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RESEARCH ARTICLE

STUDY OF MORPHOLOGICAL AND FLORAL TRAITS OF DIFFERENT LINES IN RICE (*ORYZA SATIVA* L.)

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ABSTRACT

In the present study, an attempt has been made to study the morphological and floral characters of the parental lines of the released hybrids. The morphological and floral traits of cms lines, their maintainers and restorer lines indicated that both the cms lines were morphologically different. All the parental lines had erect altitude of flag leaf blade, except MTU 9992R and IR 40750R which had horizontal and reflexed altitude of leaf blade. The floret opening angle in cms lines lR 58025A (38.8°) and PMS 2A (37.9°) was higher than their maintainers, lR 580258 (24.8°) and PMS 2B (31.7°) which is desirable for higher out crossing rate. The flag leaf angle of cms lines lR 58025A (33.7°) and PMS 2A (23.5°) was greater than restorer lines. The flag leaf angle of the restorer lines ranged from 11.0° (MTU 9992R) to 34.0° (BR 827-35R).

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INTRODUCTION

Rice (*Oryza sativa* L. 2n=24) is the most important food crop of the developing world. It provides up to two third of the calories for more than 60% of the world population. China not only developed the world's first commercial rice hybrid, but also optimized technology which made hybrid rice seed production economically viable. In India, Indian Council of Agricultural Research launched a goal oriented and time bound project on Hybrid Rice in 1989 which was coordinated by Directorate of Rice Research, Hyderabad, and resulted in the release of its first rice hybrid in 1994. So far more than 25 Rice Hybrids have been released in India (Kumar and Verma, 2006). By the year 2030, the world population is expected to reach 8.2 billion as against 6.2 billion today. Hence, a considerable quantity of rice will be required to meet future needs. By 2030, the global demand of rice is projected to be approximately 533 million tons of milled rice, as compared to 472 million tones projected for 2015. This low level of productivity can be increased substantially by growing high yielding varieties/ hybrids and by increasing the area under balanced fertilizer use and application rates. Thus, achieving self sufficiency in rice production and maintaining price stability are important issues in low income countries because of the importance of this crop in providing food security and generating employment and income for low income people (Hossain, 1995). The increase in rice production can be achieved either by improving existing plant type or developing heterotic rice hybrids. Development of heterotic rice hybrids seems to be appropriate, more promising and available short term option. Hybrid rice has a yield advantage of 15 to 20 percent or more over the best conventionally bred varieties. The cultivation of hybrid rice clearly demonstrates that it is a better option for increasing rice production than others like super rice varieties which have problems of grain quality. Rice is a self-pollinated crop, where the extent of natural crossing is only 0.3 to 3.0% (Kumar, 1996). Therefore, hybrid rice seed production requires specialized techniques which need to be thoroughly understood before embarking this venture. The success of hybrid rice seed production depends on various factors such as choice of field, seeding time, planting pattern and weather conditions during the period of flowering, synchronization in flowering of parental lines, GA_3 application, supplementary pollination techniques, rouging, proper harvesting, processing, packing and effective seed distribution system etc.

Successful hybrid rice seed production, must involve high degree of cross-pollination to economize the cost of seed. The male sterility used for hybrid rice breeding in China and elsewhere are cytoplasmic, genetic, and chemically induced

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male sterility systems. The seed production programme involves three line system which consists of cytoplasmic genetic male sterile (cms) line (A line), the corresponding maintainer lines (B line) and the fertility restorer line (R line). For the economic feasibility and commercial viability of the hybrid rice technology, the development of an efficient and economic seed production package is a pre-requisite. Seed production is the most crucial link between the breeders developing the hybrids and the farmers cultivating them. Hybrid rice seed production involves several intricacies which have to be managed satisfactorily to obtain an accepted yield of at least 1.5 to 2.0 t/ha. Besides poor panicle exsertion, the other problems encountered in hybrid rice seed production are proper identification of potential cms lines, maintainer lines, restorer lines and the development of parental lines with the desirable morphological traits that help in enhancing the out-crossing percentage. Most of the cms lines of rice are based on wild abortive (WA) cytoplasm having 87.9% share in hybrid development with the result that 25-33 percent of spikelets are enclosed in flag leaf sheath which results in poor panicle exsertion and poor seed set (Chatterjee and Banerjee, 2001). Before taking up a large scale hybrid rice seed production programme, it is essential to know the morphological and floral traits of the parental lines involved in a particular hybrid. Keeping these points in view the present investigation was conducted to study the morphological and floral traits of the cytoplasmic male sterile, maintainer and restorer lines in rice.

