Pak. J. Bot., 45(6): 1897-1904, 2013.

GENETICS OF FLORAL TRAITS IN CYTOPLASMIC MALE STERILE (CMS) AND RESTORER LINES OF HYBRID RICE (*ORYZA SATIVA* L.)

MAHALINGAM. A[1*], R. SARASWATHI[2], J. RAMALINGAM[3] AND T. JAYARAJ[4]

[1]***Centre for Plant Breeding and Genetics****, Tamil Nadu Agricultural University, Coimbatore*
[2]*Plant Breeding and Genetics Unit, Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai*
[3]*Department of Bioinformatics, Centre for Plant Molecular Biology, Tamil Nadu Agricultural University, Coimbatore*
[4]*Director, Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai*
[*]*Corresponding author's e-mail: mahalingamcpbg2008@gmail.com*

Abstract

The present scientific study was taken up at Tamil Nadu Rice Research institute (TRRI), Aduthurai to study the genetic parameters and association among the floral traits of CMS lines and identification of parental lines having potential outcrossing ability for hybrid seed production. Among the five CMS lines and fifty one tester lines studied for eleven floral traits, CMS line COMS 23A registered higher mean value for style length, breadth and panicle exsertion. The genotype COMS 24A had greater stigma breadth, while COMS 25A had long style with good stigma length and breadth. All the CMS lines had above 99.50% pollen sterility. Analysis of variance revealed significant differences among the CMS lines for all floral traits studied. High heritability coupled with high genetic advance as percent of mean was recorded for five traits *viz.,* anther length, stigma length, style breadth, glume opening angle and stigma exsertion rate suggesting the improvement of these characters through simple phenotypic selection. Association analysis of floral traits in the CMS lines revealed that glume opening angle had strong positive and significant association with stigma exsertion rate. Stigma length had positive non – significant association with stigma exsertion rate. No association between anther size and pollen fertility or spikelet fertility in tester line could be established. Out crossing will be higher in seed production of hybrids resulting from any of the four CMS lines *viz.,* COMS 23A, COMS 25A, CRMS 31A and CRMS 32A since each CMS line had some of the desirable floral trait. COMS 23A and COMS 25A had desirable stigma characters, while CRMS 31A and CRMS 32 had desirable glume opening angle which is highly associated with higher out crossing rate.

Introduction

Rice (*Oryza sativa* L.) occupies a predominant position among major food grains fulfilling about 60% dietary requirement, 20% calorie and 14% protein requirement of the world`s population. Of the annual world production of 596.485 million tonnes from 155.128 million hectares, Asia produces 540.621 million tons from 138.563 million hectares (Swaminathan & Appa Rao, 2009). In the present decade, the rate of increase in rice production is lower (1.5% per year) than the increase in population (1.8% per year). If this trend is not reversed, severe food shortage will occur in the next century (Khush, 2005). The present world population of 6.3 billion is likely to reach 8.5 billion by 2030. Out of this, 5 billion people will be rice consumers and there is a need of 38% more rice by 2030. To meet this challenge there is a need to develop rice varieties with higher yield potential and greater yield stability (Khush, 2006).

Hybrid rice is one of the practically feasible and readily adoptable technology to increase the production and productivity of rice. In India, it was included as an important component under the National Food Security Mission (NFSM). A total of 46 rice hybrids have been released in India upto 2010-11 by Indian Council of Agricultural Research, State Agricultural Universities and private companies (AICRIP Annual Workshop, 2011). Fifteen years after the release of first hybrid for commercial cultivation in the year 1994, the area planted with hybrid rice reached 14 lakh hectares (2.6% of the total rice area) during the year 2008.

In self pollinated crops like rice, hybrid breeding appeared to be difficult, as the floral traits are unfavourable for outcrossing. Use of male sterility system has immensely helped in hybrid breeding. However, all the lines do not perform equally well and also give variable heterosis with differential restoration. Thus, the characterization of CMS lines for floral traits is one of the important aspects that a breeder should keep in mind while selecting a parental line in hybrid breeding programme. In rice, outcrossing is mainly influenced by floral traits and anthesis which plays a significant role in hybrid seed production. Natural outcrossing upto 6.8% has been reported in rice varieties (Sahadevan & Namboodiri, 1963). Accessions of *O. sativa* f. *spontanea* have shown upto 50% outcrossing (Sakai & Narise, 1959) and *O.perennis* accessions have shown up to 100% outcrossing (Oka & Morishima, 1967). The extent of outcrossing on male sterile line is influenced by its floral traits *viz.,* stigma exsertion, glume angle and duration of spikelet opening and anther size, filament length and duration of spikelet opening of the pollen parent. Hence, the present scientific study was taken up with an objective of studying the genetics parameters and association among the floral traits of CMS and tester or restorer lines of hybrid rice.

