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Combining ability analysis for grain yield and its attributes in Rice (*Oryza sativa* L.)

K Modunshim Maring, Madhubala and Patel PB

Abstract
The experiment was carried out for studying the combining ability for yield and its components traits in rice. A set of 45 genotypes comprising of 32 hybrids and their 12 parents which represented 4 lines and 8 testers were planted in Randomized Block Design (RBD) with 3 replications during *kharif* – 2019-20 at Main Rice Research Centre, Navsari Agricultural University, Navsari. Among parents, the line, NVSR-453, and the testers, NVSR -409 and NAUR-1 were the good general combiners whereas the crosses, NVSR - 452 x NVSR - 486, NVSR - 453 x NVSR - 475 and GNR - 3 x Dandi were found to be good specific combiners for grain yield per plant and some of its component characters. The combining ability analysis also revealed that both additive and non-additive gene action were found controlling the expression of the traits under studied, however the magnitude of SCA variance was found to be higher than that of GCA variance for most of the characters, which indicated the predominance of non-additive gene action in the expression of most of the characters. None of the hybrids recorded significant *sca* effects for all the 13 characters studied.

Keywords: Combining ability, line x tester, rice, yield

Introduction

Rice (*Oryza sativa* L., 2n = 2x = 24) is the major diet component for more than half of the world's population, and is grown in more than one hundred countries of the world. It originated from South-East and belongs to '*poaceae'* family and genus '*Oryza'*. There are two cultivated and 21 wild species of rice under the genus, *Oryza.* The two cultivated species are *O. sativa* (Asian rice) and *O. glaberrima* (African rice). Asian rice are again classified into two subspecies, *i.e.*, *O. sativa indica* and *O. sativa japonica* (Glaszmann, 1987) [5].

Rice, which is predominantly, a self-pollinated crop, is a short day, hydrophilic and C_3 plant. It is grown mostly in the humid tropical and subtropical regions of the world. Rice cultivation extends from 40^0S to 45^0N latitude, 70^0W to 140^0S longitude and within an altitude range of 1500 – 2200 MAMSL. Rice serves as supplier of vitamins like thiamine, riboflavin and niacin. Rice bran oil is used as cooking oil and as medicines and its straw can be fed to animals. In Asia, the main producers of rice are India, China, Indonesia, Thailand, Myanmar, Bangladesh (IRRI – World Rice Statistics, 2010).

Looking at the rapidly growing populations, rice breeders are new finding ways to increase the rice productivity to fulfill the ever-increasing demands of food. Analysis of combining ability helps breeders to select the desire parents that can be used for hybridization as well as for the screening of superior hybrids. There are two types of combining ability *viz.*, General Combining Ability (GCA) and Specific Combining Ability (SCA). General combining ability is responsible for additive gene effects and specific combining ability is responsible for non-additive gene effects, including dominance and epistasis. The ultimate aim of breeder in any breeding programme is to identify the parents having good general combining ability and the crosses exhibiting high specific combining ability. Line x Tester analysis (Kempthrone, 1957) is the most used method for the study of gene effects in self-pollinated crops especially in rice breeding programme (Peng and Virmani, 1990) [19]. Generally, GCA is less influenced by the environment as compared to the SCA (Singh and Richharia, 1977) [26]. Therefore, the experiment was undertaken with an objective to study the gene action as well as the combining ability for the yield and its components traits in the rice crop.

Materials and Methods

The experimental materials consisted of 45 entries including 4 lines (Gurjari, NVSR-452, NVSR-453 and GNR-3) and eight testers (NVSR-6157, NVSR-473, NVSR-475, NVSR-486, Dandi, NVSR-403, NVSR-409, NAUR-1) and their 32 hybrids (Line x Tester mating design) and one check variety, GNR-5. The crossing programme was carried out at Main Rice Research Centre (M. R. R. C.), NAU. Navsari during *summer* – 2019 and the evaluation was carried out during *kharif* – 2020. The crossing programme which involved both emasculation and pollination was done manually by hands using these 4 lines and 8 testers. The standard agronomical practices were followed to raise a good experiment crop for evaluation. The experiment was laid out in a Randomized Block Design with three replications. Each genotype was planted in a single row which consists of 10 plants with a spacing of 20 x 15 cm^2. Five competitive plants were randomly selected in each replication to record observations on yield and its components characters *viz.,* Plant height (cm), productive tillers per plant, panicle length (cm), grains per panicle, kernel length (mm), kernel width (mm), L: B ratio, 100 grain weight (g), protein content (%), amylose content (%), and the straw yield per plant. The traits, days to 50% flowering and grain yield per plant were recorded on net plot basis. The mean values of five plants were subjected to statistical analysis. Combining ability analysis was computed by using line x tester design given by Kempthorne (1957) [10]. The biochemical analysis was done at the Central Instrumentation laboratory of N. M. College of Agriculture, NAU, Navsari.

