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Study on Physical-Chemical Characters and Heritability for Yield Components in Rice (*Oryza sativa* L.)

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Abstract. Present study was performed to analysis both physical and chemical properties of rice germplasm and heritability for yield components in combinations. A total of 44 lines/varieties obtained from Cuu Long Rice Research Institute genebank, and 30 F_1 generation combinations were evaluated. The results showed that the rice line IR79008-B-11-B-B-1 showed overall good physical characters (head rice, grain length, grain width, chalkiness). In terms of chemical characteristics, three varieties IR75499-73-1-B, OM6162, and OM4900 were found to have good amylose content, gel consistency, protein content, gelatinization temperature, and aroma. A very notable finding was that the cross between OM6162/SwarnaSub1 that low amylose content (20.2%), high gel consistency (78.2 mm), high protein content (8.1%), appropriate gelatinization temperature (scale 5), low chalkiness (level 0), high heritability (0.9) for grain yield trait/cluster, and (0.84) for the number of panicles/cluster. Moreover these characters consist of plant height, panicle length, number of panicles/cluster, number of filled grains/panicle, number of unfilled/panicle, and grain yield/ cluster showed moderate to high heritability of mean for combination OM6162/SwarnaSub1. The results suggest that the grain yield trait/cluster and the number of panicles/cluster are important yield contributing traits to rice breeders for selecting ideal combinations for higher yield and quality of next generations.

1. Introduction

Rice is an important staple food for more than half of the world's population, especially in developing countries. For thousands of years, the culture, economy and history of many countries and regions in the world have been profoundly shaped by this plant. In Vietnam, currently, one of the most important objectives of rice production is to develop new varieties, which have high quality and highly adapt to climate change. Research strategy in rice breeding is creating of rice varieties with desired traits including long grain, low amylose content (< 20%), less chalkiness, aroma, short growth duration (90-100 days), and stable tolerance to both biotic and abiotic stresses.

Grain quality in rice plays an important role in acceptance by consumers as the second most important factor behind high yield in objectives of rice breeding [1-3]. Furthermore, it determines the market price of rice [4]. Therefore, evaluation of rice quality involving chemical compositions, cooking quality, gelatinization temperature and physical properties of rice is essential [5]. The quality of rice into three groups consisting of (1) physical characteristics including moisture content, shape, size, whiteness, translucency, chalkiness, head rice, broken rice, brewers, green kernels and yellow kernels; (2) chemical characteristics including amylose content, protein content, gel consistency, expansion level of cooked rice, water absorption, and cooking time; (3) the sensory aspects of cooked rice including color, aroma, hardness, stickiness, and consistency [6]. The three key components determining cooking and eating are amylose content, gelatinization temperature and gel consistency. The chemical characteristics include the amylose content (AC), gelatinization temperature (GT), gel consistency (GC), protein content (PC) and aroma which are directly related to cooking and eating quality [7].

Beside quality of rice, a quantitative trait rice yield is a complex character of any crop. The success of a breeding program depends on the availability on genetic variability in the subjected to selection [8]. Genetic variability for agronomic traits is key component of breeding programmes for broadening the gene pool of rice [9]. Yield potential of rice can be improved with different strategies [10]. Breeding strategy in rice depends on degree of associated characters as well as its magnitude and nature of variation [11]. Commonly, plant breeders select for yield components which indirectly increase yield [9]. Moreover, heritability of traits is essential for selection based improvement as it indicates the extent of transmissibility of a character into generations [12]. Therefore, the main objective of this study were (1) to evaluate the quality levels of physical and chemical characteristics of rice germplasms in order to improve quality rice cultivars, in which several beneficial traits should be combined; and (2) to estimate the heritability of yield and yield components of F4 generation.

2. Materials and methods

2.1. Plant materials:

Rice germplasms were used in this study, including 44 lines/varieties in the genebank of Cuu Long Delta Rice Research Institute (CLDRRI).

The experiment was conducted in 2015 - 2016 dry season at Cuu long Delta Rice Research Institute, Viet Nam. After 15 days old seedling, each variety were transplanted with one plant per hill in Randomized Block Design with three replications. The row- to- row and plant-to-plant spaces of 20 cm x 15 cm were maintained. Ten-day after transplanting, the drainage through drain taps was set up; without provide the water until flowering. The fertilizer was applied at rate 100-40-30 kg $N\text{-}P_2O_5\text{-}K_2O$ ha^{-1} for dry season and 80-40-30 kg $N\text{-}P_2O_5\text{-}K_2O$ ha^{-1} for wet season. After harvesting the seeds of each line/variety were dried using solar heat to obtain 14% moisture content, and then dehulled for evaluation of the grain quality in three replications.

The hybrid materials were screened in the field and used for making crosses. Total F_1 seeds of 30 combinations were made by a single cross. The data for amylose content (AC), gel consistency (GC), protein content (PC), gelatinization temperature (GT), and aroma are main major traits for the first step to select combinations.