Materials and Methods

Five CMS lines *viz.,* COMS23A, COMS24A, COMS25A, CRMS31A, CRMS32A and 51 tester or restorer lines comprising of genetic materials from AICRIP, advanced cultures and recently stabilized breeding lines from TRRI, Aduthurai formed the basic material for this study. Experiment was conducted at Tamilnadu Rice Research Institute, Aduthurai, India. Ten floral characters *viz.,* anther length, anther breadth, stigma length, stigma breadth, style length, style breadth, glume opening angle, stigma exsertion rate, panicle exsertion rate and pollen sterility were recorded in 5 cytoplasmicaly male sterile lines and anther length, anther breadth and number of pollen grains per anther were recorded among the 51 tester lines. These floral traits were measured as per the procedure given below. Observations were recorded on three randomly selected plants per replication. The data was utilized for the estimation of genetic parameters and association among the floral traits.

Anther, stigma, style length and breadth measurement: The anther length, anther breadth, style length, style breadth, stigma length, stigma breadth were measured by using fluorescent Euromex microscope bv image focus V 2.0. build 90225p.

Number of pollen grains per anther: Number of pollen grains per anther is estimated using the formula given by Suzuki (1981).

Number of pollen grains per anther (V) = -1172 +1277 x Anther length

Glume opening angle (GOA): At the time of flowering, three well-opened florets of the primary panicle were collected. The angle of the opened floret (angle between lemma and palea) was measured using protractor and expressed in degree.

Stigma exsertion rate (SER): The ratio of spikelets with exserted stigma to the total number of spikelets in the panicle was considered as stigma exsertion rate and expressed in percentage. SER is calculated as follows:

$$\text{Stigma exsertion rate} = \frac{\text{Number of spikelets with exserted stigma}}{\text{Total number of spikelets in the panicle}} \times 100$$

Panicle exsertion rate (PER): Panicle exsertion rate is measured as the ratio of length of panicle that comes out from flag leaf sheath to the total length of panicle and expressed in percentage as follows:

$$\text{Panicle exsertion} = \frac{\text{Length of panicle that comes out from flage leaf sheath}}{\text{Total length of panicle}} \times 100$$

Pollen sterility: Pollen sterility or fertility was estimated by using 1% iodine potassium iodide (I – KI_2) solution. Anthers were collected from three randomly chosen spikelets (top, middle and bottom) and pollen grains were tweezed out of the anther on a glass slide. The fertile (fully stained) and sterile pollen grains (unstained) were counted in three microscopic fields under a light microscope. Pollen fertility was calculated and expressed in percentage as follows:

$$\text{Pollen fertility} = \frac{\text{Number of sterile pollen grains}}{\text{Total number of pollen grains (fertile and sterile)}} \times 100$$

Based on pollen fertility percentage, genotypes were classified into following groups as given in SES (Anon., 2006).

Sl. No	Fertility percentage	Fertility group
1.	Less than 5	Fully sterile
2.	5.1 to 50	Partially sterile
3.	50.1 to 80	Partially fertile
4.	More than 80	Fully fertile

Results and Discussion

The mean performance of five male sterile lines *viz.,* COMS 23A, COMS 24A, COMS 25A, CRMS 31A, CRMS 32A for 10 floral traits revealed that certain genotypes exhibited superiority over others (Table 1). In evaluating the suitability of Cytoplasmic male sterile (CMS) lines to local conditions, high out crossing rate is one of the most important character required for getting good seed yield in hybrid seed production plot. The line COMS23A registered higher mean values for style length (0.90 mm), breadth (0.22 mm) and panicle exsertion (81.00%). The genotype COMS24A had greater stigma breadth (0.51 mm), while COMS 25A had long styles (0.93 mm) with good stigma length (1.30 mm) and breadth (0.49 mm). All the CMS lines had above 99.50% pollen sterility. Similar findings were observed by Sidharthan *et al*., (2007) and Behla *et al.*, (2007).

Panicle exsertion rate (PER %) appeared to have some influence, since comparatively higher PER (more than 80%) was associated with higher out crossing rate. Virmani, (1994) reported that good panicle exsertion rate in CMS line was essential to attain high outcrossing rate. A high panicle exsertion rate in a CMS line would expose higher number of spikelets for outcrossing than that of a CMS line showing incomplete panicle exsertion. All the five CMS lines had more than 75 % panicle exsertion. The panicle exsertion rate was higher in the line COMS23A (81.00%) and COMS24A (78.64%) compared to others. Ali *et al*., (2008) reported 50% natural out crossing rate with more than 75% panicle exsertion in DRR 6A. While studying 15 male sterile lines and their respective maintainers, Madhavan **and** Subramanian (1999) observed that IR 46828A, Zhen Shah 97B and ADT 36 had wider angle of glume opening. Abeysekera *et al*., (2003) stated that spikelet opening angle and duration of opening of spikelets had a significant influence on out crossing rate of CMS lines. Present experimental results showed that CMS lines *viz.,* CRMS 31A (32.57^0) and CRMS 32A (27.06^0) have wider glume opening angle and good stigma exsertion rate which are conducive for out crossing.

