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Combining Ability Trial of Hybrid Rice at Pine Bluff, Arkansas

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Abstract: Combining Ability with yield and other traits of 30 new hybrids were tested at Pine Bluff, Arkansas in 2014. The hybrids were developed from 6 female parent sterile lines, UP-1s, UP-2, UP-3s, 11A, 13A, and 15A, to 5 male parent restorer lines, PB5, PB11, PB14, PB15, and PB16. The inbred variety Francis, which is a popular variety in the rice production, was used as the check (CK). Results showed that the grain yields of 8 hybrids were 20.5% ~ 27.4% higher than that of CK Francis. The milled rice yields of 8 hybrids were 16% ~ 24.9% higher than that of CK Francis. The head rice yields of 6 hybrids were 11% ~ 19% higher than that of CK Francis. The chalky rice rates of 3 hybrids were less than that of CK Francis. The sterile lines UP-3s, UP-2s, UP-1s and 15A have good combining ability and the average grain yields of their hybrids were over CK by22.7%, 16.4%, 14.7% and 14.1%, respectively. The restorer lines PB15, PB16, and PB05 have good combining ability and the average grain yields of their hybrids were over CK by 19.6%, 15.3% and 15.1%, respectively. The major traits (grain yield, head rice, less chalky, lower height, earlier heading date) of hybrids of two-line system were better than that of hybrids of three-line system. These results indicated that these top hybrids and their parents of the sterile lines and restorer lines are good to be used in the hybrid rice breeding and production in the future.

Keywords: Combining, Ability, Trial, Hybrid Rice, Pine Bluff and Arkansas

1. Introduction

Hybrid rice is the commercial rice crop grown from F1 seeds of a cross between two genetically dissimilar parents. Hybrid rice has the potential of yielding 15% - 20% more than the best inbred variety grown under similar conditions. The rice-growing countries need an increased supply of rice because of their increasing populations and decreasing land and water resources. Hybrid rice technology offers an opportunity to increase rice yields and thereby ensure a steady supply. [1]. Hybrids also have shown an ability to perform better under adverse conditions of drought and salinity [2].

China started hybrid rice research in 1964 and began larger scale hybrid rice commercialization in 1976. Hybrid rice has contributed greatly to food supply in China. To meet the future demand for rice production, a national program on super rice breeding was established in China in 1996. Thirty-four super hybrid rice varieties have been released commercially, growing in a total area of 13.5 million hm^2 and producing 6.7 thousand million kg more rice in 1998-2005 [3].

After the successful development and use of hybrid rice in China, IRRI took the lead in developing the technology for tropical rice-growing countries. Appropriate parental lines and hybrids involving cytoplasmic male sterility (CMS) system and thermosensitive genic male sterility (TGMS) systems have been developed and shared freely with public and private institutions in collaborating countries. The several hybrids from the public and private sectors have been released and commercialized in India, the Philippines, Vietnam, Bangladesh, and Indonesia. The commitment of public-and private-sector agencies for breeding, seed production, and marketing has increased recently. Until 2014 about 60 seed companies in the public, private, and

nongovernmental organization sectors are now producing and marketing hybrid rice seed [4].

The research of hybrid rice began in USA in 1980s and released first hybrid rice in 2000 from the company of Rice Tec [5]. Hybrid rice has been widely grown in the US now. Hybrid rice had covered about 40% ~ 60% of the rice acreage in Texas during 2014 to 2018 [6-8]. It had covered about 40% of the rice acreage in Arkansas during 2013 to 2016 [9]. Hybrid rice had covered about 21% ~27.4% of the rice acreage in Louisiana during 2013 to 2018 [10-12]. However, the seeds of hybrid rice are just only made in the company of Rice Tec and the price of hybrid seeds is kind of expensive currently. The farmers need more diversity and affordable hybrids in their rice production to make more profit. Therefore, the hybrid rice researches are very important for the objectives of involving more private and public research unites.

