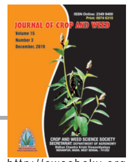
ISSN- O : 2349 9400 ; P : 0974 6315

Journal of Crop and Weed, 19(1): 58-65 (2023)



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Combining ability analysis for grain quality traits in hybrid rice (*Oryza sativa*. L)

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Received : 15.09.2022 ; Revised : 05.01.2023 ; Accepted : 15.01.2023

DOI: https://doi.org/10.22271/09746315.2023.v19.i1.1660

ABSTRACT

The two main goals of the majority of crop breeding programs are the identification of the lines that are good performers for commercial distribution and lines that can serve as parents in subsequent crossings.Keeping this in view the idea of combining ability arose. This aids in choosing the parents that have ability to transfer their genes to their progeny particularly through general combining ability and selection of superior crosses through specific combining ability.In the current experiment, the mating design used was line x tester in which four lines were crossed with eight testers and through which 32 hybrids were obtained. Parents and their hybrids along with checks are used for testing 11 quality traits for their combining ability effects. Within male sterile lines, JMS 19B showed significant desirable gca effects for six quality characters viz., hulling, milling, HRR, kernel breadth, gel consistency and alkali spreading value. Within restorers, JGL 34985 showed significant required gca effects for seven grain quality traits viz., hulling, HRR, kernel length and breadth, kernel length after cooking, gelatinization temperature and amylose content and hence they were adjudged as the best combiners for the improvement of the respective traits. Among the hybrids, CMS 64A X JGL 34984 for kernel length and breadth, JMS 13A X JGL 32467 for hulling, milling and head rice recovery and JMS 19A X JGL 34985 for gel consistency and alkali spreading value were recognized to be top hybrids which can be used in further generations.

Keywords: General combining ability, hybrid, specific combining ability, quality, traits.

The quality of rice is considered to be an important parameter all over the world because of its importance in consumption and production at the commercial level.Hence the grain appearance, its cooking quality and nutritional values play a crucial role to attract the consumers. The price for whole milled grains is determined by the quality of the grain, which is highly influenced by its size, shape, and chalkiness (Shobha *et al*., 2008). The reduction of postharvest losses during processing can be controlled by suitable analysis and knowing of physical and chemical properties (Deepak and Prasanta, 2017). Physical and chemical properties are the most used indicators for evaluating and enhancing rice quality. Some of the physical characteristics of rice include: hulling and milling, HRR, length, width, uniformity and weight of kernel, colour (whiteness and translucence). Chemical traits are as important as physical traits in determining the quality of rice. Chemical characters include: amylose content, gelatinization temperature, viscosity, texture and alkali spreading value (Amrit *et al*., 2020).

Selection of parents and crosses plays a crucial role in improving the breeding programme for the characters like grain yield and quality which are having major economic importance. For proper selection of desirable parents and crosses combining ability analysis is considered to be the most prominent tool which is used to determine combining ability effects. The nature and extent of gene effects which are regulating different traits can be known through combining ability effects. Kempthorne (1957) has given L× T analysis of combining ability which is most frequentlyused methodology to know the best parental combinations and their specific cross combinations and it depends on *gca* and *sca* effects, respectively.A combination of the kernel's physicochemical characteristics determine the quality of the rice. In light of the preceding situation, the current study was conducted to evaluate the potential of parents and hybrids through combining ability studies for features related to grain quality in hybrid rice.

MATERIAL AND METHODS

The experiment was conducted at Regional Agricultural Research Station (RARS), Polasa, Jagtial of Telangana state during *kharif*, 2019. Four Cytoplasmic male sterile(CMS) lines i.e., CMS 64A, JMS 19A, JMS 13A, CMS 14A and eight restorers *i.e.,* JGL 34984, JGL 34986, JGL 34551, JGL 34452, JGL 34985, JGL 32467, NSR 42 and NSR 61 were used to generate 32 hybrids through L x T mating design. Lines, testers and their 32 hybrids along with checks (PA 6444 and US 312) were planted at 20 x 15 cm spacing in two