MATERIALS AND METHODS

The present investigation was conducted during wet (*kharif*) season at Research Farm of Kisan P.G. College, Simbhaoli, Hapur (U.P.) for two consecutive years. The soil of the farm is sandy loam with 7.3 pH. The climate is humid and subtropical. Two cytoplasmic male sterile (cms) lines, their maintainers (B) and ten restorers of hybrids released by different states/ Rice Research Stations were selected for the study of morphological and floral traits.

Hybrid rice parental lines and their source of seed

	Varieties	Seed Source
1.	CMS Lines	
i.	IR 58025 A	GBPUA&T, Pantnagar (Uttara Khand)
ii.	PMS 2 A	Rice Research Station, Kapurthala (Punjab)
2.	Maintainers	
iii.	IR 58025 B	GBPUA&T, Pantnagar (Uttara Khand)
iv.	PMS 2 B	Rice Research Station, Kapurthala (Punjab)
3.	Restorers Lines	
v.	UPRI 92-133 R	GBPUA&T, Pantnagar (Uttara Khand)
vi.	UPRI 93-287 R	GBPUA&T, Pantnagar (Uttara Khand)
vii.	Vajram	ANGRAU, Rice Research Station, Maruteru (AP)
viii.	IR 10198 R	ANGRAU, Rice Research Station, Maruteru (AP)
ix.	MTU 9992 R	TNAU, Paddy Breeding Station Coimbatore (Tamilnadu)
x.	C 20 R	TNAU, Paddy Breeding Station Coimbatore (Tamilnadu)
xi.	BR 827-35 R	KKV, Agriculture Research Station, Karjat (Maharashtra)
xii.	IR 31802 R	GBPUA&T, Pantnagar (Uttara Khand)
xiii.	IET 8585 R (Ajaya)	GBPUA&T, Pantnagar (Uttara Khand)
xiv.	IR 40750 R	DRR, Hyderabad (AP)

The seed samples received from various Rice Research Stations were planted for study and seed multiplication during *kharif* 2005 to ensure sufficient quantity of seed available during *kharif* 2006, to conduct the final experiments. The seeds of all the lines (A, B and R) were sown on 15 May, 2005 for the study of morphological traits of parental lines as well as for seed multiplication. Thirty days old seedlings were transplanted in well puddled field on 13 June, 2005. The experiment was planted in two replications. Each entry had four rows of 3 m length. The row to row distance was 20 cm and plant to plant distance was 15 cm. Single seedling/ hill was transplanted. The crop received 100 kg N, 60 kg P_2O_5, 40 kg K_2O per hectare. Nitrogen was applied in three split doses, 50 percent at time of transplanting, 25 percent after 25 days of transplanting and rest 25 percent at the time of panicle initiation. Other cultural practices like weeding, irrigation and plant protection etc. were done whenever needed. Ten competitive plants from each entry per replication were randomly selected for recording observations on the following morphological and floral traits;

A. Morphological traits

Days to 50% flowering, plant height (cm), panicle length (cm), number of panicles per plant, number of seeds per panicle, panicle exsertion (As per Standard Evaluation System (SES) of the International Rice Research Institute, Philippines), presence of awns, distribution of awns, panicle branching, length of flag leaf (cm), width of flag leaf (cm), flag leaf length/ width ratio, flag leaf area (cm^2), flag leaf angle, altitude of leaf blade, penultimate leaf shape of ligule and 1000 seed weight (g).

Category	Percentage of panicle covered by flag leaf sheath
Well exserted	0
Moderately well exserted	0 – 10
Just exserted	26 – 40
Enclosed	Above 40

B. Floral traits

Spikelet opening angle, anther, style and stigma length.
The experiment was conducted in strip plot design as detailed below:

Horizontal strip: Three parental combinations

A1IR 58025A/ C 20R
A2IR 58025A/ BR 827-35R
A3IR 58025A/ UPRI 92-133R
Vertical strip: Three doses of gibberellic acid (GA_3)
(a) Control(b) 40 g/ha(c) 70 g/ha

