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Combining Ability and Gall Midge Resistance for Yield and Quality Traits in Hybrid Rice (*Oryza sativa* L.)

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ABSTRACT

This study was conducted to estimate combining ability and gall midge resistance for yield and quality traits in hybrid rice. Six cytoplasmic male sterile lines were crossed to seven testers in Line X Tester mating design to produce 42 hybrids. The parents and hybrids along with four checks were evaluated at a Regional Agricultural Research Station, Polasa, Jagtial of Telangana state considered to be a gall midge hot spot. Line x Tester analysis was performed to estimate combining ability for yield and gall midge resistance as well as other traits among parental lines and the hybrids. The analysis of variance for combining ability shows that mean sum of square due to lines, testers and the interaction between lines and testers was significant for most of the characters under study. Non additive gene action was predominant for all the traits and resistance to gall midge. Based on GCA and SCA effects, some lines and hybrids have been identified with good yield potential and resistance to gall midge.

Key words: *Rice, Gall midge, Combining ability, Resistance, Yield.*

INTRODUCTION

Rice is the most important cereal food crop of India covering about one-fourth of the total cropped area and providing food to about half of the Indian population. Development of new varieties with high yield and quality parameters is the prime objective of all rice breeders. The first step in a successful breeding program is to select appropriate parents. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis[13,9]. Introduction and wide adoption of high yielding varieties has led to severe incidence of different insect pests. Nearly 300 species of insect pests attack the rice crop at different stages and among them, Asian rice gall midge (GM), *Orseolia oryzae* (Wood-Mason) is one of the important insect which has been prevalent in almost all the rice growing states. Due to the biotype variations, each local breeding programme must be aimed at screening and selecting its own resistant cultures.

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Field screening by planting the test materials to coincide with high pest populations has been highly successful technique. The gall midge resistance can be easily transferred to the desirable hybrids due to its simple inheritance. Gall midge is endemic in Northern Telangana region of South India. More recently, the incidence of gall midge was increased and in India 25 per cent yield loss per year over an area of two lakh hectares is estimated. Significant advance had been made in developing rice varieties resistant to gall midge but it had been proved difficult to develop varieties of acceptable grain quality and resistance to gall midge. By using combining ability, potential hybrids resistant to gall midge can be developed. The present study was undertaken to derive information on combining ability and gall midge resistance of rice hybrids.

MATERIAL AND METHOD

A field experiment was conducted during *Kharif*, 2017 at Regional Agricultural Research Station (RARS), Polasa, Jagtial. During *Rabi* 2016-17 parents (6 lines and 7 testers) were planted in a crossing block with a spacing of 15 x 15 cm and crosses were effected in a 6 x 7, Line x Tester mating design to produce 42 hybrids. During *Kharif*, 2017, 30 days old seedlings of 57 entries (6 lines, 7 testers, 42 hybrids and 2 checks) were transplanted in the main field in randomized block design. Each entry was planted in two rows of four meters length with a spacing of 20 x 15 cm in two replications. Standard agronomical package of practices were followed to raise good crop. The plant protection measures were not taken so as to record the incidence of gall midge. Data was collected from an average of five plants from each entry in each replication on the following traits: Days to 50 per cent flowering, plant height (cm), panicle length (cm), number of productive tillers per plant, number of grains per panicle, spikelet fertility percentage, 1000-grain weight (g), grain yield per plant (g), incidence of gall midge, hulling percentage, milling percentage, head rice recovery, kernel length, kernel breadth, kernel L/B ratio, paddy length, paddy breadth and paddy L/B ratio. Analysis of variance for grain yield, gall midge resistance and other traits were performed using the model described by[6].

Gall midge incidence was recorded on hill basis at 45 days after planting during *Kharif*, 2017 season. The occurrence of silver shoots in randomly selected 10 plants was recorded and compared with susceptible check MTU 1010 and resistant check JGL 384. For scoring the gall midge incidence a total number of tillers and total number of tillers with silver shoot were recorded and the per cent tiller infestation was calculated as follows

$$\text{Per cent silver shoot} = \frac{\text{Number of infested tillers}}{\text{Total number of tillers}} \times 100$$

To check the level of resistance or susceptibility, the percentage silver shoot in each entry in each replication was converted to 0-9 scale by following the IRRI Standard Evaluation System (SES) given in Table 1.

Table 1: Standard Evaluation Systems for evaluating rice gall midge (IRRI)

Scale	Damaged plants (silver shoots)	Reaction
0	No damage	Highly resistant (HR)
1	Less than 1%	Resistant (R)
3	1-5 %	Moderately Resistant (MR)
5	6-10 %	Moderately Susceptible (MS)
7	11-25 %	Susceptible (S)
9	More than 25%	Highly Susceptible (HS)

RESULTS AND DISCUSSION

The analysis of variance for combining ability of all the traits under study has been presented in the Table 2.

The variance due to treatments was highly significant for all the characters under study. The parents exhibited significant differences for all the traits studied except for spikelet fertility, grain yield per plant, incidence of gall midge, kernel breadth and paddy L/B ratio. The variance due to crosses was found highly significant for all of the characters. The variance due to parent *vs.* crosses was also found highly significant for most of the characters except number of productive tillers per plant. The variance due to lines was found significant for all the traits except number of productive tillers per plant, spikelet fertility, number of grains per panicle, grain yield per plant, incidence of gall midge, kernel breadth and paddy L/B ratio, where as the variance due to testers was found non significant for spikelet fertility and paddy L/B ratio. When the effects of crosses was partitioned into lines, testers and line x tester effects, the interaction effects (lines x testers) were found to be significant for all the traits under study. This suggested that sufficient variability is available in the material used for study.

Similar works have been reported by Shukla and Panday[15]. for lines and line x tester interaction, Nadali and *Nadali* [10], for crosses, lines and line x tester interaction, Srikrishna Latha *et al*.[16], for treatments, hybrids, testers and line x tester and and Gaurav Dharwal *et al*.[2], for treatments, lines and line x tester. The results pertaining to the estimate of combining ability revealed that mean *sca* variance was relatively greater in magnitude than *gca* variance for all the traits except panicle length, 1000- grain weight, kernel breadth and paddy length indicating that these traits were predominantly under the control of non-additive gene action.