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How to cite : Vennela. M., Srinivas, B., Ram Reddy, V. and Balram, N. 2023. Combining ability analysis for grain quality traits in hybrid rice (*Oryza sativa*. L). *J. Crop and Weed*, 19 (1): 58-65.

replications and grown in Randomized Block Design. Observations were recorded on 11 quality traits *viz.,* hulling, milling, head rice recovery, kernel length (mm), kernel breadth (mm), length/breadth ratio, kernel length after cooking, gel consistency (mm), amylose content (%), alkali spreading value and gelatinization temperature (Úc). Statistical analysis was conducted for the data collected using Line × Tester analysis by Kempthorne (1957).

Hulling percentage (%) : In a standard dehusker, a minimum of 100 g of paddy is weighed and subjected to the dehusking process.Its percentage is determined by the formula:

$$\text{Hulling percentage} = \frac{\text{Weight of the dehusked kernel (g)}}{\text{Weight of paddy (g)}} \text{x } 100$$

Milling percentage (%) : Dehusked kernels are then placed in a conventional polisher, the total weight of polished kernels is determined, and the milling % is computed using the formula below:

$$\text{Milling percentage (\%)} = \frac{\text{Weight of polished kernel (g)}}{\text{Weight of paddy (g)}} \times 100$$

Head rice recovery percentage (%) : It is the percentage of full rice kernel obtained from a sample of paddy after milling and polishing.

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of whole polished grains (g)}}{\text{Weight of paddy (g)}} \times 100$$

Kernel length (mm): Vernier callipers were used to measure the kernel length of ten milled rice grains that were randomly chosen from each replication**.**

Kernel breadth (mm): Vernier callipers were used to measure the kernel breadth of ten milled rice kernels that were randomly chosen from each replication.

L/B ratio: Average of length and breadth of ten milled rice were recorded in millimeters and length / breadth ratio was calculated.

$$\text{L / B ratio} = \frac{\text{Mean length of grain (mm)}}{\text{Mean breadth of grain in (mm)}} \times 100$$

Kernel length after cooking : The length of cooked milled grains was estimated using graph paper.

Amylose content (%) : The milled grains were grinded to fine powder and sieved and this powder was added to 100 ml volumetric flasks and to it 1 ml of absolute ethanol and 9 ml 1N sodium hydroxide solution was added. From it 0.5 ml of solution was taken in a test tube to which 5 ml of distilled water was added which was acidified with 0.1 ml of 1N acetic acid. 0.2 ml of iodine solution was added to it and the final volume was made 10 ml using water. Then optical density was measured at 620 nm. Amylose content was measured according to scale provided by Juliano, (1992).

Gelatinization temperature (Úc): Gelatinization temperature (GT) was estimated based on alkali spreading score (ASV) of milled rice. The method developed by Little *et al.* (1958) was used to score alkali-spreading value.

Gel consistency (mm): The gel consistency test distinguishes between varieties with high amylose contents and is based on the consistency of rice paste. A quick, straightforward test based on the consistency of a cool, 4.4% milled rice paste in 0.2 N KOH was conducted by Cagampang *et al*., (1973).

Estimation of combining ability effects:

The additive model used to estimate the *gca* and *sca* effects of the ijk observations were

Xij = μ + gi + gj + sij + eijk

Where,

μ = population mean

gi = *gca*effect of ith male parent

gj = *gca*effect of jth female parent

sij = *sca*effect of ijth combination

eijk = error associated with the observation Xijk

i = number of male parents; j = number of female parents; k = number of replications

The estimation of individual effects was as follows:

$$\mu = \frac{X...}{mfr}$$

Where, X...= Total of all hybrid combinations over all replications

(i) Lines : $gi = \frac{Xi...}{fr} - \frac{X...}{mfr}$

where, Xi = Total of ith male parent over all females and replications

(ii) Testers : $gj = \frac{X.j.}{mr} - \frac{X...}{mfr}$

where, X.j.= Total of jth female parent over all male parents and replications.

