Chapter 3

Appropriate Restorer Lines for Hybrid Rice Productions

3.1 Introduction

Increasing yield per unit area is a way to reduce production cost. The use of high-yielding potential varieties, resistant to pests and tolerant to adverse conditions will enable Thailand to compete in rice world market. Utilization of hybrid vigor, hybrid rice becomes a possible way for increasing in terms of quantity and quality of yield potential.

In developing rice hybrid, a genetic system mostly used is known as three- line system which consists of the cytoplasmic genetic male sterility line (CMS line or A-line), the maintainer line (B-line) and restorer line (R-line). The A-line or CMS line refers to a special kind of breeding line whose anthers are abnormal as a result of no pollen or only abortive pollen existing in CMS anther. The B-line or maintainer line is a specific pollinator who donates pollens to the A-line for multiplying the A-line. The R line or restorer line is a pollinator variety used for hybridizing with A-line to produce F1 hybrid that becomes normal in fertility and selfing seeds production. In three line system of rice hybrid, the appropriate genetic relationship must be studied in order to meet the exploiting heterosis in F1 hybrid.

The experiment was aimed to characterize A-line or cytoplasmic genetic male sterile lines and find out R-lines or restorer lines which have abilities for F1 hybrid production.

3.2 Materials and Methods

Varietal evaluation: For evaluating of parental lines for producing hybrid crosses, three groups of rice varieties which are different in genetical bases were studied as follow:

1. Four cytoplasmic genetic male strerile lines (CMS-line) or A-line included:

(1) RD21A-23 (2) IR58025A

(3) IR62829A (4) V20A

2. Four maintainer lines (or B-line) included:

(1) RD21B-23 (2) IR58025B

(3) IR62829B (4) V20B

3. Twenty-one of restorer lines or R-lines included:

(1) RD 1 (2) RD 7

(3) RD 9 (4) RD 11

(5) RD 23 (6) RD 25

(7) Chainat 1(CNT1) (8) Pathumthani 1(PTT1)

(9) Khao Hawm Klongluang1(KLG1) (10) Supanburi 60 (SPR60)

(11) Supanburi 90 (SPR90) (12) Supanburi 1 (SPR1)

(13) IR46R (14) SPR85163-5-1-2-3

(15) SPR87032-3-1-1-2-1 (16) IR68926-61-2R

(17) IR63870-3-2-3-3R (18) IR58110-144-2-2-2R

(19) IR65620-96-2-3-3-1R (20) IR62161-1843-1-3-2R

(21) Khao Hawm Supanburi (KHSPR)

To study agronomic characters of A-line, B-line and restorer line (R-line) and pollen fertility of A-lines, spikelet fertility of R-lines, two studies were separately conducted as follow:

Study 1. Pollen Fertility and Agronomic Character Study

Field experiment: Seeds of A-lines, B-lines and R-lines were germinated on Petri dishes. Thereafter, young seedlings of each line were transplanted to large ceramic pots (about 15 inches in diameter), using three seedlings per pot. In order to optimize plant growth and development, normal cultural practices were managed such as application of 16-20-0 chemical fertilizer at the rate of 10 gm per pot plus urea fertilizer (46 % N) at 15 gm. per pot at maximum tiller stage. Leaf diseases and insect pests were controlled as needed. For preventing crop from drought damage, water level of each pot was kept about 3-5 cm high. Plots were laid out in randomized block design with three replications.

Measurement: At flowering stage, first panicle of A-lines plants were covered with brown paper bags for preventing of cross pollination. To identify pollen fertility of both A-lines and B-lines, three spikelets per plant were taken randomly from the tip, middle and base of main panicle. Fresh stamens were placed on glass slice and dropped 1 % iodine in potassium iodine (I-KI) solution. Using a small forceps to break stamens to allow pollens to expose to I-KI solution and placed with cover slip. Fertile pollens were examined under light microscope by observing blue-stained pollens which reacted with I-KI solution. (Dong *et al.*, 2002).

For study of agronomic characters, three plants were randomly selected to record on number of tiller per plant, percent of panicle exertion, number of panicle per plant and number of grain per panicle

Location and experiment period: The study was carried out at Pathumthani Rice Research Center during rainy season 2001.

