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Assessment of Combining Ability for Yield and Yield Contributing Traits in Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The current study was carried out with an objective to study Combining ability studies for yield and yield contributing traits in Rice (*Oryza sativa* L.) to identify superior crosses for commercial cultivation after testing over years band locations. Rice production plays an integral role in the national economy of India and has the maximum share in grain production, accounting for 22% of the world's rice production. Agricultural Polytechnic, Polasa, Jagtial, during *Kharif*, 2021 and *Rabi*, 2021-22. Where, crossing programme was carried out during *Kharif*, 2021 and evaluation of the crosses was taken up during *Rabi*, 2021-22. Twenty-four (24) experimental hybrids were developed using eight lines and three testers and randomized block design was utilized for the evaluation studies. The variance due to the crosses, variance due to the parent's *vs* crosses were also found highly significant for all the characters. Lines, testers and line x tester effects, the interaction effects (lines x testers) were found to be significant for all the traits studied. This indicates that the material

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under investigation has adequate variability. The study revealed that the line, CMS 46B and KNM 7787 among the testers were identified as good general combiners for grain yield per plant while, JMS 18A x RNR 21278 were identified as best specific combiners for the trait.

Keywords: Paddy- line x tester mating design-general combining ability; specific combining ability.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major cereal crops in the world and is the principal staple food for half of the world's population. Rice has shaped the culture, diets and economy of millions of people around the globe. For more than half of the mankind "Rice is Life". India is an important centre for rice cultivation and it ranks first in the area and second in production next to China (FAO, 2019). Rice production plays an integral role in the national economy of India and has the maximum share in grain production, accounting for 22% of the world's rice production (Bandumula, 2018).

Globally, about 167.20 million hectares of rice are planted, yielding 769.60 million tons with 4600 kg of productivity per hectare (FAO, 2019). In India, rice has occupied 45.07 million hectares of land, yielding 122.27 million tons and producing 2713 kilograms per hectare. On a 2.31 Mha area, Telangana's production and productivity levels were 7.70 Mt and 3327 kg ha^{-1}, respectively (Directorate of Economics and Statistics, 2021). Identification of good general and specific combiners is a continuous and very important process to exploit better heterosis for the development of high yielding hybrids to meet the global food demand.

2. MATERIALS AND METHODS

Agricultural Polytechnic College, Polasa, Jagtial is located at an altitude of 243.4 m above mean sea level on 18º49'40" N latitude and 78º56'45" E longitudes in the Northern Zone of Telangana State. The fields are uniformly fertile with even topography and a consistent texture. In addition, the fields are adjacent to a major irrigation channel which provides quick, uniform and timely irrigation. The soil type is loamy clay in the experimental plot. Proper drainage facility is provided to remove excess water in the fields.

The experimental inbred lines utilized for the present study consists of eight lines *viz.,* CMS 23A, CMS 46A, CMS 59A, JMS 11A, JMS 13A, JMS 17A, JMS 18A and CMS 64A, three testers *viz*., JGL 33124, KNM 7787 and RNR 21278.Crossing programme was affected in line x tester mating design during *Kharif*, 2021. All the parents were sown in three staggerings at 10 days interval to achieve synchronous flowering so as to obtain sufficient quantity of crossed seed.

The resultant 24 experimental hybrids were evaluated during *Rabi*, 2021-22 in Randomized Block Design along with the parents to delineate the general combining ability (*gca*) and specific combining ability effects (*sca*) for yield and yield attributing characters. Recommended crop management strategies were followed and maintained a healthy crop during the entire period of field evaluation.

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The results of analysis of variance for the traits under investigation are presented in Table 1. The analysis revealed that the variance due to treatments and parents was highly significant for all characters examined. The variance due to crosses and parents versus crosses were highly significant for all characters. Furthermore, the variance attributed to lines was significant for all traits analysed, while the variance due to testers was significant for all characters except for single plant yield, which was not significant.

When the effects of parents were divided into lines, testers, and line x tester interactions, the interaction effects (lines x testers) were found to be significant for all traits studied. This indicates that the material under investigation exhibits adequate variability. These findings align with those of El-Shamey et al. (2022) and Nagamani et al. (2022).