Developing the population F_1 and production of F_2 seeds then selecting F_2, F_2 generations from 30 combinations during 2015 dry season to 2016 wet season at Cuu Long Delta Rice Research Institute, Viet Nam. F_2 generation was grown and selected separations for generating the F_3 generation, and F_3 plants were selected. F_3 lines were planted to continue to evaluate for the F_4 generation. For the performance test agronomic characteristics such as plant height, panicle length, number of panicle/cluster, number of filled grain/panicle, number of unfilled grain/panicle, and grain yield/cluster (g) were investigated.

2.2. Evaluation of physical characteristics:

Brown rice (BR) and milled rice (MR) ratios were measured by a standard dehusker [13]. Head rice (HR) was tested by using a hundred grams of dehusked rice grains that had no visible breakage. The percentages of HR and broken rice were then calculated [13]. Chalk index was determined by placing ten dehusked rice grains on a light box and visually identifying the chalkiness of each grain. The chalkiness percentage of each rice line/variety is an average of ten values from ten grains. The following levels were used for classifying endosperm chalkiness of milled rice including level 0 (no chalkiness), level 1 (less than 10% chalkiness), level 5 (10 – 20% chalkiness), and level 9 (more than 20% chalkiness) [13]. The grain size, one of the important characteristics was measured in length (mm) and width (mm) of grain.

2.3. Evaluation of chemical characteristics:

Amylose content (AC): The amylose contents of different varieties were determined based on a standard graph (Williams 1958; Perez and Juliano 1978). Rice varieties are grouped on the basis of their AC as follows, waxy (0 - 2%), very low (3 - 9%), low (10 - 19%), intermediate (20 - 25%), and high (>25%) by [14].

Gel consistency (GC): Milled rice samples (10 grains) were ground into a fine powder in the Wig-L Bug grinder. Consistency is measured by the length in a test tube of the cold gel held horizontally for 1h after heating in 0.2 N potassium hydroxide (KOH) (2 mL) and categorized as soft (61 - 100 mm), medium (41 - 60 mm), and hard (26 - 40mm) [15].

Gelatinization temperature (GT): GT is estimated by the extent of alkali spreading, according to [15]. Ten milled rice grains were placed in a Petri dish, and then 10 mL of 1.7% KOH was added. The sample was placed in an incubator at 25 ^{o}C for 24h. The degree of spreading is measured using a 7- point scale as follows: 1 (grain not affected), 2 (grain swollen), 3 (grain swollen, collar incomplete and narrow), 4 (grain swollen, collar complete and wide), 5 (grain split or segmented, collar complete and wide), 6 (grain dispersed, merging with collar), and 7 (grain completely dispersed and intermingled). The scale includes 1-2: high (74.5 - 80 ^{o}C), 3: high intermediate, 4 - 5: intermediate (70 - 74 ^{o}C), and 6 - 7: low (<70 ^{o}C).

Protein content (PC): Protein content was determined on a dry weight basis based on nitrogen content. Nitrogen content in each grain sample was estimated by the Technicon Autoanalyser (Technicon Instrument Inc. USA). Protein content (%) = Nitrogen content (%) x 5.7, where 5.7 is the conversion factor.

Aroma: Ten leaves of rice were cut into 5 mm long pieces, and then put into a capped test tube. A volume of 5 ml of 1.7 % KOH solution was added and incubated at 50 ^{o}C for 10 min. Five panelists were asked to classify the samples as either aromatic or non-aromatic by their own smell. Aroma classification is defined as score 0 (no aroma), score 1 (slight aroma), score 2 (moderate aroma), and score 3 (strong aroma) [16].

2.4. Data analysis:

All measurements were conducted in triplicates. An analysis of variance (ANOVA) for all data was performed using the SAS 9.1 software. Broad - sense heritability (h^2) was calculated was the ratio of the genotypic variance to the phenotypic variance using the formula according to Allard [17]:

$h^2 = \sigma^2 g/\sigma^2 p$

Where h^2 = broad -sense heritability, $\sigma^2 g$ = genotypic variance and /$\sigma^2 p$ = phenotypic variance.

3. Results

3.1. Physico-chemical characteristics of parental materials

Physical characters: Evaluation of targets grain quality parent materials under drought tress were significantly for the physical - chemical characters. In this study, physical traits were evaluated consisting of characters described in Table 1.

The percentage of BR ranged 75.6 to 88%, the lowest was recorded in the line IR78966-B-16-B-B-B and the highest was WAB340-B-B-2-H2. Most of the remaining varieties had the BR percentage higher than 80%.

The percentage of BR ranged 75.6 to 88%, the lowest was recorded in the line IR78966-B-16-B-B-B and the highest was WAB340-B-B-2-H2. Most of the remaining varieties had the BR percentage higher than 80%. The lowest milling recoveries were observed in four varieties (70.0%) including IR75499-73-1-B, IR75499-21-1-B, WABC165, and IR78966-B-16-B-B-B. The highest was found in WAB340-B-B-2-H2 (77.0%). Forty varieties showed high milling (>70%). HR values ranged from 42.7 to 57.2%. The varieties WAB340-B-B-2-H2 and WAB176-42-HB had the highest head rice and the lowest was found in IR78966-B-16-B-B-B (42%). In this study, the grain length had the highest value in V3M-92-1 (8.4 mm), followed by 22 lines/varieties (7 - 7.9 mm) and the lowest was BASMATI and IR78966-B-10-B-B-B-SB1 (5.2 mm). Among 44 lines/varieties, the chalkiness ranged from level 0 to 5. Most of the lines/varieties had low chalkiness from level 0 to 1 under drought condition, except IR78913-B-10-B-B-B (level 5).