(iii) Crosses : $Sij = \frac{Xij}{r} - \frac{Xij}{Fr} - \frac{X.j.}{mr} - \frac{X...}{mfr}$

Where, Xij.=ijth comination total over all replications

RESULTS AND DISCUSSION

ANOVA of combining ability for 11 grain quality traits are given in Table 1.All the traits studied have shown highly significant variance to treatments, parents and crosses. Parent *vs.* crosses variance is significant for five traits excluding hulling, head rice recovery and all chemical quality traits indicating presence of heterosis for these characters. Lines and testers variance was found significant for all of the characters. The interaction effects had significant performance for all

Table 1: Analysis of Variance of Line × Tester mating design for grain quality traits

Source of variation	Degrees of freedom	Hulling	Milling	HRR	Kernel length	Kernel breadth	L/B ratio	Kernel length after cooking	Gel consistency	Amylose content	Alkali spreading value	Gelatinization temperature
Replicates	1	1.69	15.72	28.77*	0.0002	0.003	0.019	0.16	8.90	0.025	0.045	0.55
Treatments	43	87.96**	56.44**	160.74**	0.35**	0.097**	0.14**	0.98**	906.20**	25.03*	1.64**	109.88**
Parents	11	111.03**	72.98**	252.38**	0.38**	0.18**	0.23**	0.59**	979.34**	25.84**	1.98**	111.13**
Parents (Line)	3	133.48**	147.11**	269.40**	0.51**	0.025*	0.11**	0.76*	404.79**	21.88**	1.83**	165.45**
Parents (Testers)	7	73.92**	38.02**	207.51**	0.28**	0.28**	0.29**	0.60**	1150.13**	29.50**	2.14**	102.96**
Parents (L vs T)	1	303.51**	95.37**	515.35**	0.67**	0.003	0.13*	0.11	1507.52**	12.10**	1.33**	5.33**
Parents vs Crosses	1	3.97	55.25*	1.27	1.58**	0.45**	0.11*	3.97**	2.18	0.08	0.030	0.91
Crosses	31	82.48**	50.61**	133.36**	0.30**	0.053**	0.11**	1.02**	909.41**	25.54**	1.58**	112.95**
Line Effect	3	77.52	53.61	74.48	0.49	0.028	0.17	2.73	4132.37**	109.34**	6.20**	294.87*
Tester Effect	7	48.66	17.79	215.77	0.30	0.16**	0.22*	1.23*	1004.17	35.95*	2.21*	184.89*
Line * Tester Eff.	21	94.46**	61.13**	114.30**	0.27**	0.02*	0.06**	0.70**	417.39**	10.10**	0.70**	62.99**
Error	43	4.78	6.13	4.32	0.04	0.006	0.015	0.12	2.56	0.036	0.045	0.30
Total	87	45.86	31.11	81.91	0.19	0.05	0.076	0.55	449.26	12.39	0.83	54.46

*Significant at 5 per cent level, ** Significant at 1 percent level

Table 2: Estimates of general combining ability (*gca*) effects for lines and testers for physical and chemical quality characters in rice