3.2 General Combining Ability Effects and Specific Combining Ability Effects

The general combining ability (GCA) effects of eleven parents comprising eight lines and three testers along with the specific combining ability

Table 1. Analysis of variance for combining ability (Line x Tester) for yield and yield attributing traits in the rice genotypes

Source of variation	df	Days to 50% flowering	Plant height(cm)	Panicle length (cm)	No. of productivetillers per plant	No. of filled grains per panicle	No. of unfilled grains per panicle	Spikelet fertility (%)	1000 grain-weight (g)	Grain yieldper plant (g)
Replicates	2	0.085	2.23	0.03	0.02	34.26	35.94	2.42	0.61	0.04
Treatments	34	81.16**	57.54**	8.74**	4.88**	13501.09**	6565.75**	1587.01**	44.25**	240.48**
Parents	10	70.26**	65.69**	12.47**	2.35**	12327.54**	726.61**	67.05**	61.97**	57.91**
Parents (Lines)	7	21.47**	21.84**	7.98**	1.33**	4888.63**	508.58**	65.49**	65.49**	46.13**
Parents (Tester)	2	193.00**	252.03**	26.23**	1.00**	3076.35**	1344.83**	61.06**	1.57*	0.24
Parents (L *vs* T)	1	166.37**	0.01	16.41**	12.23**	82902.28**	1016.26**	89.99**	158.06**	255.64**
Parents *vs* Crosses	1	103.52**	116.34**	1.63**	1.68**	102877.04**	65837.77**	16960.22**	36.53**	1653.62**
Crosses	23	84.93 **	51.44 **	7.42 **	6.13 **	10125.42**	6527.46**	1579.44 **	36.88 **	258.42 **
Line Effect	7	81.58	96.94	4.32	9.87	7922.46	5863.73	1347.66	54.25	310.05
Tester Effect	2	207.18	3.30	10.28	2.63	8624.34	6373.57	1627.12	52.02	356.58
Line x Tester Eff.	14	69.13**	35.57**	8.56**	4.75**	11441.33**	6881.32**	1688.52**	26.04**	218.56**
Error	68	0.37	1.02	0.07	0.15	18.75	38.94	4.19	0.33	0.15
Total	104	26.77	19.52	2.91	1.69	4426.74	2172.64	521.6	14.69	78.71

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

Table 2. Estimates of general combining ability (GCA) effects for lines and testers of the study for yield and yield attributing traits

Source	Days to 50% flowering	Plant height (cm)	Panicle length(cm)	No. of productive tillers per plant	No. of filled grains per panicle	No. of unfilled grains per panicle	Spikelet fertility (%)	1000 grain-weight(g)	Grain yield per plant (g)
Parents									
Lines									
CMS 23 B	4.47 **	3.13**	-0.48**	1.87**	32.54**	-14.46 **	11.72**	3.27**	7.34**
CMS 46 B	3.81 **	5.53**	0.22 *	1.35**	30.94**	-38.91 **	15.25**	4.24**	9.98**
CMS 59 B	-4.53 **	-3.97**	-1.05**	-0.45**	-23.79**	10.86**	-5.25**	-2.26**	-5.23**
JMS 11 B	0.81**	0.16	1.18**	-0.38 **	30.07**	-2.76	7.74**	-0.51 *	1.27**
JMS 13 B	-0.86**	0.03	-0.12	-0.18	-7.59**	-0.92	-3.79**	-1.41**	-2.55**
JMS 17 B	-2.53**	-4.31**	-0.25 *	-0.62**	-13.33**	-6.39**	0.04	-0.66 **	-3.10**
JMS 18 B	-0.64 **	-0.81 *	0.68**	-0.38 **	0.54	0.91	-1.77 *	-0.29	-1.32**
CMS 64 B	-0.53*	0.26	-0.18	-1.18**	-49.39**	51.67**	-23.94 **	-2.37**	-6.40**
Testers									
RNR 21278	-2.15**	0.12	-0.22 **	-0.37**	-2.32 *	-5.24**	1.67**	-1.21**	-1.54**
JGL 33124	-1.19**	-0.42	-0.52**	0.23**	-17.69 ***	18.27**	-8.94**	-0.44**	-2.85**
KNM 7787	3.35**	0.29	0.74**	0.15	20.01 **	-13.03**	7.26**	1.64**	4.38**
CD 95% GCA (Line)	0.408	0.69	0.18	0.26	2.98	4.24	1.37	0.38	0.25
CD 95% GCA (Tester)	0.250	0.43	0.12	0.16	1.82	2.59	0.84	0.24	0.15