Chemical characters: Amylose content (AC), gel consistency (GC), and gelatinization temperature (GT) are shown in Table 2. The results showed that the AC ranged from 12.0 to 27.3 %. The line IR78933-B-24-B-B-2 had the lowest content. There were varieties containing 20 to 25% of AC which is classified as soft and flaky cooked rice. All materials in this study were intermediate AC, except IR78937-B-20-B-B-1 (26.3%) and WAB176-42-HB (27.3%).

Table 1. Evaluating physical characteristics of rice germplasms

No.	Name of lines/varieties	Physical characters				
		BR %	MR %	HR %	GL (mm)	chalkiness (level)
1	OM4900	80.3g	72.0def	52.3cd	6.8a-g	0
2	OM1490	81.5d-g	71.0ef	51.1de	5.3g	1
3	AS 996	80.5fg	70.2ef	51.0de	6.3b-g	0
4	M362	81.2d-g	71.3ef	51.3de	5.6fg	1
5	BASMATI	84.3c	74.2bcd	54.2b	5.2g	1
6	Basmati DB	80.4fg	70.2ef	50.2e	6.4b-g	1
7	OM6162	80.1g	70.1ef	51.2de	6.3b-g	1
8	SwarnaSub1	80.6efg	70.5ef	51.2de	7.9ab	1
9	IR64Sub1	86.2b	75.5ab	55.6ab	7.8abc	1
10	IRGA318-11-6-9-2B	82.3de	72.5cde	52.1d	7.1a-f	1
11	IR78966-B-10-B-B-B-2	82.6cd	72.3c-f	52.1d	7.2a-f	1
12	IR78913-B-10-B-B-B	81.6d-g	71.0ef	51.2de	7.8abc	5
13	IR75499-73-1-B	80.5fg	70.0f	50.2e	7.8abc	0
14	IR78913-B-19-B-B-B	82.3de	72.0def	52.4cd	7.9ab	1
15	AZUCENA	81.3d-g	71.2ef	51.2de	6.8a-g	0
16	IR78933-B-24-B-B-2	84.2c	74.0bcd	54.2b	6d-g	1
17	IR78933-B-24-B-B-3	86.3ab	72.3c-f	52.3cd	5.9efg	0
18	IR78933-B-24-B-B-4	86.2b	75.6ab	55.6ab	6.6b-g	1
19	IR79008-B-11-B-B-1	86.2b	75.0ab	55.5ab	7.1a-f	0
20	IR75499-38-1-B	82.6cd	72.4c-f	52.3cd	7.5a-e	1
21	V3M-92-1	81.2d-g	71.0ef	51.2de	8.4a	1
22	IR75499-21-1-B	80.6efg	70.0f	50.1e	7.6a-d	1
23	V3M-109-2	84.2c	74.0bcd	54.2b	6.8a-g	0
24	WAB272-B-B-8-H1	84.2c	74.0bcd	51.3de	7.6a-d	1
25	WAB340-B-B-2-H2	88.0a	77.0a	57.2a	7.4a-e	1
26	WAB176-42-HB	87.4ab	76.0ab	56.0a	5.3g	1
27	IR78937-B-20-B-B-1	81.3d-g	71.0ef	51.0de	5.6fg	1
28	WAB880-1-38-18-20-P1-HB	84.2c	74.0bcd	54.0bc	7.1a-f	1
29	WAB881SG9	81.3d-g	71.2ef	51.3de	6.2c-g	1
30	IR78997-B-16-B-B-B-SB2	81.2d-g	71.0ef	54.0bc	7.5a-e	1
31	IR78966-B-10-B-B-B-SB1	84.3c	74.2bcd	54.2b	5.2g	1
32	IR78944-B-8-B-B-B	80.4fg	70.2ef	50.2e	6.4b-g	1
33	IR78941-B-16-B-B-B	80.1g	70.1ef	51.2de	6.3b-g	1
34	IR78948-B-21-B-B-B	80.6efg	70.5ef	51.2de	7.9ab	0
35	IR78942-B-2-B-B-2	86.2b	75.5ab	55.6ab	7.8abc	1

36	IR78937-B-20-B-B-3	82.3de	72.5cde	52.1d	7.1a-f	1
37	IR78985-B-13-B-B-B	82.6cd	72.3c-f	52.1d	7.2a-f	1
38	IR78933-B-24-B-B-1	81.6d-g	71.0ef	51.2de	7.8abc	1
39	WABC165	80.5fg	70.0f	50.2e	7.8abc	1
40	IR80315-49-B-B-4-B-B-B	82.3de	72.0def	52.4cd	7.9ab	1
41	IR78966-B-16-B-B-B	75.6h	70.0f	42.0f	6.2c-g	1
42	IR78913-B-22-B-B-B	81.0d-g	74.0bcd	50.0e	6.6b-g	0
43	OMCS 2000 (check)	80.6efg	76.2ab	51.2de	7.1a-f	0
44	IR78939-B-9-B-B-B	80.5fg	72.5c-f	51.0de	6.3b-g	1
CV%		1.02	1.65	1.62	11.73	-
LSD 0.05		0.36	0.51	0.36	0.35	-