Source of variation	Hulling	Milling	HRR	Kernel length	Kernel breadth	L/B ratio	Kernel length after cooking	Gel consistency	Amylose content	Alkali spreading value	Gelatinization temperature
Parents											
Lines											
CMS 64A	-0.81	0.52	-0.96	-0.11 *	0.028	-0.08 *	-0.36 **	13.81 **	-2.14 **	0.62 **	-1.12 **
JMS 19A	2.76 **	1.95 *	3.17 **	0.03	0.044 *	-0.03	-0.14	12.12 **	-1.68 **	0.31 **	-4.06 **
JMS 13A	-2.44 **	-2.43 **	-0.58	-0.15 *	-0.03	-0.03	-0.07	-20.06 **	3.60 **	-0.81**	6.06 **
CMS 14A	0.48	-0.04	-1.61 *	0.23 **	-0.03	0.15 **	0.59 **	-5.87 **	0.22 **	-0.12 *	-0.87 **
Testers											
JGL 34984	-2.60 *	-2.61 *	-1.34	0.10	-0.015	0.05	-0.08	-0.81	-0.08	-0.12	-4.18 **
JGL 34986	-1.19	0.35	4.06 **	-0.16 *	-0.08 *	-0.006	-0.50 **	17.06 **	-2.59 **	0.50 **	-5.06 **
JGL 34551	1.79 *	1.96 *	3.14 **	0.01	-0.14 **	0.18 **	-0.16	6.31 **	-1.04 **	0.25 *	-3.56 **
JGL 34452	-4.25 **	-1.59	5.04 **	0.25 **	-0.04	0.19 ***	0.59 ***	2.43 ***	-1.10 ***	0.50 **	-0.93 **
JGL 34985	1.78 *	0.34	4.12 **	0.16 *	0.08 *	-0.02	0.50 **	-6.43 **	1.38 **	0.12	3.43 **
JGL 32467	0.28	-0.21	-0.33	-0.27 **	-0.17 **	0.08	-0.40 *	-21.31 **	4.38 **	-1.12**	7.81 **
NSR 42	1.40	1.39	-9.57**	-0.21 *	0.16 **	-0.27 **	-0.05	-3.18 **	0.18 *	-0.25*	5.06 **
NSR 61	2.79 *	0.35	-5.12**	0.12	0.22 **	-0.20 **	0.12	5.93 **	-1.13 **	0.12	-2.56 **
CD 95% GCA (line)	1.11	1.26	1.06	0.10	0.04	0.06	0.18	0.81	0.09	0.11	0.28
CD 95% GCA (tester)	1.57	1.78	1.49	0.14	0.06	0.088	0.25	1.15	0.13	0.15	0.39

*Significant at 5 per cent level, **Significant at 1 per cent level

Table 3: Estimates of specific combining ability (*sca*) effects for physical and chemical quality traits in rice