Study 2 Test of restore lines (R-line)

Field experiment: Seeds of each A-line and R-line were germinated on Petri dishes, thereafter, young seedlings of each line were transplanted to large ceramic pots (about 15 inches diameter), using three seedlings per pot. Normal cultural practices were managed as indicated in Study 1. F1 hybrid seeds of each cross were produced by hand crossing between A-line and R-line at the flowering stage. The numbers of single cross derived from four A-lines and twenty-one R-lines were equal to 84 crosses.

To study fertility restoration ability of R-lines, F1 hybrid seeds of each cross, parents and check variety (SPR1) were germinated in large ceramic pots. After twenty-five days of seeding, seedlings of tested materials were transplanted in two-row plot with hill spacing of 25 x 25 cm, adjacent to its respective R-line parent and check variety. Experimental plots were laid out in randomized block design with three replications. In order to optimize crop growth and development, normal cultural practices were managed, such as application of 50 kg/rai of 16-20-0 chemical fertilizer as basal application during the field preparation. Additional applications of nitrogen fertilizer were made twice at 15 days and 50 days after transplanting, using urea (40 % N) 20 kg/rai and 25 kg/rai, respectively. Weeds were controlled by hands

if infestation was observed. For preventing of drought damage, about 5-10 cm of water level was maintained throughout the growing season. Water was drained when the plants reached maturing stage to regulate uniform grain maturity. Leaf diseases and insect pests were controlled as needed.

Measurement: For evaluating the restorer ability of R-lines, two parameters were identified: (a) parent pollen fertility and (b) spikelet fertility of each F1 hybrid cross. Pollen fertility was examined at the flowering stage by choosing 15 spikelets randomly from the main panicle of plants. Fresh stamens were fixed with 70% ethyl alcohol. Pollens were stained with 1 % iodine in potassium iodine (I-KI). Blue stained pollens were counted to examine the percent of pollen fertility. The spikelet fertility or filled grains of each F1 hybrid cross were determined by counting from the panicles which were sampled randomly from 10 panicles within plot.

After the restorer abilities of each R-line were evaluated, category of R-line was grouped according to Virmani *et al.* (1997) as follow:

Pollen fertility (%)	**Category**	**Spikelet fertility (%)**
80.0 – 100	Restorer (R)	> 75
50.1 – 80	Partial restorer (PR)	50.1 – 75
1.1 – 50	Partial maintainer (PM)	1.1 – 50
0.0 – 1	Maintainer (M)	0.0 – 1

At maturing stage, observations were recorded on five competitive hills taken randomly in each replication to collect data for plant height, number of panicle per hill, number of grain per panicle and 1,000-grain weight.

Data analysis: Analysis of variance for all measured parameters was made in usual way. Significances of treatments were determined by F-test and least significant difference (LSD) was used to make comparison among means. Relationship between pollen fertility and spikelet fertility was examined by using simple correlation method. Both analysis of variance and correlation procedure were done according to Steel and Torrie (1960).

Location and Experimental period: The experiments were conducted at the experimental field of Pathumthani Rice Research Center during dry season 2002.

3.3 Results

3.3.1 Pollen Fertility and Agronomic Character Study

Results of both pollen fertility and agronomic characters of A-lines and its B-line are shown in Table 3.1 and Figure 3.1 which indicated as follow:

A-line RD21A-23 gave 12 tillers/hill, 94 cm of plant height, 87 days of flowering date, 26 cm of panicle length, 70% of panicle exertion, 20% of floret blooming and 92% of pollen sterility. B-line RD21B-23 gave 15 tillers/hill, 113 cm of plant height, 85 days of flowering date and 26.8 cm for panicle length.

A-line IR58025A gave 13 tillers/hill, 92 cm of plant height, 77 days of flowering date, 25 cm of panicle length, 60% of panicle exertion, 20% of floret blooming and 60% of pollen sterility. B-line IR58025B gave 18 tillers/hill, 96 cm of plant height, 75 days of flowering date and 24.5 cm of panicle length.

A-line IR62829A gave 18 tillers/hill, 83 cm of plant height, 70 days of flowering date, 23 cm of panicle length, 50% of panicle exertion, 80% of floret

blooming and 88% of pollen sterility. B-line IR62829B gave 20 tillers/hill, 85 cm of plant height, 70 days of flowering date and 22.8 cm of panicle length.

A-line V20A gave 15 tillers/hill, 70 cm of plant height, 55 days of flowering date, 20 cm of panicle length, 52% of panicle exertion, 30% of floret blooming and 92% of pollen sterility. B-line V20B gave 17 tillers/hill, 74 cm of plant height, 50 days of flowering date and 21.2 cm of panicle length.

