Journal of Applied and Natural Science 9 (3): 1557 –1565 (2017)

JANS

Gene action and combining ability estimates of newly developed CMS based heterotic rice hybrids (*Oryza sativa* L.)

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Received: December 2, 2016; Revised received: April 5, 2017; Accepted: August 2, 2017

Abstract: An insight knowledge nature and relative magnitude of gene actions involved and combining ability is useful for a breeder to assess nicking ability in self-pollinated crops. In this connection, an attempt was made to estimate the gene action and combining ability of 70 newly developed CMS based heterotic rice hybrids developed from ten newly developed CMS lines and seven testers were evaluated for grain yield and its components at Hybrid rice scheme, ZARS, V. C. Farm, Mandya. Among the lines, CMS 2 had significant *gca* effects at 1% level of significance in desired direction for four traits *viz.,* panicle weight, pollen fertility, spikelet fertility and number of spikelets per panicle. Out of seven testers, KMR 3 found to be good general combiner for five traits *viz.*, days to 50 per cent flowering, plant height, number of tillers per plant, number of panicles per plant and grain L/B ratio. Among the 70 hybrids, CMS1 × KMR3 was good specific combiner for grain yield per plant and grain L/B ratio. It further revealed that SCA variances were higher than the GCA variances for all the characters which indicated preponderance of non-additive gene action. Hence, CMS 2 and KMR 3 are identified as promising lines which can be used in further breeding programme.

Keywords: CMS lines, Combining ability, Gene action, GCA, SCA

INTRODUCTION

Rice is an important cereal crop and staple food crop of India which occupies an area of 43.97 million ha which is the largest in the world, with an annual production of around 106.3 million tonnes which is the second largest in the world after China. To meet the demands of increasing population and to maintain self-sufficiency, the present production levels need to be increased up to 120 million tons by 2020. The production of rice needs to be increased by almost 2 million tons every year. In order to keep pace with the growing population, the production and productivity of rice needs to be enhanced. It has been proved that use of Cytoplasmic Male Sterility (CMS) in developing rice hybrids increases grain yield by more than 20% relative to improved inbred rice varieties (Yuan and Virmani, 1994) and also an insight knowledge of nature and relative magnitude of gene actions involved and combining ability of the parents used in hybridization in the genetic improvement of the crop is needed for a breeder to assess nicking ability in self pollinated crops. According to Arunachalam (1976), the combining ability is a better biometrical tool to circumvent the plant breeding program. Among large array of biometrical procedures for relative estimation of genetic components, line x tester by Kempthorne (1957) is an efficient procedures as it allows for inclusion of a large number of lines and provides reliable estimates of genetic components, estimates of combining ability and gene action governing a complextrait. Therefore, the present investigation was carried out with a view to understand the nature of gene action and combining ability for yield and its attributesin newly developed CMS based heterotic rice hybrids through line × tester analysis.

MATERIALS AND METHODS

The experiment comprised of ten newly developed CMS lines (Table 1) and seven testers (Table 2) are crossed in line × tester mating design as suggested by Kempthorne (1957). Clipping and dusting method of crossing was followed to produce 70 F_1's at Hybrid rice scheme, ZARS, V. C. Farm, Mandya during summer 2014. The resulting 70 F_1's along with their parental lines

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and three standard checks *viz*., KRH-2, KRH-4 and GK5003 were evaluated at Hybrid rice scheme, ZARS, V. C. Farm, Mandya during *Kharif* 2014. The experimental site is located at latitude of 12º 30'N, longitude of 76º 50'E and altitude of 694.65 meters above mean sea level (MSL) with red sandy loam soil type. The experiment was raised by transplanting seedling with a spacing of 20 cm × 15 cm in single rows with single seedling per hill in a Randomized Complete Block Design (RCBD) with two replications. All the recommended package of practices was followed timely to ensure good crop establishment. The observation on grain yield and its 12 important component traits were recorded from five competitive plants which were selected randomly. The mean values of these ten plants were used for combining ability analysis (line × tester) as computed according to the model given by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance carried out for 12 quantitative traits studied indicated that highly significant differences at 1% level of significance existed among the genotypes, thereby justifying the use of experimental material for the study (Table 3). The mean sum of squares due to hybrids was highly significant at 1% level of significance, indicating the diverse performance of different cross combinations. The mean sum of squares due to parents versus crosses was highly significant for all traits except for grain L/B ratio, revealing the presence of heterosis due to the significant difference in the mean performance of hybrids and parents. These results were in agreement with earlier reports of Ananda Kumar *et al.* (2004), Kumar *et al.* (2008), Abhinav and Motiramani (2006) and Fiaz *et al*. (2006) in rice. Significant differences were also observed in all traits for both testers (male) and lines (females) justifying there is a scope for selection of parents in the present study.