Genetic analysis of data showed that twelve parents had significant GCA estimates of line and testers for plant height with four lines being positive and one negative, three testers being positive and one negative. Nine parents were significantly different for days to 50 per cent flowering; three were negative and six were positive. Nine parents were significant for panicle length with two lines and one tester being negative while three lines and three testers were positive. Only one tester was positively significant for number of productive tillers per plant. Nine parents displayed significant 1000- seeds weight differences; one line and two testers were negative while two lines and three testers were positive. Eight parents exhibited significance for number of grains per panicle; two lines and three testers were negative and one line and two testers were positive. Four parents were significantly different for spikelet fertility, one line and one tester being positive while one line and one tester were positive. Ten parents exhibited significance for grain yield per plant, two lines and four testers were negative and two lines and two testers were positive. One line and two testers had negative and significant GCA effect for gall midge damage while two lines and three testers had positive and significant GCA effect four lines and two testers were positively significant for hulling percentage. Nine parents were significant for milling percentage with three lines and two testers being negative while two lines and two testers were positive. All the parents displayed significant head rice recovery percentage differences; three lines and four testers were negative while three lines and three testers were positive. Two lines and three testers were positively significant for kernel length. Eight parents were significantly different for kernel breadth, among which three lines and two testers were positively significant. Seven parents were significantly different for kernel L/B ratio, three were negative and four were positive. One line and two testers for paddy length, one line and one tester for paddy breadth and two lines and three testers for paddy L/B ratio exhibited a positive significant GCA effects (Table 3).

Combining ability provides criteria to select parents for hybridization as suggested by Harer & Bapat[5]. In this study negative *gca* effects of the days to 50 per cent flowering, plant height and gall midge damage were desirable. While positive *gca* effects for other characters are needed. The perusal of the results revealed that the line JMS 20B was good combiner for days to 50 per cent flowering, panicle length, 1000 - grain weight and kernel length. Line JMS 21B was good combiner for number of grains per panicle, spikelet fertility, grain yield per plant, hulling percentage, milling percentage, head rice recovery, kernel breadth and paddy breadth, while line JMS 19B performed well for spikelet fertility, kernel L/B ratio, paddy length and paddy L/B ratio. The tester, JBR 6 was good general combiner for number of productive tillers per plant and grain yield per plant. Whereas, JMBR 44 for days to 50 per cent flowering, plant height and kernel breadth. Tester JR 85 was also good general combiner for most of the quality traits. Hence, these good general combiners of males and females may be extensively used in future hybrid rice breeding programme. With regard to gall midge damage the line JMS 21B and the testers JR 83and JR 67 displayed desirable negative *gca* effects for gall midge incidence. Based on this, these lines were classified as good general combiners and are the best lines to use to improve rice for gall midge resistance. However, CMS 52B, JR 83, JR 80 and JR 67 did not exhibit high resistance to gall midge damage, despite having high *gca* values.

Twenty seven crosses were significant for days to 50 per cent flowering, CMS 64A x JMBR 31 (-9.98) had high negative SCA and CMS 64A X JR 83 (15.01) had high positive SCA. For plant height; thirteen crosses had negative and thirteen had positive SCA effects. The highest negative SCA was recorded by JMS 20A X JBR 6 (-19.97) and the lowest recorded by JMS 11A X JR 83 (-3.81)**.** JMS 19A X JMBR 44 (-1.79) had high negative and significant SCA for panicle length while JMS 11A X JBR 6 (2.90) showed positive and significant SCA effect. Only three crosses *viz*., JMS 11A X JBR 6 (2.13), JMS 20A X JMBR 44 (1.81) and CMS 64A X JR 85 (1.79) recorded positive significant SCA effect for number of productive tillers per plant. The highest positive SCA for 1000- grain weight was recorded for the cross CMS 64A X JMBR 31 (3.06) while the highest negative SCA was recorded by JMS 11A X JMBR 31(-1.25). Nine crosses were significant for number of grains per panicle JMS 21A X JR 67 (62.60) had high positive SCA effect. JMS 11A X JBR 6 (-9.80) had high negative and significant SCA for spikelet fertility while CMS 52A X JBR 6 (13.10) showed positive and significant SCA effect. Sixteen crosses exhibited significant SCA effect for grains yield per plant. The highest positive SCA was recorded by the cross JMS 20A X JMBR 44 (13.33) and the lowest was recorded by the cross JMS 11A X JR 83 (5.37). The cross JMS 21A X JBR 6 (-4.88) recorded the highest negative SCA effect for grain yield per plant while the lowest was recorded by the cross JMS 21A X JR 85 (-15.51). Ten crosses displayed positive and significant SCA for gall midge damage. The cross CMS 64A X JBR 6 (5.25) had the lowest positive and the cross CMS 64A X JR 83 (8.30) had the highest. Nine crosses showed negative and significant SCA effect for gall midge damage. The highest negative SCA was recorded by the cross JMS 20A X JBR 6 (-11.59) and the lowest recorded by the cross JMS 19A X JR 83 (-3.86). Out of 42 crosses, sixteen crosses recorded significant positive SCA effects for hulling percentage with a range from -7.74 (CMS 64A X JMBR 31) to 4.54 (CMS 64A X JR83). SCA effects ranged from -11.91 (CMS 64A X JMBR 31) to 10.31 (CMS 52A X JMBR 31) for milling percentage. Seventeen crosses were found with highly positive and significant SCA effects and registered as best specific combiners for the trait. The range of SCA effects for head rice recovery varied from -14.62 (CMS 64A X JMBR 31) to 9.53 (CMS 52A X JMBR 31). Out of 42 hybrids, twenty hybrids recorded positive significant SCA effect. The best specific combiners for this trait are CMS 52A X JMBR 31 (9.53), CMS 64A X JBR 6 (7.91) and CMS 52A X JR 67 (6.65). Fifteen hybrids expressed significant positive SCA effects for kernel length. The cross, JMS 11A X JR 80 (0.42) recorded highest positive SCA effect followed by JMS 19A X JR 67 (0.41) and JMS 21A X JBR 6 (0.39). One cross recorded significant positive SCA effect and two crosses registered significant negative SCA effects with a range from -0.22 (JMS 21A X JR 80) to 0.15 (JMS 21A X JR 85) for kernel breadth. A range of -0.35 (JMS 21A X JR 85) to 0.35 (JMS 11A X JR 83) was recorded for SCA effects with regard to kernel L/B ratio. Three crosses exhibited negative significant SCA effect, among which JMS 21A X JR 85 (-3.55) recorded low significant SCA effect and the cross JMS 11A X JR 83 (0.35) recorded high significant SCA effect. The best specific combiners identified for this trait are JMS 11A X JR 83 (0.35), JMS 19A X JBR 6 (0.33) and CMS 52A X JMBR 44 (0.28). Out of 42 crosses, seven crosses recorded significant positive SCA effects for paddy length with a range from –1.49 (CMS 52A X JR 83) to 0.95 (CMS 64A X JR83). The best specific crosses for this trait are JMS 11A X JR 83 (0.95), CMS 52A X JR 80 (0.89) and JMS 11A X JBR 6 (0.74). The range of SCA effects for paddy breadth varied from -0.35 (JMS 21A X JMBR 44) to 0.42 (JMS 11A X JMBR 44). Out of 42 hybrids, nine hybrids recorded positive significant SCA effects. The best specific combiners identified for this trait are JMS 11A X JMBR 44 (0.42), CMS 52A X JR 85 (0.21) and CMS 64A X JR 67 (0.20). Among the crosses, eighteen crosses recorded significant SCA effects, where nine crosses showed positive SCA effects and nine crosses showed negative SCA effects. The cross JMS 11A X JBR 6 (0.71), CMS 64A X JR 85 (0.61) and JMS 20A X JR 85 (0.57) were identified as best specific combiners for this trait. (Table 4).