Different germplasms from USDA (United States Department of Agriculture) world rice collection have been utilized and accessed in the hybrid breeding. Some new sterile lines (TGMS and CMS), restorer lines and hybrids have been screened and bred from them. The identifying and evaluating activities have generated a lot of knowledge of hybrid breeding, selected resistant varieties and developed some hybrids from the our research program [13-16] Some new hybrids were made and identified for combining ability from this research team in Pine Bluff, Arkansas. This trail was to evaluate the combining ability of new hybrids that developed from two-line system and three-line system, and to compare the advantages of each system.

2. Materials and Methods

This research had conducted at the farm of University of Arkansas at Pine bluff, USA (UAPB) 2014. Geographical location of UAPB farm Latitude: 34°15'N, Longitude: 92°01'W, Elevation: 70.7 meters. Soil texture is silt loam with PH value of 5.3.

Thirty hybrids were made from 6 sterile line Up-1s (TGMS), UP-2s (TGMS), UP-3s (TGMS), 11A (CMS), 13A (CMS), and 15A (CMS) by crossing separately with 5 restorer lines PB5, PB11, PB14, PB15, and PB16 in 2013.

The sterile line Up-1s (GEMS) came from the F_7 generation of the Gobo (PI-369806)/Zhenshan 97//Xiangzaoxian No. 1///Jin23; UP-2s came from the F_7 generation of the E425 (PI-442935)//Farmbuster, //Xieqingzao/Xiangzaixian1; Sterile UP-3s came from the F7 generation of Gobo (PI369806, a native rice variety of Surinam in South America)/Zhenshan 97//Xiangzaoxian1. UP-3s is a two-line system sterile and carries the Dominant Early Maturity Gene. Using Up-3s sterile line crossing with different restorer lines can get the earlier mature hybrids. We had developed some early maturity hybrid rice combinations by usingUP-3s crossed with male parents of different late maturity restorer lines in UAPB rice research program 2011~2013 [13-15].

11A came from B_6F_1 generation of GSOR 80//IR2061-214-3/You-1, 13A came from the B_6F_1 generation of Ignap Catelo (PI-373138)/113B; 15A came from B_5F_1 generation of GSOR80 (/Zhenshan 97A)//Xiangzaoxian1/Jin23,

PB05 was from the F_6 generation of Katy/Minghui63//R647, PB11 was from F_6 generation of the Lemont/Minghui63//Jasmine-85, PB14 was from F_6 of CDR210//Katy/Minghui63, PB15 was from F_5 generation of Katy/Minghui63//Jasmine-85, and PB16 was from F_5 generation of Katy/Minghui63//02428 (Table 1).

Table 1. *Pedigree of the parents of the Thirty hybrids.*

Parent	Generation	Pedigree	Note
Up-1s	F_7	Gobo (PI-369806)/Zhenshan 97//Xiangzaoxian No. 1///Jin23	TGMS
UP-2s	F_7	E425 (PI-373139)///Farmbuster/Xieqinzao//Xiangzaoxian No. 1	TGMS
UP-3s	F_7	Gobo (PI369806, Surinam)/Zhenshan 97//Xiangzaoxian1	TGMS
11A	B_6F_1	GSOR80 (Zhenshan97 A)//IR2061-214-3/You1	CMS
13A	B_6F_1	Ignap Catelo (PI-373138)//IR2061-214-3/Jin23	CMS
15A	B_5F_1	GSOR80 (Zhenshan97 A)//Xiangzaoxian No. 1/Jin23	CMS
PB05	F_6	Katy/Minghui63//R647	Restorer
PB11	F_6	Lemont/Minghui63//Jasmine-85	Restorer
PB14	F_6	CDR210//Katy/Minghui63	Restorer
PB15	F_5	Katy/Minghui63//Jasmine-85	Restorer
PB16	F_5	Katy/Minghui63//02428	Restorer

The 30 new hybrids from those sterile and restore parents and the check inbred Francis were tested for agronomic traits and yield at Pine bluff, AR in 2014. The test entries were sowed at April 12, 2014 in the greenhouse and transplanted to field with 15 days old seedlings (about four-leaf stage) at 0.1524 meter per plant and 0.3048 meter per row space.

