Breeding Jasmine-Type Aromatic Rice for the Southern United States

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Abstract

Development of improved Jasmine-type cultivars with similar specialty characteristics (aroma, texture, and flavor) to the imports and with competitive grain and milling yields while adapted to the southern U.S. environment will help the rice industry to access to such a fast growing and high value domestic niche market. In this study, the grain shape, aroma, amylose content (AC), gelatinization temperature (GT), and Rapid Viscosity Analyzer (RVA) profiles of Thai Jasmine cultivar Khao Dawk Mali 105 (KDM 105) was compared with that of five selected U.S. cultivars or lines, including the Louisiana developed Jasmine line LA2125. Based on the known genetic and physiochemical properties of three determining specialty traits (aroma, AC, and GT) of Thai Jasmine rice, five different single cross schemes were proposed and compared for their efficiency to generate new Jasmine-type recombinants. It was found that KDM 105 had slightly longer, narrower, and slender brown and milled rice and somewhat lower AC and GT than LA2125. KDM 105 had the similar RVA profiles as Toro-2 but slightly different from LA2125. Surprisingly, the Puerto Rico-grown KDM 105 failed to produce the strong aroma and white grain that was found in imported Thai Jasmine rice. This may be attributed to the different environmental conditions. Crosses between Thai Jasmine and elite U.S. long-grain genotypes have the least chance to recover new Jasmine-type recombinants. Such low efficiency can be improved with the inclusion of U.S. specialty genotypes, such as Della and Toro, as parents. Intercrosses among different partially improved Jasmine lines have the great chance of success.

Jasmine aromatic rice, which originated and is largely produced in Thailand, makes up about 80% of U.S. aromatic rice imports (Childs, 2006). Typical Jasmine rice has a strong popcorn-like aroma and translucent slender kernels, a low AC of 15 to 18%, a low GT with the alkali spreading value of 6 to 7, and soft-cooking characteristics (Lanceras et al., 2000; Narula and Chaudhary, 2001). Commercial 'Thai Jasmine rice' is produced with 'Khao Dawk Mali 105' (KDM 105) and its derived 'RD-15'. KDM 105 is a tall, lodging susceptible, and photoperiod sensitive long-grain *indica* rice (Narula and Chaudhary, 2001).

The popcorn-like aroma in all three types of aromatic rices is generally considered to be controlled by a single recessive gene *fgr*, which is located on the chromosome 8 (Berner and Hoff, 1986). Most recently, this *fgr* gene was sequenced and found to be homologous to the gene that encodes betaine aldehyde dehydrogenase 2 (BAD2) (Bradbury et al., 2005). The allele in aromatic genotypes has a mutation (three SNPs and eight deletions), introducing a stop codon upstream of key amino acid sequences conserved in other BADs, which may contribute to the accumulation of the potent aroma component, 2-acetyl-1-pyrroline (2-AP). The identical *fgr* sequence of 14 different aromatic rice varieties, which include KDM 105, Basmati 370, and Dellmont, suggests that the aroma in domesticated rice has apparently originated from a common ancestor and may have evolved in a genetically isolated population or may be the outcome of a separate domestication event (Bradbury et al., 2005).

Both AC and physical properties of starch determine the cooking and eating quality of rice. Rice starch pasting properties measured by the Rapid Visco Analyser (RVA) are also commonly used to characterize the processing and cooking qualities of the different rice (Bergman et al., 2004). The AC seems to be controlled by a single gene, and the high AC is dominant over intermediate or low AC (Kumar and Khush, 1987; McKenzie and Rutger, 1983). Alkali spread value, an indicator of GT, has a very high heritability and may be controlled by a single gene (McKenzie and Rutger, 1983).

Objectives

1. To define the main attributors of the Jasmine rice through the comparison of Jasmine rice with U.S. long-grain rices on physiochemical attributes, grain appearance, cooking texture, and flavor.
2. To propose and compare different recombination schemes to identify the most efficient ones to facilitate such a breeding effort.

Materials and Methods

Due to its photoperiod sensitivity, KDM 105 is unable to head in the field of Crowley, LA (latitude 30° N). Instead, both KDM 105 and LA2125 (Figure 1), an improved Jasmine-type line developed in Louisiana, were grown in the winter nursery in Lajas, Puerto Rico (latitude 18° N), in the fall of 2006. Two specialty cultivars, Della (an aromatic long-grain cultivar with intermediate AC and GT) and Toro-2 (a long-grain cultivar with low AC and GT), along with conventional Cypress and CL161, were grown in Crowley in 2006. CL161 is an Imidazolinone-tolerant mutant of cultivar Cypress. Normal culture practices were applied.

Grain dimensions of either paddy, brown, or milled rice were the averages of 25 hand-picked representative kernels measured by a micrometer. Grain weight was estimated from two 500-grain samples. The 2-acetyl-1-pyrroline content (for aroma), AC, GT, and RVA of the rice samples were analyzed by Dr. Chen at the USDA-ARS Rice Quality Lab in Beaumont, TX.