S.No	Crosses	Hulling	Milling	HRR	Kernel length	Kernel breadth	L/B ratio	Kernel length after cooking	Gel consistency	Amylose content	Alkali spreading value	Gelatinization Temperature
1	CMS 64A X JGL 34984	5.60*	3.01	-4.09 *	0.81 **	0.19 *	0.14	0.53 *	-7.93 **	0.17	-0.12	-1.00 *
2	CMS 64A X JGL 34986	-5.56 *	0.10	5.34 **	-0.10	-0.02	-0.02	0.16	-5.81 **	1.48 **	0.25	9.87 **
3	CMS 64A X JGL 34551	-2.30	-1.29	3.22 *	-0.18	-0.18 *	0.12	0.05	-1.06	0.08	-0.50 *	-4.62 **
4	CMS 64A X JGL 34452	7.25 **	4.39 *	2.39	0.37 *	-0.008	0.24 *	-0.27	9.81 **	-0.35 *	0.25	5.75 **
5	CMS 64A X JGL 34985	-5.88 **	-4.36 *	2.29	-0.41 *	0.13 *	-0.33 **	-0.31	-2.31 *	-0.78 **	0.62 **	2.37 **
6	CMS 64A X JGL 32467	0.46	1.46	6.36 **	0.19	0.03	0.02	-0.13	0.06	0.06	-0.12	-0.50
7	CMS 64A X NSR 42	0.83	-1.00	-4.85 *	-0.25	-0.06	-0.07	-0.05	2.93 *	-0.48 *	0	-9.25 **
8	CMS 64A X NSR 61	-0.40	-2.30	-10.68 **	-0.42 *	-0.08	-0.10	0.02	4.31 **	-0.17	-0.37 *	-2.62 **
9	JMS 19A X JGL 34984	-0.08	3.07	3.80 *	-0.20	-0.07	-0.01	0.04	14.25 **	-2.09 **	0.18	-0.06
10	JMS 19A X JGL 34986	2.95	0.32	-2.54	0.53 **	0.008	0.25 *	0.79 *	-2.12	0.66 **	-0.93 **	-0.18
11	JMS 19A X JGL 34551	-2.93	-0.27	0.45	0.02	0.17 *	-0.21 *	0.33	-1.37	0.06	-0.18	3.31 **
12	JMS 19A X JGL 34452	5.11 *	3.78 *	9.69 **	-0.25	-0.04	-0.08	-0.14	11.50 **	-1.32 **	0.56 **	-3.81 **
13	JMS 19A X JGL 34985	-2.36	-1.29	-3.01 *	-0.09	-0.007	-0.04	-0.21	20.87 **	-3.45 **	0.93 **	-6.68 **
14	JMS 19A X JGL 32467	-1.46	-3.69 *	-8.33 **	-0.03	-0.12 *	0.13	-0.85 *	-1.75	0.64 **	0.18	2.93 **
15	JMS 19A X NSR 42	-0.59	-2.13	-3.81 *	-0.25	0.06	-0.17	-0.63 *	-30.87 **	4.29 **	-0.68 **	6.18 **
16	JMS 19A X NSR 61	-0.63	0.22	3.73 *	0.28	0.003	0.13	0.69 *	-10.50 **	1.20 **	-0.06	-1.68 **
17	JMS 13A X JGL 34984	2.68	3.39	1.11	-0.21	-0.07	-0.002	-0.57 *	-15.56 ***	3.71 ***	-0.68 ***	4.81 ***
18	JMS 13A X JGL 34986	1.81	-0.79	0.87	-0.17	0.04	-0.15	-0.15	17.56 **	-3.22 **	0.68 **	-9.31 **
19	JMS 13A X JGL 34551	2.38	2.37	1.73	0.09	-0.02	0.08	-0.18	-1.68	1.08 **	0.43 *	4.18 **
20	JMS 13A X JGL 34452	-21.21 **	-16.71 **	-18.38 **	-0.27	-0.07	-0.07	-0.55 *	-1.81	-0.30 *	-0.31 *	1.56 **
21	JMS 13A X JGL 34985	2.79	2.69	2.56	0.02	-0.03	0.04	0.14	-8.93 **	2.25 **	-0.93 **	-0.81 *
22	JMS 13A X JGL 32467	7.69 **	6.20 *	9.82 **	0.08	0.06	-0.03	0.55 *	11.43 **	-2.49 **	0.31 *	-4.18 **
23	JMS 13A X NSR 42	3.11	2.43	-1.82	0.50 *	0.06	0.18 *	1.03 **	8.31 **	-1.59 **	0.43 **	-2.43 **
24	JMS 13A X NSR 61	0.73	0.41	4.10 *	-0.05	0.03	-0.04	-0.27	-9.31 **	0.56 **	0.06	6.18 **
25	CMS 14A X JGL 34984	-8.20 **	-9.48 **	-0.83	-0.39 *	-0.04	-0.13	0.006	9.25 **	-1.79 **	0.62 **	-3.75 **
26	CMS 14A X JGL 34986	0.78	0.36	-3.67 *	-0.25	-0.02	-0.08	-0.81 *	-9.62 **	1.06 **	0	-0.37
27	CMS 14A X JGL 34551	2.85	-0.80	-5.41 **	0.06	0.02	0.002	-0.20	4.12 **	-1.23 **	0.25	-2.87 **
28	CMS 14A X JGL 34452	8.85 **	8.53 **	6.29 **	0.15	0.12 *	-0.08	0.97 **	-19.50 **	1.98 **	-0.50 **	-3.50 **
29	CMS 14A X JGL 34985	5.46 *	2.97	-1.84	0.48 *	-0.09	0.34 **	0.38	-9.62 **	1.99 **	-0.62 **	5.12 **
30	CMS 14A X JGL 32467	-6.68 **	-3.96 *	-7.86 **	-0.24	0.02	-0.12	0.43	-9.75 **	1.79 **	-0.37 *	1.75 **
31	CMS 14A X NSR 42	-3.36 *	0.70	10.49 **	0.01	-0.05	0.06	-0.34	19.62 *	-2.20 **	0.25	5.50 **
32	CMS 14A X NSR 61	0.30	1.66	2.83	0.18	0.04	0.01	-0.44	15.50 **	-1.59 **	0.37 *	-1.87 **
	CD 95 % SCA	3.15	3.57	2.99	0.29	0.12	0.17	0.51	2.30	0.27	0.30	0.79