Replication: Three

Date of transplanting:23.07.2006
Breadth of each plot:3.80 m
Breadth of main plot:3.80 x 3 + (0.5 x 4) = 13.4 m
Length of main plot:Length of each plot = 4 m
Length of each subplot = 4 m x 9 = 36 m
Length of borders alleys = 0.5 x 10 = 5 m

Total length of plot = 36 + 5 = 41 m
Total experimental area = 41 m x 13.4 m = 549.4 ≅ 550 m^2

Spacing

Between A lines	=15 cm
Between A and R lines	=20 cm
Between R lines	=30 cm

The commercial grade gibberellic acid with 90% purity was used in the experiment. GA_3 was applied in two split doses i.e. 40 percent at 5% panicle emergence and the remaining 60 percent was sprayed with a gap of one day. The requirement of GA_3 at the desired concentration of 45 g/ha and 70 g/ha at a strength of 60 ppm was calculated and weighed accordingly. At the time of spraying, the GA_3 was dissolved in 70 percent ethanol @ 20 ml ethanol/ g of GA_3. The volume of the spray was completed by adding water. To avoid losses due to drift, spraying was done in the afternoon under low wind velocity conditions.

Statistical analysis

Plot means were used for different statistical analysis. The experimental data were subjected to analysis of variance (ANOVA) with the objective of measuring the main and interaction effects between the two factors in strip plot design as suggested by Gomez and Gomez, 1984. The analysis of variance was divided into three parts: the horizontal factor analysis, the vertical factor analysis and the interaction analysis.

RESULTS AND DISCUSSION

The twentieth century culminated with spectacular achievements in several aspects of rice research viz., the report of heterosis, cytoplasmic genetic male sterility (cms) system, development and commercialization of three and two line hybrids, development of super rice genotypes, golden rice, jasmine rice, C_4 rice and recently the International Rice Genome Sequencing Programme. Hybrid rice seed production technology is considered labour and knowledge intensive. There are several risks factors, especially in the early stages when seed producers are lacking in experience. It requires specialized techniques which need to be thoroughly understood before embarking upon this venture. The success of this technology depends on various factors such as identification of cms lines, their maintainers and restorer lines; choice of field, seeding time, planting pattern, weather conditions during the period of flowering, synchronization in flowering of parental lines, GA_3 application, supplementary pollination techniques, rouging, proper harvesting, processing, packing and effective seed. The successful hybrid rice seed production depends on high genetic and physical purity of parental lines, besides good seed yield. Hence, the objective of this study was proper evaluation of important commercial cms lines, their maintainers and restorers for morphological and floral traits. The commercial exploitation of hybrid rice depends upon the identification of suitable heterotic combinations, the stability of the cytoplasmic male sterile (cms) lines, and the capacity of the restorer lines for fertility restoration, besides high quality seeds and feasible means of developing seeds through improved seed production techniques (Lavanya *et al*., 1999). The improvement in hybrid rice seed production depends upon the success of the hybrid breeding programmes and refinement of seed production techniques. These programmes bring about an improvement in the breeding material, development of stable cms lines, compatible restorers and evaluation of promising hybrid combinations in multi-location trials. Purification of parental lines involved in hybrid seed production which include the selection of typical plants of A, B, R lines, the production of testcrosses (A x R) and backcrosses (B x R), identification and seed increase of typical male sterile, maintainer and restorer lines all are highly technical in nature. These steps require that a thorough evaluation of the parental lines is made for the morphological as well as floral traits which are the base of the purification and maintenance of parental lines. The cms lines IR 58025A and PMS 2A, their maintainers and ten restorer lines were studied for their morphological as well as floral traits. The plant height of the cms lines IR 58025A, PMS 2A was lower than the restorer lines which is a desirable traits in hybrid seed production. The number of days to 50% flowering is an important trait and most crucial for deciding the seeding interval of the parental lines for good synchronization. The number of days to 50% flowering (Table 1) in the restorer lines ranged from 89 days (IR 10198R) to as high as 124 days (MTU 9992R). The characters like plant height, days to 50% flowering, panicle length, panicle number, total number of tillers, 1000 seed weight all are highly influenced by the environment due to low heritability and need to be checked from location to locations and over seasons.