Combining ability analysis of present study revealed that both GCA and SCA variances among various traits studied were important for the inheritance of traits (Table 4). It further revealed that SCA variances were higher than the GCA variances which indicated preponderance of non-additive gene action for all the characters. These results are in conformity with the findings of Ganesan *et al.* (1998), Vanaja *et al.* (2003), Anand Kumar *et al.* (2004), Sharma and Mani (2008), Utharasu and Anand Kumar, (2013) and Dadilakshmi and Upendra (2014) in rice.

Table 1. List of CMS lines along with parentage and source of cytoplasm.

Sl. No	CMS lines	Parentage	Cytoplasmic source in CMS line (A line)
1	CMS 1	KCMS 40A	CMS – WA
2	CMS 2	KCMS 48A	CMS – WA
3	CMS 3	IR 68888A/Pragathi	CMS – WA
4	CMS 4	IR 68902A/MSN- 20-12-1-2	CMS – WA
5	CMS 5	IR 68896A/MSN 43	CMS – WA
6	CMS 6	IR 68888A/IR 20	CMS – WA
7	CMS 7	IR 68888A/MSN-20-13-1-1	CMS – WA
8	CMS 8	IR 70369A/MSN 96	CMS – WA
9	CMS 9	IR 70365A/IR 20	CMS – WA
10	CMS 10	IR62829A/IR 30864	CMS – WA

Table 2. List of testers used along with their parentage.

Sl. No	Testers	Parentage
1	MSN – 36	Selection from MRP 5180a
2	KMR -3	Jaya/IR29723-143-3-2-1
3	MSN -71	IR 9761/KMR 3R
4	MSN -15-16	Jyothi/ KMR 3R
5	PBK 093-1-4-2-1	IR60919/ MSN-36
6	PBK 095-5-4-5-1	CRMS 32 B/Thanu
7	PBK 091-3-7-1-1	MSN- 98/Athira

Table 3. Analysis of variance for yield and yield contributing characters.

Source of variation	df	Days to 50% flowering	Plant height (cm)	Number of tillers/plant	Number of panicles/Plant	Panicle weight (g)	Panicle length (cm)
Replication	1	0.47	1.04	0.29	0.27	0.01	0.32
Genotype	86	20.10**	167.46**	10.59**	7.61**	1.84**	11.00**
Parent	16	28.69**	555.80**	25.23**	17.47**	1.64**	7.42**
Crosses	69	18.04**	35.09**	6.26**	4.57**	1.86**	9.80**
Crosses *Vs* Parents	1	25.04**	3087.42**	75.37**	59.28**	3.59**	151.25**
Lines(c)	9	36.75**	49.96**	7.55**	5.26**	2.26**	10.30**
Testers (c)	6	26.35**	25.63**	6.36**	4.29**	5.44**	15.06**
L×T (c)	54	14.00**	33.66**	6.03**	4.49**	1.39**	9.13**
Error	86	0.86	1.04	0.15	0.07	0.08	0.11

*Significant at P=0.05 level, **Significant at P=0.01 level

Table3. Contd….

