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RICE BREEDING FOR HIGH-YIELDING & GOOD COOKING QUALITIES IN THE MEKONG DELTA

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ABSTRACT

Developing rice cultivars with agronomic and quality traits acceptable to farmers is a feasible approach to address this goal. The study aims at developing new promising varieties with excellent cooking and eating qualities, milling and others traits. Various traditional rice genotypes have excellent cooking and eating qualities but low grain yields. Most of these varieties have intermediate amylose content, intermediate starch gelatinization temperature, and soft gel consistency. A few have low gelatinization temperature or high amylose. Recently, breeding for excellent grain qualities have received low priority because the major attention was devoted to incorporation of genes for disease and insect resistance and other adaptation traits such as shorter growth duration. Milling quality has been improved at CLRRI by eliminating bold chalky grains from nonwaxy rices characteristic of such as OM4900, OM6161, OM6162, OM7347, OM6600, in favor of long slender cooking and eating qualities have been improved by incorporating intermediate amylose content, aroma and soft gel consistency. Many types of improved varieties have excellent cooking and eating qualities after selection. The specialty varieties with quality properties such as aroma, low amylose, gel consistency were recommended to be donors in breeding to define the varietal characters associated with good quality properties. The breeding gained improved genotypes, which have excellent cooking and eating qualities such as OM4900, OM6161, OM6600, OM7347.

Key words: amylose content, aroma, gel consistency, gelatinization temperature, *Oryza sativa*

INTRODUCTION

Major world rice markets required special qualities, definite varieties, and specific processing types. These markets are highly competitive. World markets demand six basic rice types: 1) high-quality long-grain rice, 2) medium-quality long-grain rice, 3) short-grain rice, 4) parboiled rice, 5) aromatic or fragrant rice, and 6) glutinous (waxy) rice. Each depended on different markets with different preferences. The long-grain, higher quality rice is mostly sold in the world market. Improvement in rice quality worldwide is essential to meet the increasingly discriminating demands of consumers everywhere. Rice farmers always like to have good rice production, thus some plant traits can affect rice yield. Farmers experience that the traits can lead to high yield as high tillering capacity, big and erect leaf, big and long panicle. The traits affecting to yield can be avoided by select the rice varieties with the following traits short plant and hard stems to resist lodging, hidden panicles to avoid bird attack, synchronized flowering for uniformity at mature for harvest. The other characteristics related to the traders' preference are important for selling rice as long grain/slender grain, thin rice husk for high milling recovery, sweet and soft cooked rice with aroma. Quality improvements will require major adjustments in variety selection, grading, milling, price support programs, and the like. To meet these market standards, major exporters and importers have established official grades based on the relative quality of different lots. In Vietnam, the improvement of grain quality is one of the most important subjects in rice breeding. For this, genetic resources of endosperm properties must be collected, characterized, evaluated. Developing rice cultivars with good quality and agronomic traits such as excellent cooking and eating qualities, these traits are well accepted by farmers to become a feasible approach.

MATERIALS AND METHODS

Materials included 23 landrace varieties, 10 crosses in BC_2 populations. They were evaluated and analyzed to select 11 promising genotypes. IR64 was used as check.

Analysis on cooking quality (amylase content, aroma, gel consistency, gelatinization temperature) was done through IRRI protocols in 1996.

Statistical analyses

All analyses were completed on plot mean values. Analysis of variance was performed using the minimum model of ANOVA, which was comprised of entries and replications, with the entry replication interaction used as the error term. Replications and the entry replication interaction were considered as random effects. Separation of means was performed using the Duncan's Multiple Range Test.

Performance evaluation

For the performance test, agronomic characteristics such as plant height panicle length, tillers per hill, spikelets per panicle, spikelets per hill, and grain yield were investigated and compared with those of the original plant in the field trials, with three replications per lines. Evaluations of lines were done at maturity. Analysis of variance and mean comparisons of the data were carried out. The T-test value at 5% and 1 % level of significance determined the superiority of the tested lines over.