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

Table 3. Estimates of specific combining ability (SCA) effects for yield and yield attributing traits in the experimental rice hybrids

S. No.	Crosses	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of productive tillers per plant	No. of filled grains per panicle	No. of unfilled grains per panicle	Spikelet fertility (%)	1000 grain-weight (g)	Grain yield per plant (g)
1	CMS 23A x RNR 21278	-2.85**	-3.18**	-1.64**	-0.35	-43.22**	-2.78	-8.48**	-1.33**	-6.06**
2	CMS 23A x JGL 33124	1.19 **	3.85**	1.75**	0.83**	34.55**	35.39**	-1.82	-1.51**	-0.97**
3	CMS 23A x KNM 7787	1.65**	-0.66	-0.11	-0.48 *	8.65 **	-32.61**	10.31**	2.83**	7.03**
4	CMS 46A x RNR 21278	-6.18**	0.62	-0.84**	-1.42**	-80.22**	52.44**	-31.95**	-5.97**	-15.99**
5	CMS 46A x JGL 33124	3.86**	-1.75**	0.45 **	-0.03	20.56**	-41.64**	21.68**	3.53**	7.64**
6	CMS 46A x KNM 7787	2.32**	1.14	0.39 *	1.45**	59.66**	-10.81**	10.27**	2.45**	8.35**
7	CMS 59A x RNR 21278	3.15**	0.92	0.13	-0.22	50.52**	-37.29**	18.43**	1.48 **	5.32**
8	CMS 59A x JGL 33124	1.19*	0.25	-0.08	-0.03	14.89**	-55.63**	17.20**	-0.85 *	2.14**
9	CMS 59A x KNM 7787	-4.35**	-1.16	-0.04	0.25	-65.41**	92.93**	-35.63**	-0.64	-7.46**
10	JMS 11A x RNR 21278	-0.18	-1.42 *	2.39**	0.12	-25.35**	-21.56**	1.05	1.64**	-0.32
11	JMS 11A x JGL 33124	-5.14**	-3.58 **	-3.12**	-1.90**	32.63**	16.73**	2.76 *	-0.03	-2.57**
12	JMS 11A x KNM 7787	5.32**	5.01**	0.73**	1.78**	-7.27 **	4.83	-3.83 **	-1.62 **	2.89**
13	JMS 13A x RNR 21278	-0.52	-2.78**	-0.01	0.12	20.31**	-30.16**	16.52**	-0.86 *	1.61**
14	JMS 13A x JGL 33124	-3.47**	-0.25	-1.12**	-0.10	-86.91**	61.08 **	-38.26**	-1.53**	-8.18**
15	JMS 13A x KNM 7787	3.98**	3.04**	1.13**	-0.02	66.59**	-30.92**	21.74**	2.39**	6.58**
16	JMS 17A x RNR 21278	4.15**	3.85**	0.93**	1.55**	-21.95**	44.94**	-17.61**	1.68**	4.31**
17	JMS 17A x JGL 33124	0.19	1.68*	0.42 *	-0.36	55.43**	-38.39**	22.03**	-0.33	4.56**
18	JMS 17A x KNM 7787	-4.35**	-5.53**	-1.34**	-1.18**	-33.47**	-6.543	-4.43 **	-1.35**	-8.87**
19	JMS 18A x RNR 21278	6.26**	3.85 **	1.19**	1.12**	85.18**	-23.33**	20.51 **	3.24**	10.37**
20	JMS 18A x JGL 33124	-3.03**	-1.92*	0.58**	0.10	-29.24**	10.44 **	-7.09 **	1.28**	-0.42
21	JMS 18A x KNM 7787	-3.24**	-1.93*	-1.77**	-1.22**	-55.94**	12.88**	-13.41 **	-4.52**	-9.96**
22	CMS 64A x RNR 21278	-3.85**	-1.82*	-2.14**	-0.88**	1.72**	17.76 **	1.534	0.11	0.75 **
23	CMS 64A x JGL 33124	5.19**	1.72*	1.14**	1.50**	-41.91**	12.01**	-16.51**	-0.56	-2.18**
24	CMS 64A x KNM 7787	-1.35**	0.11	0.99**	-0.62**	27.19**	-29.77**	14.97**	0.46	1.43**
	CD 95% SCA	0.71	1.19	0.33	0.45	5.16	7.35	2.38	0.66	0.45

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

(SCA) effects of 24 hybrid combinations were estimated using the Line x Tester mating design procedure outlined by Kempthorne in 1957. The GCA effects of the parents (lines and testers) for each character are presented in Table 2, while the SCA effects of the hybrids are presented in Table 3.