Source of variation	df	Pollen fertility(%)	Number of spikelets/ Panicle	Spikelet fertility (%)	Seed Yield/plant (g)	1000 grain weight (g)	L/B ratio
Replication	1	0.23	29.04	2.87	0.63	1.24	0.04
Genotype	86	767.70**	2757.88**	916.47**	156.63**	21.77**	0.32**
Parent	16	42.36**	2883.52**	123.03**	30.94**	29.35**	0.32**
Crosses	69	819.72**	2763.97**	976.15**	135.22**	20.17**	0.33**
Crosses *Vs* Parents	1	8784.14**	327.33**	9493.46**	3645.26**	10.60**	0.07
Lines(c)	9	859.51**	2489.59**	867.94**	165.57**	36.26**	0.45**
Testers (c)	6	3597.86**	4277.35**	4550.08**	434.44**	25.61**	0.29**
L×T (c)	54	504.40**	2641.55**	597.09**	96.92**	16.89**	0.31**
Error	86	3.08	33.34	1.84	1.41	1.17	0.01

*Significant at P=0.05 level,**Significant at P=0.01 level

Table 4. Estimates of variance components for yield and yield contributing characters.

Sl. No	Characters	σ^2GCA	σ^2SCA	σ^2GCA/ σ^2SCA
1	Days to 50% flowering	0.08	6.59	0.01
2	Plant height (cm)	0.03	16.34	0.002
3	Number of tillers/plant	0.00	2.94	0.001
4	Number of panicles/plant	0.00	2.20	0.0007
5	Panicle weight(g)	0.01	0.66	0.01
6	Panicle length(cm)	0.01	4.51	0.002
7	Pollen fertility(%)	5.90	250.86	0.02
8	Number of spikelets/ panicle	2.29	1304.54	0.0001
9	Spikelet fertility (%)	7.09	297.66	0.02
10	Seed yield per plant (g)	0.72	48.18	0.01
11	1000 grain weight (g)	0.06	7.81	0.007
12	L/B ratio	0.00	0.15	0.001

The *gca* effects calculated for each parent are presented in Table 5. The parents with higher magnitude of *gca* effects were considered as superior to those with lower magnitude. The overall estimate of *gca* effects revealed that among 10 lines, CMS 2 had significant *gca* effects in desired direction for four traits *viz.,* panicle weight, pollen fertility, spikelet fertility and number of spikelets per panicle. Out of seven testers, KMR 3 found to be good general combiner for five traits *viz*., days to 50 per cent flowering, plant height, number of tillers per plant, number of panicles per plant and grain L/B ratio. While, PBK 091-3-7-1-1 had high *gca* effects in desired direction for number of spikelets per panicle, seed yield and 1000 grain weight. Superiority of female and male parents based on *gca* effects was also reported by Swamy *et al*. (2003), Abhinav and Motiramani (2006) and Patil *et al*. (2011) in rice.

Among 70 hybrids, CMS 9 × MSN 71 was found to be a good specific combiner for two traits *viz.,* number of tillers per plant and number of panicles per plant (Table 6). The hybrid, CMS1 × KMR3 was a good specific combiner for grain yield per plant and grain L/B ratio in desirable direction. For pollen fertility and spikelet fertility, the hybrid CMS2 × MSN 71 was found superior. Most of the hybrids showed highly significant *sca* effects for plant height, among these hybrids, CMS4 × PBK 093-1-4-4-2-1 and CMS5 × PBK 091-3-7-1-1were identified as best specific combiners for plant height. The hybrids CMS3 × PBK 095-5-4-5-1 and CMS10 × MSN 71 showed highly significant *sca* effects and are identified as best specific combiner for panicle weight and panicle length, respectively. In the same line, Swamy *et al.* (2003), Jagadeesan and Ganesan (2006), Nadali and Babaein (2010), Saidaiah *et al.* (2010), Tiwary *et al*. (2011), Patil *et al*. (2011) and Damodar *et al.* (2014) identified good specific combiners for different yield attributing traits in rice based on high *sca* effects in desirable direction.