The crosses CMS 64A X JMBR 31 and JMS 20A X JR 85 were identified as good specific combiners for days to 50 per cent flowering, JMS 20A X JBR 6 and CMS 64A X JR 80 were good specific combiners for plant height, CMS 64A X JMBR 31 and JMS 11A X JR 80 for 1000- grain weight, JMS 21A X JR 67 and JMS 19A X JR 85 for number of grains per panicle CMS 52A X JBR 6 and CMS 52A X JR 67 for spikelet fertility while, JMS 11A X JBR 6 was good specific combiner for panicle length and number of productive tillers per plant. CMS 64A X JR 83 for hulling percentage and paddy length, CMS 52A X JMBR 31 for milling percentage and head rice recovery were the potential hybrids with high SCA effects. The cross JMS 20A X JBR 6 recorded highest negative SCA effect and found to be a good specific combiner for gall midge resistance. Many authors reported similar results in rice Ghara *et al*.[3], Hasan *et al*.[4]**,** Damodar Raju *et al*. (2014), Savita Bhatti *et al*. (2015), Gaurav Dharwal *et al.*[2], and Rumanti *et al*.[12].

The lines JMS 21B, JMS 20B, JMS 19B and testers JBR 6, JR 67 were recorded significant GCA effects for grain yield per plant. These parents resulted in the production of best single crosses JMS 21A X JR 85, JMS 20A X JMBR 44, CMS 52A X JBR 6, JMS 11A X JBR 6, JMS 19A X JR 80 and JMS 11A X JBR 6 with positive SCA effects for grain yield indicating the possibility of production of desirable crosses, with high SCA effects from low yielding parents. The superior crosses identified with high x high GCA effects can be exploited through pedigree breeding method and the better crosses with high x low and low x low GCA effects can be improved through biparental mating and recurrent selection methods.

Specific combining ability (SCA) effects of hybrids alone has limited value for choosing parents in a breeding program, and must be used in combination with other parameters such as GCA of the respective parents and actual performance of the hybrids[8]. However, SCA is important to identify parents of opposite heterotic types which should be improved within and not across heterotic groups. The hybrid combinations with significant mean performance, significant and desirable heterosis and significant desirable SCA estimates and which involve at least one of the parents with high GCA would likely enhance the concentration of favorable alleles and this is what a breeder desires to improve a trait[7]. However, enhancing favorable alleles should be done separately on opposite sides of heterotic groups in this investigation; good specific combiners were identified based on SCA effects of the crosses and GCA effects of the parents involved in the cross.

Based on standard evaluation system for gall midge among crosses, the crosses JMS 19A X JR 85 and JMS 19A X JMBR 44 were found highly resistant to gall midge with no damage and the crosses JMS 19A X JR 67, JMS 21A X JR 83, JMS 21A X JMBR 44, JMS 21A X JMBR 31, JMS 21A X JR 67 and JMS 20A X JR 67 were resistant with scale less than 1. Thirteen crosses, CMS 64A X JR 85, CMS 64A X JMBR 44, JMS 11A X JR 85, JMS 11A X JBR 6, JMS 19A X JR 83, JMS 19A X JR 80, JMS 19A X JMBR 31, JMS 19A X JBR 6, CMS 52A X JR 85, JMS 21A X JR 85, JMS 21A X JR 80, JMS 21A X JBR 6, JMS 20A X JR 83, JMS 20A X JR 85, JMS 20A X JR 80, and JMS 20A X JBR 6 were found as moderately resistant to gall midge with scale 1 to 5 per cent. Remaining eighteen crosses recorded moderately susceptible and susceptible reaction to gall midge Table 5. High incidence of gall midge was recorded in check susceptible check MTU 1010 while, no incidence was recorded in resistant check JGL 384. The resistant sources found in the trial can further be exploited in breeding programme for the development of gall midge resistant commercial cultivars by determining their genetics.