Table 1. Mean performance of CMS lines for different floral traits.

Parents	Characters									
	Anther length (mm)	Anther breadth (mm)	Stigma length (mm)	Stigma breadth (mm)	Style length (mm)	Style breadth (mm)	Glume opening angle (^{0})	Panicle exsertion rate (%)	Stigma exsertion rate (%)	Pollen sterility (%)
COMS 23A	1.97*	0.47	1.27	0.45	0.90*	0.22*	25.80	81.00*	31.45	99.49
COMS 24A	1.60	0.52*	1.12	0.51*	0.89	0.20	22.62	78.64*	26.84	99.83
COMS 25A	1.64	0.42	1.30*	0.49*	0.93*	0.15	25.51	76.15	32.48	99.95
CRMS 31A	1.77	0.42	1.46*	0.46	0.83	0.18	28.83*	75.60	36.26*	99.69
CRMS 32A	2.07*	0.51*	1.13	0.41	0.81	0.22*	32.57*	76.46	35.09*	99.57
Mean	1.81	0.47	1.26	0.47	0.87	0.20	27.06	77.57	32.43	99.71
CD (1 %)	0.03	0.04	0.03	0.01	0.03	0.02	0.78	0.92	0.90	0.50

* - Significant at 1% level

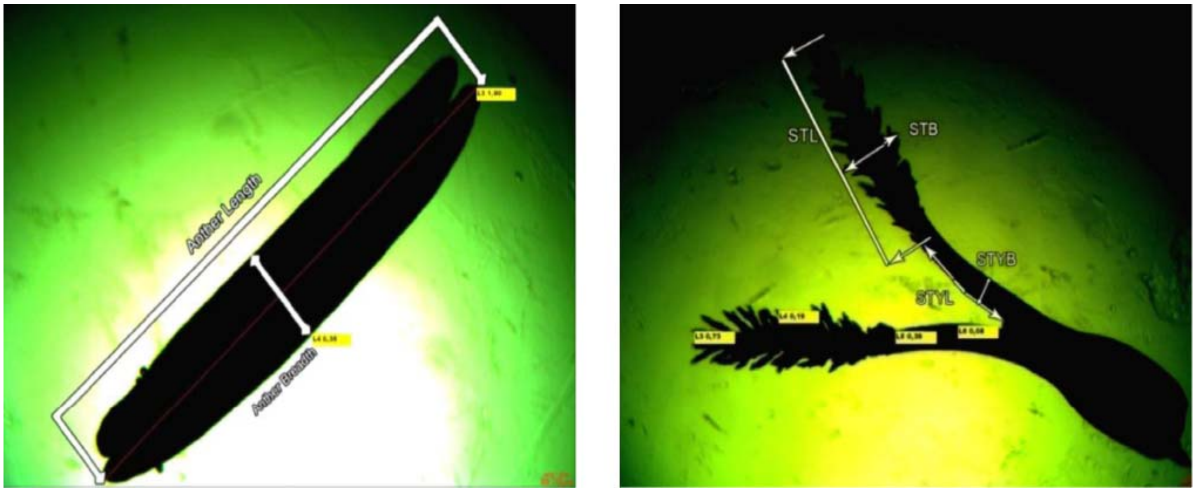
The study of genetic variability is a basic requirement in any crop improvement programme for deciding the efficiency of selection, since greater the genetic diversity, wider is the scope for selection. Environmental effects influence the genetic variation. Hence, partitioning of overall variances as genetic (heritable) and non-genetic components becomes necessary for effective selection programme. In the present study, there existed significant differences among the CMS lines for all the floral traits studied as revealed by ANOVA (Table 3). Phenotypic and genotypic variances, phenotypic and genotypic coefficient of variations were computed for all the characters. Comparison of characters based on GCV is more appropriate as it represents the heritable portion of total variability, while PCV estimates include environmental effect also (Allard, 1960). Genotypic coefficient of variation alone is not useful for selection and Burton, (1952) suggested that GCV together with heritability estimates would give the best picture of the extent of genetic gain to be expected by selection. Hence, the success of genetic advance depends on genetic variability, heritability and selection intensity. Moderate GCV and PCV estimates were observed for anther length, stigma length, style breadth, glume opening angle and stigma exsertion rate. High heritability coupled with high genetic advance as percent of mean was recorded for five traits *viz.,* anther length, stigma length, style breadth, glume opening angle and stigma exsertion rate (Table 4 & Fig. 2.). The results are in accordance with the findings of Seetharamaiah *et al*., (2001) and Ushakumari *et al.* (2002) who reported higher heritability estimates for anther length, stigma exsertion rate and panicle exsertion rate. High heritability for stigma characters was reported by Neves *et al*., (1989).