Conclusion

Among lines, CMS 2 had significant *gca* effects in desired direction for four important yield contributing traits *viz.,* panicle weight, pollen fertility, spikelet fertility and number of spikelets per panicle. Among testers, KMR 3 was found to be a good general combiner for the five important yield contributing traits *viz*., days to 50 per cent flowering, plant height, number of tillers per plant, number of panicles per plant and grain L/B ratio while, PBK 091-3-7-1-1 showed high *gca* effects in desired direction for number of spikelets per panicle, seed yield and 1000 grain weight. Among crosses,CMS1×KMR3 was identified as good specific combiner for seed yield per plant which need to be tested and released for commercial cultivation. Selection of parents with good combining ability for selective traits that could complement each other favourably in the hybrids would be a desirable approach to breed better hybrid combinations. Thus, these testers and cross combinations could be used for exploitation of heterosis in further hybrid breeding program.

Table 5. Estimates of general combining ability effects in lines and testers for yield and yield contributing character.

Lines	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
CMS 1	2.92 **	2.29 **	0.05	0.43 **	0.51**	0.48**	1.49**	7.87**	1.84**	4.77**	1.92**	-0.32**
CMS 2	-1.15 **	3.06 **	-1.33**	-0.77 **	0.57**	0.00	11.06**	14.71**	11.33**	3.16**	1.91**	0.02
CMS 3	-0.72 **	-0.34 ns	-1.03**	-0.22 **	-0.29**	1.5**	-2.25**	-31.94**	-1.68**	-1.78**	2.38**	-0.2**
CMS 4	-3.15 **	-0.84 **	0.27**	-0.52 **	-0.34**	0.36**	3.33**	2.41	4.19**	-1.05**	-1.79**	0.06*
CMS 5	0.56 *	1.93 **	0.37**	0.08 ns	0.04	0.21*	10.2**	-1.70	10.01**	1.13**	-1.16**	0.08**
CMS 6	0.85 **	0.68 *	0.12	-0.33 **	0.43**	0.12	-10.45**	9.94**	-10.98**	-3.29**	-0.23	-0.02
CMS 7	0.21 ns	-2.53 **	0.17	-0.47 **	-0.08	-0.5**	2.77**	-10.87**	1.48**	-2.61**	-1.59**	0.33**
CMS 8	0.49 *	-1.62 **	-0.04	0.29 **	-0.53**	-1.9**	-12.12**	8.68**	-11.89**	-5.85**	-1.7**	0.13**
CMS 9	-1.01 **	-1.30 **	1.32**	1.36 **	0.12	0.04	2.24**	0.87	1.87**	3.49**	-0.22	0.02
CMS 10	0.99 **	-1.34 **	0.11	0.14 ns	-0.43**	-0.3**	-6.26**	0.03	-6.18**	2.03**	0.46	-0.08**
SEm±	**0.24**	**0.26**	**0.10**	**0.07**	**0.07**	**0.08**	**0.43**	**1.52**	**0.35**	**0.19**	**0.29**	**0.02**
Testers												
MSN 36	-0.77 **	-0.97 **	-0.52**	-0.04 ns	0.09	0.4**	8.88**	-3.17*	9.8**	-1.33**	-1.64**	-0.03
KMR3	-1.27 **	-1.00 **	0.70**	0.50 **	-0.16*	-0.06	3.64**	0.78	3.23**	1.32**	1.16**	0.16**
MSN-71	0.78 **	-0.34 ns	0.30**	0.57 **	-0.79**	-0.56**	-23.53**	-15.5**	-27.21**	-6.84**	-0.76**	-0.07**
MSN-15-16	1.68 **	-0.06 ns	-0.93**	-0.58 **	-0.37**	-1.19**	-14.41**	0.48	-15.02**	-3.51**	0.74**	0.12**
PBK 093-1-4-2-1	-1.22 **	0.99 **	0.44**	0.30 **	-0.03	0.19**	5.92**	-19.05**	7.70**	-1.12**	-0.84**	0.07**
PBK 095-5-4-5-1	-0.07 ns	2.05 **	0.08	-0.41 **	0.77**	1.57**	10.11**	16.8**	11.74**	5.14**	-0.01	-0.06**
PBK 091-3-7-1-1	0.88 **	-0.67 **	-0.07	-0.35 **	0.48**	-0.36**	9.4**	19.67**	9.77**	6.33**	1.36**	-0.19**
SEm ±	**0.20**	**0.22**	**0.08**	**0.06**	**0.06**	0.07	**0.36**	**1.27**	**0.29**	**0.16**	**0.25**	**0.02**