Results and Discussion

The analysis of variance (ANOVA) for combining ability showed highly significant differences in mean squares among various crosses for all the characters (Table 1). It was found that the variation present in the hybrids were due to the effects of lines, testers and combination of both lines and testers. The GCA estimates of line (σ^2_l) were non-significant for all the characters except for the traits, days to 50% flowering and protein content, whereas for the testers, it was found significant in four traits, *viz.*, days to 50% flowering, kernel width, L: B ratio and protein content. On the other hand, specific combining ability variances for Line x Tester interactions were highly significant for all the characters. The magnitude of the GCA variances was lower than SCA variances for all the characters except days to 50% flowering and protein content. This indicates the predominance of non-additive genes as compared to additive genes in the inheritance of traits. This is also further supported by low values of σ^2gca / σ^2sca ratios. Similar results in rice has already been reported by Kumar *et al.* (2006) [12], Verma *et al.* (2006) [28], Sharma and Mani (2008) [25], Jayasudha and Sharma (2009) [3, 8, 13], Saidaiah *et al.* (2010) [21], Saleem *et al.* (2010) [22], Padmavathi *et al.* (2012) [15], Patil *et al.* (2012) [18], Sanghera and Hussain (2012) [12, 23], Utharasu and Anandakumar (2013) [27], Latha *et al.* (2013) [13], Adilakshmi and Upendra (2014) [1], Dar *et al.* (2014) [4], Mallikarjuna *et al.* (2014) [14], Bedi and Sharma (2014) [3, 8, 13], Patel *et al.* (2015) [17], Sathya and Jebaraj (2015) [24], Kishor *et al.* (2017) [11], Rumanti *et al.* (2017) [20], Goswami (2018) [6]. The presence of higher magnitude of non-additive gene action in controlling the traits provides an opportunity for the exploitation of hybrid vigor through heterosis breeding.

General Combining Ability Effects and Specific Combining Ability Effects

Combining ability is useful in the selection of a suitable parent for incorporation in the hybridization. The parents are selected based on their performance in a series of crosses. General combining ability is the average performance of a genotype in a series of cross combinations whereas specific combining refers to the deviation of a particular cross from a general combining ability. The *gca* effect of parents and *sca* effect of crosses for all the studied traits are presented in the Table 2 and Table 3.

Days to 50% flowering

The genotypes which are having early flowering for this trait, days to 50% flowering are the desirable ones. So, the genotypes having negative *gca* and *sca* values were the good general combiners and good specific combiners, respectively. Two lines, Gurjari and GNR-3 and only one tester, Dandi exhibited significant *gca* effect in desirable directions. Whereas all the *sca* effect of cross combinations were non-significant.

Plant height (cm)

The genotypes of shorter plant height are preferred for the rice crop to minimize lodging problem. Two parents, GNR-3 and NVSR-486 were found to possess a significant *gca* effect in desirable directions. Total of 15 crosses had negative *sca* effect out of which, four crosses *viz.,* NVSR-453 x Dandi, NVSR-452 x NAUR-1, Gurjari x NVSR-473 and NVSR-452 x NVSR-475 were found significant.

Productive tillers per plant

The productive tillers per plant have a significant contribution to the overall yield of the rice crop. One line, Gurjari and one tester, NVSR-475 exhibited significant *gca* effect in a desirable direction. As for the crosses, half of 10 hybrids showing significant *sca* effects were in positive direction were considered as better specific combiners for productive tillers per plant. Among five hybrids, GNR-3 x NVSR-403 exhibited the highest significant and positive *sca* effect.

Panicle length (cm)

The effect of *gca* for the parents revealed that, out of two lines having significant *gca* effect, one line *i.e.,* NVSR-453 had significant *gca* effect in the positive direction and was considered as the best general combiner for this trait. Three testers were observed to have significant *gca* effects, out of which two testers, NAUR-1 and NVSR-409 had positive estimates for panicle length. Out of 12 hybrids exhibiting significant *sca* effect, six hybrids having positive estimates were taken as good specific combiners for longer panicle length. The cross showing the maximum positive and significant *sca* effect was NVSR-453 x NVSR-475, followed by NVSR-452 x NVSR-486 and Gurjari x NAUR-1, etc.