RESULTS AND DISCUSSION

Survey on germplasm

Traditional genotypes are prized because of aroma, extreme grain elongation on cooking of soaked milled rice, and soft texture of cooked rice like Nang Thom Cho Dao, Nang Nhen, etc... Good quality and high yielding rice genotypes are mainly produced in Mekong Delta as Jasmine 85, OM4900, OM3536 which have intermediate AC (amylose content), low GT (gelatinization temperature), and medium GC (gel consistency) (Table 1). It properly exhibited aroma.

Differences in cell wall arrangement contribute to differences in the direction of expansion during cooking. Elongating rices with poor aroma or without one were recognized.

Table 1. Aroma and grain quality properties of given landraces and checks

No.	Designation	Aroma			AC (%)	GC (mm)	GT (score)
		shoot	leaf	seed			
1	Nang thom Cho Dao	1	1	0	23.5	77.2	5
2	Pha Ka Ruom Duôi So	1	1	2	22.1	74.2	5
3	Nho thom	1	1	2	18.3	76.2	5
4	Nhen thom	1	1	2	24.5	56.3	3
6	Neang chen	1	1	1	18.3	78.9	5
7	Nhen thuong	1	1	1	24.3	54.2	3
8	Nang Thom Lai	1	1	2	16.9	88.2	5
9	Nang Thom Doc Trang	1	1	2	24.3	68.1	3
10	Huong Lai	1	1	2	18.2	77.4	5
11	Nep Tau Huong	1	1	1	1.2	100.0	9
12	Ghe hanh vang	1	1	1	13.6	89.0	5
13	Phra nla kas	1	1	1	12.3	87.2	5
14	Tai Nguyen cao	1	1	1	22.1	78.2	5
15	Pha Ka Ruom Duoi	1	1	1	23.1	69.5	3
16	Nang Thom	1	1	2	22.3	71.2	3
17	Nep Thai	1	1	1	2.3	100.0	9
18	Nanh Chon	1	1	2	23.4	69.8	3
19	Lun Sua	1	1	1	22.3	77.3	3

No.	Designation	Aroma			AC (%)	GC (mm)	GT (score)
		shoot	leaf	seed			
20	Run Chong	1	1	2	15.6	85.2	7
21	Nong Col	1	1	1	12.4	86.5	7
22	KDML105 (check)	1	1	2	19.5	78.5	7
23	Jasmine 85 (check)	1	1	2	20.3	70.1	5

Twenty-three aromatic or scented rices from CLRRI were analyzed for aroma. They are richer in the principal aroma compound. Their grain properties such as amylose content gaining 15-24.5% exhibited the genotypes belonging to typical intermediate AC and low GT. Some genotypes obtained waxy grain such as Nep Thai, Nep Tau Huong with low AC and high GC. Amylose is an essentially linear molecule composed of Δ-(1,4)-linked glucosidic chains, although recently another type of amylose possessing some very short-branched chains was reported. Amylopectin is a highly branched glucan with Δ-(1,6) glucosidic bonds that connect linear chains. A cluster model for amylose among traditional varieties was reported (Lang et al. 2006). Most traditional rices have intermediate GT (alkali spreading value) and good cooking (Table 1).

Segregation BC_2 for amylose, aroma and gel consistency

Segregation distortion was a significant feature of the advanced backcross population. Chi-square tests showed that for many loci the introgression was below that expected based on Mendelian segregation (at $P<0.001$ as shown in table 2). Segregation distortion is a common feature of inter-gene pool crosses in common in rice. The BC_2 progenies from these crosses segregated into 3:1 resistance to susceptible, suggesting that a dominant gene controls for GC in C43 / Jasmine 85, OM1314 / OM2514. This was confirmed by reaction of BC_2 progenies, which segregated into homozygous low and hight amylose contents to segregating. Inheritance of amylose is much more complicated than that of agronomic characters. High amylose content is incompletely dominant to low amylase. It is controlled by one major gene and several modifiers. High GT is dominant to low GT gel consistency. Hard gel consistency is conditioned by a single dominant gene (table 2).

Table 2. Inheritance of aroma, amylose (AC), gel consistency (GC) and allelic relationships of genes for cooking quality.

