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Genetics of fertility restoration in hybrid rice

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Summary. The cross combination involving 14 male-sterile lines in rice, when crossed with different maintainers, showed fertility restoration in certain combinations. When F_2 segregating populations were classified based on spikelet fertility, fertility restoration was shown to be governed by 3:1, 9:3:3:1, and 12:3:1, due to allelic differences. This indicated that the cytosterility of the same group showed monogenic fertility restoration, whereas crossing plants belonging to different cystosterile groups showed a digenic pattern of segregation.

Key words: Male sterility – Cytosterile – Restoration – Allelic differences

Introduction

During the last two decades the majority of countries in tropical Asia have made spectacular advances in rice production and productivity. In India, the production level has increased from less than 39 million tons in 1965 to more than 64 million tons in 1985/86. This impressive accomplishment, largely attributable to the spread of high-yielding dwarf varieties, has merely taken us to the state of self-sufficiency. At the present rate of population growth, with no possibility of expanding the area under rice cultivation, rice yield must be increased to 2.5 tons/ha within the decade, in order to sustain self-sufficiency. To accomplish this, hybrid rice is the only prospective tool, and it has been commercially exploited during the 1970s in China (Lin and Yuan 1980). Yet from a practical point of view, apart from China only a few countries, e.g., South Korea, Indonesia, and Thailand, have reported the commercial exploitation of hybrid rice. However, in India we have had little success due to the non-stability of the genotype as regards to sterility, as well as to the poor restorability of the cultures. Hence, an attempt was made to acquire basic understanding of the sterility and genetics of restorability of already available male-sterile sources.

Materials and methods

Fourteen male-sterile lines, viz., IR 46826 A, IR 46827 A, IR 46829 A, Pushpa A, Madhu A, Mangala A, Pragathi A, MS 577 A, Erjiunan 1A, V 41 A, Yar Ai Zhao 1A, MS 31 A, MS 37 A, and MS 47 A, were collected (Table 1) and crossed with their respective maintainers as well as with other maintainers. In addition, certain male-sterile lines were crossed with restorer lines and varieties. The F_1 hybrids were raised, spikelet fertility was assessed in individual plants, and average spikelet fertility was determined (Table 2). In the A × B crosses, it was intersting to note that nine cross combinations showed more than 80% seed fertility. These plants were harvested individually plant-wise, and the seeds were forwarded to the F_2 generation from October 1989 to February 1990. In the F_2 generation all seeds were raised and transplanted to the main field. The plants were harvested individually, and the fertility percentage was worked out using the formula:

$$\frac{\text{Poorly filled} + \text{chaff grains}}{\text{Total no. of grains}} \times 100.$$

Based on fertility, the individual plants were grouped into class intervals of >80%, 80–50%, 50–1%, and <1%.

Results and discussion

The 14 male-sterile lines originated in different regions, viz., The Phillipines, Korea, China, and India (Table 1). The fertility of F_1 hybrid combinations is presented in Table 2. The maintainers IR 46828 B and Erjiunan 1B, when combined with IR 46829 A, showed a poor fertility level, indicating that they were a good maintainer of sterility for IR 46829 A also. The crosses IR 46827 A ×

Table 1. The origin and source of different male-sterile lines

Sel. no.	Male-sterile line	Cytoplasm	Parentage	Source
1	Pushpa A	WA	MS 577 (Korea)	Karnataka
2	Madhu A	WA	MS 577 (Korea)	Karnataka
3	Mangala A	WA	MS 577 (Korea)	Karnataka
4	Erjiunan 1A	WA	*O. sativa spontanea*/Erjiunan	China
5	Yar Ai Zhao 1 A	Gambiaca	Gambiaca/YAZ	China
6	V 41 A	WA	–	China
7	IR 46826 A	WA	97 A/IR 10154-23-3-3	IRRI
8	IR 46827 A	WA	–	IRRI
9	IR 46829 A	WA	V 20/IR 19792-15-2-3-3	IRRI
10	MS 31 A	WA	V41 A/ADT 31	TNAU

Table 2. F_1 fertility percentage of cms line with different maintainers, restorers, and varieties

Sel. no.	Cross	Fertility percentage
1	IR46827 A/IR 46828 B	96.11[a]
2	Pushpa A/Mangala B	87.79[a]
3	Madhu A/Pushpa B	92.79[a]
4	Erjiunan 1A/Yar Ai Zhao 1 B	95.00[a]
5	Yar Ai Zhao 1A/Madhu B	96.48[a]
6	IR46829 A/Madhu B	94.80[a]
7	IR46829 A/MS 31 B	82.87[a]
8	MS31 A/Yar Ai Zhao 1 B	95.29[a]
9	IR46829 A/Erjiunan 1 B	31.81
10	IR46826 A/IR46828 B	15.60
11	IR46826 A/MS31 B	90.92[a]
12	MS37 A/IR36 R	92.82
13	MS37 A/IR9761 R	91.34
14	Puspha A/IR9761 R	96.06
15	MS31 A/IR36 R	97.46
16	MS31 A/IR9761 R	88.42
17	MS47 A/IR9761 R	97.60
18	Pragathi A/IR46 R	98.10
19	V41 A/IR9761 R	96.80
20	ZS97 A/IR9761 R	95.90
21	Puspha A/IR 50 R	85.20
22	MS577 A/IR36 R	93.91
23	IR46829 A/IR36 R	43.66
24	IR46828 A/IR50	95.97
25	IR46826 A/PMK 1	72.67
26	MS31 A/CO 37	73.95
27	Yar Ai Zhao 2 A/ADT 36	92.92