Results of this study further indicated that A-lines V20A and RD21A-23 were considered as promising cytoplasmic genetic male sterility lines since both lines gave more than 90 percent of pollen sterility and possessed good agronomic characters such as number of tillers per hill, plant height, panicle length and percent of panicle exertion.

Table 3.1 Agronomic characters of A-line and B-line rice studied at Pathumthani Rice Research Center in rainy season 2002.

No	Varieties/Lines	Tiller/hill	Plant height (cm)	Day to50% flowering	Panicle length (cm)	Panicle exsertion (%)	Floret blooming (%)	A- line sterility (%)
	A- line							
1	RD21A-23	12	94	87	26	70	20	90
2	IR58025A	13	92	77	25	60	20	60
3	IR62829A	18	83	70	23	50	80	88
4	V20A	15	70	55	20	52	30	92
	B- line							
1	RD21B-23	15	113	85	26.8			
2	IR58025B	18	96	75	24.5			
3	IR6289B	20	85	70	22.8			
4	V20B	17	74	50	21.2			

3.3.2 Relationship between Pollen Fertility and Spikelet Fertility of R-lines.

Pollen fertility and spikelet fertility ratio among the R-lines is shown in Table3.2. It was found that some R-lines which were able to produce good ratio of these two characters included IR58110-144-2-2-2R, SPR1, IR62161-1843-1-3-2R, RD1, RD7, IR68926-61-2R, IR63870-3-2-3-3R, RD11, CNT1, IR46R, IR65620-2-3-1R and RD23 which gave pollen fertility : spikelet ratio of 95:82, 93:82, 94:80, 90:80, 95:80, 94:80, 95:81, 96:78, 95:78, 91:78, 92:78 and 95:76 percent, respectively.

3.3.3 Fertility restoration of R-lines

Characters of R-lines on fertility restoration were determined by examining filled grain percentage of F1 as shown in Table 3.3. Rice varieties which were classified as R-lines included IR58110-144-2-2-2R, IR63870-3-2-3-3R, IR62161-1843-1-3-2R, IR68926-61-2R, IR46R and IR65620-96-2-3-3-R, received from the International Rice Research Institute (IRRI), being able to restore male fertility of A-lines averaging 82.3, 82.0, 80.7, 80.2, 78.2 and 78.0 percent, respectively. Thai rice varieties, SPR1, RD1, RD7, RD11, CNT1 and RD23 did not show significant difference from IRRI lines, giving spikelet fertility in F1 hybrids for 82.2, 80.3, 80.3, 78.5, 78.3 and 76.3 percent, respectively. Varieties or lines which performed as partial R-lines were SPR87032-3-1-1-2-1, SPR90, SPR85163-5-1-2-3 and PTT1 and gave F1 hybrid fertility for 71.65, 65.15, 63.70, 57.20 and 44.65 percent while SPR90, RD9, KHSPR, KLG1 and RD25 variety gave quite low percent of F1 hybrids fertility for 26.35, 16.00, 12.35, 8.45 and were classified as partial maintainer.