Table 2: Analysis of variance for combining ability (Line x Tester) for yield and quality traits in rice

Source of variation	d.f	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of productive tillers per plant	1000-grain weight (g)	No. of grains per panicle	Spikelet fertility (%)	Grain yield per plant (g)
Replicates	1	0.03	4.85	0.38	5.68*	1.57	440.00	62.02	30.22
Treatments	54	86.17**	226.31**	7.34**	3.16**	16.01**	4420.20**	126.02**	136.23**
Parents	12	57.78**	170.97**	4.27**	3.12*	15.22**	2917.96*	71.32	20.04
Parents (Lines)	5	31.20**	140.94**	3.95*	2.28	9.63**	1770.13	58.99	14.44
Parents (Testers)	6	82.83**	217.92**	5.01*	4.31*	15.77**	4205.11**	85.18	25.62*
Parents (L *vs* T)	1	40.38**	39.50*	1.43	0.26	39.83**	934.15	49.71	14.49
Parents *vs* Crosses	1	17.08**	104.01**	10.49*	0.22	16.05**	7594.43*	859.99**	72.34*
Crosses	41	96.17**	245.49**	8.16**	3.24**	16.25**	4782.47**	124.13**	171.80**
Line effect	5	66.72	533.90*	30.07**	1.86	45.80**	10574.88*	226.24	501.30*
Tester effect	6	324.46**	672.23**	12.37*	3.94	42.48**	9301.44*	207.48	185.60
Line x Tester effect	30	55.42**	112.08**	3.66**	3.33**	6.07**	2913.27*	90.44*	114.12**
Error	54	0.88	3.89	1.15	1.20	0.52	875.50	45.28	11.25
Total	109	43.13	114.09	4.21	2.21	8.21	2627.59	85.43	73.34

Table 2 (Cont.)

Source of variation	d.f	Incidence of gall midge (%)	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	Kernel L/B ratio	Paddy length (mm)	Paddy breadth (mm)	Paddy L/B ratio
Replicates	1	46.21*	34.00**	6.08**	1.93	0.02*	0.00	0.00	0.00	0.02*	0.08
Treatments	54	77.17**	13.54**	29.43**	89.71**	0.37**	0.04**	0.16**	1.18**	0.05**	0.38**
Parents	12	13.33	9.28**	10.32**	36.46**	0.29**	0.01	0.12**	0.44*	0.03**	0.03
Parents (Lines)	5	1.35	0.57**	8.50**	22.20**	0.34**	0.01	0.08*	0.36*	0.02*	0.01
Parents (Testers)	6	22.47*	14.35**	12.32**	35.56**	0.28**	0.02*	0.17**	0.41*	0.03**	0.06
Parents (L *vs* T)	1	18.35	22.41**	7.46**	113.16**	0.08**	0.00	0.01	1.07*	0.06**	0.00
Parents *vs* Crosses	1	655.76**	0.61*	22.53**	14.26**	0.53**	0.09*	0.88**	4.82**	0.09**	2.32**
Crosses	41	81.75**	15.10**	35.19**	107.14**	0.39**	0.04**	0.16**	1.31**	0.06**	0.43**
Line effect	5	114.87	46.41*	50.14	396.62*	1.44**	0.19**	0.35*	2.34	0.04	0.95*
Tester effect	6	135.40	9.08	6.86	32.14	0.62*	0.05*	0.29*	1.73	0.09	0.75*
Line x Tester effect	30	65.49**	11.08**	38.36**	73.89**	0.17**	0.01*	0.10**	1.05**	0.05**	0.28**
Error	54	7.31	0.07	0.41	0.52	0.00	0.01	0.03	0.13	0.00	0.03

Table 3: Estimates of general combining ability (*gca*) effects for lines and testers for yield and quality traits in rice

Source	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of productive tillers per plant	1000 - grain weight (g)	No. of grains per panicle	Spikelet fertility (%)	Grain yield per plant (g)	Incidence of gall midge (%)
PARENTS									
LINES									
CMS 64B	-0.01	-12.26**	-2.30**	-0.29	-3.39**	-24.75**	-3.52	-8.45**	0.81
JMS 11B	2.77**	3.79**	-1.08**	0.20	0.07	-20.32*	3.24	-3.90**	2.12*
JMS 19B	-0.29	4.25**	1.09**	0.41	0.39	15.32	-3.04	4.42**	2.60**
CMS 52B	0.48	2.35**	0.05	-0.44	1.38**	-8.67	-3.36	-0.42	-0.78
JMS 21B	0.91**	1.46*	0.59*	0.34	-0.11	48.39**	6.08*	8.52**	-5.30**
JMS 20B	-3.86**	0.39	1.64**	-0.22	1.66**	-9.96	0.60	-0.16	0.55
TESTERS									
JR 83	-10.72**	-11.94**	1.64**	-0.54	-1.47**	-35.0**	4.68*	-4.60**	-4.89**
JR 85	3.27**	9.70**	0.85*	0.20	1.79**	15.91	-5.57*	3.23	0.68
JR 80	2.94**	5.27**	1.38**	-0.21	0.30	27.50*	-0.90	-3.13*	-1.48
JMBR 44	-2.39**	-4.81**	-0.33	0.61	1.72**	-28.75*	-5.47*	-2.10*	3.19**
JMBR 31	0.27	-4.92**	0.00	-0.54	-0.82**	4.58	1.90	-2.40*	1.88*
JR 67	3.44**	2.48**	-0.71*	-0.38	-3.10**	34.75**	1.70	3.98**	-3.37**
JBR 6	3.19**	4.22**	0.45	0.86*	1.57**	-19.00*	3.66	5.03**	3.99**
CD 95% GCA (Line)	0.50	1.06	0.57	0.59	0.39	15.97	3.63	1.81	1.45
CD 95% GCA (Tester)	0.54	1.15	0.62	0.63	0.42	17.25	3.92	1.95	1.57

Table 3 Cont.)