Traits	BC_2	Numbers of segregants			Ratio	χ^2	p
		<20%	**20-25%**	**>25%**			
AC	C53/Jasmine 85	11	33	64	1:5:10	2.87	0.25-0.10
	C51/Jasmine 85	2	123	73	2:30:16	5.48	0.10-0.05
	D 26/IR 68	4	120	16	1:27:4	0.24	0.90-0.75
	C43/Jasmine 85	19	5	57	4:1:11	0.39	0.90-0.75
	C3/D 4	5	102	77	1:27:20	0.38	0.90-0.75
	AS996/OM3536	0	95	54	9:7	3.41	0.10-0.05
	C27/IR 64	1	7	24	1:5:10	2.20	0.50-0.25
	OM1314/ OM2514	14	7	44	3:1:12	2.86	0.25-0.10
	IR 28/ AS 996	5	75	68	1:24:23	1.90	0.50-0.25
	C43/Jasmine 85	1	133	99	1:40:39	5.46	0.10-0.05

Traits	BC_2	Numbers of segregants			Ratio	χ^2	p
		<20%	**20-25%**	**>25%**			
		≤40 mm	**40-60 mm**	**≥60 mm**			
GC	C53/Jasmine 85	0	65	42	9:7	0.88	0.50-0.25
	C51/Jasmine 85	0	1	21	1:15	0.11	0.75-0.50
	D 26/IR 68	1	6	24	1:3:12	0.48	0.90-0.75
	C43/Jasmine 85	0	61	20	3:1	0.004	0.95-0.90
	C3/D 4	5	1	39	3:1:12	3.39	0.25-0.10
	AS996/OM3536	1	7	31	1:3:12	0.97	0.75-0.50
	C27/IR 64	0	1	31	1:15	0.53	0.50-0.25
	OM1314/ OM2514	0	48	17	3:1	0.05	0.90-0.75
	IR 28/ AS 996	23	58	57	3:7:6	0.95	0.75-0.50
	C43/Jasmine 85	2	3	27	1:1:14	0.54	0.90-0.75
		Score 2	**Score 1**	**Score 0**			
Aroma	C53/Jasmine 85		7	101	1:15	0.01	0.95-0.90
	C51/Jasmine 85		1	197	1:63	1.44	0.25-0.10
	D 26/IR 68		2	138	1:63	0.02	0.90-0.75
	C43/Jasmine 85		6	75	1:15	0.19	0.75-0.50
	C3/D 4		0	184	1:63	2.90	0.10-0.05
	AS996/OM3536		0	149	1:63	2.40	0.25-0.10
	C27/IR 64		1	31	1:15	0.53	0.50-0.25
	OM1314/ OM2514		6	46	1:15	2.49	0.25-0.10
	IR28/ AS 996		0	96	1:63	1.52	0.25-0.10
	C43/Jasmine 85		0	233	1:63	3.58	0.10-0.05

Excellent Cooking and Eating Qualities

Long slender translucent grains are often required in common markets. Consequently, their milling recovery is also highly needed (Table 3). In recent years, we have developed improved genotypes with intermediate AC, intermediate GT, and soft GC. The tested lines must be compared to IR64 (check) (Table 4). Most new lines grown in Mekong Delta exhibited their intermediate AC, intermediate GT, and soft GC. Improved varieties like IR64 will have greater acceptance in all the indica rice growing areas; it is becoming a mega rice in the world. Therefore, we are developing new promising lines with these characteristics and with resistance to insects and diseases (Table 4). Progress in improving the grain quality of high yielding varieties has been made in several steps. Earlier improved leading varieties such as IR50404 had short, chalky grains of low milling recovery, with high amylose and predominantly low GT. Thus, its grain quality was considered poor for most consumers. We, therefore, set the goal of developing high yielding varieties with these grain quality characteristics: long slender or medium-long slender translucent grains, high milling recovery, intermediate AC, intermediate GT, soft GC, aroma, and grain elongation.