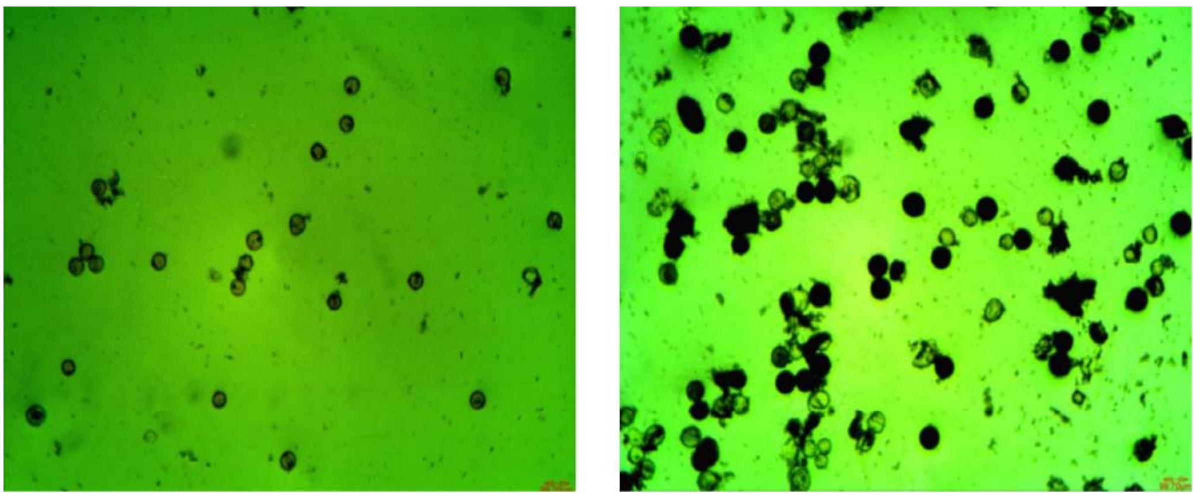
Morphological and floral traits that appeared to be associated with high outcrossing rate are panicle exsertion rate, total spikelets per panicle, spikelet opening angle and duration. In the present study association analysis among the floral traits in CMS lines *viz.,* stigma length, breadth, style length, breadth, glume opening angle and panicle exsertion rate with stigma exsertion rate indicated that glume opening angle had strong positive and significant association with stigma exsertion rate. Stigma length had positive non–significant association with stigma exsertion rate (Table 2). Study of anther traits in tester lines indicated that 20 and 19 testers recorded significantly higher anther length and breadth respectively than the grand mean (Table 5). Both the traits were significant in 10 testers. In this study, 21 testers were identified as restorers based on the pollen and spikelet fertility in hybrid combinations with five CMS lines (Table 6). These measurements are given in Plate 1 and expressed in millimeter (mm). Various pollen fertility classes are given in Fig 1. An examination of these restorers with anther size indicates that anther length and breadth were significantly higher than the mean in 10 and seven testers respectively. Both were significant in 3 testers *viz.,* AD 09533, AD 07073 and AD 09223. Also, there may not be any association between the size of the anthers and pollen or spikelet fertility because, the tester AD 08009 which expressed 100% pollen fertility did not show significance for anther length or breadth. Another tester IET 20932 had more number of pollen grains per anther (2122.66) but its spikelet fertility was only 75%. It was observed that glume opening angle had negative significant association with stigma breadth and style length. Greater the glume opening angle, greater the stigma exsertion and this leads to higher seed setting. Therefore a new CMS line should have a longer floret opening period, more stigma length and wider glume opening angle to increase the seed setting percentage and to achieve higher yield. It could be concluded that outcrossing will be higher in seed production of hybrids involving any of the four CMS lines *viz.,* COMS 23A, COMS 25A, CRMS 31A and CRMS 32A since each CMS line had some of the desirable floral trait. COMS 23A and COMS 25A had desirable stigma characters, while CRMS 31A and CRMS 32 had desirable floral traits like glume opening angle which is highly associated with higher out crossing rate.

Table 2. Mean performance of different tester lines for anther length, anther breadth and number of pollen grains per anther.

