *et al*. (2014) [17], Bhatti *et al.* (2015) [8], Patel and Patel (2015) [20], Sasikala *et al*. (2015) [27], Sreenivas *et al*. (2015) [31], Satheeshkumar *et al.* (2016) [28], Kumar and Singh (2017) [15], Rumanti *et al.* (2017) [24], Sudeepthi *et al*. (2017) [32] and Goswami (2018) [12].

General combining ability (GCA) and Specific combining ability (SCA) effects

The GCA and SCA effects of parents and their crosses for different traits were presented in Table 2 and Table 3, respectively. The general combining ability is defined as the average performance of a strain in a series of cross combinations. Dhillon (1975) [10] 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) and Tiwari *et al*. (1993) had also suggested that parents having high GCA effects could produce transgressive segregants in F_2 or later generations.

Days to 50% flowering

Genotypes which flowers early along with negative gca and sca values are preferred for this character and would be considered as good general combiner and good specific combiner, respectively. Out of 7 lines, NVSR-395 and NVSR-2394 exhibited significant gca effects in desirable direction whereas, among testers, GNR-6 had significant gca effects in desirable direction. The sca effects for days to 50% flowering, the cross combinations NVSR-395 x NAUR-1 depicted higher sca effect in desirable direction followed by 3 different crosses *viz*., NVSR-2475 x GNR-3, NVSR-396 x GR-4 and NVSR-2394 x GR-4.

Plant height (cm)

As regards to gca effects, 2 parents had reported significant negative gca effect for plant height. Among lines, NVSR-2394 possessed significant negative gca effect while that of among testers was by GNR-3. An examination of sca effects revealed that, total 14 crosses had negative sca effects ranged from -7.93 (NVSR-395 x NAUR-1) to -0.47 (NVSR-395 x GNR-6), but none of the hybrids had negative and significant sca effects.

Panicles/plant

Higher number of panicles are desirable feature in rice for better yield. Estimates of gca effects revealed that lines NVSR-398 and NVSR-396 whereas, tester NAUR-1 had significant gca effects in desirable direction. The highest positive sca effect was exhibited by NVSR-396 x NAUR-1 followed by NVSR-398 x GNR-6 Sand NVSR-395 x GR-4.

Panicle length (cm)

Analysis of gca effects depicted that among all the 7 lines, NVSR-2394 had positive significant gca effect, while that is among testers, NAUR-1 had positive significant gca effect. The highest sca effect in desirable direction was recorded by only the cross NVSR-2394 x GNR-3 (3.08) only.

Grains/panicle

Higher number of grains in a panicle is a desirable and important characteristic feature in rice since it is related to higher seed yield. The estimates of gca effects of parents revealed that among lines, NVSR-398 recorded significant and positive gca effects followed by NVSR-396 and NVSR-2475 and among tester, none of the testers reported significant and positive gca effect. Although, testers GR-4 reported non-significant and positive gca effect followed by other two testers, *i.e*., NAUR-1 and GNR-3. Out of 28 crosses, only 2 crosses NVSR-397 x GR-4 and NVSR-2475 x NAUR-1 reported significant sca effect in desirable direction.

Grain yield/plant (g)

Among lines, only NVSR-398 (5.35) reported positive and significant gca effect, while among testers, GNR-3 and NAUR-1 reported positive and significant gca effect and were considered as good general combiner. Highest positive and significant sca effect was recorded by NVSR-391 x GNR-3 followed by NVSR-396 x NAUR-1 and NVSR-2394 x GR-4.

L/B ratio

Among the lines, NVSR-398 and NVSR-2394 had highly significant and positive gca effect, while among testers, GR-4 and GNR-6 highly significant gca effect for L/B ratio. A total of 15 crosses were found to be positive for this character; from which 7 crosses had significant sca effect for L/B ratio. The top ranking specific cross combinations were NVSR-2394 x GR-4, NVSR-397 x GNR-3 and NVSR-397 x NAUR-1. All the cross which had positive and significant sca effects were classified as good specific combiners for rice varieties with high L/B ratio.