The morphological features such as altitude of leaf blade, presence and distribution of awns, altitudes of panicle branching, panicle exsertion and shape of ligule are comparatively stable and very helpful in the proper identification of the cms, maintainer and restorer lines. Higher panicle exsertion is an important trait in cms lines as these lines have WA type of cytoplasm hence poor panicle exsertion in the cms lines (IR 58025A, PMS 2A). The maintainers (IR 58025B, PMS 2B) have well exserted panicles because their cytoplasm is normal. Good panicle exsertion was noticed in restorer lines, UPRI 92-133R, UPRI 93-287R, Vajram, C 20R, BR 827-35R, IR 31802R, IET 8585R whereas, the panicles were just exserted in MTU 9992R, IR 10198R and IR 40750R (Table 2, 3, 4 and 5). 1,000 seed weight is an important character. The seeds with bold size are favoured as compared to the medium size seeds. Hence, higher seed weight is the desirable character. However, there cannot be too much variation between the seed shape and size of the female parent and the restorer lines as it will reduce the consumer's acceptability of the commercial product due to segregation (Table 6). It is therefore, desirable that the grain shape and size of the cms line and the restorer parent is similar and there are no marked differences in the grains produced on F_1 plants. Flag leaf length and width is also an important trait which is useful in hybrid rice seed production. Small and horizontal flag leaves are favourable for out crossing as compared to long and erect leaves. In the present study, the cms (A) lines, IR 58025A and PMS 2A had mean flag leaf length of 27.4 cm and 34.1 cm, respectively which was small as compared to their maintainers.

Table 1. Plant height, days to 50% flowering and panicle length of cms, maintainer and restorer lines

	Parental lines	Plant height (cm)			Days to 50% flowering			Panicle length (cm)		
		2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	80.7	72.7	76.7	95	100	98	25.3	21.6	23.5
2.	IR 58025B	89.1	86.4	87.8	93	97	95	26	26.5	26.3
3.	PMS 2A	80.7	78.1	79.4	100	104	102	23.0	20.1	21.6
4.	PMS 2B	90.2	82.1	86.2	100	98	99	25.9	23.5	24.7
5.	UPRI 92-133R	81.3	83.3	82.3	100	96	98	23.5	20.8	22.2
6.	UPRI 93-287R	97.7	98	97.9	104	104	104	21.5	22	21.8
7.	Vajram	100.8	90.3	95.6	112	117	115	22.9	18	20.5
8.	MTU 9992R	107.6	105.5	106.6	125	123	124	25.2	23	24.4
9.	IR 10198R	92.4	84.5	88.5	90	88	89	25.7	23	24.4
10.	C 20R	93.9	89.2	91.6	105	107	106	19.6	18.7	19.2
11.	BR 827-35R	101.9	102.8	102.4	110	105	108	24.5	22.8	23.7
12.	IR 31802R	101.7	101.8	101.8	101	102	102	25.3	24	24.7
13.	IET 8585R	96.3	95.8	96.1	100	107	104	26	22.4	24.2
14.	IR 40750R	99.1	97.3	98.2	107	111	109	25.3	21.6	23.5

Table 2. Altitude of blade and presence of awns in cms, maintainer and restorer lines

	Parental lines	Altitude of blade		Awn/ Awnless	
		2005	2006	2005	2006
1.	IR 58025A	Erect	Erect	Awned	Awned
2.	IR 58025B	Erect	Erect	Awned	Awned
3.	PMS 2A	Erect	Erect	Awned	Awned
4.	PMS 2B	Erect	Erect	Awnless	Awnless
5.	UPRI 92-133R	Erect	Erect	Awned	Awned
6.	UPRI 93-287R	Erect	Erect	Awned	Awned
7.	Vajram	Erect	Erect	Awnless	Awnless
8.	MTU 9992R	Horizontal	Horizontal	Awnless	Awnless
9.	IR 10198R	Erect	Erect	Awnless	Awnless
10.	C 20R	Erect	Erect	Awnless	Awnless
11.	BR 827-35R	Erect	Erect	Awnless	Awnless
12.	IR 31802R	Reflexed	Reflexed	Awnless	Awnless
13.	IET 8585R	Erect	Erect	Awned	Awned
14.	IR 40750R	Horizontal	Horizontal	Awnless	Awnless

Table 3. Distribution of awns and altitude of panicle branching of cms, maintainer and restorer lines

