Chapter 5

Yield Trial and Agronomic Character Evaluation for F1 Hybrid Lines

5.1 Introduction

In the next three decades, the world will need at least 40% more rice than what is produced today to feed the extra billions population. The research theme must response to the wind of need for many rice growers to change from subsistence from subsistence farming to farming for profit.

The successful development of hybrid rice is a great breakthrough in rice breeding, providing an effective approach to increase rice yield up to 15-20% (Rothschild, 1998). Hybrid rice breeding uses several concepts, skills and procedures which are strikingly different from those used for inbred rice breeding. The success of hybrid varieties depends mainly on their yielding, resistance to disease and insect pests, capability in comparison with local popular ones, quality of rice and the benefit of farmers.

Yield trial of F1 hybrids is one of the most importance tasks in hybrid rice breeding program. It should be wise to take into this issue before releasing new hybrid varieties for massive cultivation at field level. The objectives of this Chapter's experiments were to evaluate yielding ability and characteristic of F1 hybrid crosses derived from crossing among A-lines and R-lines which had been evaluated in Chapter 3 and tested for both combining ability and heterotic effects in Chapter 4 under experimental field conditions for two successive growing seasons.

5.2 Materials and Methods

5.2.1 Yield Trial of Hybrid Cross

Results obtained from combining ability and heterosis evaluation in Chapter 4 indicated obviously that there were 16 F1 hybrid crosses, being superior in grain yields and agronomic characters. These 16 hybrid crosses were selected for yield test performances in two successive growing seasons, dry and rainy season at Pathumthani Rice Research Center.

In dry growing season, 12 F1 hybrid crosses were included in yield test, comprising of:

(1) RD21A-23/RD1 (2) RD21A-23/RD7

(3) RD21A-23/RD11 (4) RD21A-23/SPR1

(5) RD21A-23/IR68926-61-2R (6) RD21A-23/IR58110-144-2-2-2R

(7) IR62829A/RD1 (8) RD21A-23/IR65620-96-2-3-3-1R

(9) IR62829A/RD7 (10) IR62829A/CNT

(11) IR62829A/SPR1 (12) IR62829A/IR63870-3-2-3-3R

In rainy growing season, 16 F1 hybrid crosses were included in yield test comprising of:

(1) RD21A-23/RD7 (2) RD21A-23/RD11

(3) RD21A-23/SPR1 (4) RD21A-23/IR68962-61-2R

(5) RD21A-23/IR58110-144-2-2-2R (6) RD21A-23/IR65620-2-3-3-1R

(7) RD21A-23/IR46R (8) RD21A-23/CNT1

(9) IR62829A/RD7 (10) IR62829A/RD11

(11) IR62829A/SPR1 (12) IR62829A/IR68926-61-2R

(13) IR65620-2-3-3-1R (14) IR62829A/IR58110-144-2-2-2R

(15) IR62829A/IR46R (16) IR62829A/CNT1

In both dry and rainy season trials, three rice varieties were included CNT 1,SPR1 and SPR88096-17-3-2-2, assigned as check or standard varieties.

Seedling preparation: Seedlings of F1 hybrids and check varieties were separately germinated and sown uniformly on 1 x 2 m seed bed. In order to obtain healthy and vigorous seedlings, 5 kg/rai of urea fertilizer (46 % N) was applied to plot about 15 days after seeding. Water level was maintained about 3 cm high for controlling weeds and avoiding drought damage. Leaf diseases and insect pests were controlled as needed. About 25 days after seeding, seedlings were tall and strong enough for transplanting.

Experimental design and cultural practice: Seedlings of F1 hybrid crosses and check varieties were transplanted in a six-row plot of 4.6 m long with spacing of 20 x 20 cm within and between rows and transplanting one seedling per hill. Plots were laid out in randomized complete block with three replications. Plots were applied with 18-6-6 kg/rai of N-P_2O_5-K_2O fertilizer during the field preparation. An additional 30 kg/rai of 16-0-0 fertilizer plus 10 kg/rai of potassium chloride (KCl) were incorporated into the plots as basal application just one to two days before transplanting.

In order to maximize crop growth and development, more nitrogen fertilizer was added twice, 15 days and 50 days after transplanting, using 15 and 10 kg/rai, respectively. Weed control during the growing period was done by hands. Baylucide chemical was used to control and kill apple snail. Leaf diseases and insect pests were controlled as required. Water level was maintained at 5-10 cm high through out the growing period for controlling weed and avoiding crops from drought damage. At harvesting period, water was drained out from the plots in order to regulate uniform grain maturity.

Measurements: At harvesting period, observations were made on five competitive hills selected randomly in each plot and each replication to record on the following parameters, plant height, number of tiller per hill, number of panicle per hill, number of filled grains and 1,000 grain-weight. Grain yield of each plot was measured by harvesting plot size of 0.8 x 3 m. Panicles of each sample were dried under sunlight for 2-3 days and grains were threshed by small windnowing machine. Grains were dried and cleaned again for 1-2 days to reduce grain moisture content. Weight of grain yield of each sample was adjusted to 14 % standard moisture basis.