We have made remarkable progress in achieving these objectives. Grain appearance is received by our immediate attention. All varieties released such as OM4900, OM6600, OM6161… are becoming leading varieties in Mekong Delta. Besides having intermediate AC and intermediate GT, high quality rices in all the indica rice growing areas have varying various degrees of aroma. Therefore, we are now in the process of incorporating aroma into the superior variety with short growth duration, low AC, intermediate GT, and soft GC. Grain elongation is a special characteristic of several high grain quality varieties such as OM4900, OM6161, OM7347, OM6600 are being used as donors. Many rices with intermediate amylose, intermediate GT, and soft gel consistency are being evaluated in our advanced yield trials. Additional reliable, fast screening methods are required in place of sensory

evaluation to evaluate rices with similar starch properties. Similar situations exist among waxy lines OM7348 breeding program where selection is made for low GT followed by sensory evaluation of the low-GT, waxy lines (OM 7348.). Some lines in the crosses have been developed. They exhibited similar size and shape, low amylose content, low GT, and soft gel consistency. Although milling quality has improved through breeding for translucent grains, the head rice yielded at the range of 41- 55 % for OM4900, 55% for OM10420, 41% for IR64 (Table 4). Alkali-spreading value and protein level are similar types. IR50504 is a leading rice variety produced in limited amounts for local markets due to its poor quality.

Table 4. Average physicochemical, cooking, and processing characteristics of new varieties of CLRRI at 2010 Dry Season (DS)

No.	Designation	Brown (%)	White (%)	Head (%)	Grain Length (mm)	L/l ratio	AC (%)	GC (mm)	GT (score)	Protein (%)	Aroma
1	OM4900	81cd	72cd	55a	7.14b	3.2a	16.2e	78a	5	8.5bc	1
2	OM6161	80d	74ab	51d	7.12bc	3.0c	16.9e	79a	5	8.6ab	1
3	OM6600	84a	71d	50d	7.14b	2.9d	19.0cd	76a	5	8.0e	1
4	OM7347	82bc	72cd	50d	7.23a	3.0c	18.5d	77a	5	8.4cd	1
5	OM7348	83ab	75a	46e	7.10cd	3.0c	2.1f	78a	5	8.3de	1
6	OM10420	80d	73bc	55a	7.05e	3.2a	20.0c	77a	5	8.4cd	1
7	OM10040	80d	70d	51cd	7.10cd	3.1b	18.6cd	77a	5	8.2d	1
8	OM10041	80d	71d	54b	7.08d	3.0c	18.7cd	77a	5	8.6ab	1
9	OM9922	80d	74ab	52bc	7.12bc	3.0c	24.0ab	65b	3	8.7a	0
10	OM10383	80d	71d	50d	7.10cd	3.2a	23.0b	64b	3	8.6ab	1
11	IR 64	80d	72cd	41f	7.05e	3.1b	24.5a	62b	3	8.5bc	0
	CV(%)	1.11	1.16	1.50	0.21	0.60	4.28	2.73	-	-	-
	F	**	**	**	**	**	**	**	-	-	-

Table 5. Yield and yield component some good quality rice in 2009 WS

No.	Designation	Growth duration (days)	Pl. Hgt. (cm)	Spikelets /panicle	Unfilled Grain (%)	Panicle length (cm)	1,000 GW (gr)	HI	Yield (t/ha)
1	OM4900	105	107	198	13.0	28.5	27.2	0.55	6.5
2	OM6161	100	115	199	10.5	27.8	26.0	0.57	6.2
3	OM6600	100	117	168	10.5	26.5	26.0	0.56	7.0
4	OM7347	101	111	201	15.0	29.6	26.6	0.55	7.2
5	OM7348	95	108	210	11.0	25.6	26.1	0.58	6.8
6	OM10420	100	102	168	8.0	26.5	26.1	0.53	6.5
7	OM10040	95	105	166	11.0	26.4	26.0	0.54	5.6
8	OM10041	95	100	175	12.0	26.5	26.5	0.51	6.9
9	OM9922	100	100	187	16.5	29.1	27.4	0.50	5.1
10	OM10383	95	102	198	15.0	25.6	26.1	0.56	6.2
11	IR64	108	115	158	18.9	25.8	26.2	0.50	4.3