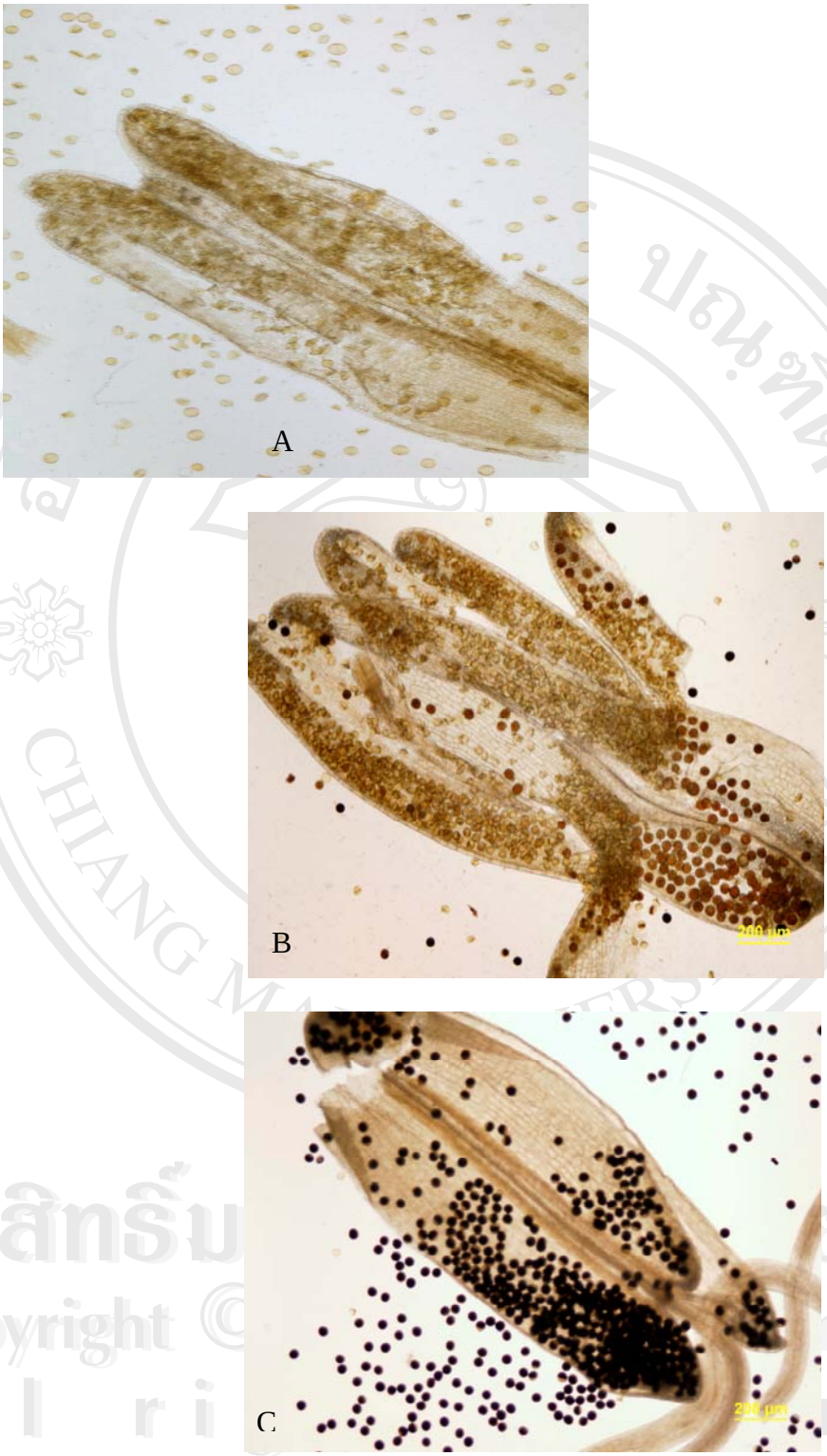

Figure 3.1 Pollen of F1 hybrid stained with I-IK solution: A) sterile pollen B) partially-fertile pollen C) fertile pollen.

Partial restorer lines SPR87032-3-1-1-2-1, SPR90, SPR85163-5-1-2-3 and PTT1 gave pollen fertility:spikelet fertility ratio of 91:71, 83:65, 85:63 and 67:57.

Partial maintainer lines SPR60, RD9, KHSPR, KLG1 and RD25 gave 44:44, 36:26, 28:16, 21:12 and 21:8 percent for pollen fertility and spikelet fertility ratio.

Relationship between pollen fertility and spikelet fertility among the F1 hybrids developed from crossing A-lines and R-lines is shown in Figure 3.2 It was found that there was highly significant positive correlation between pollen fertility and spikelet fertility ($r = 0.96513^{**}$, $R^2 = 0.9312^{**}$).