Grain yield of each F1 hybrid cross was also determined for physical and chemical properties. Analyses of chemical characters were made on percent amylose content, gel consistency and elongation ratio of boiled grain. Physical characters were measured on length, width, chalkiness and ratio of length to width (L/W ratio).

Data analysis: Analyses of variance for all measured agronomic parameters were carried out in normal way. Significance of treatments were determined by F-test. Duncan's multiple range test (DMRT) was used to make comparison among means (Steel and Torie, 1960).

Location and experimental period: The experiments were carried out in dry season and rainy season 2004. The experimental site was rice field experiment of Pathumthani Rice Research Center. Physical and chemical properties of grains were analysed at Rice Quality Laboratory of this center as well.

5.2.2 Blast disease and Brown planthopper Resistance Test

5.2.2.1 Blast Resistance Test

Field experiment: Forty-eight of F1 hybrid crosses were planted for evaluating rice blast disease reaction. Upland short-row technique was used for growing the testing lines or varieties as described by Wachara (1991). Ten grams of F1 seeds of each cross were drilled in two-row plot of 1 m long with spacing of 10 cm between rows. Every 2 tested crosses, KDML 105 rice variety was planted for susceptibility check. And every 10 tested crosses, KDML 105 and SPR 90 were planted for susceptible and resistant check varieties. Plots were laid out in randomized complete block design with three replications. Plots were applied weekly with ammonium phosphate fertilizer (16-20-0) at the rate of 10 kg/rai in order to optimize seedling growth and stimulate epidemic of blast disease. To minimize leaf wilting due to temporary drought, plots were applied daily with sufficient water.

Evaluation procedure: F1 hybrid seedlings were scored for rice blast resistance at one month after seeding or when susceptible varietal check was affected up to 90 percent of leaf infection.

Rice blast reaction score was used according to Standard Evaluation System for Rice (IRRI, 1996), given as follow:

Score	Description
0	No lesion observed.
1	Small brown speck of pin-point size or larger brown specks.

Score	Description
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin.
Score	**Description**
3	Lesion type is the same as in scale 2, but significant numbers of lesions are on the upper leaves.
4	Typical susceptible blast lesions 3 mm or longer, infecting less than 4% of the leaf area.
5	Typical blast lesions infecting 4-10% of the leaf area.
6	Typical blast lesions infecting 11-25% of the leaf area.
7	Typical blast lesions infecting 26-50% of the leaf area.
8	Typical blast lesions infecting 51-75% of the leaf area and many leaves dead.
9	More than 75% leaf area affected.

Location and experimental period: The experiment was carried out at Kao Hin Son Development Study Center, Chachoengsao Province, during August to November 2004.

5.2.2.2 Brown planthopper Resistance Test

Field experiment: Forty-eight of F1 hybrid crosses were planted for evaluating brown planthopper resistance reaction. Testing procedure was used according to Watchara (1991). Germinated seeds of F1 hybrids, their respective parents, susceptible and resistant check varieties were drilled in 60 x 45 x 10 cm wooden boxes. Each box contained fine-textured soil with 5 cm depth. Each F1 hybrid cross was drilled in two rows with spacing of 1 cm and 4 cm within and between rows and drilled 25 seeds per row. Each box could be planted for 22 crosses together with their parents, susceptible and resistant check varieties. TN 1 and RD 23 were used as susceptible and resistant variety, respectively.

Evaluation procedure: At 10 days old of seedlings, two stages of nymph, pre-adult and adult were released into the rearing boxes, using 7 to 8 nymphs per seedling. Brown planthopper reaction would be scored when susceptible variety was completely damaged and died. The reaction score was used for evaluating resistance and susceptibility according to Standard Evaluation for Rice (IRRI, 1996), given as follow:

Score	**Description**
0	No damage
1	Very slightly damaged
3	First and 2nd leaves of most plants partially yellowing.
5	Pronounced yellowing and stunting or about 10-25% of the plants wilting.
7	More than half of the plants wilting or dead and remaining plants severely stunted or dying.
9	All plants dead

Location and experimental period: The experiment was carried out under insectory house condition at Pathumthani Rice Research Center during March to May 2003.

5.3 Results

5.3.1 Yield Trial of Hybrid Cross

Yield trial of F1 hybrids were carried for two successive growing seasons, dry and rainy season in 2004. Results obtained from each growing season were summarized and given as follow:

Dry season

Yield performance of hybrid cross: Results of yield trial of 12 F1 hybrids in dry growing season are shown in Table 5.1. It indicated that there were significant difference of yielding ability among the hybrids. It is important to note that there was only one hybrid cross which showed significantly higher grain yield than three standard varieties. Eleven hybrids gave significantly higher yield than two standard varieties (CNT1 and SPR1) and one hybrid showed higher significance than SPR88096-17-3-2-2 standard variety. Hybrid RD21A-23/IR58110-144-2-2-2R gave the highest grain yield of 1121 kg/rai and was higher significantly than three standard varieties, CNT1, SPR1 and SPR88096-17-3-2-3 for 282, 273 and 255 kg/rai that accounted for higher than 25, 24 and 13 percent, respectively.