Grains per panicle

The number of grains in panicle is one of the important components that affect the final grain yield of the rice crop. The *gca* estimates of the parents revealed that only one line, NVSR-453 had significant and positive *sca* effect and among testers, NAUR-1 and NVSR-409 reported significant and positive *gca* effect. Out of total 32 crosses, five hybrids reported significant *sca* effect in desirable directions, among which, NVSR-452 x NVSR-486, NVSR-453 x NVSR-475 and Gurjari x NAUR-1, were found to be the top three best specific combiners.

Kernel length (mm)

The *gca* effect of all the lines were found to be significant for kernel length but only two lines, Gurjari and NVSR-453 exhibited significance in positive directions. Whereas four testers *viz.,* NVSR-409, NVSR-486, NAUR-1 and NVSR-473 exhibited significant *gca* effect in positive directions. For crosses, 12 hybrids had positive *sca* effects out of which, the cross combination, NVSR-453 x NAUR-1 were found to possess the highest and positive *sca* effect, followed by Gurjari x NVSR-403 and NVSR-452 x NVSR-6157.

Kernel width (mm)

The estimates of *gca* effect of the lines depicted that NVSR-453 showed significant and positive *sca* effect followed by NVSR-452, whereas for testers, six testers showed significant *gca* effect in desirable directions of which, NVSR-486 and Dandi were the top ranked followed by NVSR-6157, NVSR-475, NVSR-403 and NAUR-1. Out of total nine crosses showing significant *sca* effect in desirable direction, the cross Gurjari x NVSR-473 showed the highest, followed by NVSR-452 x NAUR-1 and NVSR-452 x NVSR-409.

L: B ratio

Among the lines, Gurjari was highly significant and showed positive *gca* effect followed by NVSR-453, whereas among testers, NVSR-409 had highly significant and positive *gca* effect for L: B ratio, followed by NVSR-473 and NVSR-486. A total of 26 crosses were found to have significant *sca* effect out of which 13 crosses were in desirable directions for L: B ratio. The top-ranking crosses were NVSR-453 x NAUR-1, Gurjari x NVSR-403 and NVSR-452 x NVSR-473. All the crosses which showed positive and significant *sca* effects were considered as a good specific combiner.

100 grain weight (g)

For 100 grain weight, two lines *viz.*, Gurjari and NVSR-453 recorded significant positive *gca* effect. Among testers, NVSR-486 and NVSR-6157 exhibited significant *gca* effect in positive direction. For hybrids, 13 crosses showed positive and significant *sca* effect out of which, NVSR-453 x NAUR-1 was the highest, followed by Gurjari x NVSR-403 and Gurjari x NVSR-473.

Protein content (%)

With regards to the *gca* effect for protein content, two lines namely, Gurjari and NVSR-452 had significant positive *gca* effects. Among testers, the highest significant positive *gca* effect for protein content was reported in NVSR-6157 followed by NVSR-473 and NVSR-403. The cross combination, NVSR-453 x NVSR-473 had the highest significant *sca* effect in desirable direction followed by Gurjari x NVSR-409 and NVSR-453 x NVSR-475.

Amylose content (%)

The amylose content of the rice is responsible for the softness or firmness of the rice when cooked. Among parents, two lines namely, NVSR-45 and NVSR-452 possessed significant *gca* effect for the character amylose content. Also, the two testers, NVSR-403 and NVSR-6157, were found to show significant *gca* effect in desirable direction. A total of 11 crosses had significant *gca* in desirable directions. Among these 11 crosses, the top three ranking cross combinations were, Gurjari x NVSR-6157, Gurjari x Dandi and GNR-3 x NVSR-475. All the crosses which had significant *sca* effect were considered as good specific combiners for the trait, amylose content.

Grain yield per plant (g)

The trait, grain yield per plant is the most important character which is resulted due to combinations of various other components traits. The estimates of *gca* effect were significant and positive for the line, NVSR-453 and the testers, NAUR-1 and NVSR-409. In case of hybrids significant *sca* effect in positive direction was recorded in the cross, NVSR-452 x NVSR-486, followed by NVSR-453 x NVSR-475 and GNR-3 x Dandi.

Straw yield per plant (g)

The line, Gurjari and the testers NAUR-1 and NVSR-403 showed significant *sca* effect in desirable direction and were taken as good general combiners for higher straw yield per plant. The crosses which showed significant and positive *sca* effect, namely GNR-3 x NVSR-403 followed by

Table 1: Analysis of variance for combining ability for different characters in rice.