*Significant at P=0.05 level, **Significant at P=0.01 level;X1: Days to 50% flowering; X2: Plant height (cm) ; X3:Number of tillers/plant ; X4: Number of panicles/plant; X5: Panicle weight (g); X6: Panicle length (cm) ; X7: Pollen fertility (%); X8: Number of spikelets/panicle; X9: Spikelet fertility (%); X10: Seed yield per plant (g) X11:1000 grain weight (g) X12: Grain L/B ratio

Table 6. Estimates of specific combining ability effects in crosses for yield and yield contributing characters

Hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
CMS1×Tester1	2.13 **	-0.66	1.75**	0.50 *	-0.60**	0.53*	-3.30**	-54.93**	-3.58**	-4.91**	2.42**	-0.59**
CMS1×Tester2	-1.87 **	0.36	3.22**	3.44 **	1.10**	1.44**	19.78**	10.12*	22.08**	18.34**	1.29	-0.42**
CMS1×Tester3	2.58 **	-7.29 **	-1.52**	-1.01 **	-1.02**	-2.61**	-11.14**	-14.60**	-11.18**	-7.57**	-3.92**	-0.49**
CMS1×Tester4	0.18	1.37	-2.44**	-1.06 **	0.76**	0.03	5.92**	-14.08**	6.63**	-5.94**	0.86	0.75**
CMS1×Tester5	2.08 **	0.02	-1.11**	-0.49 *	-0.48*	-0.06	1.28	-25.45**	1.85	3.67**	1.92*	-0.00
CMS1×Tester6	-1.07	4.91 **	-0.38	-0.83 **	1.02**	-0.53*	-1.50	59.60**	-2.45*	-2.74**	-3.25**	0.54**
CMS1×Tester7	-4.02 **	1.28	0.48	-0.55 **	-0.79**	1.20**	-11.02**	39.33**	-13.35**	-0.85	0.67	0.22**
CMS2×Tester1	-2.30 **	-0.99	-0.52	0.14	-0.16	1.91**	-4.16**	13.53**	-2.83**	1.41**	-1.00	0.08
CMS2×Tester2	-3.80 **	1.08	0.11	0.06	-0.06	-1.63**	-1.77	10.94**	-6.08**	1.70**	0.42	-0.02
CMS2×Tester3	2.15 **	-1.72 *	-1.58**	-1.47 **	1.17**	-0.93**	27.40**	-14.24**	34.02**	6.08**	5.48**	0.10
CMS2×Tester4	-1.75 **	-5.20 **	1.04**	-0.36	0.55**	-1.00**	14.21**	-7.32	14.15**	4.86**	1.02	-0.19**
CMS2×Tester5	3.15 **	7.55 **	1.72**	1.76 **	-0.24	0.92**	-7.15**	-30.08**	-8.67**	-1.93**	-1.33	0.02
CMS2×Tester6	4.00 **	3.14 **	-0.24	-0.64 **	-1.15**	-1.05**	-2.90*	-14.74**	-2.73**	-5.93**	-1.81*	-0.13
CMS2×Tester7	-1.45 *	-3.85 **	-0.53	0.51 *	-0.11	1.78**	-25.63**	41.90**	-27.85**	-6.19**	-2.77**	0.14
CMS3×Tester1	-2.23 **	-0.04	-0.77**	-0.96 **	0.15	0.45	-9.78**	37.48**	-14.87**	-4.58**	1.12	0.29**
CMS3×Tester2	-0.23	-0.67	-1.25**	-0.49 *	0.00	2.94**	25.61**	-20.46**	26.81**	5.68**	3.03**	-0.17*
CMS3×Tester3	0.72	-5.12 **	-1.75**	-1.76 **	-0.57**	0.28	-10.59**	29.51**	-11.97**	0.01	-1.78*	0.26**
CMS3×Tester4	0.32	-0.50	0.38	-0.02	0.56**	-1.12**	10.55**	16.53**	13.10**	3.55**	1.49	-0.07
CMS3×Tester5	1.72 **	3.05 **	3.21**	3.26 **	-0.23	1.53**	-9.72**	-28.03**	-9.72**	-0.64	0.83	0.00
CMS3×Tester6	0.07	1.24	1.69**	1.21 **	1.37**	0.74**	-2.96*	-10.59*	-2.78**	6.28**	3.13**	0.24**
CMS3×Tester7	-0.38	2.05 **	-1.52**	-1.24 **	-1.29**	-4.82**	-3.11**	-24.45**	-0.57	-10.29**	-7.83**	-0.55**
CMS4×Tester1	-0.80	-2.49 **	1.54**	0.94 **	-0.20	-0.84**	-4.31**	-33.47**	-3.80**	1.74**	6.00**	-0.41**
CMS4×Tester2	1.20	-4.32 **	-0.47	-1.69 **	0.05	0.08	0.05	1.18	-0.07	-4.85**	-3.86**	1.02**
CMS4×Tester3	1.15	4.78 **	-0.98**	0.39	1.13**	1.38**	20.20**	16.16**	22.42**	8.21**	0.67	0.09
CMS4×Tester4	2.25 **	3.70 **	1.19**	0.38	-0.44*	2.25**	-28.85**	22.98**	-29.99**	-3.92**	2.16**	-0.28**