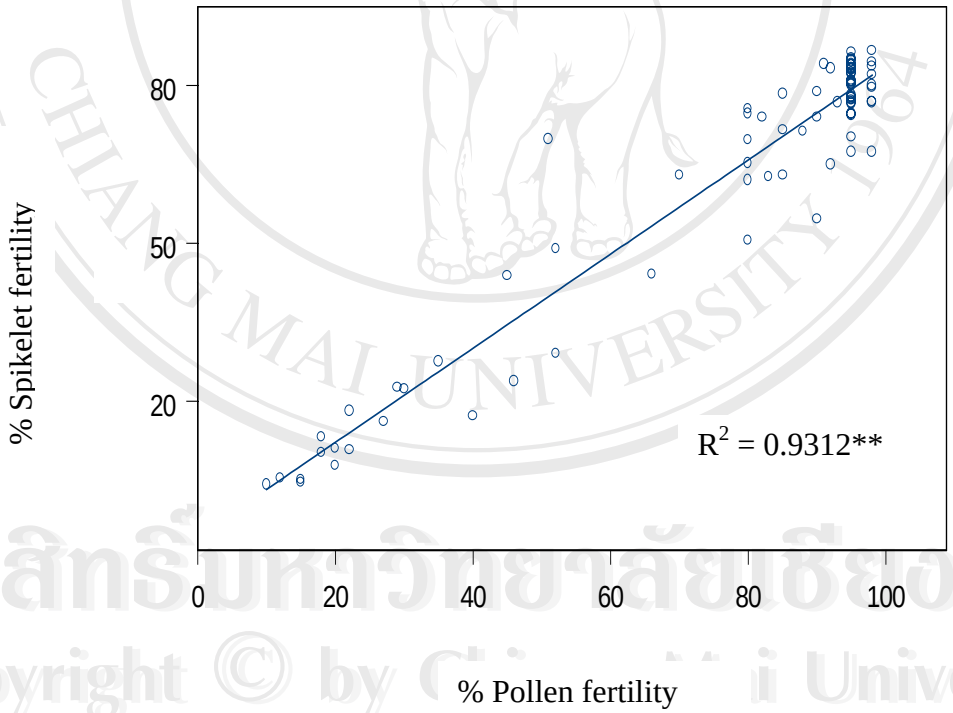

Figure 3.2 Relationship between pollen fertility and spikelet fertility in F1hybrid crosses.

3.3.4. Evaluation of Variety/line Performance

(a) Grain yield

Grain yield of F1 hybrids obtained from crossing among A-lines and tested varieties/lines is shown in Table 3.4. It was found that average grain yield per plant was significantly different among the varieties/lines within cross. Varieties/lines which were classified as R-line gave higher grain yield per hill than PR-lines and PM-lines. R-lines which gave high grain yield per plant included IR58110-144-2-2-2R, IR68926-61-2R, IR46R, IR65620-96-2-3-3-1R, SPR1, CNT1, SPR87032-3-1-1-2-1, RD11, RD1, SPR85163-5-1-2-3, IR63870-3-2-3-3R, RD7, and IR62161-1843-1-3-2R, which gave grain yield of 39.14, 37.41, 35.80, 35.21, 33.54, 32.77, 32.25, 32.02, 31.44, 30.49, 30.08, 30.07 and 29.29 gm/plant, respectively. For PR-lines SPR87032-3-1-1-2-1, SPR85163-5-1-2-3, RD23 and SPR 90, they gave medium to high grain yield per plant, 32.25, 30.49, 26.91 and 25.69 gm, respectively. PM-lines KHSPR, RD9, KLG1 and RD25 gave quite low grain yield per plant, 12.22, 11.12, 4.76 and 5.81 gm., respectively.

(b) Number of panicles per hill

Number of panicles per hill of F1 hybrids obtained from crossing among A-lines and tested varieties/line is shown in Table 3.5. It was found that average of panicles per hill was not significantly different among the varieties/lines. Average panicles per hill among crosses ranged from 9.65 to19.80 panicles/hill.

(c) Number of grains per panicle

Number of grains per panicle of F1 hybrids obtained from crossing among A-line and tested varieties/lines is shown in Table 3.6. It was found that number of

grains per panicle was significantly different among the tested varieties/lines. R-lines which gave high number of grains/panicle were RD1, IR65620-2-3-3-1R, IR58110-144-2-2-2R, RD11, IR63870-3-2-3-3R, SPR1, CNT1, IR46R, RD7, IR68926-61-2R and IR62161-1843-1-3-2R which gave 126.42, 121.24, 116.71, 116.65, 114.96, 113.41, 112.49, 104.28, 104.13, 103.65 and 100.48 grains/panicle respectively. While PR-line, PTT1, SPR90, SPR85163-5-1-2-3, RD23 and SPR87032-3-1-1-2-1 gave moderate to high number of grains per panicle of 104.81, 115.71, 118.08, 118.44 and 135.54 grains/panicle. However, PM-lines RD9, RD25, KLG1 and KHSPR also gave high number of grain/panicle as well, being 117.78, 114.83, 111.53, 132.09 grains/panicle, respectively.

Table 3.2 Pollen fertility and spikelet fertility of F1 hybrids of rice varieties studied at Pathumthani Rice Research Center, dry season 2002.