3.3 Days to 50% Flowering

The GCA effects among the lines ranged from -4.53 (CMS 59B) to 4.47 (CMS 23B) and among the testers, it ranged from -2.15 (RNR 21278) to 3.35 (KNM 7787). Based on negative and significant GCA value the parent CMS 59B (-4.53) and the tester RNR 21278 (-2.15) showed good GCA for the days to 50% flowering. Negative GCA effects are desirable in breeding for early maturity. Conversely, the lines CMS 23B (4.47), CMS 46B (3.81), and JMS 11B (0.81) showed significantly positive GCA effects.

Out of the 24 hybrids, 21 displayed high significant SCA effects. Among these, 11 hybrids exhibited significant positive SCA effects, while 10 hybrids exhibited significant negative SCA effects. The hybrids, CMS 46A x RNR 21278 (-6.18) followed by JMS 11A x JGL 33124 (-5.14), CMS 59A x KNM 7787 and JMS 17A x KNM 7787 (-4.35) were observed good specific combiners with highest negative value for early maturity. These findings are consistent with the results reported by Malathi and Suresh (2019) and Sari et al. (2020).

3.4 Plant Height

Five lines and none of the testers among the parents recorded significant *gca* effects The lines, JMS 17B (-4.31), CMS 59B (-3.97) and JMS 18B (-0.81) displayed highly significant negative *gca* effects. Lines with negative effects could be effectively used in the development of dwarf and semi-dwarf hybrids and are ideal general combiners for dwarfness. Conversely, two lines *viz.,* CMS 46B (5.53) and CMS 23B (3.13) exhibited significantly positive *gca* effects.

Out of 24 hybrids, 16 hybrids displayed significant *sca* effects. It was found that seven hybrids recorded significantly positive *sca* effects while, nine hybrids displayed significantly negative *sca* effects. Highest and negative significantly negative *sca* effect was recorded by the cross, JMS 17A x KNM 7787 (5.53) followed by JMS 11A x JGL 33124 (3.58). The cross combination, JMS 17A x KNM 7787 was recognized as the best specific combiner among all the crosses. Similar results were reported by Sari et al*.* (2020) and Barhate et al*.* (2021).

3.5 Panicle Length

Six lines and all the three testers (Parents) displayed significant *gca* effects for panicle length. The lines, JMS 11B (1.18), JMS 18B (0.68) and CMS 46B (0.22) exhibited significantly positive *gca* effects and the testers, KNM 7787 (0.74) recorded significantly positive *gca* effect. Hence, the line JMS 11B and the tester, KNM 7787 were observed as good general combiners for panicle length.

Among all the cross combinations, 19 hybrids displayed significant *sca* effects. 12 hybrids displayed significantly positive *sca* effects. The cross, JMS 11A x RNR 21278 (2.39) displayed the highest positive significant *sca* effect followed by CMS 23A x JGL 33124 (1.75) and CMS 64A x JGL 33124 (1.14). Among the crosses, JMS 11A x RNR 21278 was observed as the best specific combiner for the trait. These results are in accordance with the findings of Ambikabathy et al*.* (2019) and Nagamani et al*.* (2022).

3.6 Number of Productive Tillers Per Plant

Seven lines displayed significant *gca* effects; out of 8 lines, two lines displayed significantly positive *gca* effects ranging from 1.87 (CMS 23B) followed by 1.35 (CMS 46B). Only one tester *i.e.,* JGL 33124 (0.23) displayed significantly positive *gca* effect. Hence, the line CMS 23B and the tester, JGL 33124 were observed as good general combiners for number of productive tillers per plant.