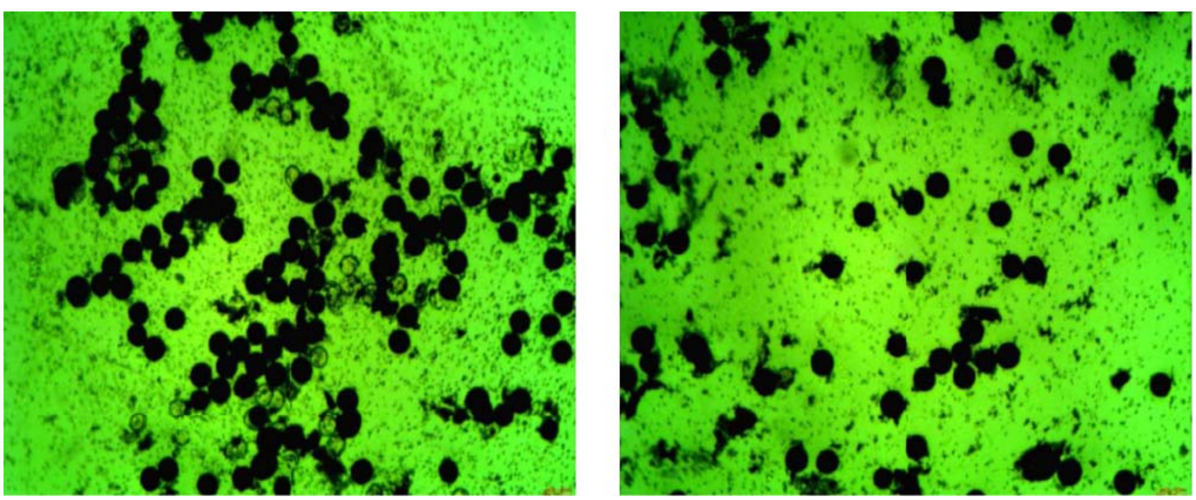
Sl. No	Parents	Anther length (mm)	Anther breadth (mm)	Number of pollen grains per anther
1.	IET 19922	2.01	0.52*	1390.51
2.	IET 19863	2.20*	0.30	1637.40*
3.	IET 20601	1.96	0.36	1326.66
4.	IET 20605	1.79	0.31	1109.57
5.	IET 20881	2.32*	0.32	1786.38*
6.	IET 20885	1.98	0.33	1360.72
7.	IET 20888	2.27*	0.45*	1731.05*
8.	IET 20890	1.86	0.27	1198.96
9.	IET 20895	1.72	0.27	1020.18
10.	IET 20896	1.55	0.34	803.09
11.	IET 20897	2.34*	0.33	1811.92*
12.	IET 20898	2.47*	0.32	1982.19*
13.	IET 20899	2.13	0.34	1543.75
14.	IET 20904	2.10	0.42*	1509.70
15.	IET 20932	2.58*	0.66*	2122.66*
16.	IET 20937	1.96	**0.67***	1330.92
17.	IET 20944	2.00	0.42*	1386.26
18.	IET 20945	2.42*	0.35	1922.60*
19.	AD 04072	2.22*	0.41	1662.94*
20.	AD 06084	2.06	0.44*	1462.88
21.	AD 07073	2.62*	0.53*	2169.48*
22.	AD 07076	2.40*	0.58*	1897.06*
23.	AD 07083	2.04	0.45*	1437.34
24.	AD 07158	1.54	0.36	798.84
25.	AD 07309	2.11	0.32	1518.21
26.	AD 08005	2.33*	0.33	1799.15*
27.	AD 08009	1.93	0.36	1296.87
28.	AD 08010	1.84	0.36	1177.68
29.	AD 08013	2.01	0.31	1390.51
30.	AD 09193	2.33*	0.61*	1803.41*
31.	AD 09194	1.99	0.35	1364.97
32.	AD 09203	2.03	0.49*	1424.57
33.	AD 09206	2.28*	0.58*	1735.30*
34.	AD 09216	1.64	0.32	922.28
35.	AD 09222	1.63	0.30	905.25
36.	AD 09223	2.66*	0.43*	2220.56*
37.	AD 09231	1.96	0.35	1335.18
38.	AD 09241	2.07	0.57*	1471.39
39.	AD 09522	2.13	0.37	1548.01
40.	AD 09523	1.86	**0.24**	1203.22
41.	AD 09524	1.85	0.32	1186.19
42.	AD 09525	2.00	0.33	1382.00
43.	AD 09526	1.75	0.38	1067.01
44.	AD 09527	2.41*	0.29	1909.83*
45.	AD 09528	2.71*	0.42*	2284.41*
46.	AD 09529	1.99	0.33	1369.23
47.	AD 09530	1.84	0.43*	1181.94
48.	AD 09531	2.51*	0.36	2033.27*
49.	AD 09532	2.24*	0.39	1684.22*
50.	AD 09533	2.16*	0.47*	1582.06*
51.	AD 09534	2.17*	0.56*	1594.83*
	Mean	2.10	0.40	1505.78
	CD (1 %)	0.04	0.02	47.33

* - Significant at 1% level





Fully sterile **Partially sterile**



Partially fertile **Fully fertile**

Fig 1. Anther, style, stigma and various pollen fertility classes.