Variety/Line	RD21A-23			IR58025A			IR62829A			V20A			Average	
	Pollen fertility (%)	Spikelet fertility (%)	Category	Pollen fertility (%)	Spikelet fertility (%)	Category	Pollen fertility (%)	Spikelet fertility (%)	Category	Pollen fertility (%)	Spikelet fertility (%)	Category	Pollen fertility (%)	Spikelet fertility (%)
RD1	91	84	R	95	81	R	95	80	R	95	77	R	90	80
RD7	95	77	R	95	78	R	95	81	R	95	85	R	95	80
RD9	46	24	PM	30	22	PM	52	49	PM	18	10	PM	36	26
RD11	95	83	R	98	84	R	98	77	R	95	70	PR	96	78
RD23	95	83	R	95	75	R	98	80	R	95	68	PR	95	76
RD25	10	4	PM	15	5	PM	40	17	PM	20	8	PM	21	9
CNT 1	95	84	R	98	78	R	95	78	R	95	74	R	95	78
PTT 1	80	74	R	66	44	PM	45	44	PM	80	65	R	67	57
KLG1	15	5	PM	27	16	PM	29	23	PM	12	5	PM	21	12
SPR 60	22	18	PM	70	63	PR	35	28	PM	51	70	PR	44	44
SPR 90	82	74	PR	90	74	PR	80	62	PR	80	51	PR	83	65
SPR 1	95	83	R	95	85	R	95	82	R	90	79	R	93	82
KHSPR	18	13	PM	52	29	PM	20	11	PM	22	11	PM	28	16
SPR85163-5-1-2-3	85	63	PR	83	63	PR	95	75	R	90	55	PR	88	63
SPR87032-3-1-1-2-1	95	85	R	80	70	PR	98	67	PR	92	65	PR	91	71
IR68926-61-2R	95	8	R	85	78	R	98	80	R	98	82	R	94	80
IR63870-3-2-3-3R	92	8	R	95	78	R	95	80	R	98	87	R	95	81
IR58110-144-2-2-2R	95	86	R	95	77	R	95	82	R	95	84	R	95	82
IR65620-2-3-3-1R	95	81	R	85	72	PR	95	82	R	95	78	R	92	78
IR62161-1843-1-3-2R	95	84	R	98	84	R	88	71	PR	95	83	R	94	80
IR46R	95	81	R	80	75	R	95	80	R	93	77	R	91	78

Category of R-line: R = Restorer, PR = Partial restorer, PM = Partial maintainer.

Table 3.3 Percentage of filled grain of F1 hybrids derived from crossing between A- line and R- line studied at Pathumthani Rice Research Center, dry season 2002.

Variety/Line	Category of R-line	%Filled grain				Average (%)
		RD21A-23	IR58025A	IR62829A	V20A	
RD1	R	84.0	80.8	80.0	76.6	80.3
RD7	R	77.2	77.8	81.0	85.2	80.3
RD9	PM	23.8	22.4	49.0	10.2	26.4
RD11	PR	83.3	83.6	77.0	70.2	78.5
RD23	PR	83.4	74.5	79.6	67.4	76.3
RD25	PM	4.2	4.6	17.2	7.8	8.4
CNT 1	R	83.8	76.8	78.2	74.4	78.3
PTT 1	R	75.6	44.2	43.8	65.2	57.2
KLG1	PM	5.2	16.2	22.6	5.4	12.3
SPR 60	PR	18.2	63.0	27.6	69.8	44.6
SPR 90	PR	74.0	74.0	62.0	50.6	65.2
SPR 1	R	83.0	85.0	82.2	78.8	82.2
KHSPR	PM	13.2	29.0	11.0	10.8	16.0
SPR85163-5-1-2-3	PR	63.0	62.6	74.6	54.6	63.7
SPR87032-3-1-1-2-1	PR	84.6	69.6	67.4	65.0	71.6
IR68926-61-2R	R	80.4	78.4	80.0	82.0	80.2
IR63870-3-2-3-3R	R	83.6	77.6	80.2	86.6	82
IR58110-144-2-2-2R	R	86.4	76.8	82.4	83.8	82.3
IR65620-2-3-3-1R	R	80.6	71.6	82.2	77.8	78.0
IR62161-1843-1-3-2R	R	84.0	84.4	71.2	83.2	80.7
IR46R	R	81.0	74.6	80.4	76.8	78.2
LSD 0.05 *		7.36	10.29	9.75	11.20	
CV (%)		9.14	13.09	12.41	14.55	

* Least Significant Difference at $p < 0.05$.