Data within a column by same letter are not significantly different (P<0.05); CV, coefficient of variation; BR: brown rice, MR: milled rice, HR: head rice, GL: grain length: GW: grain wide

Table 2. Evaluating chemical characteristics of rice germplasms

No.	Name of lines/varieties	Chemical characters					
		GW (mm)	AC (%)	GC (mm)	PC (%)	GT (scale)	Aroma (score)
1	OM4900	3.2abc	19.8j-m	82.3d	8.6ab	3	2
2	OM1490	2.8bcd	24.3cd	51.2q	7.6b	3	0
3	AS 996	3.4ab	24.5c	48.7rs	8.9ab	3	0
4	M362	3.0abc	24.1cd	55.2p	8.6ab	3	0
5	BASMATI	3.2abc	22.6d-g	76.3fg	7.93b	3	2
6	Basmati DB	3.2abc	24.3cd	49.3r	8.7ab	3	0
7	OM6162	3.3ab	18.3m	84.2c	8.2ab	3	2
8	SwarnaSub1	3.1abc	24.3cd	49.3r	8.7ab	3	0
9	IR64Sub1	3.2abc	23.5c-f	68.7kl	8.5ab	7	0
10	IRGA318-11-6-9-2B	2.9a-d	24.2cd	48.2rst	7.5b	3	0
11	IR78966-B-10-B-B-B-2	3.0abc	21.0hij	77.5ef	8.3ab	3	0
12	IR78913-B-10-B-B-B	2.3d	20.1jkl	71.0hi	8.5ab	3	0
13	IR75499-73-1-B	3.1abc	18.9klm	78.9e	8.2ab	3	1
14	IR78913-B-19-B-B-B	3.1abc	18.7lm	88.1b	8.4ab	5	0
15	AZUCENA	3.0abc	24.5c	48.9rs	8.4ab	5	1
16	IR78933-B-24-B-B-2	3.4ab	12.0o	100.0a	8.5ab	3	0
17	IR78933-B-24-B-B-3	3.5a	24.0cde	45.6uv	7.9b	5	2
18	IR78933-B-24-B-B-4	3.2abc	24.5c	52.1q	7.5b	5	1
19	IR79008-B-11-B-B-1	3.3ab	24.2cd	48.3rst	7.9b	7	2
20	IR75499-38-1-B	3abc	20.5ijk	72.5h	8.4ab	5	1
21	V3M-92-1	3.1abc	18.3m	62.8n	7.8b	2	0
22	IR75499-21-1-B	3.2abc	21.2hij	70.3ij	10.3a	2	0
23	V3M-109-2	3.4ab	23.6c-f	65.3m	7.8b	5	2
24	WAB272-B-B-8-H1	3.2abc	16.4n	75.3g	8.5ab	3	0
25	WAB340-B-B-2-H2	3.2abc	24.5c	62.1n	8.1ab	3	0
26	WAB176-42-HB	3.1abc	27.3a	42.8w	7.8b	3	0
27	IR78937-B-20-B-B-1	3.4ab	26.3ab	44.6v	8.2ab	3	0
28	WAB880-1-38-18-20-P1-HB	2.6cd	24.2cd	46.8tu	8.3ab	3	0
29	WAB881SG9	3.2abc	24.1cd	47.6st	8.4ab	3	0
30	IR78997-B-16-B-B-B-SB2	3.2abc	23.5c-f	49.2r	7.6b	3	0

31	IR78966-B-10-B-B-B-SB1	3.3ab	24.1cd	66.5m	7.6b	3	0
32	IR78944-B-8-B-B-B	3.4ab	25.0bc	60.1o	8.5ab	3	0
33	IR78941-B-16-B-B-B	3.5a	24.5c	66.3m	8.4ab	3	0
34	IR78948-B-21-B-B-B	3.1abc	16.2n	85.4c	8.9ab	5	2
35	IR78942-B-2-B-B-2	3.2abc	24.0cde	48.6rs	7.6b	3	1
36	IR78937-B-20-B-B-3	2.9a-d	23.4c-f	44.5v	7.7b	3	0
37	IR78985-B-13-B-B-B	3.0abc	23.5c-f	69.7i-l	7.8b	3	0
38	IR78933-B-24-B-B-1	2.3d	24.5c	66.4m	8.5ab	1	0
39	WABC165	3.1abc	21.1hij	70.2ijk	8.7ab	3	0
40	IR80315-49-B-B-4-B-B-B	3.1abc	24.7bc	69.4jkl	8.1ab	3	0
41	IR78966-B-16-B-B-B	3.1abc	23.5c-f	66.5m	7.6b	3	0
42	IR78913-B-22-B-B-B	3.4ab	22.1ghi	68.7kl	7.9b	3	0
43	OMCS 2000 (check)	3.2abc	24.1cd	68.5l	8.1ab	3	0
44	IR78939-B-9-B-B-B	3.4ab	24.3cd	48.7rs	7.93b	5	0
CV%		10.72	3.72	1.23	0.26	-	-
LSD 0.05		0.14	0.36	0.33	0.33	-	-