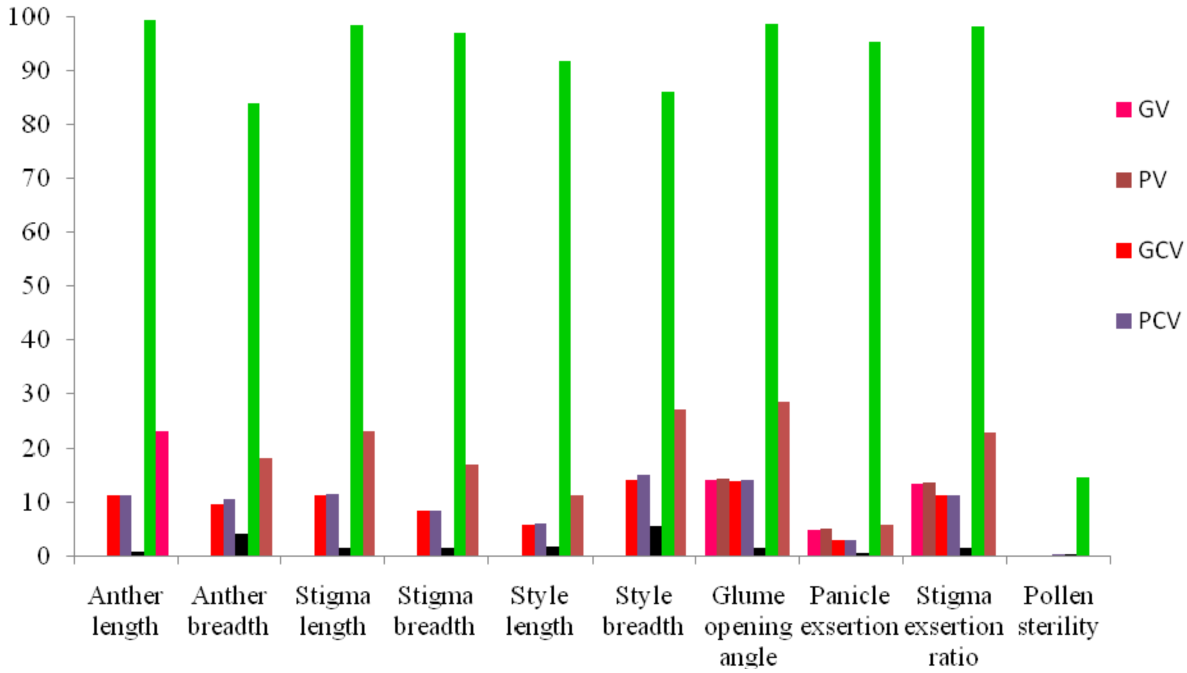


Fig. 2. Estimates of genetic parameters for various floral traits of CMS lines.

Table 3. Analysis of variance for various floral traits in CMS lines of rice.

Source	DF	Mean sum of squares									
		Anther length	Anther breadth	Stigma length	Stigma breadth	Style length	Style breadth	Glume opening angle	Panicle exsertion	Stigma exsertion ratio	Pollen sterility
Replication	2	0.001	0.003	0.02	0.0007	0.000	0.0001	0.031	0.15	0.40	0.214**
Genotypes	4	0.126**	0.006**	0.06**	0.005**	0.008**	0.003**	42.90**	15.07**	40.47**	0.105**
Error	8	0.002	0.0004	0.0003	0.000	0.0002	0.0001	0.17	0.24	0.23	0.069

** - Significant at 1% level

Table 4. Estimates of genetic parameters for different floral traits among CMS lines.

Characters	Genotypic variation	Phenotypic variance	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Environmental coefficient of variation (%)	Heritability (h^2)	Genetic advance as percent of mean
Anther length	0.041	0.042	11.24	11.27	0.82	99.47	23.10
Anther breadth	0.002	0.002	9.68	10.57	4.23	83.95	18.27
Stigma length	0.02	0.021	11.34	11.43	1.45	98.4	23.17
Stigma breadth	0.002	0.002	8.40	8.52	1.47	97.03	17.04
Style length	0.003	0.003	5.77	6.02	1.71	91.90	11.39
Style breadth	0.001	0.001	14.08	15.16	5.63	86.22	26.93
Glume opening angle	14.24	14.41	13.94	14.03	1.53	98.82	28.56
Panicle exsertion	4.95	5.19	2.87	2.94	0.63	95.36	5.77
Stigma exsertion ratio	13.42	13.65	11.30	11.39	1.48	98.32	23.07
Pollen sterility	0.012	0.082	0.11	0.29	0.26	14.7	0.09

Table 5. Genotypic correlation among the floral traits in CMS lines of rice.

Characters	Stigma length	Stigma breadth	Style length	Style breadth	Glume opening angle	Panicle exsertion rate	Stigma exsertion rate
Stigma length	1	0.006	-0.019	-0.580	0.087	-0.349	0.585
Stigma breadth		1	0.736	-0.580	-0.899**	0.035	-0.709
Style length			1	-0.560	-0.835*	0.390	-0.643
style breadth				1	0.332	0.568	-0.100
Glume opening angle					1	-0.492	0.860**
Panicle exsertion rate						1	-0.608
Stigma exsertion rate							1

** - Significant at 1% level; * - Significant at 5% level

Table 6. Spikelet fertility percentage in 255 test crosses in rice.