	Parental lines	Distribution of awns		Altitude of panicle branching	
		2005	2006	2005	2006
1.	IR 58025A	Upper quarter	Upper quarter	Erect to semi-erect	Erect to semi-erect
2.	IR 58025B	Upper quarter	Upper quarter	Erect to semi-erect	Erect to semi-erect
3.	PMS 2A	Upper quarter	Upper quarter	Erect to semi-erect	Erect to semi-erect
4.	PMS 2B	Absent	Absent	Erect to semi-erect	Erect to semi-erect
5.	UPRI 92-133R	Upper quarter	Upper quarter	Semi-erect to spreading	Semi-erect to spreading
6.	UPRI 93-287R	Upper quarter	Upper quarter	Semi-erect to spreading	Semi-erect to spreading
7.	Vajram	Absent	Absent	erect	Erect
8.	MTU 9992R	Absent	Absent	Semi-erect	Semi-erect
9.	IR 10198R	Absent	Absent	erect	Erect
10.	C 20R	Absent	Absent	Erect to semi-erect	Erect to semi-erect
11.	BR 827-35R	Absent	Absent	Semi-erect to spreading	Semi-erect to spreading
12.	IR 31802R	Absent	Absent	spreading	Spreading
13.	IET 8585R	Upper tip	Upper tip	spreading	Spreading
14.	IR 40750R	Absent	Absent	Semi-erect to spreading	Semi-erect to spreading

Table 4. Panicle exsertion and penultimate shape of ligule of cms, maintainer and restorer lines

	Parental lines	Panicle exsertion		Penultimate shape of ligule	
		2005	2006	2005	2006
1.	IR 58025A	Exserted	Exserted	Split	Split
2.	IR 58025B	Well exserted	Well exserted	Split	Split
3.	PMS 2A	Exserted	Exserted	Split	Split
4.	PMS 2B	Well exserted	Well exserted	Split	Split
5.	UPRI 92-133R	Well exserted	Well exserted	Split	Split
6.	UPRI 93-287R	Well exserted	Well exserted	Acute	Acute
7.	Vajram	Well exserted	Well exserted	Acute	Acute
8.	MTU 9992R	Exserted	Exserted	Split	Split
9.	IR 10198R	Exserted	Exserted	Split	Split
10.	C 20R	Well exserted	Well exserted	Split	Split
11.	BR 827-35R	Well exserted	Well exserted	Split	Split
12.	IR 31802R	Well exserted	Well exserted	Split	Split
13.	IET 8585R	Well exserted	Well exserted	Split	Split
14.	IR 40750R	Exserted	Exserted	Split	Split

Table 5. Filled, unfilled and total number of spikelets of cms, maintainer and restorer lines

	Parental lines	Filled spikelets (No.)			Unfilled spikelets (No.)			Total spikelets (No.)		
		2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	6	4	5	147	139	143	153	143	148
2.	IR 58025B	183	180	180	9	6	8.0	192	186	189
3.	PMS 2A	5	5	5	185	165	175	190	170	180
4.	PMS 2B	185	170	178	5	8	7.0	191	183	187
5.	UPRI 92-133R	175	183	179	11	19	15	186	202	194
6.	UPRI 93-287R	160	164	162	19	12	15.5	179	176	177.5
7.	Vajram	216	220	218	13	16	14.5	229	236	232.5
8.	MTU 9992R	135	120	128	9	11	10	144	131	138
9.	IR 10198R	105	108	107	7	9	8	112	115	114
10.	C 20R	155	180	168	11	13	12	166	193	180
11.	BR 827-35R	183	180	182	8	7	7.5	191	187	189
12.	IR 31802R	133	125	129	11	13	11	144	138	141
13.	IET 8585R	174	174	174	8	9	8.5	182	183	183
14.	IR 40750R	168	170	169	7	6	6.5	175	175	176

Table 6. Number of panicles and tillers per plant and 1000 seed weight of cms, maintainers and restorers lines

	Parental lines	Panicle number (No.)			Total number of tillers			1000 seed weight (g)		
		2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	18	15	17	15	13	14	21.21	20.73	20.97
2.	IR 58025B	17	15	16	16	17	17	22.00	23.74	22.87
3.	PMS 2A	12	11	12	12	14	13	25.10	23.56	24.33
4.	PMS 2B	12	13	13	13	17	15	23.01	21.76	22.39
5.	UPRI 92-133R	10	14	12	13	15	14	24.43	26.24	25.34
6.	UPRI 93-287R	14	17	16	14	17	16	24.48	23.06	23.77
7.	Vajram	11	11	11	11	12	12	17.19	18.08	17.64
8.	MTU 9992R	13	17	15	10	20	17	18.19	21.06	19.63
9.	IR 10198R	28	22	25	19	15	14	23.36	20.74	22.00
10.	C 20R	12	10	11	17	10	15	25.03	25.69	25.70
11.	BR 827-35R	17	17	17	17	18	18	30.19	28.4	29.30
12.	IR 31802R	17	15	16	16	15	16	27.15	25.64	26.39
13.	IET 8585R	23	21	22	23	25	24	25.35	23.40	24.37
14.	IR 40750R	23	20	22	24	22	23	21.28	19.38	20.33