Hybrid RD21A-23/IR68926-61-2R was the second rank and gave 1042 kg/rai which was significantly different from the first rank and from three standard varieties for 203, 194 and 76 kg/rai that accounted for higher than 20, 19 and 7 percent, respectively. Hybrid RD21A/RD11 was the third rank and gave 1016 kg/rai which was significantly different from the first rank but not different from the second rank, giving 1016 kg/rai which was higher significantly than three standard check for 177, 168 and 50 kg/rai that accounted for 17, 16 and 5 percent, respectively.

Agronomic performances of hybrid cross: Agronomic performances of 12 hybrid crosses are presented in Table 5.2. It was obviously indicated that all of measured traits including panicle per hill, percent of filled grain, number of grain per panicle and 1000-grain weight were significantly different among the hybrid crosses and standard varieties. Hybrids gave number of panicle per hill ranging from 10-16 panicles/hill compared with 11-12 panicles/hill of three standard varieties.

For percent of filled grain, number of grain per panicle and 1000-grain weight, hybrids gave average of 64-80%, 85-135 grains/panicle and 21.49-28.18 gm. compared with 73-80%, 86-88 grains/panicle and 27.08-30.18 gm of standard varieties, respectively. It was also importantly indicated that hybrid crosses which gave higher grain yield would also possess good agronomic characters, for example, hybrid RD21A-23/IR58110-144-2-2-2R which gave highest grain yield (1121 kg/rai) possessed 12 panicles/hill, 80% filled grain, 123 grains/panicle and 26.88 gm. of 1000-grain weight. In contrast with hybrid IR62829A/IR63870-3-2-3-R which gave the lowest yield, it possessed only 73% filled grain, 94 grains/panicle and 22.02 gm. of 1000-grain weight.

Rainy season

Yield performance of hybrid cross: Results of yield trial of 16 F1 hybrid crosses in rainy growing season are shown in Table 5.3. It was also clearly indicated that there were significant difference of yielding abilities among the hybrids. As for yield performance of hybrids in dry season, there were two hybrids that showed significantly higher yield than three standard varieties, two hybrids gave significantly higher yield than two standard varieties (CNT1 and SPR1) and two hybrids showed significantly higher yield than SPR88096-17-2-2 standard variety. Hybrids which were rated first to eighth of yield rank did not show differently among crosses but differed significantly from three standard varieties. Hybrid IR62829A/RD7 gave highest grain yield of 960 kg/rai and significantly higher than three standard varieties CNT1, SPR1 and SPR88096-17-3-2-3, for 209, 156 and 155 kg/rai that accounted for higher than 28, 16 and 16 percent, respectively. Hybrid RD21A-23/IR58110-144-2-2-2R was the second rank, giving 912 kg/rai and higher significantly than three standard checks for 161, 108 and 106 kg/rai that accounted for 18, 12 and 11%, respectively.

Agronomic performance of hybrid cross: Agronomic performances of 16 hybrid crosses are presented in Table 5.4. It also obviously indicated that all of measured traits including number of panicle per hill, percent filled grain, number of grain per panicle, 1000-grain weight and number of panicle per m^2 were significant different among the hybrid crosses and standard varieties. Hybrids gave number of panicle per hill and panicle per m^2 ranging from 8-13 panicles/hill and 172-310 panicles/m^2, respectively.

For percent of filled grain, number of grain per panicle and 1000-grain weight, hybrids gave average of 72-85%, 123-195 grains/panicle and 21.24-28.09 gm. compared with 80-87%, 145-176 grains/panicle and 26.11-27.62 gm. of standard varieties.

As described in dry season, hybrids which were higher in grain yield ability would also provide good agronomic characters, for example, hybrid IR6829A/RD7 which gave highest grain yield (960 kg/rai) possessed 11 panicles/hill, 82% filled grain, 172 grains /panicle, 242 panicle/m^2 and 24.14 gm. of 1000-grain weight in contrast with hybrid RD21A-23/CNT1 which gave lowest grain yield (728 kg/rai), possessed only 8 panicles/hill, 81% filled grain, 165 grains/panicle and 183 panicles/m^2.

It should be importantly noted that the yield ability of F1 hybrids also depended upon crosses. F1 hybrids derived from Thai male parents, RD7, RD11 and SPR1 were able to give higher grain yield than other F1 hybrids which were combined with exotic male parents. F1 hybrids crossed among RD21A-23 and Thai or exotic male parents were able to give higher grain yield than standard CNT1 and SPR1 and SPR88096-17-3-2-2 up to 5 to 16 percent, (Table 5.1 and 5.2).