The herbicide Command (1 pint/acre) and Permit (1 oz/acre) applied in the pre-emergent herbicides condition on April. Nitrogen fertilizer was applied 150 kg N/ha. The flood was maintained throughout the growing season. Heading dates were recorded when 50% of the plants were headed. Panicles of each plot with 0.762 meter × 1.524 meter = (1.161 m^2/plot) were harvested about 40 days after heading. Plant heights were measured before harvest. Grain yield, milled rice rate, head rice rate, and chalky rice rate also were measured.

Daily maximum temperatures (Table 2) were recorded by the sensor of NRCS Arkansas scan site where is 50 meters away from field of study [17]. Average Yields and stand error of the mean were analyzed with SAS 9.2.

Table 2. *Daily maximum air temperature (°F) in the UAPB field from June to September 2014.*

Day	June	July	August	September
1	83	91	75	90
2	85	89	84	85
3	89	81	87	92
4	89	81	88	95
5	87	85	93	95
6	86	90	94	88
7	91	91	89	86
8	77	90	89	90
9	78	85	86	93
10	78	89	91	91
11	83	86	91	82
12	86	93	85	67
13	83	96	86	69
14	87	94	86	77
15	90	81	88	82
16	90	81	93	85
17	90	73	93	88
18	90	66	88	84
19	88	75	93	85
20	92	84	92	92
21	91	87	92	91
22	92	90	94	78
23	89	90	95	80
24	87	82	96	85
25	89	89	96	84
26	86	93	92	86
27	82	94	91	83
28	87	87	93	84
29	89	82	92	87
30	90	80	80	88
31		75	87	
Average	87	86	90	85

3. Results

3.1. The Grain Yield of New Hybrid Rice

The results showed that all the yields of hybrids are higher than check Francis (Table 3). The yields of top 8 hybrid rice were 20.5% ~ 27.4% higher than that of check Francis; 14 middle yield hybrids were 10.6% ~ 19.1% higher than that of check Francis; and 8 low yield hybrids were 4.6% ~ 9.9% over than that of check Francis (Table 3).

Table 3. *The grain yield of new hybrids at Pine Bluff, Arkansas, 2014.*

Order	F1 Cross Sterile/Restorer	Kg/plot	Sdt Err mean	Kg/Hectar	Over CK (%)	Rank
3	UP-3s/PB05	1.263	0.01	11082.4	27.4	1
27	UP-3s/PB16	1.27	0.01	10938.9	25.7	2
1	UP-1s/PB05	1.263	0.01	10881.4	25.1	3
23	13A/PB15	1.243	0.04	10709.2	23.1	4
15	UP-3s/PB14	1.24	0.04	10680.5	22.8	5
24	15A/PB15	1.233	0.03	10623	22.1	6
21	UP-3s/PB15	1.23	0.03	10594.3	21.8	7
20	UP-2s/PB15	1.217	0.03	10479.5	20.5	8
22	11A/PB15	1.203	0.03	10364.6	19.1	9
2	UP-2s/PB05	1.197	0.02	10307.2	18.5	10
30	15A/PB16	1.19	0.04	10249.8	17.8	11
9	UP-3s/PB11	1.17	0.03	10077.5	15.8	12
26	UP-2/PB-16.	1.167	0.03	10048.8	15.5	13
16	11A/PB14	1.163	0.04	10020.1	15.2	14
14	UP-2s/PB14	1.16	0.02	9991.4	14.9	15
29	13A/PB16	1.153	0.03	9934	14.2	16
13	UP-1s/PB14	1.147	0.04	9876.5	13.5	17
18	15A/PB14	1.143	0.03	9847.8	13.2	18
8	UP-2s/PB11	1.14	0.02	9819.1	12.9	19
12	15A/PB11	1.127	0.03	9704.3	11.6	20
19	UP-1s/PB15	1.123	0.03	9675.6	11.2	21
7	UP-1s/PB11	1.117	0.04	9618.2	10.6	22
25	UP-1s/PB16	1.11	0.01	9560.7	9.9	23
28	11A/PB16	1.097	0.02	9445.9	8.6	24
6	15A/PB05	1.093	0.01	9417.2	8.3	25
5	13A/PB05	1.077	0.02	9273.6	6.6	26
10	11A/PB11	1.073	0.01	9244.9	6.3	27
17	13A/PB14	1.07	0.02	9216.2	5.9	28
11	13A/PB11	1.06	0.02	9130.1	5	29
4	11A/PB05	1.057	0.05	9101.4	4.6	30
31	Francis (CK)	1.01	0.02	8699.4	/	31