Table 7. Flag leaf length and flag leaf width of cms, maintainer and restorer lines

	Parental lines	Flag leaf length (cm)			Flag leaf width (cm)		
		2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	27.9	26.8	27.4	1.7	1.6	1.7
2.	IR 58025B	30.1	32.3	31.2	1.5	1.5	1.5
3.	PMS 2A	35.3	32.7	34.0	1.3	1.5	1.4
4.	PMS 2B	33.1	34.2	33.7	1.5	1.5	1.5
5.	UPRI 92-133R	27.2	27.7	27.4	1.6	1.5	1.6
6.	UPRI 93-287R	34.2	34.0	34.1	1.3	1.3	1.3
7.	Vajram	35.6	36.5	36.1	1.8	1.8	1.8
8.	MTU 9992R	35.6	34.4	35.6	1.4	1.4	1.4
9.	IR 10198R	27.7	27.2	27.5	1.4	1.4	1.4
10.	C 20R	24.9	24.9	24.9	1.3	1.3	1.3
11.	BR 827-35R	35.6	32.5	34.1	1.3	1.3	1.3
12.	IR 31802R	36.9	37.0	37.0	1.3	1.3	1.3
13.	IET 8585R	38.0	38.0	38.1	1.6	1.6	1.6
14.	IR 40750R	38.2	38.1	38.1	1.4	1.4	1.4

Table 8. Flag leaf length/width ratio and flag leaf area of cms, maintainers and restorers lines

	Parental lines	Flag leaf length/ width ratio			Flag leaf area (cm^2)			Flag leaf angle (°)		
		2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	16.41	16.75	19.78	35.57	32.16	33.86	34	32	33.0
2.	IR 58025B	20.06	21.60	20.83	33.86	36.34	35.10	27	25	26.0
3.	PMS 2A	27.15	22.92	25.04	34.42	33.53	33.98	25	22	23.5
4.	PMS 2B	22.06	22.76	22.41	37.23	38.42	37.83	20	22	21.0
5.	UPRI 92-133R	17.00	18.44	17.72	32.64	31.72	32.18	14	16	15.0
6.	UPRI 93-287R	26.30	26.16	26.23	33.35	33.16	33.30	18	15	16.5
7.	Vajram	19.76	20.28	20.02	48.06	49.23	48.65	26	23	23.5
8.	MTU 9992R	25.42	24.57	25.00	37.38	36.12	36.75	12	10	11.0
9.	IR 10198R	19.80	19.48	19.64	29.09	28.56	28.82	12	14	13.0
10.	C 20R	19.15	19.16	19.16	24.28	24.30	24.29	23	26	24.5
11.	BR 827-35R	27.38	25.00	26.19	34.71	31.69	33.20	33	35	34.0
12.	IR 31802R	28.38	28.46	28.42	35.98	36.98	36.03	19	20	19.5
13.	IET 8585R	23.75	23.75	23.75	45.61	45.60	45.61	14	17	15.5
14.	IR 40750R	27.27	27.21	27.24	40.09	40.05	40.07	11	14	12.5

Table 9. Floral traits for cms (A lines) and their maintainers and restorers lines