HI: Harvest index

Environmental and cultural factors affecting physicochemical properties of rice (Juliano et al. 1980) include location and season of growth, date of seeding and harvest, ratoon cropping, age of crop (new crop versus old), fertility, and other cultural practices and these studies clearly show the influences on specific physicochemical indices of quality. However, there is little published research examining the impact of environmental and cultural practices under actual processing conditions, primarily because of manufacturing's proprietary nature (Khush et al. 1979). Rice product manufacturers regularly need to adjust processing methods within a crop season even for the same variety. A better understanding of the impact of environment and cultural practices on physicochemical characteristics and their relation to actual processing conditions could help to explain why interseason and intraseason adjustments are necessary. The influence of season of growth on physicochemical, cooking, eating, and processing characteristics is illustrated in Table 6. Some characteristics vary greatly by wet season; others seem unaffected. The effect of season amylose and gel consistency is illustrated by the some varieties in Table 5, it is consistent for most varieties sampled in 2009 wet season. These environmental effects suggest, for example, that varieties may be area- and/or environment-specific in quality attributes. The wet season with variety OM6161, because of conscious effort, contains 2-3% higher amylose than dry season varieties and gel consistency is also different. Only alkali spreading value exhibited similarly in both two seasons.

Table 6. Average physicochemical, cooking, and processing characteristics of new varieties of CLRRI at 2009 wet season

No.	Designation	Brown (%)	White rice (%)	Head rice (%)	Grain Length (cm)	L/l ratio	AC (%)	GC (mm)	GT	Protein (%)	Aroma
1	OM4900	81	70	50	7.14b	3.2a	16.9	77.0	5	8.7	1
2	OM6161	78	71	49	7.12bc	3.0c	19.2	75.0	5	8.6	1
3	OM6600	82	70	48	7.14b	2.9d	19.9	77.7	5	8.4	1
4	OM7347	79	71	45	7.23a	3.0c	19.7	76.5	5	8.4	1
5	OM7348	80	73	32	7.10cd	3.0c	2.9	77.4	5	8.1	1
6	OM10420	82	71	44	7.05e	3.2a	20.1	75.0	5	8.5	1
7	OM10040	79	70	46	7.10cd	3.1b	19.5	76.0	5	8.7	1
8	OM10041	77	70	41	7.08d	3.0c	19.7	71.0	5	8.6	1
9	OM9922	79	71	50	7.12bc	3.0c	24.5	60.0	3	7.9	0
10	OM10383	78	70	42	7.10cd	3.2a	23.1	62.3	3	8.2	1
11	IR64	78	70	39	7.05e	3.1b	24.9	64.0	3	8.3	0

CONCLUSION

Rice consumers in all markets need product qualities that they consider optimum. Although grain cooking and eating quality can be differentiated by tests for amylose, gelatinization temperature (alkali spreading value), gel consistency, and texture, similar quality may not mean identical eating quality. Survey on the specialty varieties, quality characters such aroma, amylase, alkali spreading value, gel consistency for landraces varieties were recognized. Define the varietal characters associated with good quality in rice was conducted. Development of improved varieties, which have excellent cooking and eating qualities such as OM4900, OM6161, OM6600, OM7347 was successfully made in Mekong Delta. Most grain quality characters are apparently highly heritable and can be selected at early generations. Selection for quality characters leads to varieties

more readily acceptable to farmer and consumer. In addition, improvements in milling quality lead to more edible product per ton of rough rice produced.

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Chọn tạo giống lúa phẩm chất gạo ngon ở đồng bằng sông cửu long

Đánh giá tập đoàn giống lúa địa phương, giống lúa đặc sản trong ngân hàng gen của Viện Lúa ĐBSCL. Thực hiện trên 23 giống bản địa và 10 quần thể con lai của 10 tổ hợp hồi giao BC_2. Nghiên cứu này nhằm xác định các dòng con lai có triển vọng đáp ứng thị trường gạo hạt dài có mùi thơm, hàm lượng amylose trung bình và thấp, GT trung bình, GC mềm. Các dòng triển vọng đã được phát triển rộng trong sản xuất là OM4900, OM6161, OM6162, OM7347, OM6600.