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

the characters that were studied. The material studied was found to have adequate variability. Comparable works were described by Thorat *et al*. (2017) and Vanave *et al.* (2018) for lines and Sharma *et al*. (2013) for testers, Devi and Lal (2015) for crosses and line x tester effects, Upadhyay and Jaiswal (2015) for treatments, parents and L x T effects and Kolom *et al*. (2014) for treatments, Bano and Singh (2019) for parents *vs* crosses. The estimates of *gca* and *sca* effects of the parents and crosses are mentioned in Table 2 and 3, respectively.

Hulling percentage: For this trait, significant and positive *gca* effects were ranged from -2.44 (JMS 13B) to 2.76 (JMS 19B) in lines and from -4.25 (JGL 34452) to 2.79 (NSR 61) in testers. Among lines JMS13B (2.76) and among testers NSR 61 (2.79), JGL 34551 (1.79) and JGL 34985 (1.78) were found to be good general combiners for this trait.

Out of 32 crosses, twelve crosses recorded significant *sca* effects for this trait with a range from -21.21 (JMS 13A X JGL 34452) to 8.85 (CMS 14A X JGL 34452). The cross CMS 14A X JGL 34452 (8.85) showed highest positive significant *sca* effect followed by JMS 13A X JGL 32467 (7.69) and CMS 64A X JGL 34452 (7.25) for this trait and are said to be best specific combiners.

Similar findings were earlier reported by Ashok (2014), Sreenivas *et al*. (2014), Santha *et al.* (2017) and Singh *et al.* (2020).

Milling percentage: Among the lines milling percentage ranged from 1.95 (JMS 19B) to -2.43 (JMS 13B) and for testers from 1.96 (JGL 34551) to -2.61 (JGL 34984).

Among 32 hybrids *sca* effects ranged from -16.71 (JMS 13A X JGL 34452) to 8.53 (CMS 14A X JGL 34452). Four crosses *viz.,* CMS 14A X JGL 34452 (8.53), JMS13A X JGL 32467 (6.20) and CMS 64A X JGL 34452 (4.39) and JMS 19A X JGL 34452 (3.78) recorded positive and significant values and identified as good specific combiners for this trait.

Similar results were reported by Akanksha and Jaiswal (2019) and Singh *et al.* (2020).

Head rice recovery percentage: The range of *gca* effects for this trait varied from -1.61 (CMS 14B) to 3.17 (JMS 19B) among lines, while it varied from -9.57 (NSR 42) to 5.04 (JGL 34452) among testers. The line JMS 19B (3.17) and testers JGL 34452 (5.04), JGL 34985 (4.12) and JGL 34986 (4.06) recorded highly positive and significant *gca* effects and they were considered as good general combiners for this trait.

Among 32 hybrids 20 had recorded significant *sca* effects in which 10 had positive significant *sca* effect and 10 had negative significant *sca* effect. The range of *sca* effects for this trait varied from -18.38 (JMS 13A X JGL 34452) to 10.49 (CMS 14A X NSR 42). The best specific combiners for this trait were CMS 14A X NSR 42 (10.49), JMS 13A X JGL 32467 (9.82) and JMS 19A X JGL 34452 (9.69).

The results are in accordance with the earlier findings of Santha *et al*. (2017), Devi *et al.* (2018), Akanksha and Jaiswal (2019) and Singh *et al.* (2020).

Kernel length: The range of *gca* effects ranged from -0.15 (JMS 13B) to 0.23 (CMS 14B) in lines and from 0.25 (JGL 34452) to -0.27 (JGL 32467) in testers. The line CMS 14B (0.23) and testers JGL 34452 (0.25) and JGL 34985 (0.16) were found to be good general combiners for this trait.