Source	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	Kernel L/B ratio	Paddy length (mm)	Paddy breadth (mm)	Paddy L/B ratio
PARENTS									
LINES									
CMS 64B	-3.52**	-0.71**	-1.54**	-0.51**	-0.11**	-0.06	0.14	-0.07**	0.20**
JMS 11B	-0.29**	1.87**	3.46**	-0.06*	-0.08*	0.10*	0.10	0.00	0.04
JMS 19B	1.19**	-0.23	-4.30**	-0.09**	-0.09**	0.12*	0.39**	-0.05*	0.25**
CMS 52B	0.45**	-1.53**	3.77**	0.31**	0.05	0.05	0.09	0.03	-0.04
JMS 21B	1.25**	2.68**	6.14**	-0.02	0.17**	-0.29**	-0.80**	0.08**	-0.48**
JMS 20B	0.91**	-2.06**	-7.53**	0.38**	0.07*	0.06	0.06	0.00	0.015
TESTERS									
JR 83	1.74**	-0.26	-1.56**	-0.01	-0.07*	0.13**	0.01	-0.15**	0.27**
JR 85	0.49**	1.24**	2.49**	0.33**	-0.03	0.26**	0.48**	0.01	0.20*
JR 80	-0.09	0.72**	-0.57*	0.17**	0.03	0.00	0.43**	-0.01	0.21**
JMBR 44	-0.51**	0.10	0.92**	-0.07**	0.08*	-0.18*	-0.01	0.03	-0.06
JMBR 31	-0.62**	-0.96**	1.45**	-0.11**	0.04	-0.14*	-0.16	0.13**	-0.29**
JR 67	-0.27**	-0.37	-1.80**	-0.37**	0.08*	-0.06	-0.62**	0.03	-0.34**
JBR 6	-0.72**	-0.46*	-0.93**	0.07*	0.03	-0.00	-0.13	-0.04*	0.01
CD 95% GCA (Line)	0.14	0.35	0.39	0.04	0.05	0.10	0.19	0.03	0.10
CD 95% GCA (Tester)	0.15	0.37	0.42	0.04	0.05	0.10	0.21	0.04	0.11

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

Table 4: Estimates of specific combining ability (*sca)* effects for yield and quality traits in rice

S.No.	Crosses	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	No. of productive tillers per plant	1000- grain weight (g)	No. of grains per Panicle	Spikelet fertility (%)	Grain yield per plant (g)	Incidence of gall midge (%)
1	CMS 64A X JR 83	15.01**	4.54*	0.61	0.54	1.77*	34.50	-7.55	3.51	8.30**
2	CMS 64A X JR 85	-3.48**	-4.10*	0.61	1.79*	-2.76**	-37.91	-1.09	-4.11	6.76*
3	CMS 64A X JR 80	4.84**	-11.27**	-1.41	-786.00	-3.53**	32.50	7.42	1.25	-5.71*
4	CMS 64A X JMBR 44	-5.82**	0.31	1.00	-0.11	1.86**	-27.25	-3.39	0.01	1.05
5	CMS 64A X JMBR 31	-9.98**	-7.17**	-0.23	-1.45	3.06**	-28.58	-0.92	-2.48	-10.23**
6	CMS 64A X JR 67	-4.65**	3.41*	-0.61	0.38	-1.84**	-5.75	4.02	-2.86	-5.43*
7	CMS 64A X JBR 6	4.09**	14.27**	0.01	0.36	1.45*	32.50	1.51	4.68	5.25*
8	JMS 11A X JR 83	-5.77**	-3.81*	-0.49	1.04	-1.80*	48.07*	2.03	5.37*	-4.21*
9	JMS 11A X JR 85	9.22**	4.43*	-1.39	-0.70	0.54	-31.84	4.58	-9.66**	-1.85
10	JMS 11A X JR 80	-1.94*	10.27**	2.27*	-0.78	2.33**	-8.92	0.36	-0.89	0.49
11	JMS 11A X JMBR 44	-3.60**	-6.74**	-1.11	-0.61	0.37	-16.67	6.03	-0.52	-1.70
12	JMS 11A X JMBR 31	0.22	-4.82*	-0.74	0.04	-1.25*	-36.01	2.31	-0.62	6.39*
13	JMS 11A X JR 67	3.06**	-0.54	-1.42	-1.11	-0.87	11.82	-5.53	-4.21	0.20
14	JMS 11A X JBR 6	-1.19	1.22	2.90**	2.13*	0.67	33.57	-9.80*	10.54**	0.68
15	JMS 19A X JR 83	-2.70**	-2.66	0.71	-0.16	-0.33	-14.07	-2.48	4.24	-3.86*
16	JMS 19A X JR 85	1.29	-1.61	0.71	0.08	0.35	55.01*	-4.17	0.81	-1.63
17	JMS 19A X JR 80	0.63	0.61	-0.11	1.50	-0.15	0.42	1.35	10.57**	-6.08*
18	JMS 19A X JMBR 44	2.46**	-5.20**	-1.79*	-1.33	0.05	3.17	8.77	0.94	-0.38
19	JMS 19A X JMBR 31	-0.70	11.31**	0.76	-0.66	-2.04**	21.34	-6.25	-6.75*	3.21
20	JMS 19A X JR 67	-0.86	-5.00**	-0.11	-0.33	1.14*	-45.82*	-3.15	1.36	2.24
21	JMS 19A X JBR 6	-0.11	2.56	-0.18	0.91	0.97	-20.07	5.93	-11.18**	6.51*
22	CMS 52A X JR 83	-3.48**	-2.56	-0.03	-1.31	-0.86	-25.57	0.13	-6.51*	-0.33
23	CMS 52A X JR 85	3.01**	2.38	0.96	-0.06	0.97	-1.98	-2.30	1.05	-0.75
24	CMS 52A X JR 80	-1.65*	7.31**	-2.77**	-0.64	0.79	-15.07	-9.92*	-3.97	5.62*
25	CMS 52A X JMBR 44	1.17	1.99	0.84	0.02	-0.18	-7.32	-10.85*	-3.61	6.84**