Data within a column by same letter are not significantly different (P<0.05); CV, coefficient of variation; AC: Amylose content; GC: gel consistency; GT: gelatinization temperature; PC: protein content

The highest GC was found in IR78933-B-24-B-B-2 (100 mm) and the lowest was WAB176-42-HB (42.8 mm). There were 28 lines/varieties belonging to the categories soft rice, 19 lines/varieties belonging to medium. The gelatinization temperature (GT) is the temperature at which the starch granule begins to swell irreversibly in hot water with a simultaneous loss of crystalline. In this study, the GT scales had a large variation among lines/varieties which ranged from scale 1 to 7. The highest GT scale was observed in the line IR78933-B-24-B-B-1, and the lowest was IR64sub1. There were 31 varieties which obtained a GT score of 3 and two varieties IR78933-B-24-B-B-1 and V3M-92-10 had score 2. These lines/varieties had score 5 including IR78913-B-19-B-B-B, AZUCENA, IR78933-B-24-B-B-3, IR78933-B-24-B-B-4, WAB326-B-B-7-H1, IR75499-38-1-B, V3M-109-2, and IR78948-B-21-B-B-B. The protein content of 44 lines/varieties ranged from 7.5 to 10.3%. Twenty-six lines/varieties had protein content higher than 8%. The highest protein content was IR75499-21-1-B and the lowest was found in two varieties IRGA318-11-6-9-2B and IR78933-B-24-B-B-4 (P>0.05). The results showed that only six varieties obtained moderate aroma, similar to aroma of Basmati including OM4900, OM6162, IR78933-B-24-B-B-3, IR79008-B-11-B-B-1, V3M-109-2, and IR78948-B-21-B-B-B. Five varieties had slight aroma, consisting of IR75499-73-1-B, AZUCENA, IR78933-B-24-B-B-4, IR75499-38-1-B, and IR78942-B-2-B-B-2 and the remaining lines/varieties had no aroma.

The results demonstrated that the line IR79008-B-11-B-B-1 was the best in term of good physical characteristics, such as head rice, grain length, grain width, and chalkiness. The three lines/varieties that came out on top of the chemical characteristics were IR75499-73-1-B, OM6162, and OM4900. Identifying those lines that exhibit the best characteristics will be useful for improving the quality of future rice breeding programs. This will be helpful in assessing the varietal characters for selecting parents.

3.2. Grain quality characteristics of combinations

The grain quality traits of F_1 generation of 30 hybrid combinations were evaluated, shown in Table 3. The AC of all combinations ranged from 20 to 26.3%. There were six combinations consisting of IR65191-3B-2-2-2-2/IR64Sub1, IR78933-B-24-B-B-3/IR64Sub1, OM6162/SwarnaSub1, WAB326-B-B-7-H1/IR64Sub1, V3M-170-1/IR64Sub1, and IR75499-29-2-B//IR64Sub1 had low AC (20 - 21.3%).

Majority of combinations had an average GC more than 40 mm and were categorized as soft and medium. Total eleven combinations including IR78933-B-24-B-B-31/IR64Sub1, WAB99-47/IR64Sub1, OM6162/SwarnaSub1, WAB326-B-B-7-H1/IR64Sub1, IR78913-B-10-B-B-B/IR64Sub1, IR65191-3B-2-2-2-2/IR64Sub1, IR78913-B-19-B-B-B/IR64Sub1, V3M-170-1/IR64Sub1, IR78913-B-19-B-B-B/IR64 Sub1, V3M-167-2-B/IR64Sub1, and IR75499-21-1-B/IR64sub1 had good GC (71.2 to 85.3 mm).

The protein contents of 30 combinations were from 6.8 to 8.5%. A high protein content was observed in nine combinations (IR75499-73-1-B/IR64Sub1, V3M-103-2/Sawanasub1, IR78933-B-24-B-B-4/IR64Sub1, WAB326-B-B-7-H1/IR64Sub1, IR75499-84-1-B/IR64Sub1, V3M-167-2-B/IR64Sub1, IR78913-B-19-B-B-B/IR64Sub1, IR65191-3B-2-2-2-2/IR64Sub1, and OM6162/SwarnaSub1).

Therefore, selection of non-chalky grain should be made in an earlier generation in rice breeding programs. The chalkiness of combinations ranged from level 0 to 5. The combinations having a minimum level of chalkiness were good quality grains. The best quality grains were observed in the combinations WAB326-B-B-7-H1/IR64Sub1, IR65191-3B-2-2-2-2/IR64Sub1, IR78913-B-10-B-B-B/IR64Sub1, and OM6162/SwarnaSub1.