Five hybrids expressed significant positive *sca* effects. The cross, CMS 64A X JGL 34984 (0.81) recorded highest positive *sca* effect followed by JMS 19A X JGL 34986 (0.53) and JMS 13A X NSR 42 (0.50) which were said to be best specific combiners for this trait.

The results are in conformity with the findings of Allahgholipour and Ali (2014), Devi *et al.* (2018), Pon *et al.* (2019) and Singh *et al.* (2020).

Kernel breadth: Among lines JMS 19B (0.044) only recorded positive and significant value for *gca* effects and among testers, the range varied from -0.17 (JGL 32467) to 0.22 (NSR 61) for this trait. JMS 19B (0.044), NSR 42 (0.16) and NSR 61 (0.22) were found to be good general combiners for kernel breadth.

Four hybrids expressed significant and positive *sca* effects for kernel breadth. The cross, CMS 64A X JGL 34984 (0.19) recorded highest positive *sca* effect followed by JMS 19A X JGL 34551 (0.17) and CMS 64A X JGL 34985 (0.13) and said to be best specific combiners for the trait.

Priyanka *et al*. (2014), Santha*et al.* (2017), Devi *et al.* (2018) and Pon *et al.* (2019) reported similar findings for kernel breadth.

L/B ratio: The values for *gca* effects varied from -0.08 (CMS 64B) to 0.15 (CMS 14B) among lines and from -0.27 (NSR 42) to 0.19 (JGL 34452) among testers. High positive significant *gca* effects were recorded for CMS 14B (0.15) among lines and JGL 34452 (0.19) and JGL 34551 (0.18) among testers.

A range of -0.33 (CMS 64A X JGL 34985) to 0.34 (CMS 14A X JGL 34985) *sca* effects were recorded for this trait. Four crosses exhibited positive and significant *sca* effects and CMS 14A X JGL 34985 (0.34) identified as best specific combiner.

The results are in accordance with the findings of Priyanka *et al*. (2014), Santha *et al.* (2017), Devi *et al.* (2018), Saravanan *et al*. (2018), Kirubha *et al.* (2019), Pon *et al.* (2019) and Singh *et al.* (2020).

Kernel length after cooking: The values for *gca* effect were ranged from -0.36 (CMS 64B) and 0.59 (CMS 14B) in lines and from -0.50 (JGL 34986) and 0.59 (JGL 34452) in the testers. CMS 14B (0.59), JGL

34452 (0.59) and JGL 34985 (0.50) are considered to be good combiners within the parents.

Among 32 hybrids eleven were recorded significant *sca* effects. The range was from -0.85 (JMS 19A X JGL 32467) to 1.03 (JMS 13A X NSR 42). The best specific combiner identified was JMS 13A X NSR 42 (1.03) followed by CMS 14A X JGL 34452 (0.97) and JMS 19A X JGL 34986 (0.79).

Similar findings were observed with the results of Rajeswari *et al*. (2010), Upadhyay and Jaiswal (2015) and Devi *et al*. (2018).

Gel consistency: The range of *gca* effects for this trait varied from -20.06 (JMS 13B) to 13.81 (CMS 64B) among lines and from -21.31 (JGL 32467) to 17.06 (JGL 34986) among testers. The lines CMS 64B (13.81) and JMS19B (12.12) and testers JGL 34986 (17.06), JGL 34551 (6.31) and NSR 61 (5.93) recorded highly positive and significant *gca* effects and they were considered as good general combiners for this trait.

Among 32 hybrids 25 had recorded significant *sca* effects in which 13 had positive and 12 had negative. The range of *sca* effects for this trait varied from -30.87 (JMS 19A X NSR 42) to 20.87 (JMS 19A X JGL 34985). The best specific combiners for this trait were JMS 19A X JGL 34985 (20.87), CMS 14A X NSR 42 (19.62) and JMS 13A X JGL 34986 (17.56).

The results are in accordance with the earlier findings of Kaur *et al*. (2011) and Kirubha *et al.* (2019).