5.3.2 Blast Disease Resistance Evaluation

Results of blast disease resistance evaluation of 48 hybrids are shown in Table 5.5. Results suggested that hybrids reacted differently to blast disease range, from resistance (R) to susceptible (S) levels. There were only 10 hybrids which reacted obviously at resistant level (R) to rice blast disease. These hybrids included:

(1) RD21A-23/CNT1 (2) RD21A-23/SPR1

(3) RD21A-23/IR68926-61-2R (4) RD21A-23/IR62161-1843-1-3-2R

(5) IR58025A/IR63870-3-2-3-3R (6) IR62829A/RD1

(7) IR62829A/RD7 (8) IR62829A/CNT1

(9) V20A/CNT1 (10) V20A/IR63870-3-2-3-3R

It is important to point out that hybrids which showed higher grain yield in yield trial would react at R to MR levels to disease, especially hybrids that were given the first and second rank of yield trial in dry season, RD21A-23/IR58110-144-2-2-2R and RD21A-23/IR68926-61-2R reacted at moderately-resistant and resistant level to disease. As well, hybrids which were given first rank and second rank of hybrid trial in rainy season, IR62829A/RD7 and RD21A-23/IR58110-144-2-2-2R reacted as resistant and moderately-resistant to disease, respectively. However, some other hybrids which gave moderate to high yielding abilities also reacted at resistant to moderately-resistant levels. These hybrids included IR62829A/IR85110-144-2-2-2R, RD21A-23/IR65620-2-3-3-1R and IR62829A/SPR1.

F1 hybrids which were combined from male parents, CNT1, SPR1, IR68926-61-2R, IR63870-3-2-3-3R, IR58110-144-2-2-2R, IR65620-2-3-3-1R and IR62161-1843-1-3-2R were determined as resistant (R) and moderately-resistant (MR). However, there were A-line such as IR58025A, crossed with SPR1, IR68926-61-2R, IR58110-144-2-2-2R and A-line IR62829A, crossed with IR65620-2-3-3-1R and IR62161-1843-1-3-2R which were susceptible (S) to rice blast of F1 hybrids (Table 5.5).

Male parents RD11, RD7, RD23 and IR46R, when crossed with A-lines, were gave almost susceptible to rice blast of F1 hybrids, except IR62829A. There was no F1 hybrid derived from RD11 male parent that showed resistance to rice blast disease.

5.3.3 Brown plant hopper Resistance Estimation

Results of brown planthopper resistance evaluation of 48 hybrids are shown in Table 5.5. Results revealed that there were only 3 hybrids which reacted obviously as resistant to brown planthopper insects. These hybrids included RD21A-23/IR68926-61-2R, RD21A-23/IR63870-3-2-3R, and V20A/CNT1.

It is important to point out that hybrids which performed best yielding ability in dry season, RD21A-23/IR58110-144-2-2-2R reacted at moderately-susceptible level to insect while hybrid IR62829A/RD7 which performed highest yielding ability in rainy season reacted at very susceptible level to insect. However, there were other hybrids that gave moderate to high yielding abilities reacted at moderately-resistant to susceptible levels, including; RD21A-23/IR65620-2-3-3-1R and RD21A-23/SPR1 crosses.

These results indicated that F1 hybrids RD21A-23/IR68926-61-2R and RD21A-23/IR63870-3-2-3-3R reacted at resistant level (R) to brown planthopper and F1 hybrid of V20A/IR63870-3-2-3-3R which reacted with moderate resistance (MR) showed moderately high grain yields. However, almost F1 hybrids showed susceptible reactions to brown planthopper.

5.3.4 Physical and Chemical Evaluation of Grain

Results of physical and chemical evaluation for grain of hybrid crosses are shown in Table 5.6. For physical property, it was obviously indicated that hybrid grain performed well in terms of length, width, length/width ratio and chalkiness and were most similar to standard varieties.

Length, width, length/width ratio and chalky appearance of hybrid grain ranged from 7.06-8.00 mm, 2.03-2.37 mm, 3.13-3.60 and 0.60-2.66 compared with 7.17 and 8.28, 2.21 and 2.22, 3.23 and 3.76 and 0.10 and 1.45 of CNT1 and SPR1 standard varieties, respectively. As well, chemical property of hybrid grain exhibited good performance for percent starch of amylose, alkali test, gel consistency and elongation ratio. Hybrid grain showed amylose content of 20.48-27.71%, alkali test 4.9-7.0 score, gel consistency 30-98 mm and elongation ratio 1.60-1.80 compared with amylose content of 26.44%, alkali test 5.0 score, gel consistency 39 mm and elongation ratio 1.71 of CNT1 and amylose content of 27.09%, alkali test 5.0 score, gel consistency 96 mm and elongation ratio 1.64 of SPR1 standard check varieties, respectively.

It is important to point out that hybrid RD21A-23/IR58110-144-2-2-2R which performed highest yield in dry season also gave both good physical and chemical character, especially for amylose content (20.90%), good for gel consistency (68 mm), alkali test (5.1), elongation ratio (1.66) and chalkiness (1.8). As well, hybrid RD21A-23/RD7 that showed highest yield in rainy season also exhibited well for amylose content (21.8%), gel consistency (64 mm), alkali test (5.1), elongation ratio (1.70) and chalkiness (1.5).