3.1.1. Specific Hybrids and Higher Yield Hybrids

The top 8 hybrids as follows:

The yield of hybrid UP-3s/PB05 was 11082.4 kg/hectare and 27.4% higher than check Francis. The yield of hybrid UP-3s/PB16 was 10938.9 kg/hectare and25.7% higher than CK Francis. The yield of hybrid UP-1s/PB05 was 10881.4 kg/hectare and 25.1% higher than check Francis. The yield of hybrid 13A/PB15 was 10709.2 kg/hectare and 23.1% higher than CK. The yield of hybrid UP-3s/PB14 was

10680.5kg/hectare and 22.8% higher than check Francis. The yield of hybrid 15A/PB15 was 10623 kg/hectare and 22.1% higher than check Francis. The yield of hybrid UP-3s/PB15 was 10594.3kg/hectare and 21.8% higher than check Francis. The yield of hybrid UP-2s/PB15 was 10479.5kg/hectare and 20.5% higher than check Francis (Table 3).

3.1.2. Average Grain Yields of Hybrids from the Same Sterile Line Crossing with 5 Restorer Lines; and the Same Restorer Line Crossing with 6 Sterile Lines (Table 4)

Table 4. *Average hybrid grain yields (kg/hectare) from one parent line crossing other relevant and different parents.*

Restorer Sterile	PB5	PB11	PB14	PB15	PB16	Average	% Over CK
UP-1s	10881.4	9618.2	9876.5	9675.6	9560.7	9922.5	14.1
UP-2s	10307.2	9819.1	9991.4	10479.5	10048.8	10129.2	16.4
UP-3s	11082.4	10077.5	10680.5	10594.3	10938.9	10674.7	22.7
Sub-average	10757.0	9838.3	10182.8	10249.8	10182.8	10242.1	17.7
% over CK	23.7	13.1	17.1	17.8	17.1	17.7	
11A	9101.4	9244.9	10020.1	10364.6	9445.9	9635.4	10.8
13A	9273.6	9130.1	9216.2	10709.2	9934.0	9652.6	11.0
15A	9417.2	9704.3	9847.8	10623.0	10249.8	9968.4	14.7
Sub-average	9264.1	9359.8	9694.7	10565.6	9776.6	9752.1	12.2
% over CK	6.5	7.6	11.4	21.5	13.5	12.2	
Average	10010.5	9599	9938.8	10407.7	10029.7	9997.1	14.9
% Over CK	15.1	10.3	14.2	19.6	15.3	14.9	

i. Table 4 (horizontally) listed the average yields of hybrids from the same sterile line crossed with 5 different restorer lines, PB5, PB11, PB14, PB15 and PB16.

Hybrids developed from the sterile line UP-3s had the highest average yield of 10,674.7 kg/hectare and over CK Francis by 22.7%.

Hybrids developed from sterile line UP-2s had the second high average yield of 10129.2 kg/hectare and over CK Francis by 16.4%.

Hybrids developed from sterile line 15 A had the third high average yield of 9968. 4 kg/hectare and was over CK Francis 14.7%.

Hybrids developed from sterile line UP-1s had the fourth high average yield of 9922.5 kg/hectare and over CK Francis 14.1%.

Hybrids developed from sterile line 13A had the average yield of 9652.6kg/hectare and was over CK Francis 11%.