[a] Plants forwarded to F_2 generation

IR 46828 B, Pushpa A × Mangala B, Madhu A × Pushpa B, Erjiunan 1A × Yar Ai Zhao 1B, Yar Ai Zhao 1A × Madhu B, IR 46829 A × Madhu B, IR 46829 A × MS 31B, MS 31A × Yar Ai Zhao 1B, and IR 46826 A × MS 31B showed more than 80% spikelet fertility, indicating allelic difference in restoration ability, even though it was the basic cytosterile source of the wild abortive type. This was in accordance with the earlier report of Govindaraj and Virmani (1988). The restorers IR 36 R, IR 9761 R, IR 31 R, IR 46 R, and IR 50 R were found to show a high level of fertility restoration. Once again with IR 46829 A, IR 36 R showed only partial fertility restoration. Varieties such as PMK 1 and CO 37 also did not restore fully.

When the fertile cross combinations were forwarded to F_2 generations, the plants fell into different class intervals (Table 3). The gene controlling fertility restoration was found to be monogenic and digenic. Five cross combinations, viz., IR 46827 A × IR 46828 B, IR 46829 A × MS 31 B, IR 46826 A × MS 31 B, Pushpa A × Mangala B, and Madhu A × Pushpa B, had a segregation pattern of 1:2:1, indicating monogenic control. This is in accordance with earlier findings of Govindaraj and Virmani (1988) and Huang et al. (1985). Interestingly, the origin of these lines were IRRI/IRRI or IRRI/India of both WA/WA types or Korea/Korea type of both MS 577/MS 577 source. When a Chinese male-sterile line was crossed with different Chinese maintainers or with Korean maintainers, it produced a 12:3:1 ratio (Erjiunan 1A × Yar Ai Zhao 1B, Yar Ai Zhao 1A × Madhu B, and MS 31A × Yar Ai Zhao 1B). Only one cross, IR 46829A × Madhu B, i.e., IRRI/Korean combination, showed 9:3:3:1. Govindaraj and Virmani (1988) and Singh and Sinha (1988) reported inhibitory gene action of 12:3:1 in the Chinese line V 20 A. Young and Virmani (1985) reported digenic action in the ZS 97 A × IR 54 A cross with 9:3:3:1 genetic action. The findings thus far indicate that there were four groups of cytosteriles, designated S_1, S_2, S_3, and S_4.

S_1 present in P 203 A – designated as BT, Shinjyo (1969);

S_2 present in 97 A and V 20 A – Lin and Yuan (1980);

S_3 present in Yar Ai Zhao A – Lin and Yuan (1980);

S_4 present in MS 577 A – Govindaraj and Virmani (1988).

Based on this the parents were monogenic or digenic, as presented in Table 4. When cytosteriles of the same group showed monogenic fertility restoration while crossing, different cytosterile groups showed differential action of fertility restoration following a digenic pattern.

Table 3. Segregation pattern in F_2 generation

Gef.	Cross	F_2 plant population	Observed				Expected				o-e / E	Ratio (probability)
			>80%	80–50%	50–1%	<1%	>80%	80–50%	50–1%	<1%		
1	IR 46827 A/ IR 46828 B	225	60	67 112	45	53	56.2	112.5	–	56.2	0.44	1:2:1 (80–90)
2	Pushpa A/ Mangala B	131	33	36 68	32	30	32.7	65.5	–	32.7	0.33	1:2:1 (80–90)
3	Madhu A/ Pushpa B	176	42	50 96	46	38	44.0	88.0	–	44.0	1.64	1:2:1 (30–50)
4	Erjiunan 1 A/ Yar Ai Zhao 1 B	158	114	26 36	10	8	118.5	29.6	–	9.8	2.42	12:3:1 (30–50)
5	Yar Ai Zhao 1 A Madhu B	378	277	42 81	39	20	283.5	70.8	–	23.6	2.16	12:3:1 (30–50)
6	IR 46829 A/ Madhu B	202	114	39	40	9	112.6	37.8	37.8	12.6	1.19	9:3:3:1 (70–80)
7	IR 46829 A/ MS 31 B	164	39	43 88	45	37	41.0	82.0	–	41.0	0.92	1:2:1 (50–70)
8	MS 31 A/ Yar Ai Zhao 1 B	123	88	17 28	11	7	92.2	23.1	–	7.7	1.31	12:3:1 (50–70)
9	IR 46826 A/ MS 31 B	171	41	61 93	32	37	42.7	85.5	–	42.7	1.30	1:2:1 (50–70)

Table 4. Genetic ratio and allelic relationship between cytosteriles

Sel. no.	Cross	Cytosterile system	Genetic ratio
1	IR 46827 A/IR 46828 B	$S_2 \times S_2$	1:2:1
2	Pushpa A/Mangala B	$S_4 \times S_4$	1:2:1
3	Madhu A/Pushpa B	$S_4 \times S_4$	1:2:1
4	Erjiunan 1 A/Yar Ai Zhao 1 B	$S_2 \times S_3$	12:3:1
5	Yar Ai Zhao 1 A/Madhu B	$S_3 \times S_4$	12:3:1
6	IR 46829 A/Madhu B	$S_2 \times S_4$	9:3:3:1
7	IR 46829 A/MS 31 B	$S_2 \times S_2$	1:2:1
8	MS 31 A/Yar Ai Zhao 1 B	$S_2 \times S_3$	12:3:1
9	IR 46826 A/Ms 31 B	$S_2 \times S_2$	1:2:1

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