Table 3.4 Grain yield (gm/ plant) of F1 hybrids studied at Pathumthani Rice Research Center, dry season 2002.

Variety/Line	Grain yield (gm/ plant)				Average
	RD21A-23	IR58025A	IR62829A	V20A	(gm/plant)
RD1	42.04	31.93	33.19	18.62	31.44
RD7	38.00	28.14	40.11	14.02	30.07
RD9	8.83	9.00	24.24	2.40	11.12
RD11	38.21	34.54	31.91	23.42	32.02
RD23	36.20	25.31	32.00	14.14	26.91
RD25	2.27	8.05	5.23	3.52	4.76
CNT 1	34.48	39.69	37.86	19.08	32.77
PTT 1	31.68	12.04	21.10	11.92	19.17
KLG1	1.74	10.93	8.34	2.22	5.81
SPR 60	5.26	3.44	13.20	8.68	7.63
SPR 90	27.38	24.50	32.60	18.26	25.69
SPR 1	34.26	36.34	42.19	21.38	33.54
KHSPR	5.39	35.75	4.38	3.34	12.22
SPR85163-5-1-2-3	24.43	34.54	36.23	28.16	30.49
SPR87032-3-1-1-2-1	41.38	28.49	31.05	28.08	32.25
IR68926-61-2R	44.79	29.83	35.98	39.02	37.41
IR63870-3-2-3-3R	37.65	32.44	29.37	20.84	30.08
IR58110-144-2-2-2R	41.03	39.71	38.28	37.52	39.14
IR65620-2-3-3-1R	37.40	33.98	46.08	23.38	35.21
IR62161-1843-1-3-2R	28.49	33.40	39.13	16.14	29.29
IR46R	36.39	39.03	39.06	28.74	35.81
LSD 0.05*	2.068	1.600	5.574	1.891	
CV (%)	5.78	4.67	6.91	8.24	

* Least Significant Difference at $p < 0.05$.

Table 3.5 Number of panicles per hill of F1 hybrids studied at Pathumthani Rice Research Center, dry season 2002.

Variety/Line	Panicle/hill				Average Panicle/hill
	RD21A-23	IR58025A	IR62829A	V20A	
RD1	9.20	10.20	20.20	9.80	12.35
RD7	7.60	9.60	19.20	14.40	12.7
RD9	20.00	16.20	25.20	17.80	19.8
RD11	8.20	7.80	15.20	7.40	9.65
RD23	11.00	13.60	17.40	10.40	13.1
RD25	18.00	15.20	24.60	13.20	17.71
CNT 1	13.80	13.60	9.20	10.40	11.75
PTT 1	14.80	13.80	22.20	13.00	15.95
KLG1	19.40	15.20	25.00	12.60	18.05
SPR 60	13.40	14.00	10.40	19.40	14.3
SPR 90	18.80	11.60	20.80	11.80	15.75
SPR 1	12.20	15.00	21.40	11.00	14.9
KHSPR	12.40	11.40	30.20	16.60	17.65
SPR85163-5-1-2-3	15.60	15.00	25.50	17.40	18.38
SPR87032-3-1-1-2-1	12.60	11.40	20.60	15.20	14.95
IR68926-61-2R	17.20	20.80	13.40	14.20	16.4
IR63870-3-2-3-3R	13.20	16.00	20.00	10.80	15.0
IR58110-144-2-2-2R	16.60	21.20	18.60	13.40	17.45
IR65620-2-3-3-1R	16.20	22.00	16.20	9.60	16.0
IR62161-1843-1-3-2R	14.80	20.00	18.80	14.20	16.95
IR46R	15.20	21.20	13.40	12.20	15.5
LSD 0.05*	5.815	5.669	4.969	5.974	
CV (%)	31.71	30.05	19.77	35.75	

* Least Significant Difference at $p < 0.05$.

Table 3.6 Number of grains per panicle of F1 hybrids studied at Pathumthani Rice Research Center, dry season 2002.