*Significant at P=0.05 level,**Significant at P=0.01 level; Tester 1: MSN 36; Tester 2: KMR3; Tester 3: MSN-71; Tester 4: MSN-15-16; Tester 5: PBK 093-1-4-2-1; Tester 6: PBK 095-5-4-5-1; Tester 7: PBK 091-3-7-1-1

Table 6. Contd…

Hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
CMS4×Tester5	-0.85	-7.35 **	-1.00**	-0.34	-0.23	-1.00**	12.49**	6.31	11.60**	1.47**	-2.96**	0.34**
CMS4×Tester6	-1.00	1.24	-0.86**	-0.04	-1.64**	-0.51*	-9.74**	-26.94**	-8.60**	-10.66**	-1.65*	-0.58**
CMS4×Tester7	-1.95 **	4.45 **	0.58*	0.36	1.35**	-1.35**	10.16**	13.79**	8.44**	8.01**	-0.35	-0.19**
CMS5×Tester1	-2.01 **	3.52 **	2.70**	2.53 **	-0.03	1.61**	0.92	48.24**	1.51	12.52**	-2.63**	0.02
CMS5×Tester2	2.49 **	2.87 **	-3.36**	-2.39 **	-0.28	-1.83**	-9.96**	-37.00**	-5.83**	-9.85**	0.20	-0.36**
CMS5×Tester3	-4.06 **	1.61 *	0.95**	0.79 **	-0.75**	0.53*	-9.27**	-24.63**	-15.46**	-2.83**	3.77**	-0.22**
CMS5×Tester4	-1.46 *	-0.17	-0.72**	-0.56 **	-0.22	-1.67**	11.99**	-34.11**	14.45**	-4.02**	0.41	0.15*
CMS5×Tester5	-1.06	4.43 **	-1.19**	-1.34 **	0.09	2.29**	5.66**	3.33	3.75**	-0.84	0.80	-0.02
CMS5×Tester6	2.79 **	-5.83 **	-0.94**	-0.68 **	0.34	-3.26**	2.48*	4.77	3.69**	-2.91**	-1.24	-0.44**
CMS5×Tester7	3.34 **	-6.43 **	2.56**	1.66 **	0.83**	2.34**	-1.81	39.41**	-2.10*	7.93**	-1.31	0.87**
CMS6×Tester1	-1.30 *	2.94 **	-2.07**	-1.35 **	0.23	2.70**	10.46**	32.30**	8.85**	0.81	-2.64**	-0.16*
CMS6×Tester2	3.20 **	3.07 **	1.53**	1.25 **	-0.87**	-2.31**	-23.80**	52.25**	-24.88**	-0.82	1.80*	0.20**