Test weight (g)

For the character test weight, 3 lines *viz*., NVSR-398, NVSR-2394 and NVSR-2475 were depicted significant positive gca effect. Among testers, only GNR-3 depicted significant and positive gca effect. Total of 3 crosses reported positive significant sca effect from which NVSR-397 x NAUR-1 had highest sca effect in desirable direction followed by NVSR-2394 x GNR-3 and NVSR-391 x GR-4.

Table 1: Mean sum of squares due to general and specific combining ability for various characters in rice

Sources of variation	df	Characters							
		Days to 50% flowering	Plant height (cm)	Panicles/ plant	Panicle length (cm)	Grain/ panicle	Grain yield/ plant (g)	L/B ratio	Test weight (g)
Replications	2	25.11	15.08	0.60	3.27	93.75	4.61	0.01	0.34
Hybrids	27	52.96**	173.93**	2.71**	7.81**	259.43**	37.43**	0.35**	10.08**
Line effect	6	98.33*	272.53	5.57*	8.35	541.55*	87.84**	0.61*	12.53*
Tester effect	3	95.00	253.86	2.02	23.90*	273.72	102.65**	0.79*	39.29**
Line × Tester	18	30.84**	127.74**	1.84**	4.94	163.01**	9.76*	0.19**	4.39**
Error	54	9.03	48.62	0.59	3.12	67.48	5.29	0.02	0.86
Estimates									
σ^2_l		7.43*	18.79	0.43*	0.44	40.19*	6.99**	0.05*	0.97*
σ^2_t		4.09	9.85	0.07	0.99*	10.21	4.70**	0.04*	1.83**
σ^2gca		5.31**	13.10**	0.20**	0.79**	21.11**	5.53**	0.04**	1.52**
σ^2sca		7.24**	26.89**	0.47**	0.62	34.57**	1.94**	0.06**	1.16**
σ^2gca/σ^2sca		0.73	0.49	0.43	1.27	0.61	2.85	0.67	1.31

* and ** indicates significance at 5% and 1% levels of probability, respectively

Table 2: Estimation of General Combining Ability (GCA) effects of parents for various characters in rice

Genotypes	Characters							
	Days to 50% flowering	Plant height (cm)	Panicles/plant	Panicle length (cm)	Grains/ panicle	Grain yield/ plant (g)	L/B ratio	Test weight (g)
Lines								
NVSR- 391	3.39**	-2.63	0.11	-0.06	-5.36*	-1.36*	-0.01	-0.25
NVSR- 395	-4.44**	2.00	-0.33	-0.89	-3.88	-2.52**	-0.01	-1.34**
NVSR- 396	-0.86	4.74*	0.49*	0.18	5.58*	0.61	-0.47**	-0.90**
NVSR- 397	3.06**	1.42	-0.26	-0.78	-10.81**	-2.11**	0.04	-0.40
NVSR- 398	-1.19	-1.80	0.89**	-0.18	6.92**	5.35**	0.20**	1.63**
NVSR- 2394	-1.77*	-8.60**	0.32	1.64**	2.65	1.09	0.20**	0.66*
NVSR- 2475	1.81 *	4.87*	-1.21**	0.10	4.90*	-1.06	0.06	0.60*
SE (G_i)	0.87	1.98	0.19	0.51	2.22	0.57	0.04	0.28
Testers								
NAUR- 1	1.89 **	2.92	0.35*	1.25**	1.47	0.90*	-0.04	0.29
GNR -3	-0.54	-3.79*	-0.16	0.09	0.45	2.55**	-0.25**	1.33**
GNR- 6	-2.77**	-2.12	0.15	0.01	-5.14**	-0.89*	0.09**	0.31
GR - 4	1.42 *	2.99	-0.35*	-1.35**	3.22	-2.56**	0.20**	-1.92**
SE (G_j)	0.66	1.50	0.15	0.38	1.68	0.43	0.03	0.21

* and ** indicates significance at 5% and 1% levels of probability, respectively

Table 3: Estimation of Specific Combining Ability (SCA) effect of hybrids forvarious characters in rice