Variety/Line	No. of grains / panicle				Average (grain/ panicle)
	RD21A-23	IR58025A	IR62829A	V20A	
RD1	134.40	153.90	129.80	87.57	126.42
RD7	87.76	112.75	123.50	92.50	104.13
RD9	112.70	130.33	128.30	99.80	117.78
RD11	122.40	154.39	117.00	72.80	116.65
RD23	150.40	123.95	133.20	66.20	118.44
RD25	103.15	129.95	103.40	122.80	114.83
CNT 1	123.95	117.20	129.60	79.20	112.49
PTT 1	121.05	108.80	102.20	87.20	104.81
KLG1	124.10	104.30	135.70	82.00	111.53
SPR 60	142.05	130.55	129.65	91.40	123.41
SPR 90	122.60	142.90	130.85	66.50	115.71
SPR 1	118.00	137.69	119.40	78.55	113.41
KHSPR	137.05	185.90	120.85	84.55	132.09
SPR85163-5-1-2-3	90.20	144.00	135.70	102.40	118.08
SPR87032-3-1-1-2-1	112.55	167.00	166.59	96.00	135.54
IR68926-61-2R	83.80	113.80	105.60	111.40	103.65
IR63870-3-2-3-3R	112.20	129.82	139.20	78.60	114.96
IR58110-144-2-2-2R	139.15	122.40	108.30	97.00	116.71
IR65620-2-3-3-1R	119.05	147.60	124.85	93.85	121.34
IR62161-1843-1-3-2R	91.60	109.00	115.55	85.75	100.48
IR46R	108.40	106.60	107.70	94.40	104.28
LSD 0.05*	24.537	33.533	19.289	23.416	
CV (%)	16.67	19.80	17.21	14.99	

* Least Significant Difference at $p < 0.05$.

3.4 Discussion

Results of evaluation of pollen fertility of A- line of rice varieties indicated that there were three A- lines which were able to maintain high level of their sterilities. These A- lines included V20A (92%), RD21A-23 (90%) and IR62829A (88%). Similar results were reported by Zebing and Yingguo (1988) which reported A- line that gave the same high level of sterility as well. These three A- lines exhibited good level of sterility since their sterilities were rather stable under varied environments and controlled by two pairs of homozygous recessive genes as well as sterile cytoplasm A- line IR58025A gave quite low, only 60% of sterility, was probably due to its incomplete nuclear gene control and sterile cytoplasm. Unfavorable environments also modified sterility ability, i. e., high temperature and low humidity can stimulate some anther dehiscence and a few spikelet had selfed seed set. However, Virmani *et al.* (1997) suggested that the use of A- line should have stable and complete sterility across environments and easily maintained, otherwise diversed genotypes can be converted into new poor A- lines.

Evaluation of 21 rice varieties/ lines for developing pollen fertility restorer line or R- line indicated that there were only 12 rice varieties/ lines, classified as R- lines, which were able to restorer high acceptable pollen fertility and spikelet fertility in F1 hybrids. This results were supported by Zebing and Yingguo (1988) who reported that R- line under their study performed good restoring of pollen fertility and gave good spikelet fertility in F1 hybrids. Reasons were explained why these R- lines performed well for restoring fertility since this character was solely controlled by genes. Young *et al.* (1984) analysed restorer genes in some IR restorer lines and

reported that there were two pairs of homozygous dominant restorer genes, $R_1R_1R_2R_2$ with R_1R_1 appearing to be more important that R_2R_2. Hu and Li (1985) also reported that R- lines were controlled by two pairs of major fertility genes in the same linkage group.

The authors evaluated rice varieties/ lines showed low level of pollen fertility in F1 hybrids and were classified as partial restorer and partial maintainer lines were probably due to their narrow genetic diversity background and poor combination with A- line. Unfavorable climate also influences fertility restoring ability of R- line. Virmani (1994) pointed out that when some promising R- line crossed with A- lines, the fertility of F1 hybrid revealed the restorer differed in fertility restoring ability especially high temperature and low humidity occurred during the pollen mother cell meiosis stage or heading stage.

As well as A- line, the promising or elite R- line should posses following good characteristics for developing F1 hybrids, as suggested by Yuan *et al.* (2003): (a) having strong fertility restoring ability (b) good agronomic character and combining ability (c) well developed anthers with heavy pollen load, good flowering habit and normal dehiscence. Rutger (1988) further recommended that tall paternal plant type of R- line would benefit for wind-blown pollen dispersal onto female parent. Results of this study, some R- lines such as CNT1, RD7, RD11, SPR1 and IR58110-144-2-2-2R possessed these suggested characters. F1 hybrids developed from these R- lines produced healthy pollen fertility as shown in Figure 3.1(C) and having good agronomic characters such as grain yield, number of panicle/ hill, number of grain/ panicle and so on as presented in Table 3.3 to Table 3.6.