Genotypes	COMS 23A	COMS 24A	COMS 25A	CRMS 31A	CRMS 32A
IET 19922	9.52 (P.M)	11.98 (P.M)	6.11 (P.M)	60.53(P.R)	88.61(R)
IET 19863	90.21(R)	95.16 (R)	81.01 (R)	88.56 (R)	86.49(R)
IET 20601	6.28 (P.M)	5.25 (P.M)	Nil	Nil	85.22(R)
IET 20605	8.10 (P.M)	0.00	4.36(M)	0.00	15.98 (P.M)
IET 20881	94.19 (R)	81.82 (R)	81.36 (R)	90.84 (R)	90.19(R)
IET 20885	90.69 (R)	82.99 (R)	82.53 (R)	81.37 (R)	81.15(R)
IET 20888	81.60 (R)	4.13 (M)	84.27 (R)	80.59 (R)	81.16(R)
IET 20890	17.42 (P.M)	15.28 (P.M)	11.44 (P.M)	13.72(P.M)	87.84(R)
IET 20895	80.07 (R)	29.89 (P.M)	63.15(P.R)	14.07 (P.M)	77.69(P.R)
IET 20896	85.81 (R)	48.74 (P.M)	58.53(P.R)	83.46 (R)	88.21(R)
IET 20897	92.27 (R)	93.74(R)	81.48 (R)	90.97 (R)	82.10(R)
IET 20898	95.56 (R)	92.92 (R)	93.50 (R)	91.49 (R)	90.34(R)
IET 20899	35.95 (P.M)	28.31(P.M)	4.68 (M)	48.41 (P.M)	58.69(P.R)
IET 20904	5.60 (P.M)	5.93 (P.M)	7.48 (P.M)	5.77 (P.M)	3.23(M)
IET 20932	15.37 (P.M)	15.22 (P.M)	97.36 (R)	7.37 (P.M)	72.32(P.R)
IET 20937	92.54 (R)	82.32 (R)	92.79 (R)	82.08 (R)	90.50(R)
IET 20944	75.14(P.R)	6.66 (P.M)	59.56(P.R)	53.09(P.R)	45.54 (P.M)
IET 20945	80.63 (R)	91.33 (R)	82.49 (R)	80.26 (R)	81.74(R)
AD 04072	85.70 (R)	65.19(P.R)	86.78 (R)	15.78 (P.M)	7.68 (P.M)
AD 06084	80.72 (R)	81.04 (R)	92.73 (R)	93.16 (R)	90.35(R)
AD 07073	90.63(R)	80.54 (R)	80.94 (R)	92.75 (R)	80.35(R)
AD 07076	1.28(M)	25.47 (P.M)	16.06 (P.M)	35.10 (P.M)	10.72 (P.M)
AD 07083	90.70 (R)	93.90(R)	82.25 (R)	81.63 (R)	91.99(R)
AD 07158	50.82 (P.R)	10.58 (P.M)	65.72(P.R)	82.72 (R)	24.71 (P.M)
AD 07309	27.80 (P.M)	86.31 (R)	82.90 (R)	88.41 (R)	93.42(R)
AD 08005	82.55 (R)	90.53 (R)	80.67 (R)	81.30 (R)	90.54(R)
AD 08009	92.75 (R)	83.24(R)	81.49 (R)	81.48(R)	90.60(R)
AD 08010	40.59 (P.M)	10.81(P.M)	12.22 (P.M)	47.67 (P.M)	84.70(R)
AD 08013	71.92(P.R)	32.32 (P.M)	3.63(M)	84.02 (R)	81.48(R)
AD 09193	76.86 (P.R)	54.35(P.R)	4.92(M)	55.21(P.R)	68.89(P.R)
AD 09194	92.01 (R)	81.04(R)	82.21 (R)	92.31(R)	82.06(R)
AD 09203	19.84 (P.M)	22.86 (P.M)	30.16 (P.M)	16.00 (P.M)	48.51 (P.M)
AD 09206	45.28 (P.M)	24.71 (P.M)	53.06(P.R)	3.94 (M)	5.39 (P.M)
AD 09216	91.20(R)	82.33 (R)	82.08 (R)	80.83 (R)	85.90(R)
AD 09222	27.72 (P.M)	22.57 (P.M)	56.52(P.R)	55.57 (P.R)	54.39(P.R)
AD 09223	91.43 (R)	90.06 (R)	80.75 (R)	93.28 (R)	80.53(R)
AD 09231	16.48 (P.M)	20.40 (P.M)	5.40 (P.M)	12.02 (P.M)	40.96 (P.M)
AD 09241	4.44(M)	8.04 (P.M)	46.69 (P.M)	52.94(P.R)	26.19(P.M)
AD 09522	91.28 (R)	91.72 (R)	83.97 (R)	80.64 (R)	81.00(R)
AD 09523	81.13 (R)	90.08 (R)	81.08 (R)	80.41 (R)	81.73(R)
AD 09524	9.73 (P.M)	33.30 (P.M)	59.56(P.R)	7.24 (P.M)	7.24 (P.M)
AD 09525	81.66 (R)	90.69 (R)	81.20 (R)	93.85 (R)	83.19(R)
AD 09526	36.26 (P.M)	33.66 (P.M)	15.18 (P.M)	31.47 (P.M)	68.60(P.R)
AD 09527	47.32 (P.M)	45.43 (P.M)	58.28(P.R)	83.38 (R)	85.47(R)
AD 09528	56.86(P.R)	35.39 (P.M)	47.91 (P.M)	54.13(P.R)	45.98 (P.M)
AD 09529	25.75 (P.M)	82.95 (R)	71.99(P.R)	25.47 (P.M)	83.68(R)
AD 09530	82.45 (R)	80.60 (R)	80.42 (R)	84.21 (R)	91.41(R)
AD 09531	91.16 (R)	80.57 (R)	81.36 (R)	81.90 (R)	81.35(R)
AD 09532	21.47 (P.M)	5.37 (P.M)	30.63 (P.M)	9.10 (P.M)	15.34(P.M)
AD 09533	88.59 (R)	80.89 (R)	91.81 (R)	90.13 (R)	80.95(R)
AD 09534	51.28(P.R)	28.52 (P.M)	48.37 (P.M)	12.88(P.M)	29.57 (P.M)