Table 3. Cooking quality on traits of hybrid combinations

No.	Name of combinations	AC (%)	GC (mm)	GT (scale)	Protein (%)	Chalkiness (level)
1	IR75499-21-1-B/IR 64 sub1	24.1bcd	75.8d	3	7.5bcd	3
2	IR78937-B-3-B-B-3/IR64Sub1	25.6ab	68.2ij	3	7.6bc	3
3	WAB326-B-B-7-H1/IR64Sub1	24.6bc	45.3m	3	8.2ab	3
4	IR78913-B-10-B-B-B/IR64Sub1	23.5cde	69.2ghi	3	7.8bc	1
5	IR75499-73-1-B/IR64Sub1	24.5bcd	48.6l	3	7.2bcd	3
6	IR78933-B-24-B-B-3/IR64Sub1	20.6g	85.3a	3	7.5bcd	1
7	IR78933-B-24-B-B-4/IR64Sub1	25.3ab	64.2k	3	7.6bc	5
8	V3M-103-2/Swarnasub1	26.3a	42.3n	3	8.4ab	1
9	V3M-103-2/IR64sub1	23.5cde	69.3ghi	3	7.5bcd	1
10	WAB99-47/IR64Sub1	25.6ab	78.5b	3	7.6bc	5
11	IRAT302//IR64Sub1	23.5cde	68.6hi	5	7.9bc	5
12	IR75499-29-2-B//IR64Sub1	21.3fg	66.8j	3	7.5bcd	5
13	IR75499-84-1-B//IR64Sub1	23.1cde	70.2fgh	5	8.2ab	1
14	V3M-170-1/IR64Sub1	21.2fg	72.1e	5	7.4bcd	3
15	V3M-167-2-B/IR64Sub1	23.2cde	71.2ef	5	8.2ab	1
16	RR166-645/IR64Sub1	24.2bcd	68.2ij	5	8.1ab	5
17	WAB99-5/IR64SUB1	23.5cde	68.9ghi	3	7.5bcd	5
18	IR78982-B-24-B-B-B/IR64Sub1	24.3bcd	68.5i	3	7.7bc	5
19	IR78937-B-3-B-B-3/IR64Sub1	23.5cde	66.8j	1	6.8d	3
20	WAB326-B-B-7-H1/IR64Sub1	21.2fg	77.3b	5	7.8bc	0
21	IR78913-B-10-B-B-B/IR64Sub1	22.3ef	74.5d	5	7.9bc	1
22	IR75499-73-1-B/IR64Sub1	24.3bcd	65.2k	3	8.5a	5
23	IR78913-B-19-B-B-B/IR64Sub1	23de	72.3e	3	8.2ab	3
24	AZUCENA//IR64Sub1	24.3bcd	49.5l	3	7.2bcd	1
25	BP225D-TB-6-8/IR64Sub1	24.1bcd	64.2k	3	8.2ab	1
26	IR78933-B-24-B-B-31/IR64Sub1	23.5cde	71ef	3	7.9bc	0
27	IR78933-B-24-B-B-4/IR64Sub1	24.2bcd	68.2ij	3	8.4ab	1
28	IR65191-3B-2-2-2-2/IR64Sub1	20g	74.5d	3	8.1ab	0
29	BP227D-MR-2-12/IR64Sub1	23.2cde	70.4fg	5	7.8bc	1
30	OM6162/SwarnaSub1	20.2g	78.2b	5	8.1ab	0
CV%		3.42	1.34	-	10.63	-
LSD 0.05		1.31	1.48	-	1.36	-

Note: Data within a column by the same letter are not significantly different (P<0.05); CV: coefficient of variation; AC: Amylose content; GC: Gel consistency; GT: Gelatinization temperature.

Selecting line of F_3 generation and production F_4 seeds: In lines selected generation with combinations were recorded in Table 4. Therefore, selection was 10 combinations recorded on phenotypic and relatively good yield and growth duration less than 100 days. The F_3 generation recorded through individual selection from many crosses reached segregation with many different shape, include grain shape and color of grain hulls. Result through the F_3 generation were recorded with 282 of selected lines were in planting to continue to evaluate for planting the F_4 generation from 10 combinations.

Table 4. Number of individual in the generations of the F1, F2, F3

No.	Combinations	F1 (Number of individual)	F2 (Number of individual)	F3 (Number of individual)
1	IR75499-29-2-B//IR64Sub1	50	200	00
2	IR78937-B-3-B-B-3/IR64Sub1	100	200	00
3	IR75499-84-1-B//IR64Sub1	100	200	20
4	V3M-167-2-B/IR64Sub1	100	200	19
5	WAB326-B-B-7-H1/IR64Sub1	175	200	19
6	IR75499-73-1-B/IR64Sub1	148	152	28
7	IR78913-B-19-B-B-B/IR64Sub1	126	400	35
8	IR65191-3B-2-2-2-2/IR64Sub1	125	400	56
9	BP227D-MR-2-12/IR64Sub1	200	400	50
10	OM6162/ SwarnaSub1	250	1200	55

Selecting line of F_4 generation: F_4 generations was continued to grow and select to evaluate recorded. Total 8 combinations were selected relatively high yields. Two combinations IR75499-29-2-B//IR64Sub1 and IR78937-B-3-BB-3/IR64Sub1 generating seeds with beard should continue to be removed. In the F_4 generation was grown with 8 combinations recorded (Table 5).