Hybrids developed from sterile line 11A had the average yield of 9635.4 kg/hectare and was over CK Francis 10.8%.

ii. Table 4 (vertically) listed the average yields of hybrids for the same restorer line crossed with 6 different sterile lines 11A, 13A, 15A, UP-1s, UP-2s, and UP-3s.

Hybrids developed from PB15 crossed with the 6 sterile lines had the highest average yield 10407.7 kg/hectare and was over CK Francis 19.6%.

Hybrids developed from PB16 crossed with the 6 sterile lines had the second high average yield of 10029.7 kg/hectare and was over CK Francis 15.3%.

Hybrids developed from PB5 crossed with the 6 sterile lines had the third high average yield of 10010.5 kg/hectare and was over CK Francis 15.1%.

Hybrids developed from PB14 crossed with the 5 sterile lines had the fourth high average yield of 9938.8 kg/hectare and was over CKFrancis14.2%.

Hybrids developed from PB11 crossed with the 6 sterile lines had the average yield of 9599 kg/hectare and was over CK Francis 10.3%.

iii. Table 4 also lists the sub-average yield of two-line system (UP-1s, UP-2s, and UP-3s) hybrids and three-line system (11A, 13A, and 15A) hybrids. Total sub-average yield of two-line system hybrids was 10242.1kg/hectare and 17.7% over CK Francis (table 4). The highest sub-average yield of tow-line hybrids was PB5 crossed with 3 TGSM sterile lines was 10757 kg/hectare and was 23.7% over CK Francis. Total sub-average yield of three-line system hybrids was 9752.1kg/hectare and 12.2% over CK Francis. The highest sub-average yield of three-line hybrids was PB15 crossed with 3 CMS sterile lines was 10565.6 kg/hectare and 21.5% over CK Francis (table 4).

3.2. The Heading Days from Planting to Heading

The heading days of 6 hybrids, UP-3/PB05, UP-3s/PB11, UP-3/14, UP-3s/15, UP-3/PB16, and UP-2/PB14, were just one or two days later than CK Francis; 6 Hybrid, UP-1s/PB14, 11A/PB14, 13A/PB14, 15A/PB14, UP-1s/PB16, UP-2s/PB16, were 4~6 days later than CK Francis; 6 hybrids, UP-1s/PB05, UP-2s/PB05, UP-1s/PB11, UP-2s/PB11, UP-1s/PB15, and UP-2s/PB15, were 7~10 days later than CK Francis. Other 12 hybrids (all are 3-line hybrids) were 11~16 days later than CK Francis (Table 5).

Table 5. *Heading date and plant heights of new hybrids at Pine Bluff, AE 2014.*

Order	Cross Sterile/Restorer	Seeding date	Seeding to Heading	Plant height cm		Lodging
		(M_D)	Totale days	Average	Std Err mean	
1	11A/PB05	7_11	90	124	1.15	Lodging
2	11A/PB11	7_9	88	129	1.15	Lodging

Order	Cross Sterile/Restorer	Seeding date	Seeding to Heading	Plant height cm		Lodging
		(M_D)	Totale days	Average	Std Err mean	
3	11A/PB14	7_4	83	124	2.08	Lodging
4	11A/PB15	7_15	94	122	1.15	None
5	11A/PB16	7_12	91	127	1.15	Lodging
6	13A/PB05	7_10	89	127	1	Lodging
7	13A/PB11	7_10	89	126	1.53	Lodging
8	13A/PB14	7_3	82	127	1.55	Lodging
9	13A/PB15	7_14	93	124	2.08	None
10	13A/PB16	7_14	93	126	1.53	Lodging
11	15A/PB05	7_12	91	129	1.15	Lodging
12	15A/PB11	7_11	90	129	1.53	Lodging
13	15A/PB14	7_4	83	129	1.15	Lodging
14	15A/PB15	7_14	93	120	0.58	None
15	15A/PB16	7_14	93	129	0.58	Lodging
16	UP-1s/PB05	7_9	88	106	1.15	None
17	UP-1s/PB11	7_9	88	101	0.58	None
18	UP-1s/PB14	7_5	84	105	1	None
19	UP-1s/PB15	7_8	87	105	0.58	None
20	UP-1s/PB16	7_3	82	95	1.15	None
21	UP-2s/PB05	7_7	86	108	1.53	None
22	UP-2s/PB11	7_8	87	111	1.15	None
23	UP-2s/PB14	6_30	79	109	1.15	None
24	UP-2s/PB15	7_7	86	108	0.58	None
25	UP-2s/PB16	7_2	81	103	0.58	None
26	UP-3s/PB15	6_30	79	107	1.15	None
27	UP-3s/PB05	7_1	80	105	1.53	None
28	UP-3s/PB11	6_30	79	104	1	None
29	UP-3s/PB14	7_13	92	107	0.58	None
30	UP-3s/PB16	7_1	80	112	1	None
31	Francis (CK)	6_29	78	99	1.15	None