References

Abeysekera, S.W., S.N. Jayawardena, K.D.S. Kiriwaththuduwage and D.S. de Z. Abeysiriwardena. 2003. Hybrid rice research and development in Sri Lanka. International Rice Research İnstitute, Manila, Philippines. pp. 341-355.

Ali, S.S., M. Akhter, M. Sabar and M. Ali. 2008. Evaluation of rice CMS lines from diverse male sterility sources in Pakistan. *J. Agric. Res.,* 3(1): 1-5.

Allard, R.W. 1960. *Principles of Pl. Breed,* John Wiley and Sons, Inc. New York.

Behla, R.S., A. Rang and T.S. Bharaj. 2007. Floral and morphological traits of some A, B and R lines of rice. *Crop Improv.,* 34(1): 24-26.

Burton, G.W. 1952. Quantitative inheritance of yield and yield traits in rice. *Oryza,* 32: 53-54.

Gurdev. K. Khush. 2006. Rice Research challenge for the 21st century. *J. Rice Res*., 1(1).

Madhavan, J. and M. Subramanian. 1999. Studies on floral biology and anthesis in certain A, B and R lines of rice. *Vistas Rice Res*., 1: 39-151.

Khush, G.S. 2005. What it will to take to feed 5.0 billion rice consumers in 2030. *Plant Mol. Biol.,* 59: 1-6.

Neves, P., C.F. De, E.P. Guimaraes and J. Taillebois. 1989. Correlation between allogamic and agronomic traits in rice. *Int. Rice Res. Newsl*., 14(2): 12.

Oka, H.T. and H. Morishma. 1967. Variations in the breeding systems of wild rice. *Evolution*, 21(2): 249-258.

Sahadevan, P.C. and K.M.N. Namboodiri. 1963. Natural crossing in rice. *Proc. Indian Acad. Sci. Societ*., 58(2): 176-185.

Sakai, K.I. and T. Narise. 1959. Studies on the breeding behaviour of wild rice. *Annu. Rep. Natl. Inst. Genet. Jpn*., 9(1): 64-65.

Seetharamaiah, K.V., R.S. Kulkarni and M. Mahadevappa. 2001. Variability and genetic parameters of floral and morphological traits influencing outcrossing in Rice (*Oryza sativa* L.). *Andhra Agric. J.,* 48(2): 181-184.

Sidharthan, B., K. Thiyagarajan and S. Manonmani. 2007. Cytoplasmic male sterile lines for hybrid rice production. *J. Applied Sci. Res*., 3(10): 935-937.

Swaminathan, M.S. and S.A. Rao. 2009. Rice improvement in the genomics era. Chapter. 14. Rice for Sustainable Food and Nutritions Security. CRC Press. pp. 375-415.

Usha kumari, R., P. Rangasamy and S.M. Gomez. 2002. Variability in floral characters in wild species of (*Oryza sativa* L.) paddy. *Int. J. Mendel.,* 19(1): 51.

Virmani, S.S. and D.S. Athwal. 1973. Genetic variability in floral characteristics influencing out-crossing in *Oryza sativa* L. *Crop Sci.,* 13(1): 66-67.

Virmani. S.S. 1994. Heterosis and rice breeding. Out crossing mechanism and hybrid seed production practices in rice. International rice research institute, Manila, Philippines. pp. 79-96.

(Received for publication 2 January 2012)