Sources of variation		Characters												
		Days to 50% flowering	**Plant height (cm)**	**Productive tillers per plant**	**Panicle length (cm)**	**Grains per panicle**	**Kernel length (mm)**	**Kernel width (mm)**	**L: B ratio**	**100 grain weight (g)**	**Protein content (%)**	**Amylose content (%)**	**Grain yield per plant (g)**	**Straw yield per plant (g)**
Replications	2	29.34	7.59	0.71	0.64	16.89	0.02	0.01	0.002	0.01	0.004	1.74	0.18	3.48
Hybrids	31	138.67**	457.49**	10.25**	19.00**	2288.49**	2.82**	0.20**	0.71**	0.42**	4.79**	17.78**	98.68**	437.70**
Line effect	3	1148.63**	568.29	8.74	18.86	2570.02	5.98	0.08	0.60	0.91	3.25**	16.95	121.93	490.83
Tester effect	7	70.00**	365.76	4.85	13.76	1807.35	3.84	0.50**	1.81**	0.51	17.88**	9.77	66.79	613.78
Line x Tester	21	17.29	472.24**	12.26**	20.77**	2408.66**	2.02**	0.12**	0.36**	0.33**	0.64**	20.58**	105.98**	371.42**
Error	62	14.55	102.62	1.22	2.41	301.87	0.05	0.002	0.01	0.01	0.02	0.84	8.27	27.85
Estimates														
σ^2_l		47.12**	19.89	0.28	0.69	96.49	0.25	0.003	0.02	0.04	0.13*	0.67	4.73	19.38
σ^2_t		4.35**	22.90	0.24	0.95	129.43	0.32	0.04**	0.15*	0.04	1.49**	0.73	4.87	49.01
σ^2_{gca}		32.87**	20.89	0.27	0.78	107.47	0.27**	0.02**	0.07**	0.04*	0.59**	0.69	4.78	29.26*
σ^2_{sca}		-0.15	127.08**	3.42**	6.14**	718.17**	0.66**	0.04**	0.12**	0.11**	0.21**	6.53**	32.52**	115.26**
$\sigma^2_{gca}/\sigma^2_{sca}$		-219.13	0.16	0.08	0.13	0.15	0.41	0.50	0.58	0.36	2.81	0.11	0.15	0.25

*, ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 2: Estimates of general combining ability effect of parents for different characters in rice

Sources of variation	Characters												
	Days to 50% flowering	**Plant height (cm)**	**Productive tillers per plant**	**Panicle length (cm)**	**Grains per panicle**	**Kernel length (mm)**	**Kernel width (mm)**	**L: B ratio**	**100 grain weight (g)**	**Protein content (%)**	**Amylose content (%)**	**Grain yield per plant (g)**	**Straw yield per plant (g)**
Lines													
Gurjari	-7.90**	-2.25	0.72*	-0.55	-5.86	0.57**	0.01	0.21**	0.22**	0.32**	-1.02**	-1.10	6.06**
NVSR-452	8.71**	-0.16	-0.75*	0.06	0.35	-0.34**	0.03**	-0.15**	-0.05**	0.28**	0.46*	0.07	-3.59**
NVSR-453	1.18	6.82**	0.08	1.23**	14.41**	0.26**	0.05**	0.04*	0.07**	-0.15**	0.88**	3.11**	-3.32**
GNR-3	-1.99*	-4.41*	-0.05	-0.74*	-8.90**	-0.49**	-0.09**	-0.10**	-0.24**	-0.45**	-0.32	-2.08**	0.85
SE (G_i)	0.86	1.95	0.29	0.31	3.25	0.04	0.01	0.02	0.02	0.03	0.2	0.59	1.03
Testers													
NVSR-6157	-2.24	-5.12	-0.42	-0.84	-11.58*	-0.10	0.12**	-0.17**	0.11**	1.96**	1.03**	-2.88**	-3.05*
NVSR-473	-2.07	-0.65	0.001	-0.08	-1.40	0.21**	-0.33**	0.45**	-0.25**	1.10**	-0.26	-0.20	-2.43
NVSR-475	-0.32	-0.92	1.16**	-0.38	-6.07	-0.77**	0.10**	-0.41**	-0.16**	-0.69**	-1.20**	-1.61	-0.93
NVSR-486	1.52	-6.87*	-0.72	-1.57**	-14.57**	0.67**	0.17**	0.05*	0.44**	-0.53**	-0.93**	-2.37**	-5.15**
Dandi	-2.82*	1.95	-0.74	0.34	3.28	-0.63**	0.17**	-0.41**	-0.08**	-0.22**	-0.41	1.36	-6.22**
NVSR-403	0.52	-3.88	0.08	-0.42	-5.17	-0.34**	0.04*	-0.20**	-0.06*	1.02**	1.37**	-0.64	4.33**
NVSR-409	0.93	7.64**	0.21	1.31**	16.87**	0.76**	-0.31**	0.67**	0.01	-1.51**	0.46	2.97**	-2.43
NAUR-1	4.48**	7.84**	0.44	1.64**	18.63**	0.21**	0.04*	0.02	0.003	-1.12**	-0.07	3.38**	15.88**
SE (G_j)	1.22	2.75	0.41	0.44	4.60	0.06	0.02	0.02	0.02	0.04	0.29	0.84	1.46

*, ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 3: Estimates of specific combining ability effect of hybrids for different characters in rice

Crosses	Days to 50% flowering	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Grains per panicle	Kernel length (mm)	Kernel width (mm)	L: B ratio	100 grain weight (g)	Protein content (%)	Amylose content (%)	Grain yield per plant (g)	Straw yield per plant (g)
Gurjari x NVSR-6157	-1.52	-6.47	-1.51	-1.82*	-15.14	-0.27*	0.04	-0.14**	-0.11*	0.19*	2.89**	-2.87	-5.16
Gurjari x NVSR-473	-1.35	-15.27**	2.74**	-4.00**	-36.66**	0.18*	0.38**	-0.38**	0.38**	-0.87**	-3.16**	-6.54**	4.26
Gurjari x NVSR-475	0.57	-4.02	1.25	-0.16	-3.33	0.46**	-0.08*	0.24**	0.09	-0.32**	-0.97	-0.14	-2.54
Gurjari x NVSR-486	0.74	-4.57	-0.10	-0.35	-10.16	-0.43**	-0.02	-0.15**	-0.17**	0.47**	-3.23**	-3.44*	9.24**
Gurjari x Dandi	0.74	4.21	-0.02	1.89*	12.33	0.62**	-0.02	0.22**	0.18**	0.18*	2.81**	2.91	-4.12
Gurjari x NVSR-403	-1.27	1.04	0.49	-0.02	2.44	1.23**	0.02	0.45**	0.42**	-0.72**	2.16**	-0.79	-17.76**
Gurjari x NVSR-409	1.65	5.80	0.70	1.30	9.48	-0.47**	-0.27**	0.21**	-0.47**	0.63**	-0.53	4.04*	6.53*
Gurjari x NAUR-1	0.44	19.29**	-3.53**	3.16**	41.04**	-1.32**	-0.06	-0.46**	-0.32**	0.45**	0.03	6.83**	9.55**
NVSR-452 x NVSR-6157	2.88	5.50	0.79	0.82	12.98	0.76**	-0.12**	0.39**	0.11*	0.05	-5.72**	1.37	15.16**
NVSR-452 x NVSR-473	-0.29	3.52	-1.12	1.39	8.80	-0.10	-0.37**	0.42**	-0.42**	-0.10	1.58**	0.98	0.38
NVSR-452 x NVSR-475	2.29	-12.77*	0.38	-2.93**	-29.87**	0.07	0.03	0.003	0.09*	0.48**	0.38	-5.98**	-11.79**
NVSR-452 x NVSR-486	-1.54	19.20**	-0.40	3.78**	46.03**	0.32**	-0.03	0.14**	0.08	0.22**	1.88**	10.46**	-2.61
NVSR-452 x Dandi	2.46	6.55	-1.22	1.21	9.52	-0.45**	0.03	-0.18**	-0.16**	-0.30**	-0.13	1.76	18.54**
NVSR-452 x NVSR-403	-0.54	1.15	-0.87	0.07	2.90	0.03	0.01	-0.001	0.04	0.11	-0.25	3.76*	-1.42
NVSR-452 x NVSR-409	-2.96	-7.08	2.50**	-0.97	-11.13	-0.34**	0.21**	-0.45**	0.08	-0.48**	-0.11	-4.38**	-7.49*
NVSR-452 x NAUR-1	-2.31	-16.06**	-0.06	-3.38**	-39.23**	-0.29*	0.24**	-0.31**	0.19**	0.01	2.37**	-7.96**	-10.77**
NVSR-453 x NVSR-6157	1.07	1.96	1.13	1.15	6.26	-0.18	-0.04	-0.02	-0.04	-0.21**	0.76	1.69	1.39
NVSR-453 x NVSR-473	-0.43	9.64	0.21	2.26*	24.14**	0.46**	-0.08*	0.31**	0.21**	0.93**	1.16*	5.70**	0.70
NVSR-453 x NVSR-475	-1.18	22.42**	1.36	3.79**	44.14**	-0.78**	-0.01	-0.26**	-0.31**	-0.09	-1.84**	8.22**	11.90**
NVSR-453 x NVSR-486	-1.02	-6.31	0.94	-0.78	-11.76	-0.55**	-0.08*	-0.11**	-0.24**	-0.47**	1.39*	-3.50*	1.22
NVSR-453 x Dandi	-0.35	-24.65**	-0.88	-5.76**	-55.61**	0.25*	-0.13**	0.21**	0.10*	-0.05	2.09**	-12.21**	-4.14