	Parental lines	Style length (mm)			Stigma length (mm)			Total length (mm)		
		2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	1.95	2.03	1.99	0.69	0.62	0.66	2.64	2.65	2.65
2.	IR 58025B	1.97	2.05	2.01	0.55	0.50	0.53	2.52	2.55	2.54
3.	PMS 2A	1.81	1.86	1.84	0.71	0.79	0.75	2.52	2.57	2.55
4.	PMS 2B	1.83	1.85	1.84	0.71	0.71	0.71	2.54	2.64	2.59
5.	UPRI 92-133R	2.35	2.55	2.45	0.59	0.59	0.59	2.94	3.14	3.04
6.	UPRI 93-287R	1.46	1.39	1.42	0.58	0.52	0.55	1.34	1.34	1.34
7.	Vajram	2.15	2.22	2.19	0.75	0.74	0.75	2.90	2.96	2.93
8.	MTU 9992R	1.89	1.98	1.94	1.05	1.05	1.05	2.98	3.03	3.01
9.	IR 10198R	2.49	2.57	2.53	0.58	0.54	0.56	3.07	3.11	3.09
10.	C 20R	1.40	1.40	1.40	0.50	0.50	0.50	1.90	1.90	1.90
11.	BR 827-35R	1.37	1.59	1.48	0.51	0.61	0.56	1.88	2.20	2.04
12.	IR 31802R	1.83	1.95	1.89	0.52	0.59	0.55	2.35	2.54	2.45
13.	IET 8585R	1.69	2.00	1.85	0.48	0.59	0.54	2.17	2.59	2.38
14.	IR 40750R	2.20	2.20	2.20	0.50	0.75	0.63	2.70	2.95	2.83

Table 10. Length of anther and angle of opening of lemma and palea of cms, maintainer and restorer lines

	Parental lines	Anther length (mm)			Opening angle of lemma and palea (°)		
		2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	2.14	2.17	2.16	35.8	41.8	38.8
2.	IR 58025B	2.20	2.21	2.22	21.8	27.8	24.8
3.	PMS 2A	1.54	1.64	1.59	36.0	39.8	37.9
4.	PMS 2B	1.80	1.92	1.86	32.8	30.6	31.7
5.	UPRI 92-133R	2.50	2.65	2.58	30.7	33.7	32.2
6.	UPRI 93-287R	2.27	2.34	2.31	39.7	35.7	37.7
7.	Vajram	2.63	2.68	2.66	33.8	30.8	32.3
8.	MTU 9992R	2.54	2.72	2.63	37.9	32.8	35.4
9.	IR 10198R	2.34	2.15	2.25	19.7	25.1	22.4
10.	C 20R	1.92	1.92	1.92	25.4	29.3	27.4
11.	BR 827-35R	1.32	2.11	1.72	30.2	33.7	31.9
12.	IR 31802R	2.02	2.11	2.07	43.2	38.2	40.7
13.	IET 8585R	2.04	2.00	2.02	35.7	39.8	37.8
14.	IR 40750R	2.29	2.35	2.32	32.7	37.5	35.1

Table 11. Percentage fertility and sterility of cm lines, maintainer and restorer lines

	Parental lines	Fertility (%)			Sterility (%)		
		2005	2006	Mean	2005	2006	Mean
1.	IR 58025A	3.92	2.79	3.35	96.08	97.21	96.65
2.	IR 58025B	95.31	96.77	96.04	4.69	3.23	3.96
3.	PMS 2A	2.70	3.03	2.86	97.36	97.05	97.22
4.	PMS 2B	97.36	95.50	96.43	2.64	4.50	3.57
5.	UPRI 92-133R	94.08	91.00	92.54	5.92	9.00	7.46
6.	UPRI 93-287R	89.38	93.10	91.24	10.62	6.90	8.76
7.	Vajram	94.32	93.22	93.77	5.68	6.78	6.23
8.	MTU 9992R	93.75	91.60	92.75	6.25	8.40	7.25
9.	IR 10198R	93.75	93.91	93.83	6.25	6.09	6.17
10.	C 20R	93.37	93.26	93.32	6.63	6.74	6.70
11.	BR 827-35R	95.81	96.25	96.03	4.19	3.75	3.97
12.	IR 31802R	93.36	90.57	91.47	7.64	9.43	8.54
13.	IET 8585R	95.60	95.08	95.34	4.40	4.91	4.70
14.	IR 40750R	96.00	96.59	96.59	4.00	3.41	3.71