3.3. The Plant Heights

Plant heights of 30 new hybrids were 103 cm - 129 cm (Table 5). Plant heights of the two-line system hybrids were below 112 cm: 7 hybrids, UP-3/PB05, UP-1s/PB11, UP_3s/PB11, UP-1s/PB11, UP-1s/PB15, UP-1s/PB16, and UP-2s/PB16, were below 106 cm, and other 8 hybrids were 106~112cm. The three-line system hybrids were over 120~129 cm. (Table 5).

3.4. The Milled Rice Rate and Milled Rice Yield of New Hybrids (Table 6)

The milled rice rates of 30 new hybrids were between 66.7% ~ 69.8.7% and all were lower than Check Francis (70.9%). However, most of the hybrids have higher total milled rice than CK because their total rice grains were higher than CK.

Table 6. *The milled rice rate or yield, head rice rate or yield, and chalky rate for new hybrid rice.*

Oder	Hybrid cross	Milled rice				Head rice			
		%	Std Err mean	kg/hectare	% Over CK	Rank	%	Std Err mean	kg/hectare
1	UP-1s/PB05	68.5	0.68	7453.8	20.8	3	57.8	0.49	6289.4
2	UP-2s/PB05	69.4	0.18	7153.2	16.0	8	61.4	0.64	6328.6
3	UP-3s/PB05	69.5	0.09	7702.3	24.9	1	59.5	0.34	6594.0
4	11A/PB05	67.9	0.25	6179.9	0.2		57.7	0.45	5251.5
5	13A/PB05	67.3	0.12	6241.1	1.2		57.8	0.15	5360.1
6	15A/PB05	69.3	0.48	6526.1	5.8		60.2	0.43	5669.2
7	UP-1s/PB11	68.6	0.22	6598.1	7.0		58.3	0.61	5607.4
8	UP-2s/PB11	68.3	0.12	6706.4	8.7		58.1	0.25	5704.9
9	UP-3s/PB11	68.9	0.15	6943.4	12.6		57.2	0.46	5764.3
10	11A/PB11	66.8	0.09	6175.6	0.1		55.6	0.50	5140.2
11	13A/PB11	68.1	0.15	6217.6	0.8		58.5	0.28	5341.1
12	15A/PB11	67.4	0.15	6540.7	6.0		53.3	0.50	5172.4
13	UP-1s/PB14	67.8	0.23	6696.3	8.6		56.5	0.50	5580.2
14	UP-2s/PB14	69.3	0.24	6924.0	12.3		58.5	0.54	5845.0
15	UP-3s/PB14	69.1	0.12	7380.2	19.7	4	60.6	0.46	6472.4
16	11A/PB14	68.6	0.44	6873.8	11.4		55.7	0.49	5581.2
17	13A/PB14	68.3	0.27	6294.7	2.1		57.6	0.43	5308.5
18	15A/PB14	66.7	0.28	6568.5	6.5		51.8	0.55	5101.2
19	UP-1s/PB15	68.0	0.34	6579.4	6.7		57.4	0.24	5553.8
20	UP-2s/PB15	69.2	0.15	7251.8	17.6	4	58.9	0.43	6172.4