After harvesting, grain yield of F1 hybrids was prepared for physical and chemical measurement. The results as shown in Table 5.9 revealed that F1 hybrids' grain were determined as slender shape with 7.22 to 7.95 mm in length, 2.03 to 2.37 in width and 3.13 to 3.67 for length/width ratio. Grains chalkiness varied in range 0.62 to 2.66. Based on amylose content analysis, grains of F1 hybrids could be classified into two groups: (1) Intermediate amylose content contained about 21.80 to 24.81 percent involving 10 crosses. Hybrids included in this group; i. e, RD21A-23/RD1, RD21A-23/RD7, RD21A-23/CNT11, RD21A-23/IR68926-61-2R, RD21A-23/IR58110-144-2-2-2R, RD21A-23/IR46R, IR62829A/RD7, IR62829A/IR68926-61-2R, IR62829A/IR58110-144-2-2-2R and IR62829A/IR65620-2-3-3R and (2) High amylose content which had about 25.17 to 27.71 percent involving 8 crosses. Hybrids included in this group: i. e., RD21A-23/RD11, RD21A-23/SPR1, RD21A-23/IR65620-96-2-3-1R, IR62829A/RD1, IR62829A/RD11, IR62829A/CNT1, IR62829A/SPR1 and IR62829A/IR46R. Gel consistency of grains of F1 hybrid varied between low to high, ranging from 30 to 96 mm. For alkali test for gel temperature, most of hybrids were classified as intermediate group which ranged from 4.9 to 5.6. Elongation ratio of cooked grains varied from 1.60 to 1.80 fold. Grain quality of four F1 hybrids that gave high yielding performance in yield trial also possessed good grain quality, described as follow:

Hybrid RD21A-23/IR68926-61-2R, grain was determined as slender shape with 3.17 length/width ratio, 7.51 mm in length, high chalkiness with 1.84, 20.90 percent amylose content, 68 mm soft gel consistency, 5.1 for intermediate gel temperature and good elongation ratio with 1.66 fold.

RD21A-23/IR68926-61-2R, grain was determined as slender shape with 3.18 length/width ratio, 7.55 mm for length, high chalkiness with 1.93, 20.52 percent amylose content, hard gel consistency of 36, 5.6 for low gel temperature and good elongation ratio with 1.74 fold.

IR62829A/RD7, grain was classified as slender shape with 3.24 for length/width ratio, 7.26 mm in length, high chalkiness up to 2.66, 21.77 percent amylose content, soft gel consistency for 70, 5.0 for intermediate gel temperature and good elongation ratio with 1.63 fold.

Hybrid RD23A-23/RD7, grain was classified as slender shape with 3.19 length/width ratio, 7.56 mm in length, high chalkiness for 1.48, 21.8 percent for amylose content, soft gel consistency with 64, 5.1 for intermediate gel temperature and good elongation ratio with 1.70 fold.

Table 5.1 Grain yield among F1 hybrids crosses of yield trial conducted at Pathumthani Rice Research Center, dry season 2004.

No.	Cross/Variety	Grain yield[1]/ (kg/rai)	Rank	Different from check		
				CNT1	SPR1	SPR88096-17-3-2-2
1	RD21A-23/RD1	938 d-h	9	98.80*	89.68*	-28.49
2	RD21A-23/RD7	1008 bcd	5	168.81**	159.69**	41.52
3	RD21A-23/RD11	1016 bcd	3	177.38**	168.26**	50.09
4	RD21A-23/SPR1	932 d-h	10	92.83*	83.71*	-34.46
5	RD21A-23/IR68926-61-2R	1042 bc	2	203.17**	194.05**	75.88
6	RD21A-23/IR58110-144-2-2-2R	1121 a	1	282.58**	273.46**	155.29**
7	RD21A-23/IR65620-96-2-3-3-1R	990 b-e	6	150.75**	141.63**	23.46
8	IR62829A/RD1	878 g-j	12	39.47	30.35	-87.82*
9	IR62829A/RD7	1009 bcd	4	170.12**	161.00**	42.83
10	IR62829A/CNT1	920 e-l	11	81.58*	72.46	-45.71
11	IR62829A/SPR1	977 cde	7	138.45**	129.33**	11.16
12	IR62829A/IR63870-3-2-3-3R	862 hij	13	23.44	14.32	-103.85**
13	CNT1 (CK)	839 ij	15	-	-9.12	-127.29**
14	SPR1 (CK)	847 ij	14	9.12	-	-118.17**
15	SPR88096-17-3-2-2 (CK)	966 c-f	8	127.29**	118.17**	-
	CV (%)	4.7				

*, ** Significant at $p < 0.05$ and $p < 0.01$, respectively.

[1]/The same alphabet in column shows nonsignificant difference according to DMRT test.