Amylose content: This trait recorded *gca* effects in a range from -2.14 (CMS 64B) to 3.60 (JMS 13B) among lines and from -2.59 (JGL 34986) to 4.38 (JGL 32467) among testers. JMS 13B (3.60) among lines and JGL 32467 (4.38), JGL 34985 (1.38) and NSR 42 (0.18) among testers exhibited significant *gca* effects in positive direction and were considered as good general combiners for amylose content.

Among 32 hybrids 27 had recorded significant *sca* effects and 13 hybrids of them expressed positive values for this trait. The best specific combiners identified for this trait were JMS 19A X NSR 42 (4.29), JMS 13A X JGL 34984 (3.71) and JMS 13A X JGL 34985 (2.25).

The results are in conformity with the findings of Kaur *et al*. (2011), Santha *et al.* (2017), Kirubha *et al.* (2019) and Singh *et al.* (2020).

Alkali spreading value: The range of *gca* effects for this trait varied from -0.81 (JMS 13B) to 0.62 (CMS 64B) among lines and from -1.12 (JGL 32467) to 0.50 (JGL 34986 and JGL 34452) among testers. The lines CMS 64B (0.62) and JMS 19B (0.31) and testers JGL 34986 (0.50), JGL 34452(0.50) and JGL 34551 (0.25) recorded highly positive and significant *gca* effects and they were considered as good general combiners for this trait.

Among 32 hybrids 19 had recorded significant *sca* effects in which 9 had positive and 10 had negative values. The range of *sca* effects for this trait varied from -0.93 (JMS 19A X JGL 34986) to 0.93 (JMS 19A X JGL 34985). The best specific combiners identified were JMS 19A X JGL 34985 (0.93), JMS 13A X JGL 34986 (0.68), CMS 64 A X JGL 34985 (0.62) and CMS 14A X JGL 34984 (0.62).

Similar findings were observed with the results of Rajeswari *et al*. (2010), Upadhyay and Jaiswal (2015), Devi *et al*. (2018) and Sreelakshmi *et al.* (2019).

Gelatinization temperature: *Gca* effects for this trait ranged from -4.06 (JMS 19B) to 6.06 (JMS 13B) among lines and from -5.06 (JGL 34986) to 7.81 (JGL 32467) among testers. JMS 13B (6.06) among lines and JGL 32467 (7.81), NSR 42 (5.06) and JGL 34985 (3.43) among testers exhibited significant *gca* effects in positive direction and considered as good general combiners for gelatinization temperature.

Among 32 hybrids 28 have shown significant *sca* effects and of them 13 recorded positive values for this trait. The best specific combiners identified for this trait were CMS 64A X JGL 34986 (9.87), JMS 19A X NSR 42 (6.18) and JMS 13A X NSR 61 (6.18).

The findings were similarly reported by Santha *et al.* (2017),Kirubha *et al.* (2019) and Singh *et al.* (2019).

Amongst the lines, JMS 19A presented significant desirable *gca* effects for six quality characters*viz.,* hulling, milling, HRR, kernel breadth, gel consistency and alkali spreading value and within the testers, JGL 34985 showed significant desirable *gca* effects for seven characters*viz*., hulling, HRR, kernel length and breadth, kernel length after cooking, gelatinization temperature and amylose content hence, they were obtained as best parental general combiners which can be used for improving the particular characters. Among the hybrids, CMS 64A X JGL 34452, CMS 14A X JGL 34985 and JMS 19A X JGL 34985 were recognized to have good quality traits and can be considered as best hybrids subsequently they exposed significant *sca* effects for five, five and four grain quality characters, individually.

CONCLUSION

The existing investigation revealed that the parents CMS 14A, JMS 19A among lines and NSR 61, JGL 34986 and JGL 34985 among testers are considered to be good general combiners for quality characters and based on *sca* effects crosses like CMS 64A X JGL 34452, CMS 14A X JGL 34985 and JMS 19A X JGL 34985 were found to be prominent for physical and chemical quality parameters. In breeding program, the abovementioned parents and crosses can be used in future for exploitation of heterosis.

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