26	CMS 52A X JMBR 31	2.51**	-5.88**	-0.28	1.19	0.96	43.34*	1.02	4.08	-1.77
27	CMS 52A X JR 67	-1.15	-0.20	1.02	0.52	0.73	-41.32	8.82	-2.69	-1.29
28	CMS 52A X JBR 6	-0.40	-3.03*	0.26	0.27	-2.41**	47.92*	13.10*	11.65**	-8.31**
29	JMS 21A X JR 83	-3.91**	-5.88**	0.01	-1.09	0.40	17.35	1.14	-4.25	2.20
30	JMS 21A X JR 85	-0.91	-2.33	-0.28	-0.34	0.87	0.44	5.50	15.51**	-1.85
31	JMS 21A X JR 80	-1.58*	-0.40	-0.01	0.57	-0.69	-10.14	1.52	-8.52**	-1.20
32	JMS 21A X JMBR 44	2.25*	5.58**	-0.09	0.23	-1.65*	3.10	-5.59	-10.15**	-4.30*
33	JMS 21A X JMBR 31	1.08	0.40	0.36	0.40	-1.39*	11.27	4.92	6.34*	-4.06*
34	JMS 21A X JR 67	0.91	-2.31	0.18	-0.76	0.40	62.60*	3.47	5.96*	1.74
35	JMS 21A X JBR 6	2.16*	4.95**	-0.18	0.98	2.06**	-84.64**	-10.98*	-4.88*	7.47**
36	JMS 20A X JR 83	0.86	10.38**	-0.82	0.97	0.82	-60.28*	6.72	-2.36	-2.10
37	JMS 20A X JR 85	-9.13**	1.23	-0.62	-0.77	0.02	16.29	-2.51	-3.60	-0.67
38	JMS 20A X JR 80	-0.29	-6.52**	2.04*	0.14	1.26*	1.21	-0.74	1.56	6.88**
39	JMS 20A X JMBR 44	3.53**	4.05*	1.16	1.81*	-0.44	44.96*	5.03	13.33**	-1.49
40	JMS 20A X JMBR 31	6.86**	6.17**	0.12	0.47	0.66	-11.369	-1.09	-0.56	6.45*
41	JMS 20A X JR 67	2.70**	4.65*	0.94	1.31	0.43	18.46	-7.64	2.44	2.53
42	JMS 20A X JBR 6	-4.54**	-19.97**	-2.82**	-3.94	-2.76**	-9.28	0.24	-10.80**	-11.59**
43	CD 95 % SCA	1.34	2.81	1.53	1.56	1.03	42.25	9.61	4.79	3.86

Table 4 (cont.)

S.No.	Crosses	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	Kernel L/B ratio	Paddy length (mm)	Paddy breadth (mm)	Paddy L/B ratio
1	CMS 64A X JR 83	4.54**	7.41**	6.29**	0.36**	0.01	0.23	0.95**	0.19**	0.05
2	CMS 64A X JR 85	2.13**	-0.03	-6.76**	0.01	-0.15*	0.33*	0.58*	-0.17*	0.61**
3	CMS 64A X JR 80	-1.12**	-1.03*	5.15**	-0.12*	0.06	-0.18	-0.01	-0.08	0.16
4	CMS 64A X JMBR 44	3.92**	3.69**	2.65**	-0.12*	0.01	-0.12	-0.56*	-0.08	-0.11
5	CMS 64A X JMBR 31	-7.74**	-11.91	-14.62**	0.06	0.11	-0.17	-1.06**	-0.08	-0.35*
6	CMS 64A X JR 67	0.00	1.12*	-0.61	-0.27**	-0.10	0.01	0.10	0.20**	-0.30*
7	CMS 64A X JBR 6	-1.74**	0.75	7.91**	0.07	0.07	-0.09	0.00	0.03	-0.08
8	JMS 11A X JR 83	-1.51**	0.93*	3.54**	0.41**	-0.05	0.35*	0.29	0.09	0.31*
9	JMS 11A X JR 85	-2.10**	-0.50	5.23**	-0.13*	0.05	-0.20	-1.07**	0.04	-0.58**
10	JMS 11A X JR 80	1.44**	5.44**	1.35*	0.42**	0.08	0.07	0.07	0.17*	-0.29*
11	JMS 11A X JMBR 44	-0.80**	-3.63**	-2.09**	-0.42**	-0.01	-0.19	0.42	0.42**	-0.48*
12	JMS 11A X JMBR 31	0.96**	-1.89**	5.72**	0.01	-0.07	0.13	-0.42	-0.17*	0.07
13	JMS 11A X JR 67	-0.17	-2.82**	-5.31**	-0.02	0.00	-0.02	-0.05	-0.18**	0.25
14	JMS 11A X JBR 6	2.18**	2.48**	-8.44**	-0.27**	-0.00	-0.14	0.74*	-0.19**	0.71**
15	JMS 19A X JR 83	-0.82**	-0.20	-0.04	-0.35**	0.06	-0.33*	0.51	-0.03	0.35*
16	JMS 19A X JR 85	0.66*	0.87	3.94**	-0.10	-0.07	0.09	-0.15	0.00	-0.09
17	JMS 19A X JR 80	-1.14**	-2.86**	-6.98**	-0.03	-0.00	-0.01	-1.20**	-0.16*	-0.22
18	JMS 19A X JMBR 44	-1.44	-0.95*	-3.82**	0.16*	-0.00	0.05	-0.15	-0.01	-0.05
19	JMS 19A X JMBR 31	1.04**	-0.80	-2.00**	-0.14*	0.08	-0.24	0.49	0.08	0.05
20	JMS 19A X JR 67	-0.87**	1.97**	6.22**	0.41**	0.07	0.11	0.35	-0.02	0.17
21	JMS 19A X JBR 6	2.58**	1.98**	2.68**	0.06	-0.11	0.33*	0.16	0.15*	-0.22
22	CMS 52A X JR 83	-0.76**	-10.56**	-11.72**	-0.06	0.01	-0.05	-1.49**	-0.11	-0.47*
23	CMS 52A X JR 85	0.10	1.36*	-2.08**	0.18*	0.07	-0.05	0.34	0.21**	-0.22
24	CMS 52A X JR 80	0.79**	1.57*	0.10	0.25**	0.09	-0.01	0.89*	-0.05	0.49**
25	CMS 52A X JMBR 44	0.06	-0.97*	3.71**	0.20**	-0.10	0.28*	0.24	0.09	-0.05
26	CMS 52A X JMBR 31	2.57**	10.31**	9.53**	-0.55**	-0.11	-0.08	0.49	0.09	0.07
27	CMS 52A X JR 67	0.97**	1.57*	6.65**	-0.19**	0.02	-0.13	0.35	-0.11*	0.34*