Table 5. Selection individual of the F3, F4

No.	Combinations	F3 (Number of individual)	F4 (Number of individual)
1	IR75499-29-2-B//IR64Sub1	20	150
2	V3M-167-2-B/IR64Sub1	19	200
3	WAB326-B-B-7-H1/IR64Sub1	19	200
4	IR75499-73-1-B/IR64Sub1	28	200
5	IR78913-B-19-B-B-B/IR64Sub1	35	200
6	IR65191-3B-2-2-2-2/IR64Sub1	56	289
7	BP227D-MR-2-12/IR64Sub1	50	250
8	OM6162/ SwarnaSub1	55	250

Heritability: Phenotypic analysis of genetic traits was estimated in F_4 population of cross from IR75499-29-2-B//IR64Sub1 with n=150. The analysis results showed that yield traits and yield components combination varied from minimum of 80 cm by plant height, 19 cm by panicle length, 3 by panicles/ cluster, 65 by number of filled grains/panicle, 12 by number of unfilled grains/panicle and 10.58 g by grain yield/cluster to a maximum of 119 cm, 29.4 cm, 17 panicles/ cluster, 165 number of filled grains/panicle, 83 number of unfilled grains/panicle and 42.12 g/cluster, respectively.

Similarly, as the analysis of the F4 generation of combination OM6162/SwarnaSub1 with n = 250. Data genetic parameters of yield traits and yield components of combination OM6162/SwarnaSub1 gained highest plant height (129.0 cm), lowest plant height (90.0 cm) and medium (105.4 cm). The panicle length was highest (30.4 cm), lowest (20 cm), and medium (25.54 cm). The highest number of panicles/cluster (17), lowest (3) and medium (8.2) were attained by combination OM6162/SwarnaSub1 different from IR75499-29-2-B//IR64 Sub1 which was not statistically. Data regarding number of filled grains/panicle revealed that highest (183), lowest (65) and medium (153,19). Trait number of unfilled/panicle in combination OM6162/SwarnaSub1 which showed that significant highest (63), lowest (5) and medium (18.5).

Analysis of genetic parameters for grain yield trait and yield components is presented in Table 6. Significant heritability (h^2) of high yield, panicle length, number of unfilled grain/panicles and plant height at P<0.01 was 0.98; 0.74; 0.56; and 0.5, respectively by IR75499-29-2-B//IR64Sub1. The highest heritability was noticed in grain yield trait/cluster. Medium to significant heritability at P<0.05 was observed in number of filled grain/panicle trait.

The high heritability was observed in all most of the traits of combination OM6162/SwarnaSub1 at significant P<0.01. The heritability estimates observed for traits ranged from 0.4 to 0.9. High heritability observed for panicle length, number of panicles/cluster, number of filled grains/panicle, number of unfilled/ panicle, and grain yield/cluster. The final resultant of yield components was grain yield/ cluster. Combination OM6162/SwarnaSub1 attained statistically the highest grain yield/cluster (120 g) whereas combination IR75499-29-2-B//IR64 Sub1 (42.12 g), lowest (10.58 g), and medium (26.5 g).

Table 6. Analysis of genetic parameters of yield traits and yield components in combinations.

Combinations	Traits	Highest	Lowest	Medium	CV	*p*	h^2
IR75499-29-2-B/IR64 Sub1	PH(cm)	119.0	80.0	105.7	10.09	**	0.51
	PL(cm)	29.4	19.0	25.4	1.19	**	0.74
	NP/C	17.0	3.0	8.2	3.99	ns	-
	NFG/P	163.0	65.0	153.2	39.36	*	0.30
	NUFG/P	83.0	12.0	17.6	13.86	**	0.56
	GY/C (g)	42.1	10.6	26.0	1.31	**	0.98
OM6162/SwarnaSub1	PH(cm)	129.0	90.0	105.4	11.09	*	0.40
	PL(cm)	30.4	20.0	25.5	1.15	**	0.74
	NP/C	20.0	10.0	13.2	4.90	**	0.84
	NFG/P	183.0	65.0	163.9	9.35	**	0.70
	NUFG/P	63.0	5.0	18.5	5.74	**	0.76
	GY/C (g)	120.0	10.6	26.5	1.15	**	0.90

**: significant at p < 0.01, *: significant at p < 0.05, ns: no significantly; h^2: heritability
PH: Plant height; PL: Panicle length; NP/C: Number of panicles/cluster; NFG/P: Number of filled grains/panicle; NUFG/P: Number of unfilled/ panicle; GY/C (g): Grain yield/ cluster (gram)