CMS6×Tester3	2.15 **	-1.09	1.11**	0.05	1.16**	-2.04**	-0.05	45.93**	-0.54	5.39**	1.74*	-0.02
CMS6×Tester4	1.25	-3.82 **	-1.81**	-1.11 **	-1.06**	-2.48**	-7.07**	-60.55**	-7.57**	-1.30*	-1.70*	0.18**
CMS6×Tester5	-4.35 **	5.43 **	-1.83**	-0.68 **	0.15	0.87**	5.78**	38.18**	10.75**	-2.03**	-2.88**	0.31**
CMS6×Tester6	-3.00 **	-4.93 **	2.36**	1.17 **	0.75**	4.50**	6.36**	-58.07**	5.60**	0.57	1.31	-0.46**
CMS6×Tester7	2.05 **	-1.61 *	0.71*	0.67 **	-0.36	-1.24**	8.32**	-50.04**	7.79**	-2.62**	2.37**	-0.05
CMS7×Tester1	4.34 **	-0.55	0.05	0.50 *	0.59**	-1.55**	4.17**	18.91**	3.03**	4.63**	0.47	0.34**
CMS7×Tester2	0.84	-1.27	-0.19	0.36	-0.76**	0.91**	-40.74**	-10.23*	-43.35**	-11.31**	-5.67**	-0.09
CMS7×Tester3	-4.21 **	-2.75 **	0.92**	-0.86 **	0.88**	0.41	-12.19**	-19.91**	-12.84**	-2.29**	-1.07	-0.39**
CMS7×Tester4	-2.11 **	-0.71	-0.55*	0.39	0.55**	1.04**	14.64**	-13.54**	15.93**	4.26**	-0.73	0.29**
CMS7×Tester5	1.79 **	-0.66	0.08	-0.59 **	0.56**	0.82**	12.14**	9.05*	11.08**	4.06**	0.57	-0.31**
CMS7×Tester6	-0.36	3.68 **	-0.69*	0.17	-0.05	-1.72**	13.98**	37.94**	16.06**	4.83**	1.93*	0.26**
CMS7×Tester7	-0.31	2.25 **	0.37	0.02	-0.01	0.08	8.00**	-22.22**	10.08**	-4.16**	4.50**	-0.10
CMS8×Tester1	2.06 **	-2.71 **	-1.76**	-1.22 **	0.49*	-2.13**	6.10**	-13.24**	8.76**	0.45	-0.35	0.55**

*Significant at P=0.05 level ; **Significant at P=0.01 level;Tester 1: MSN 36; Tester 2: KMR3; Tester 3: MSN-71; Tester 4: MSN-15-16;Tester 5: PBK 093-1-4-2-1; Tester 6: PBK 095-5-4-5-1; Tester 7: PBK 091-3-7-1-1