However, the cms lines had erect flag leaves which is undesirable and need clipping to facilitate pollen movement for out crossing. The restorer lines, MTU 9992R, IR 40750R had horizontal type of flag leaves which is desirable character for out crossing (Table 7). Rest of restorers had erect type of leaves except IR 31802R which had reflexed type of leaves which is again not very suitable for free flow of the pollen. The flag leaf angle of the cms lines, their maintainers and restorers also was recorded. The mean flag leaf angle in the cms lines IR 5805A (33.0°) and PMS 2A (23.5°) was higher than their maintainers (Table 8) IR 58025B (26.0°) and PMS 2B (21.0°). This is a desirable trait that flag leaf angle should be more in cms lines to facilitate out-crossing. The flag leaf angle of the restorers ranged from 11.0° (MTU 9992R) to 34.0° (BR 827-35R). Higher flag leaf angle promotes cross-pollination resulting in higher seed production. The success of hybrid seed production also depends on well developed floral traits. The length of the stigma, style, anther and filament length, stigma exsertion and angle of glume opening are important floral traits influencing outcrossing in rice (Virmani and Edward, 1983). The style length observed in A, B and R lines under the present study showed that IR 58025A had mean style length of 1.99 mm. It was 1.84 mm in PMS 2A (Table 9). Madhavan and Subramanian (1999) reported that the style length in A line to range from 0.94 (MS 31A) to 1.83 mm (IR 46827 A) with a mean of 1.20 mm. Parmar *et al*. (1979) have observed varying style length from 0.6 mm to 3.2 mm in cultivated rice. Virmani and Athwal (1974) reported that style length is a polygenically controlled trait; hence through pedigree method of selection, this character can be improved. The stigma length of the cms lines ranged from 0.66 mm in IR 58025A to 0.71 mm in PMS 2A, while in maintainers it ranged from 0.53 mm in IR 58025B to 0.75 mm in PMS 2B. Madhavan and Subramanian (1999) reported the range of stigma length from 0.86 mm (ES 18 A) to 1.31 mm (V 20A) with a mean of 1.08 mm and from 0.81 mm (MS 31B) to 1.29 mm (V 20B) with an average of 1.11 mm in A and B lines, respectively. Parmar *et al*. (1979) observed the stigma length ranging from 0.20 mm to 2.60 mm in rice cultivars. The results of the present study as well as the previous findings indicate that there is every possibility of improving the stigma size of the cms lines utilizing the natural variability, available in the rice germplasm. Wide angle of opening in the spikelets of A line is important for exposing the stigmatic surface better to pollen in the air for fertilization. In the present study, the glume opening of IR 58025 A was 38.8°, while that of PMS 2A was only 24.8°, which is not very desirable (Table 10). Wide opening angle of lemma and palea in IR 58025A may be one of the reasons for widespread utilization of this cms, line in the hybrid rice breeding programme. The mean glume opening angle in maintainer lines IR 58025B and PMS 2B was only 24.8° and 31.7°, respectively.

With regard to the restorer lines, the mean opening angle of lemma and palea ranged from 22.4° (IR 10198R) to 40.7° (IR 31802R). According to McNeal and Zieglar (1975), the wider angle of glume opening in wheat might be due to larger lodicule size. The variations for angle of glume opening observed among A, B and R 18 lines were attributed to both genic and environmental causes by Parmar *et al*. (1979) and Anonymous (1983). Wide opening in B and R lines promotes easy release of pollen grains into the air for pollination. In the present study, the restorer lines UPRI 93-287R, IR 31802R and IET 8585R were identified for wider angle of opening of glumes. These may be of good breeding value. Parmar *et al.* (1979) have observed that angle of opening is under genetic control. Several workers have reported that the floral characters are highly stable and heritable. Breeding lines can be improved for floral traits promoting cross-pollination. The mean fertility percent and sterility percent of the cms lines, their maintainers and restorer lines were also observed (Table 11). The mean sterility percent (natural out crossing) for cms lines IR 58025A (3.35%), PMS 2A (2.86%) was almost constant during both the years. The fertility may be due to natural pollination as the panicles or cms lines were left open during crop season. The fertility percent of maintainers IR 58025B (96.04%) and PMS 2B (96.43%) was also almost constant during both the years. The fertility percent of the restorer lines ranged from 91.47% (IR 31802R) to 96.30% (IR 40750R) which is within normal limits. Some spikelets remain unfilled in almost all the high yielding rice varieties due to physiological and environmental factors.

As the parental lines of highest purity are required for the hybrid seed production programme. Therefore, the present investigations will help in the identification of morphological and floral characteristics that are useful to maintain the purity of the parental lines. The floral traits are least influenced by environmental factors and are relatively stable. On the other hand, morphological characters such as plant height, days to 50% flowering, panicle length are highly influenced by environment. Thus the floral characters can help in maintaining the purity of the lines.

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