4. Discussion

Grain quality in rice is determined by the factors as grain appearance, nutritional value, cooking and eating quality [18]. The head rice recovery is the main factor effecting milling quality. In this study, most lines/varieties had more than 50% of HR recovery. However, previous studies showed that the HR should have a value of at least 70% [19]. In fact, rice grains in this study were evaluated under drought condition, so the HR average was lower. HR levels depend on different factors, such as grain type, chalkiness, environment during dry conditions, variety, and cultural practices [19,20]. The grain size is an important quality in rice trade with different preferences among consumers [21. The grain size was controlled by genetic traits [22]. Also, grain size is bred at the level of early generation, and the long grain type is generally preferred in Mekong Delta. The size and shape were stable varietal properties that could be used to identify a variety [23]. The most acceptable grain length is around 6 mm [24]. The shapes of milled rice, in terms of length - width ratio are slender > 3.0, medium (2.1 - 3.0), bold (1.1 - 2.0), and round (1.1) [25]. Based on the classification, rice materials could be defined as medium to long grain. Since the grain length and width of rice are of importance to those involved in the rice industry, these characteristics are seriously considered in the breeding of new varieties [26]. Thus, grain size is the first criteria of rice quality that researchers need to concentrate in the development of new varieties.

The chalkiness is influenced by both genetic and environment factors, as temperature immediately after flowering and other factors, such as soil fertility and water management [27] and drought stress during ripening and blast disease [28]. Most of the lines/varieties had low chalkiness from level 0 to 1. The line/varieties having minimum level of the chalkiness can be used as donors for breeding varieties of quality rice from the commercial point of view. Amylose content (AC) is one of the most important characteristics for cooking and processing practices [29]. Commonly, consumers like rice with intermediate AC ranged between 20 to 25% [30]. Gelatinization temperature (GT) is another important quality to determining the cooking quality of rice. GT is not associated with other grain traits except amylose content [25]. In this study, there were large variations of GT among lines/varieties. The nutritional values of rice depend on the total of protein. High protein content equates with higher nutritive value. A wide range of protein content (4.5 - 15.9%) was found among 2,674 rice varieties [31]. The aromatic level in rice is one of the other important traits in breeding and may cause high demand in the market [32]. Total of 114 different volatile compounds that are responsible for rice fragrance [33]. The biochemical basis of aroma was identified as 2-acetyl-1-pyrroline [34] which stands out as the main fragrance compound in both jasmine and basmati varieties.

Moreover, good quality characteristics should be evaluated for grain quality and more advanced lines at early generations for nutritional factors in breeding processes. Among 30 hybrid combinations, there were six combinations consisting of IR65191-3B-2-2-2-2/IR64Sub1, IR78933-B-24-B-B-3/IR64Sub1, OM6162/SwarnaSub1, WAB326-B-B-7-H1/IR64Sub1, V3M-170-1/IR64Sub1, and IR75499-29-2-B//IR64Sub1 obtaining low AC (20 - 21.3%). According to Jennings et al [25] homozygous dominant (AA) defines the high AC, and the homozygous recessive (aa) produces low AC, so the heterozygous unsteadily generates the average AC.

The chalkiness is influenced by both genetic and environment factors [27]. If selection non-chalky is made only in the late generations (F6 - F7), it is difficult to eliminate. Therefore, selection of non-chalky grain should be made in an earlier generation in rice breeding programs.

In order to evaluate the association among characteristics is an important factor, particularly yield to determine the direction of selection and number of traits to be considered of rice yield. Heritability provides better genetic advance for selecting plant material regarding these traits. The highest heritability was noticed for grain yield trait/cluster both of two combinations. Results showed that high heritability for the number of spikelets per panicle, 1000 grain weigh and nuber of the panicles per plant [35]. In this study, high heritability observed in combination OM6162/SwarnaSub1 0.74 for panicle length, 0.84 for number of panicles/cluster, 0.7 for number of filled grains/panicle, 0.76 for number of unfilled/panicle, and 0.9 for grain yield/cluster. Previous study also reported that high heritability 41.74% for number of panicles per plant [36]. Results of high heritability and genetic advance of grain yield/plant are also in accordance with those reported by [37- 39]. Heritability serves as a good index for transmission of traits from one generation to next and it should be considered in terms of selection concept [40]. Since high heritability do not always indicate high genetic gain, heritability with genetic advance considered together should be used in breeding [41].

4. Conclusions

Among 44 rice germplasms, IR79008-B-11-B-B-1 showed good physical characteristics (head rice, grain length, grain width, chalkiness), three varieties (IR75499-73-1-B, OM6162, OM4900) showed good chemical characteristics (amylose content, gel consistency, protein content, gelatinization temperature, and aroma). The important highlight of the study was that the cross between OM6162 and SwarnaSub1 produced a low amylose content, high gel consistency, high protein content, and low chalkiness.

These characters consist of plant height, panicle length, number of panicles/cluster, number of filled grains/panicle, number of unfilled/panicle, and grain yield/cluster showed moderate to high heritability of mean for combination OM6162/SwarnaSub1. Most of above traits have resulted that highest heritability was noticed for grain yield trait/cluster, and the number of panicles/cluster. Therefore, the results suggest that the grain yield trait/cluster and the number of panicles/cluster are important yield contributing traits and selection based on these characters would be most effective for rice breeding.

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