Table 6. Contd…

Hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
CMS8×Tester2	0.56	-1.43 *	0.97**	1.84 **	0.64**	-0.52*	11.42**	10.12*	9.99**	1.84**	-0.98	0.30**
CMS8×Tester3	-0.49	3.66 **	1.28**	0.63 **	-0.18	-2.19**	-1.56	-26.01**	0.24	1.11*	-0.30	0.10
CMS8×Tester4	-3.39 **	2.48 **	1.33**	0.80 **	-0.65**	2.61**	-12.78**	12.71**	-13.69**	0.46	0.12	-0.45**
CMS8×Tester5	0.51	-2.67 **	0.29	-0.25	0.96**	-0.60*	21.99**	4.85	22.78**	11.29**	1.08	-0.09
CMS8×Tester6	-1.64 *	-4.73 **	0.49	0.10	-1.55**	1.35**	-31.45**	15.09**	-37.54**	-7.94**	-0.69	-0.14*
CMS8×Tester7	2.41 **	5.39 **	-2.59**	-1.90 **	0.29	1.48**	6.28**	-3.52	9.45**	-7.21**	1.12	-0.27**
CMS9×Tester1	-3.44 **	-4.53 **	-1.11**	-1.28 **	-1.06**	-2.93**	-0.25	-54.33**	-1.12	-6.82**	1.97*	-0.31**
CMS9×Tester2	-3.44 **	1.27	0.48	-1.57 **	-0.41*	2.03**	-0.05	13.52**	2.24*	-0.44	0.64	-0.11
CMS9×Tester3	0.01	2.34 **	4.01**	4.71 **	-0.88**	0.20	-15.92**	-38.90**	-16.48**	-6.43**	-3.32**	-0.12
CMS9×Tester4	5.11 **	5.46 **	1.20**	1.80 **	0.70**	1.50**	9.99**	7.82	4.25**	7.46**	0.06	0.07
CMS9×Tester5	-2.99 **	-3.99 **	-2.08**	-2.37 **	0.16	-4.05**	-6.53**	0.75	-2.28*	-7.59**	-1.95*	0.03
CMS9×Tester6	2.86 **	3.50 **	-1.89**	-1.12 **	1.25**	2.57**	7.63**	56.00**	9.79**	9.48**	0.96	0.63**
CMS9×Tester7	1.91 **	-4.04 **	-0.61*	-0.17	0.24	0.67**	5.13**	15.13**	3.59**	4.34**	1.64*	-0.20**
CMS10×Tester1	3.56 **	5.51 **	0.19	0.19	0.59**	0.24	0.15	5.51	4.06**	-5.25**	-5.37**	0.19**
CMS10×Tester2	1.06	-0.97	-1.05**	-0.80 **	0.59**	-1.12**	19.47**	-30.44**	19.09**	-0.29	3.13**	-0.36**
CMS10×Tester3	0.01	5.58 **	-2.44**	-1.46 **	0.82**	4.98**	13.13**	46.68**	11.79**	-1.67**	-1.28	0.69**
CMS10×Tester4	-0.39	-2.60 **	0.38	-0.28	-0.75**	-1.15**	-18.59**	69.56**	-17.27**	-5.41**	-3.70**	-0.45**
CMS10×Tester5	0.01	-5.80 **	1.92**	1.05 **	-0.74**	-0.71**	-35.94**	21.09**	-41.14**	-7.44**	3.93**	-0.28**
CMS10×Tester6	-2.64 **	-2.21 **	0.46	0.65 **	-0.35	-2.08**	18.08**	-63.06**	18.96**	9.02**	1.32	0.08
CMS10×Tester7	-1.59 *	0.50	0.55*	0.65 **	-0.16	-0.15	3.70**	-49.33**	4.51**	11.03**	1.97*	0.14*

*Significant at P=0.05 level, **Significant at P=0.01 level;Tester 1: MSN 36 Tester 2: KMR3 Tester 3: MSN-71 Tester 4: MSN-15-16;Tester 5: PBK 093-1-4-2-1 Tester 6: PBK 095-5-4-5-1; Tester 7: PBK 091-3-7-1-1;X1: Days to 50% flowering; X2: Plant height (cm) X3:Number of tillers/plant X4: Number of panicles/plant X5: Panicle weight (g) X6: Panicle length (cm); X7: Pollen fertility (%); X8: Number of spikelets/panicle ; X9: Spikelet fertility (%); X10: Seed yield per plant (g) X11:1000 grain weight (g) X12: Grain L/B ratioX1: Days to 50% flowering X2: Plant height (cm); X3:Number of tillers/plant X4: Number of panicles/plant X5: Panicle weight (g) X6: Panicle length (cm) X7: Pollen fertility (%); X8: Number of spikelets/panicle X9: Spikelet fertility (%); X10: Seed yield per plant (g) X11:1000 grain weight (g) X12: Grain L/B ratio X1: Days to 50% flowering; X2: Plant height (cm);X3:Number of tillers/plant X4: Number of panicles/plant X5: Panicle weight (g); X6: Panicle length (cm); X7: Pollen fertility (%); X8: Number of spikelets/panicle X9:

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