Crosses	Days to 50% flowering	Plant height (cm)	Panicles/ plant	Panicle length (cm)	Grains/ panicle	Grain yield/plant (g)	L/B ratio	Test weight (g)
NVSR-391 x NAUR-1	1.27	-7.44	-0.60	0.21	-6.19	-1.32	-0.25**	-0.07
NVSR-391 x GNR-3	-1.30	-4.74	0.57	-0.62	4.21	2.60*	0.05	-0.80
NVSR-391 x GNR-6	0.61	2.26	-0.53	-0.03	2.95	-1.57	0.14	-0.701
NVSR-391 x GR-4	-0.58	9.92*	0.56	0.44	-0.97	0.29	0.07	1.57**
NVSR-395 x NAUR-1	-5.23**	-7.93	-0.30	0.30	1.69	-1.23	0.17*	-1.03
NVSR-395 x GNR-3	2.87	7.61	-0.40	-0.69	-0.31	-0.81	-0.26**	-0.17
NVSR-395 x GNR-6	0.77	-0.47	-0.17	0.29	-0.82	0.48	0.03	0.36

NVSR-395 x GR-4	1.58	0.80	0.86*	0.10	-0.56	1.57	0.07	0.84
NVSR-396 x NAUR-1	-0.81	-0.58	1.55**	1.49	-3.77	2.57*	-0.28**	0.80
NVSR-396 x GNR-3	1.95	-3.97	-0.01	-1.58	7.64	-0.94	-0.11	-1.33*
NVSR-396 x GNR-6	3.19	3.83	-0.72	-0.37	0.40	-0.89	0.23**	-0.07
NVSR-396 x GR-4	-4.33*	0.72	-0.82*	0.46	-4.28	-0.75	0.16*	0.60
NVSR-397 x NAUR-1	3.61*	6.25	0.37	0.42	4.86	1.28	0.25**	1.74**
NVSR-397 x GNR-3	-1.30	5.89	-0.66	-1.64	-14.24**	-2.20	0.28**	-0.80
NVSR-397 x GNR-6	-2.06	-7.58	0.23	0.48	-0.83	0.84	-0.03	0.86
NVSR-397 x GR-4	-0.25	-4.56	0.06	0.74	10.22*	0.09	-0.50**	-1.80**
NVSR-398 x NAUR-1	-2.48	0.20	0.35	0.22	2.19	1.16	0.22**	0.45
NVSR-398 x GNR-3	0.28	-5.83	-0.08	0.04	6.57	0.73	-0.21**	0.57
NVSR-398 x GNR-6	-0.48	7.63	1.02*	0.14	-6.02	1.27	0.07	0.72
NVSR-398 x GR-4	2.67	-2.01	-1.29**	-0.39	-2.74	-3.16**	-0.09	-1.74**
NVSR-2394 x NAUR-1	3.11	5.23	-1.02*	-2.47*	-8.97*	-2.51*	-0.03	-1.27*
NVSR-2394 x GNR-3	1.87	-5.46	0.56	3.08**	2.33	0.30	0.14	1.59**
NVSR-2394 x GNR-6	-0.89	-1.50	0.32	-0.51	-0.81	-0.29	-0.39**	-0.79
NVSR-2394 x GR-4	-4.08*	1.73	0.15	-0.09	7.45	2.50*	0.29**	0.47
NVSR-2475 x NAUR-1	0.524	4.27	-0.35	-0.18	10.20*	0.05	-0.08	-0.62
NVSR-2475 x GNR-3	-4.38*	6.51	0.02	1.42	-6.20	0.33	0.12	0.93
NVSR-2475 x GNR-6	-1.143	-4.17	-0.15	0.01	5.13	0.17	-0.05	-0.37
NVSR-2475 x GR-4	5.00**	-6.61	0.48	-1.25	-9.13*	-0.54	0.01	0.06
SE (S_{ij})	1.74	3.96	0.39	1.02	4.45	1.14	0.07	0.55

* and ** indicates significance at 5% and 1% levels of probability, respectively

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