NVSR-453 x NVSR-403	2.32	-2.23	-2.70**	-0.03	-3.16	-1.40**	-0.07*	-0.46**	-0.53**	0.10	-2.34**	-1.63	-1.76
NVSR-453 x NVSR-409	2.57	5.32	-1.50	0.22	10.21	0.23	0.15**	-0.13**	0.23**	-0.03	1.07	2.60	-8.57**
NVSR-453 x NAUR-1	-2.98	-6.16	1.44	-0.84	-14.23	1.98**	0.25**	0.46**	0.58**	-0.18*	-2.30**	-0.87	-0.74
GNR-3 x NVSR-6157	-2.43	-0.99	-0.41	-0.15	-4.10	-0.32**	0.12**	-0.23**	0.04	-0.03	2.06**	-0.18	-11.39**
GNR-3 x NVSR-473	2.07	2.11	-1.83*	0.36	3.72	-0.53**	0.06	-0.34**	-0.17**	0.05	0.42	-0.14	-5.34
GNR-3 x NVSR-475	-1.68	-5.63	-2.99**	-0.70	-10.95	0.25*	0.07*	0.02	0.14**	-0.06	2.43**	-2.11	2.43
GNR-3 x NVSR-486	1.82	-8.32	-0.44	-2.65**	-24.12**	0.66**	0.12**	0.12**	0.34**	-0.23**	-0.04	-3.52*	-7.85**
GNR-3 x Dandi	-2.85	13.90*	2.12**	2.66**	33.77**	-0.42**	0.12**	-0.26**	-0.12**	0.17*	-4.76**	7.55**	-10.28**
GNR-3 x NVSR-403	-0.52	0.05	3.09**	-0.02	-2.18	0.14	0.04	0.01	0.07	0.50**	0.43	-1.33	20.94**
GNR-3 x NVSR-409	-1.27	-4.04	-1.70*	-0.55	-8.55	0.58**	-0.09**	0.37**	0.16**	-0.12	-0.43	-2.26	9.53**
GNR-3 x NAUR-1	4.85	2.92	2.15**	1.06	12.42	-0.37**	-0.44**	0.31**	-0.46**	-0.28**	-0.10	1.99	1.96
SE(S_{ij})	2.43	5.51	0.82	0.89	9.20	0.12	0.03	0.04	0.04	0.07	0.57	1.67	2.92

*, ** significant at 0.05 and 0.01 levels of probability, respectively.

NVSR-452 x Dandi and NVSR-452 x NVSR-6157 were considered to be the three best specific cross combinations for higher straw yield per plant.

Conclusion

The knowledge of combining ability helps the breeder in selecting the right materials for hybridization and specific crosses for further exploitation. Based on *gca* effects, the parents, NVSR-453 and NAUR-1 were found to be good general combiners for the trait, grain yield per plant and other component traits, like, panicle length, grains per panicle, kernel width, amylose content and straw yield per plant. Hence, hybridization and selection breeding methods can be adopted to these genotypes to develop new variety. Biparental cross technique suggested by Joshi and Dhawan (1966) [9] may also be utilized for accumulation of additive gene effects and breaking undesirable linkage. Based on *sca* effects, the most promising hybrids for grain yield per plant, NVSR-452 x NVSR-486 and NVSR-453 x NVSR-475, are found to be performing well in other characters like grains per panicle, panicle length, productive tillers per plant and straw yield per plant. This suggested that imposing high selection intensity, sib-pollination technique originally suggested by Palmer (1953) [16] and subsequently modified by Andrus (1963) [2] would be effectively used.

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