Table 5.2 Yield components among F1 hybrids crosses of yield trial conducted at Pathumthani Rice Research Center, dry season 2004.

No.	Cross/Variety	No. of [1]/ panicle/hill	% Filled grain	No.of grain/panicle	1000- grain weight (gm)
1	RD21A-23/RD1	11 ef	76 abc	113 a	28.18 b
2	RD21A-23/RD7	10 f	68 def	122 abc	27.62 b
3	RD21A-23/RD11	10 f	73 a-d	135 ab	27.30 b
4	RD21A-23/SPR1	11 ef	70 c-f	85 c	27.21 b
5	RD21A-23/IR68926-61-2R	12 def	77 ab	105 abc	27.68 b
6	RD21A-23/IR58110-144-2-2-2R	14 a-d	80 a	123 abc	26.88 b
7	RD21A-23/IR65 6-2-3-3-1R	15 abc	71 b-e	120 bc	23.58 cd
8	IR62829A/RD1	13 cde	69 def	117 bc	22.02 de
9	IR62829A/RD7	16 ab	65 ef	118 bc	23.81 c
10	IR62829A/CNT1	14 b-e	64 ef	109 abc	22.86 cde
11	IR62829A/SPR1	16 a	70 b-f	127 abc	21.49 e
12	IR62829A/IR63870-3-2-3-3R	15 abc	73 a-d	94 def	22.02 de
13	CNT1 (CK)	11 ef	73 a-d	113 abc	30.18 a
14	SPR1 (CK)	12 def	80 a	105 abc	27.08 b
15	SPR88096-17-3-2-2 (CK)	12 def	78 ab	132 abc	28.41 b
	CV (%)	10.1	5.2	13.5	3.7

[1]/The same alphabet in column shows nonsignificant difference according to DMRT test.

Table 5.3 Grain yield among F1 hybrids crosses of yield trial conducted at Pathumthani Rice Research Center, rainy season 2004.

No	Cross/Variety	Grain yield (kg/rai) 1/	rank	Different from check		
				CNT1	SPR1	SPR88096-17-3-2-2
1	RD21A-23/RD7	784 def	17	33.01	-20.04	-21.61
2	RD21A-23/RD11	812 c-f	12	61.65	8.59	7.03
3	RD21A-23/SPR1	810 c-f	13	59.20	6.14	4.58
4	RD21A-23/IR68926-61-2R	900 abc	3	149.00 **	95.95 *	94.38 *
5	RD21A-23/IR58110-144-2-2-2R	912 ab	2	161.34 **	108.29 *	106.72 *
6	RD21A-23/IR6562 -3-1R	870 a-d	7	119.72 **	66.67	65.10
7	RD21A-23/IR46R	830 b-e	9	79.65	26.59	25.03
8	RD21A-23/CNT1	728 f	19	-23.10	-76.15	-77.72
9	IR62829A/RD7	960 a	1	209.67 **	156.62 **	155.05 **
10	IR62829A/RD11	822 b-f	10	71.12	18.06	16.50
11	IR62829A/SPR1	885 abc	5	134.49 **	81.43	79.87
12	IR62829A/IR68926-61-2R	888 abc	4	137.28 **	84.22	82.66

Table 5.3 Continue

No	Cross/Variety	Grain yield (kg/rai) [1]/		rank	Different from check		
					CNT1	SPR1	SPR88096-17-3-2-2
13	IR62829A/IR58110-144-2-2-2R	820	b-f	11	69.52	16.46	14.90
14	IR62829A/IR65620-2-3-3-1R	804	c-f	15	52.90	-0.16	-1.72
15	IR62829A/IR46R	846	b-e	8	95.05 *	42.00	40.43
16	IR62829A/CNT1	880	a-d	6	128.83 **	75.77	74.21
17	CNT1 (CK)	751	ef	18	-	-53.06	-54.62
18	SPR1 (CK)	804	c-f	15	53.06	-	-1.56
19	SPR88096-17-3-2-2 (CK)	805	c-f	14	-0.05	-53.11	-
	CV (%)	5.9					

*, ** Significant at $p < 0.05$ and $p < 0.01$, respectively.

[1]/The same alphabet in column shows nonsignificant difference according to DMRT test.

Table 5.4 Yield components among F1 hybrids crosses of yield trial conducted at Pathumthani Rice Research Center, rainy season 2004.