28	CMS 52A X JBR 6	-3.74**	-3.28**	-6.20**	0.15**	0.00	0.06	-0.84*	-0.12*	-0.15
29	JMS 21A X JR 83	-0.03	1.69**	-2.34**	-0.32**	-0.00	-0.18	0.30	-0.06	0.21
30	JMS 21A X JR 85	-0.79**	-1.453*	1.94**	-0.17*	0.15*	-0.35*	-0.36	0.06	-0.28*
31	JMS 21A X JR 80	0.19	1.00*	1.83**	-0.30**	-0.22*	0.20	-0.26	0.04	-0.209
32	JMS 21A X JMBR 44	-1.01**	0.2	-0.40	0.04	0.12	-0.11	-0.36	-0.35**	0.39*
33	JMS 21A X JMBR 31	1.44**	1.86**	1.75*	0.23**	0.06	0.03	-0.11	0.04	-0.07
34	JMS 21A X JR 67	0.42*	-0.68	-3.98**	0.14*	-0.09	0.22	0.66*	0.13*	0.09
35	JMS 21A X JBR 6	-0.22	-2.70**	1.19*	0.39**	-0.01	0.20	0.15	0.12*	-0.13
36	JMS 20A X JR 83	-1.40**	0.74	4.28**	-0.03	-0.00	-0.01	-0.56*	0.11*	-0.45*
37	JMS 20A X JR 85	-0.00	-0.22	-2.27**	0.21**	-0.04	0.18	0.66*	-0.15*	0.57**
38	JMS 20A X JR 80	-0.17	-4.12**	-1.45*	-0.21**	-0.02	-0.06	0.51	0.08	0.07
39	JMS 20A X JMBR 44	-0.71**	1.59*	-0.04	0.13*	-0.02	0.10	0.41	-0.067	0.29*
40	JMS 20A X JMBR 31	1.71**	2.43**	-0.38	0.37**	-0.08	0.33*	0.61*	0.03	0.21
41	JMS 20A X JR 67	-0.35	-1.17*	-2.96**	-0.06	0.10	-0.19	-1.42**	-0.025	-0.57**
42	JMS 20A X JBR 6	0.94**	0.75	2.85**	-0.41**	0.08	-0.35*	-0.21	0.00	-0.11
43	CD 95 % SCA	0.38	0.92	1.03	0.10	0.14	0.26	0.52	0.10	0.28

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

Table 5: Reaction of genotypes against gall midge

S. No.	Genotypes	Damaged plants (silver shoots)	Scale (0-9)	Gall Midge Reaction
1	CMS 64B	11-25 %	7	Susceptible
2	JMS 11B	11-25 %	7	Susceptible
3	JMS 19B	1-5 %	3	Moderately resistant
4	CMS 52B	11-25 %	7	Susceptible
5	JMS 21B	Less than 1%	1	Resistant
6	JMS 20B	No damage	0	Highly resistant
7	JR 83	11-25 %	7	Susceptible
8	JR 85	1-5 %	3	Moderately resistant
9	JR 80	6-10 %	5	Moderately susceptible
10	JMBR 44	6-10 %	5	Moderately susceptible
11	JMBR 31	11-25 %	7	Susceptible
12	JR 67	11-25 %	7	Susceptible
13	JBR 6	6-10 %	5	Moderately susceptible
14	CMS 64A X JR 83	11-25 %	7	Susceptible
15	CMS 64A X JR 85	1-5 %	3	Moderately resistant
16	CMS 64A X JR 80	6-10 %	5	Moderately susceptible
17	CMS 64A X JMBR 44	1-5 %	3	Moderately resistant
18	CMS 64A X JMBR 31	11-25 %	7	Susceptible
19	CMS 64A X JR 67	11-25 %	7	Susceptible
20	CMS 64A X JBR 6	6-10 %	5	Moderately susceptible
21	JMS 11A X JR 83	11-25 %	7	Susceptible
22	JMS 11A X JR 85	1-5 %	3	Moderately resistant
23	JMS 11A X JR 80	6-10 %	5	Moderately susceptible
24	JMS 11A X JMBR 44	11-25 %	7	Susceptible
25	JMS 11A X JMBR 31	11-25 %	7	Susceptible

26	JMS 11A X JR 67	6-10 %	5	Moderately susceptible
27	JMS 11A X JBR 6	1-5 %	3	Moderately resistant
28	JMS 19A X JR 83	1-5 %	3	Moderately resistant
29	JMS 19A X JR 85	No damage	0	Highly resistant
30	JMS 19A X JR 80	1-5 %	3	Moderately resistant
31	JMS 19A X JMBR 44	No damage	0	Highly resistant
32	JMS 19A X JMBR 31	1-5 %	3	Moderately resistant
33	JMS 19A X JR 67	Less than 1%	1	Resistant
34	JMS 19A X JBR 6	1-5 %	3	Moderately resistant

Table 4.16

S. No.	Genotypes	Damaged plants (silver shoots)	Scale (0-9)	Gall Midge Reaction
35	CMS 52A X JR 83	11-25 %	7	Susceptible
36	CMS 52A X JR 85	1-5 %	3	Moderately resistant
37	CMS 52A X JR 80	6-10 %	5	Moderately susceptible
38	CMS 52A X JMBR 44	11-25 %	7	Susceptible
39	CMS 52A X JMBR 31	11-25 %	7	Susceptible
40	CMS 52A X JR 67	11-25 %	7	Susceptible
41	CMS 52A X JBR 6	6-10 %	5	Moderately susceptible
42	JMS 21A X JR 83	Less than 1%	1	Resistant
43	JMS 21A X JR 85	1-5 %	3	Moderately resistant
44	JMS 21A X JR 80	1-5 %	3	Moderately resistant
45	JMS 21A X JMBR 44	Less than 1%	1	Resistant
46	JMS 21A X JMBR 31	Less than 1%	1	Resistant
47	JMS 21A X JR 67	Less than 1%	1	Resistant
48	JMS 21A X JBR 6	1-5 %	3	Moderately resistant
49	JMS 20A X JR 83	1-5 %	3	Moderately resistant
50	JMS 20A X JR 85	1-5 %	3	Moderately resistant
51	JMS 20A X JR 80	1-5 %	3	Moderately resistant
52	JMS 20A X JMBR 44	6-10 %	5	Moderately susceptible
53	JMS 20A X JMBR 31	6-10 %	5	Moderately susceptible
54	JMS 20A X JR 67	Less than 1%	1	Resistant
55	JMS 20A X JBR 6	1-5 %	3	Moderately resistant
56	HRI 174	11-25 %	7	Susceptible
57	US 312	11-25 %	7	Susceptible
58	MTU 1010	6-10 %	5	Moderately susceptible
59	JGL 384	No damage	0	Highly resistant