Out of 24 hybrids, 13 hybrids displayed significant *sca* effects. Out of 24 hybrids, Six hybrids displayed significantly positive *sca* effects. The cross, JMS 11A x KNM 7787 (1.78) followed by JMS 17A x RNR 21278 (1.55), CMS 64A x JGL 33124 (1.50) and CMS 46A x KNM 7787 (1.45) showed the highest significantly positive *sca* effect. The cross, JMS 11A x KNM 7787 was observed as the best specific combiner for number of productive tillers per plant. The findings are similar to the results of Patel et al*.*(2019) and Salah et al*.* (2020).

3.7 Number of Filled Grains Per Panicle

The line, CMS 23B (32.54) displayed the highest significantly positive *gca* effect followed by CMS

46B (30.94) and JMS 11B (30.07) while the tester, KNM 7787 (20.01) displayed significantly positive *gca* effect. Hence, it was observed that the line, CMS 23B and the tester, KNM 7787 were good general combiners.

All the 24 hybrids exhibited significant *sca* effects in which, eleven hybrids displayed significantly negative effects and the remaining thirteen hybrids exhibited significantly positive *sca* effects. The hybrids, JMS 18A x RNR 21278 (85.18), JMS 13A x KNM 7787 (66.59), CMS 46A x KNM 7787 (59.66) and JMS 17A x JGL 33124 (55.43) displayed the highest significantly positive *sca* effects.

In terms of the number of grains per panicle, the good general combiners were CMS 23B (among lines) and KNM 7787 (among testers). The best specific combiner was JMS 18A x RNR 21278. These findings are in concurrence with results reported by Ramesh et al. (2018) and Yuga et al. (2018).

3.8 Number of Unfilled Grains Per Panicle

Five lines and all the three testers displayed significant *gca* effects. The lines, CMS 46B (-38.91) followed by CMS 23B (-14.46) displayed significantly negative *gca* effects. Among the testers, KNM 7787 (-13.03) and RNR 21278 (-5.24) displayed significantly negative *gca* effects.

Twenty-one hybrids displayed significant *sca* effects. Ten hybrids displayed significantly positive *sca* effects while eleven hybrids displayed significantly negative *sca* effects. The highest negative significant *sca* effect was exhibited by the cross, CMS 59A x JGL 33124 (-55.63) followed by CMS 46A x JGL 33124 (-41.64), JMS 17A x JGL 33124 (38.39) and CMS 59A x RNR 21278 (-37.29).

The line, CMS 46B and KNM 7787 among testers were observed as the good general combiners due to their high significantly negative *gca* effects. The hybrid, CMS 59A x JGL 33124 was observed as the best specific combiner for the character. Current finding is in concurrence with the reports of Ramesh et al. (2018).

3.9 Spikelet Fertility (%)

Three lines, CMS 46B (15.25), CMS 23B (11.72) and JMS 11B (7.74) and two testers *i.e.,* KNM 7787 (7.26) and RNR 21278 (1.67) displayed significantly positive *gca* effects.

Out of 24 hybrids, 21 hybrids displayed significant *sca* effects out of which ten hybrids exhibited negative significant *sca* effects and remaining 11 hybrids displayed significantly positive *sca* effects. The hybrid, JMS 17A x JGL 33124 (22.03) followed by JMS 13A x KNM 7787 (21.74), CMS 46A x JGL 33124 (21.68) and JMS 18A x RNR 21278 (20.51) displayed the highest positive and significant *sca* effects.

Based on combining ability effects, the line, CMS 46B and KNM 7787 among the testers were observed as good general combiners for spikelet fertility. The hybrid, JMS 17A x JGL 33124 was observed as the best specific combiner for spikelet fertility. These findings are in consonance with results of Salah et al. (2020) and Mohan et al. (2021).

3.10 1000 Grain Weight

Seven lines and three testers exhibited significant *gca* effects. Among the lines, CMS 46B (4.24) displayed significantly positive *gca* effect followed by CMS 23B (3.27) and the tester, KNM 7787 (1.64) exhibited significantly positive *gca* effect.

Out of 24 hybrids, 18 hybrids displayed significant *sca* effects in which each nine hybrids displayed significantly positive *sca* effects and nine crosses exhibited significantly negative *sca* effect indicating that this trait is under the control of non-additive gene action. The hybrids, CMS 46A x JGL 33124 (3.53) displayed the highest positive *sca* effect followed by JMS 18A x RNR 21278 (3.24), CMS 23A x KNM 7787 (2.83) and CMS 46A x KNM 7787 (2.45). These results are similar to the findings of Patel et al. (2019) and Nagamani et al. (2022).