No.	Cross/Variety	No. of panicle/hill 1/	% Filled grain	No. of grain/panicle	1000- grain weight (gm)	Panicle/m^2
1	RD21A-23/RD7	9 efg	72 b	167 a-d	24.26 d	192 gh
2	RD21A-23/RD11	8 fg	79 ab	195 a	26.62 bc	172 h
3	RD21A-23/SPR1	9 efg	83 a	165 a-d	28.09 a	198 fgh
4	RD21A-2[illegible]8926-61-2R	9 efg	80 a	165 a-d	28.02 a	206 e-h
5	RD21A-23/IR58110-144-2-2-2R	9 efg	83 a	183 a-b	26.35 c	206 e-h
6	RD21A-23/IR65620-2-3-3-1R	10 def	83 a	156 a-e	24.63 d	207 e-h
7	RD21A-23/IR46R	10 def	85 a	187 a	24.30 d	206 e-h
8	RD21A-23/CNT1	8 g	81 a	165 a-d	27.25 ab	183 gh
9	IR62829A/RD7	11 b-e	82 a	172 a-d	24.14 d	242 cde
10	IR62829A/RD11	11 b-e	82 a	144 cde	24.02 d	224 d-g

Table 5.4 Continue

No.	Cross/Variety	No. of panicle/hill [1]/	% Filled grain	No. of grain/panicle	1000- grain weight (gm)	Panicle/m^2
11	IR62829A/SPR1	12 abc	82 a	133 de	24.00 d	273 abc
12	IR62829A/IR68926-61-2R	13 a	84 a	123 e	23.88 d	286 ab
13	IR62829A/IR58110-144-2-2-2R	12 abc	82 a	135 de	22.34 e	299 ab
14	IR62829A/IR65620-2-3-3-1R	13 a	85 a	137 de	21.79 ef	310 a
15	IR62829A/IR	12 abc	84 a	146 b-e	21.24 f	262 bcd
16	IR62829A/CNT1	13 a	79 ab	167 a-d	24.13 d	286 ab
17	CNT1 (CK)	11 b-e	87 a	145 b-e	27.62 a	237 c-f
18	SPR1 (CK)	9 efg	85 a	176 abc	27.46 a	222 d-g
19	SPR88096-17-3-2-2 (CK)	10 def	80 ab	161 a-e	26.11 c	236 c-f
	CV (%)	10.60	5.40	12.60	1.90	9.60

[1]/The same alphabet in column shows nonsignificant difference according to DMRT test.

Table 5.5 Reaction of F1 hybrids for blast and brown planthopper resistance.

Line/Variety	RD21A-23		IR58025A		IR62829A		V20A	
	Blast	BPH	Blast	BPH	Blast	BPH	Blast	BPH
RD1	MS	VS	MS	S	R	VS	MS	S
RD7	MS	S	MS	S	R	VS	MS	S
RD11	S	VS	S	S	MS	S	MS	S
RD23	MS	S	MS	VS	MR	S	MS	S
CNT1	R	S	MR	MS	R	S	R	S
SPR1	R	S	MS	S	MR	VS	MR	MS
IR68926-61-2R	R	R	MS	S	MR	MS	MR	MS
IR63870-3-2-3-3R	MR	R	R	S	MR	MS	R	MR
IR58110-144-2-2-2R	MR	MS	MS	MS	MR	VS	MR	MS
IR65620-2-3-3-1R	MR	MS	MR	S	MS	S	MR	S
IR62161-1843-1-3-2R	R	S	MR	S	MS	S	MR	VS
IR46R	MR	S	MS	MS	MS	S	MR	VS

VR = Very Resistance R = Resistance MR = Moderate resistance

MS = Moderate susceptible S = Susceptible VS = Very susceptible

Table 5.6 Physical and chemical characteristic of grain of F1 hybrids.

Hybrid cross	Physical character				Chemical character			
	L (mm)	W (mm)	L/W	Ch	Amylose (%)	G.C. (mm)	Alkali	E.R.
RD21A-23/RD1	7.71	2.34	3.29	0.9	23.92	30	7.0	1.67
RD21A-23/RD7	7.56	2.37	3.19	1.5	21.8	64	5.1	1.70
RD21A-23/RD11	7.35	2.25	3.2	1.3	26.2	55	5.2	1.60
RD21A-23/CNT1	8.03	2.30	3.49	0.6	24.81	44	5.6	1.69
RD21A-[illegible]R1	7.53	2.30	3.28	1.4	25.75	79	4.9	1.63
RD21A-23/IR68926-61-2R	7.55	2.37	3.18	1.9	20.52	36	5.6	1.74
RD21A-23/IR58110-144-2-2-2R	7.51	2.37	3.17	1.8	20.90	68	5.1	1.66
RD21A-23/IR65620-96-2-3-3-1R	7.35	2.25	3.27	1.7	27.45	54	5.0	1.65
RD21A-23/IR46R	7.29	2.33	3.13	0.6	23.83	55	5.4	1.80
IR62829A/RD1	7.26	2.16	3.36	1.50	25.17	44	5.6	1.62
IR62829A/RD7	7.26	2.24	3.24	2.66	21.77	70	5.0	1.63
IR62829A/RD11	7.28	2.15	3.39	1.91	26.28	49	5.0	1.66