CONCLUSION

There is potential for breeding rice for gall midge resistance using land race derived parental lines. Based on GCA and SCA effects, some lines and crosses have been identified with resistance to gall midge as well as other desirable yield related characters. On the whole based on the overall performance, among the testers JBR 6 and JMBR 44 among the lines JMS 20B, JMS 21B and JMS 19B were found to be the best in the present investigation. These lines could be used as parental materials and play an important role in breeding rice for gall midge resistance. Moreover, general and specific combining ability were found to be significant for gall midge resistance and other yield related characters. Variances due to SCA were higher in magnitude than GCA for midge resistance and yield related traits. Thus non-additive gene action was found to play an important role in controlling these traits. On the other hand, based on mean performance the crosses JMS 19A X JR 85 and JMS 19A X JMBR 44 were found to be the best gall midge resistant hybrids. The crosses JMS 19A X JR 80, JMS 19A X JR 83 and JMS 19A X JBR 6 were found to be the best hybrids for grain yield.

Future strategy

- The good general combiners identified in the present study can be used in future breeding programme to develop new commercial rice hybrids.
- The hybrids developed may be further tested extensively in different agro-climatic zones over seasons and years for their resistance reaction superiority and stability before commercial release.
- The other gall midge resistant parents can be used to develop rice hybrids with gall midge resistance. The identified gall midge resistant restorers would be useful in future hybrid breeding programmes to develop more restorers with diverse genetic background.The gall midge resistant lines identified as maintainer can be used to develop new gall midge resistant male sterile lines with diverse genetic background.

REFERENCES

1. Damodar Raju, Ch., Sudheer Kumar, S., Surender Raju, Ch. and Srijan, A., Combining ability studies in the selected parents and hybrids in rice (*Oryza sativa* .L), *Int.J. Pure App. Biosci.* **2(4):** 271-279 (2014).
2. Dharwal, G., Verma, O.P. and Verma, G.P., Combining ability analysis for grain yield and other associated traits in rice. *Int. J. Pure App. Biosci.* 5**(2):** 96-100 (2017).
3. Ghara, A.G., Nematzadeh, G., Bagheri, N., Ebrahimi, A. and Oladi, M., Evaluation of general and specific combining ability in parental lines of hybrid rice. *IJRR.* **2(4):** 455-460 (2012).
4. Hasan, M.J., Kulsum, U.K., Lipi, L.F. and Shamsuddin, A.K.M., Combining ability studies for developing new rice hybrids in Bangladesh. *Bangladesh J. Bot.* **42(2):** 215-222 (2013).
5. Harer, P.N. and Bapat, D.R., Line X tester analysis of combining ability in grain sorghum. *J. Maharashtra Agric. Univ.* (1982).
6. Kempthorne, O., *An Introduction to Genetic Statistics*. John Wiley and Sons Inc: New York, (1957).
7. Kenga, R., Albani, S.O. and Gupta. S.C., Combining ability studies in tropical sorghum [*Sorghum bicolor* L. (Meonch)]. *Field Crop Res*. **88:** 251-260 (2004).
8. Marilia, C.F., Servio, T.C., Vatter, O.R., Clibas, V. and Siu, T.M., Combining ability for nodulation in common bean (*Phaseolus vulgaris* L.) genotype from Andean and middle American gene pools. *Euphytica*. **118:** 265-270 (2001).
9. Muhammad, R., Cheema, A.A. and Muhammad, A., Line X tester analysis in Basmati rice. *Pak J Bot*. **39(6):** 2035-2042 (2007).
10. Nadali, B. and *Nadali, B.J,*. Heterosis and combining ability analysis for yield and yield related traits in hybrid rice. *I J B.* **2(2):** 222-231 (2010).
11. Pasalu, I. C. and Katti, G., Advances in ecofriendly in rice IPM. *Journal of Rice Research.* **1(1):** 83-90 (2006).
12. Rumanti, I.A., Purwoko, B.S., Dewi, I.S., Aswidinnoor, H. and Widyastuti, Y., Combining ability for yield and agronomic traits in hybrid rice derived from wild abortive, gambiaca and kalinga cytoplasmic male sterile lines. *SABRAO J BREED GENET*. **49(1):** 69-76 (2017).
13. Sarker, U., Biswas, P.S., Prasad, B. and Khaleque, M.M.A., Heterosis and genetic analysis in rice hybrid. *Pakistan Journal of Biological Science.* **5(1):** 1-5 (2002).
14. Bhatti, S., Pandey, D.P. and Dhirendra Singh., Combining ability and heterosis for yield and its component traits in rice (*Oryza sativa* L.). *EJPB.* **6(1):** 12-18 (2015).

15. Shukla, S.K. and Pandey, M.P., Combining ability and heterosis over environments for yield and yield components in two line hybrids involving thermosensitive genic male sterile lines in rice (*Oryza sativa* L.). *Plant Breed*. **127:** 28-32 (2008).
16. Latha, S.K., Sharma, D., Gulzar. and Sanghera, S., Combining ability and heterosis for grain yield and its component traits in rice (*Oryza sativa* L.). *Not Sci Biol*. **5(1)*:*** 90-97 (2013).