3.11 Grain Yield Per Plant

All the parents, *i.e.,* eight lines and three testers exhibited significant *gca* effects for single plant yield. The lines, CMS 46B (9.98), CMS 23B (7.34) and JMS 11B (1.27) and KNM 7787 (4.38) among testers displayed significantly positive *gca* effcts.

Out of 24 hybrids, 22 hybrids displayed significant *sca* effects. Thirteen hybrids displayed significantly positive effects and 9 hybrids displayed significant negative effects. Highest positive significant effects are recorded in the hybrid, JMS 18A x RNR 21278 (10.37) followed by CMS 46A x KNM 7787 (8.35), CMS

46A x JGL 33124 (7.64), CMS 23A x KNM 7787 (7.03) and JMS 13A x KNM 7787 (6.58).

CMS 46B among the lines and KNM 7787 among the testers were identified as good general combiners for grain yield per plant while, JMS 18A x RNR 21278 were identified as best specific combiners for the trait. The results are in agreement with the findings of Patel et al*.* (2019) and Salah et al*.* (2020) and Gupta et al, 2024.

In general, negative effects are desirable for days to 50% flowering to obtain early maturing types. Whereas, positive effects are desirable for the other characters. From the above findings it is understood that the line, CMS 46B was found to be good general combiner for spikelet fertility, number of unfilled grains per panicle, 1000 grain weight and grain yield per plant. CMS 23B was identified as good general combiner for number of productive tillers per plant, number of filled grains per panicle. CMS 59B was identified as good general combiner for days to 50% flowering. JMS 11B was identified as good general combiner for panicle length and JMS 17B was identified as good general combiner for plant height to develop dwarf and semi dwarf varieties.

Among testers, KNM 7787 was identified as good general combiner for panicle length, number of filled grains per panicle, number of unfilled grains per panicle, spikelet fertility, 1000 grain weight and grain yield per plant. RNR 21278 was found to be good general combiner for days to 50% flowering and JGL 33124 was identified as good general combiner for number of productive tillers per plant.

The hybrids, CMS 46A x RNR 21278 and JMS 11A x JGL 33124 were identified as good specific combiners for days to 50% flowering. Though, t he hybrids, JMS 17A x KNM 7787 and JMS 11A x JGL 33124 were identified as good specific combiners for dwarfness, the, JMS 11A x KNM 7787, CMS 23A x JGL 33124, JMS 17A x RNR 21278 and JMS 18A x RNR 21278 were found to be good specific combiners to achieve higher yield.

The cross, JMS 11A x RNR 21278 was identified as good specific combiner for panicle length. JMS 11A x KNM 7787, JMS 17A x RNR 21278 and CMS 64A x JGL 33124 were identified as good specific combiners for number of productive tillers per plant. The crosses, JMS 18A x RNR 21278 followed by JMS 13A x KNM 7787 were identified as good specific combiners for number of filled grains per panicle.

The crosses, CMS 59A x JGL 33124 followed by CMS 46A x JGL 33124 crosses were identified as good specific combiners for number of unfilled grains per panicle. JMS 17A x JGL 33124 followed by JMS 13A x KNM 7787 and CMS 46A x JGL 33124 were identified as good specific combiners for spikelet fertility. CMS 46A x JGL 33124, JMS 18A x RNR 21278 crosses were identified as the best specific combiners for 1000 grain weight. JMS 18A x RNR 21278, CMS 46A x KNM 7787, CMS 46A x JGL 33124, CMS 23A x KNM 7787 and JMS 13A x KNM 7787 were identified as best specific combiners for grain yield per plant.

4. CONCLUSION

The lines, CMS 46B, CMS 23B and the tester, KNM 7787 showed significant positive *gca* effects for grain yield per plant. Parents having positive significant *gca* effects for grain yield per plant, emphasizing their capability of producing superior crosses from low yielding parents, with high *sca* effects. The pedigree method can be used to exploit superior crosses with high x high *gca* effects. Whereas, biparental mating and recurrent selection methods can be used to develop the obtained better crosses with high x low and low x low *gca* effects.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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