Oder	Hybrid cross	Milled rice				Head rice			
		%	Std Err mean	kg/hectare	% Over CK	Rank	%	Std Err mean	kg/hectare
21	UP-3/PB15	69.5	0.17	7363.0	19.4	5	57.3	0.42	6070.5
22	11A/PB15	67.4	0.19	6985.7	13.3		53.6	0.35	5555.4
23	13A/PB15	67.6	0.15	7239.4	17.4	6	56.5	0.38	6050.7
24	15A/PB15	67.5	0.32	7170.5	16.3	7	53.7	0.45	5704.6
25	UP-1s/PB16	67.8	0.19	6482.2	5.1		54.3	0.41	5191.5
26	UP_2s/PB16	68.9	0.67	6923.6	12.3		58.1	0.52	5838.4
27	UP-3s/PB16	69.8	0.52	7635.4	23.8	2	60.5	0.38	6618.0
28	11A/PB16	68.6	0.45	6479.9	5.1		56.1	0.52	5299.1
29	13A/PB16	67.8	0.29	6735.3	9.2		56.5	0.38	5612.7
30	15A/PB16	67.7	0.24	6939.1	12.5		54.3	0.24	5565.6
31	Francis (CK)	70.9		6167.9			63.8		5550.2

Table 6. *Continued.*

Oder	Hybrid cross	Chalky rice					
		% Over CK	Rank	%	Std Err	% over CK	Rank
1	UP-1s/PB05	13.3	5	27	0.52	-10	
2	UP-2s/PB05	14.0	4	20	0.62	-3	
3	UP-3s/PB05	18.8	2	19	0.47	-2	5
4	11A/PB05	-5.4		26	0.55	-9	
5	13A/PB05	-3.4		28	0.30	-11	
6	15A/PB05	2.1		29	0.15	-12	
7	UP-1s/PB11	1.0		16	0.52	1	3
8	UP-2s/PB11	2.8		20	0.58	-3	
9	UP-3s/PB11	3.9		23	0.28	-6	
10	11A/PB11	-7.4		37	0.32	-20	
11	13A/PB11	-3.8		25	0.49	-8	
12	15A/PB11	-6.8		24	0.77	-7	
13	UP-1s/PB14	0.5		25	0.86	-10	
14	UP-2s/PB14	5.3		14	0.28	3	1
15	UP-3s/PB14	16.6	3	20	0.34	-3	
16	11A/PB14	0.6		30	0.50	-13	
17	13A/PB14	-4.4		29	0.35	-12	
18	15A/PB14	-8.1		27	0.38	-10	
19	UP-1s/PB15	0.1		22	0.28	-5	
20	UP-2s/PB15	11.2	6	18	0.26	-1	4
21	UP-3/PB15	9.4		21	0.40	4	
22	11A/PB15	0.1		24	0.35	-7	
23	13A/PB15	0.1		28	0.61	-11	
24	15A/PB15	2.8		24	0.26	-7	
25	UP-1s/PB16	-6.5		15	0.60	2	2
26	UP_2s/PB16	5.2		19	0.26	-2	
27	UP-3s/PB16	19.2	1	24	0.30	-7	
28	11A/PB16	-4.5		27	0.35	-10	
29	13A/PB16	1.1		27	0.41	-10	
30	15A/PB16	0.3		23	0.44	-6	
31	Francis (CK)			17	0.24	/	

The top 5 hybrids came from sterile lines UP-3s, UP-2s, and UP-1s. The first ranking hybrid UP-3s/PB5 had milled rice rate 69.5%. Its milled rice yield was 7702.3 kg/Hectare and over CK Francis 24.9%. The second ranking hybrid UP-3s/PB16 had milled rice rate 69.8%. Its milled rice yield was 7635.4 kg/Hectare, and over CK Francis 22.8%. The third ranking hybrid UP-1s/PB5 had milled rice rate 68.5%. Its milled rice yield was 7453.8 kg/Hectare, and over CK Francis 20.8%. The forth ranking hybrid UP-3s/PB14 had milled rice rate 69.1%. Its milled rice yield was 7380.2 kg/hectare, and over CK Francis 19.7%. The fifth ranking hybrid UP-3s/PB15 had milled rice rate 69.5%. Its milled rice yield was 7363 kg/Hectare, and over CK Francis 19.4%. The next three hybrids13A/PB15, 15A/PB15, and UP-2s/PB05 had milled rice rate was 69.8%, 67.5% and 69.4% respectively. Their milled rice yield were 7239.4 kg/Hectare, 7170.5 kg/Hectare, and 7153.2 kg/Hectare, respectively, and over CK Francis 17.4%, 16.3% and 16%, respectively (Table 6).