Table 5.6 Continue

Hybrid cross	Physical character				Chemical character			
	L (mm)	W (mm)	L/W	Ch	Amylose (%)	G.C. (mm)	Alkali	E.R.
IR62829A/CNT1	7.56	2.18	3.47	1.16	25.95	49	5.0	1.69
IR62829A/SPR1	7.22	2.13	3.39	0.98	27.71	98	5.0	1.68
IR62829A/I[illegible]26-61-2R	7.62	2.16	3.50	2.11	24.15	45	5.2	1.70
IR62829A/IR58110-144-2-2-2R	7.50	2.12	3.15	2.10	22.39	54	5.1	1.70
IR62829A/IR65620-2-3-3R	7.46	2.03	3.68	1.02	20.48	46	5.1	1.66
IR62829A/IR46R	7.06	2.08	3.39	1.07	26.35	72	5.0	1.65
CNT1 (CK)	8.28	2.21	3.76	0.10	26.44	39	5.0	1.71
SPR1 (CK)	7.17	2.22	3.23	1.45	27.09	96	5.0	1.64

L = Length, W = Width, L/W = Length/Width ratio, Ch = Chalkiness, G.C. = Gel consistency, E.R. = Elongation ratio.

5.4 Discussion

According to both growing season yield trials, F1 hybrids derived from crossing among those of IR-line male with local Thai-line female, especially RD21A-23/IR58110-144-2-2-2R and IR62829A/RD7, gave higher grain yield than F1 hybrids among Thai-line crosses. The concerning factors might be due to more effectiveness of combining ability of A-line and R lines. Supporting reasons were described in Chapter 4 that all of these A-line and R-line gave good g.c.a. and s.c.a. and exhibited high heterotic effects in F1 hybrid crosses (Tables 4.2-4.8 and Tables 4.10-4.16).

Therefore, male parental lines including IR58110-144-2-2-2R, RD7, RD11, IR65620-96-2-3-3-1R and SPR1 were able to combine with female parental lines or A-line to produce higher-yielding F1 hybrids over standard varieties. Virk *et al*. (2002) suggested that improvement in the yield potential of parental lines and broadening of their genetic bases should lead to the identification of hybrid combinations with even higher heterosis.

Increasing the magnitude of heterosis by broadening the genetic base of parental lines, incorporating insect pest and disease resistance, and improving grain quality of parental line are the most important prerequisites for making hybrid rice technology more profitable and sustainable (Ramesha *et al.,* 2002)

For large-scale adoption of hybrid rice technology, released hybrids should have a distinct yield advantage over popular varieties. They should also possess a high degree of resistance to major diseases and pests in the target area. Blast disease caused by *Pyricularria grisea* and brown planthopper insect pest (*Nilarpavata lugens*) are evaluated as important disease and insect pest in various rice-growing areas. According to results shown in Table 5.5, F1 hybrids, RD21A-23/IR68926-61-

2R, RD21A-23/IR63870-3-2-3-3R and V20A/IR63870-3-2-3-3R reacted multiple resistances to rice blast disease and brown planthopper. Siddiq *et al.* (1998) suggested that the hybrids are resistant if the parents are resistant. If one parent is susceptible, the hybrids are either resistant or susceptible, depending on whether the gene (s) imparting resistance is dominant or recessive. If the genes conferring the resistance are recessive, then both parents must have these genes in the recessive condition for hybrid to be resistant.

For this given result, parental line either male or female parent, especially Thai rice parent which involved in hybrid combination, performed such distinctive resistance to both disease and insect pest. Physical and chemical properties of grain were evaluated as good grain quality since these characters were inherited from Thai rice parents. However, grain qualities of hybrids depended largely on genetic control. As pointed out by Shivani *et al.* (2002), effects of nucleo-cytoplasmic interactions will affect on expression of quality characteristics for hulling, milling and head rice recovery percentages which generally are lower in A-lines and A x B crosses than their corresponding maintainers (B lines) and B x R crosses. The negative effects of the male sterile – inducing cytoplasm were observed for kernel length, L/W (length/width) ratio and kernel length after cooking.

Elongation ratio was positively influenced by sterility-inducing cytoplasm but showed significant negative effect on water uptake. Lower water uptake exhibited in A-lines and A x R hybrid than in B-lines and B x R hybrid. The most significant effect of the sterility-inducing cytoplasm was the reduction in amylose content in all the A-lines and A x R hybrids. The amylose content of A line and A x B hybrid was generally 1-2% less than their corresponding B lines and B x R hybrids. Male sterility- inducing cytoplasm had no effect on aroma.

Besides combining ability and heterosis which have been discussed in Chapter 4, the characteristic of parental lines must be considered for efficiency of F1 seed production. In case of RD21A-23 which performed as good combining ability with IR58110-144-2-2-2R and showed high heterosis level in hybrid combination but this female parent was taller than male parent of which may cause problem for natural out crossing in F1 seed production. The tall male parental plants would be desirable for windblown pollen dispersal onto semidwaft female plants (Rutger, 1988). However, results of study of this chapter suggested that yield trial of these obtained promising hybrids should be further evaluated for their adaptabilities and yield potential expression under various agro-ecological and climatic conditions in order to obtain better hybrid rice varieties for increasing rice yield production of the country.