3.5. The Head Rice Rates and Head Rice Yield of New Hybrids (Table 6)

Head rice rates of 30 new hybrids were between 51.8% - 61.4%. All head rice rates of hybrids were lower than check Francis (63.8%), but most of hybrids had higher total head rice yields than CK. The first ranking hybrid UP-3s/PB16

had head rice rate 60.5%. Its head rice yield 6618kg/hectare and over CK 19%. The second hybrid UP-3s/PB5 had head rice rate 59.5%. Its head rice yield 6594 kg/hectare and over CK 19%. The third hybrid UP-3s/PB14 had head rice rate 60.6%. Its head rice yield 6472.4 kg/hectare and over CK 17%. The fourth ranking hybrid UP-2s/PB5 had head rice rate 61.4%. Its head rice yield 6328.6 kg/hectare over CK 14%. The fifth ranking hybrid UP-1s/PB5 had head rice rate 57.8%. Its head rice yield 6289.4 kg/hectare and over CK 13%.

3.6. The Chalky Rice of New Hybrids (Table 6)

Hybrid UP-2s/PB14 had chalky rice rate 14% and 3% less than CK Francis (17%). Hybrid UP-1s/PB16 had chalky rice rate 15% and 2% less than CK Francis.

Hybrid UP-1s/PB11 had chalky rice rate 16% and 1% less than CK Francis. Hybrid UP-2s/PB15 and UP-3s/PB5 had chalky rice rate 18% and 19%, respectively and they were only light higher than CK Francis.

4. Discussions

Hybrids from the 4 sterile lines UP-3s, UP-2s, UP-1s and 15A, and the 4 restorer lines PB15, PB16, PB5, and PB14 were performed well in this experiment. As parents, these four sterile lines and 4 restorer lines worth to pay more attention in the future breeding and the seed production for obtaining the high yielding hybrids. UP-1s, UP-2s and UP-3s are two-line system sterile lines (TGMS). 15A is three-system sterile line (CMS). Up-3s has a dominant early maturity gene. The early maturity hybrid rice will be obtained when this sterile line crosses to late restorer lines.

Hybrids UP-3s/PB16, UP-3s/PB5, UP-3s/PB14, UP-2s/PB5, and UP-1s/PB5 were higher head rice yield Hybrids.

The heading dates of 6 hybrids UP-3/PB05, UP-3s/PB11, UP-3/14, UP-3s/15, UP-3/PB16, and Up-2/PB14 were only 1 or 2 days later than CK Francis.

The plant heights of 7 hybrids UP-3/PB5, UP-1s/PB11, UP-3s/PB11, UP-1s/PB11, UP-1s/PB15, UP-1s/PB16, and UP-2s/PB16 were below 106 cm.

The Major traits (grain yield, head rice, less chalky, lower height, earlier heading date) of hybrids of two-line system were better than that of hybrids of three-line system.

The plant heights of three line system hybrids were too tall (120cm ~129cm). It is a challenge to breed the three-line system hybrid rice with the shout plant height (100cm~115cm) in future.

5. Conclusions

The sterile lines UP-3s, UP-2s, UP-1s and 15A have good combining. The restorer lines PB-05, PB15, and PB16 have good combining ability. The major traits (grain yield, head rice, less chalky, lower height, earlier heading date) of hybrids of two-line system were better than that of hybrids of three-line system. Five top hybrids and their parents of the sterile lines and restorer lines are good to be used in the future hybrid rice breeding.

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