Results and Discussions

The paddy rice of KDM 105 appears to be longer, wider, and thicker than four U.S. rice genotypes, including the improved Jasmine line LA2125 (Table 1). This difference becomes less evident or disappears in brown or milled rice. KDM 105 also has the slenderest grains (either paddy, brown, or milled) among all five tested genotypes. Compared with LA2125, brown rice of KDM 105 is slightly longer (7.59 vs 7.33 mm) and slenderer (L/W ratio of 3.50 vs 3.26) (L/W ratio of 3.50 vs 3.26) but is somewhat narrower (2.18 vs 2.25 mm), thinner (1.58 vs 1.79 mm), and lighter (19.98 vs 20.95 mg).

The aroma of the improved Jasmine-type line LA2125 appears to be similar to or even stronger than that of KDM 105 grown in Puerto Rico, as indicated by the 2-AP concentration (Table 2). KDM 105 has the lower AC and lower GT than LA2125. Toro-2 has similar low AC and GT as KDM 105. For milled rice, Della has the whitest grain; however, KDM 105 has the darkest grain. Our results verify the previous reports that the strong aroma and whiteness associated with the imported Thai Jasmine is area dependant (Yoshihashi et al., 2004). This may undermine our breeding efforts to develop adapted Jasmine-type rice with the same special characteristics as the imports.

Compared with LA2125, KDM 105 has a slightly higher peak and breakdown viscosity and a lower setback viscosity (Table 3). However, KDM 105 and Toro-2 have very similar RVA profiles. Our findings suggest that there are some differences on rice starch pasting property between KDM 105 and the U.S. bred Jasmine-type line, but such differences can be overcome by incorporating rice germplasm with similar RVA profiles, such as Toro-2.

Table 1. Average paddy, brown, and milled individual grain dimensions and weight of Khao Dawk Mali 105 (KDM 105), LA2125, Toro-2, Della, and Cypress. KDM 105 and LA2125 were harvested from the winter nursery in Lajas, Puerto Rico, in November 2006, while the three other varieties were harvested in Crowley, LA, in August 2006.

Cultivar/Line	Length (L)	Width (W)	Thickness	L/W Ratio	Weight
	----------mm----------				---mg---
Paddy rice					
KDM 105	10.44±0.41	2.60±0.17	2.36±0.13	4.04±0.34	26.25
LA2125	9.45±0.49	2.47±0.19	2.15±0.09	3.85±0.27	25.87
Toro-2	10.18±0.44	2.60±0.22	2.15±0.09	3.93±0.30	30.83
Della	9.51±0.56	2.52±0.13	2.02±0.09	3.79±0.32	23.67
Cypress	9.42±0.49	2.53±0.15	2.16±0.10	3.73±0.32	26.79
Brown rice					
KDM 105	7.59±0.37	2.18±0.12	1.58±0.06	3.50±0.29	19.98
LA2125	7.33±0.31	2.25±0.11	1.79±0.10	3.26±0.27	20.95
Toro-2	7.75±0.37	2.42±0.21	1.78±0.07	3.23±0.29	24.45
Della	7.23±0.36	2.20±0.13	1.57±0.06	3.29±0.23	19.69
Cypress	7.10±0.40	2.24±0.15	1.72±0.07	3.19±0.23	20.43
Milled rice					
KDM 105	6.98±0.33	2.08±0.09	1.56±0.05	3.37±0.22	18.14
LA2125	6.91±0.29	2.13±0.11	1.70±0.10	3.25±0.20	19.31
Toro-2	7.02±0.37	2.18±0.15	1.68±0.06	3.23±0.27	21.77
Della	6.64±0.41	2.10±0.09	1.53±0.06	3.17±0.25	17.36
Cypress	6.61±0.28	2.17±0.12	1.61±0.06	3.05±0.18	18.96

Based on the known genetic and physiochemical properties of the three most important traits (aroma, AC, and GT) that distinguish Thai Jasmine rice from the others, five different single cross schemes are proposed (Table 4). Among the five, intercrosses among improved Jasmine- type lines (J x J) theoretically will not segregate for those three traits. However, this effort can only be successful when there are a large number of diverse partially improved Jasmine-type breeding lines with good agronomical traits. Due to the fact that U.S. long-grain genotypes (commercial cultivars and elite lines) have the most desirable agronomy traits and best adaptability, crosses must be made between Jasmine-type rice and the long-grain rice even though they have the least chance to recover Jasmine-type recombinants. Single seed descent may be the option for the progeny advancement in early generations to improve the chance of recovery. Aided by the molecular markers such as SSRs or SNPs for aroma, AC, and GT, backcrossing with long-grain genotypes as recurrent parents will certainly improve the efficiency. Chance of selection for improved Jasmine-type genotypes will also be increased by the adoption of U.S. bred specialty rices such as Della- and Toro-type that pose some of Thai Jasmine's specialty traits and have acceptable yield potential and agronomic traits. Since Della has the same *fgr* gene as KDM 105 and Toro has the same low AC and GT, and soft-cooking characteristics as KDM 105, thus crosses between these two types will produce Jasmine-type rice. Both D x J and J x LG crosses have the same lowest chance to recover the Jasmine recombinants, but the former does not involve the exotic germplasm such as KDM 105, hence it will be a good population to work with.

Table 2. Specialty attributes of Khao Dawk Mali 105 (KDM 105), LA2125, Toro-2, Della, and CL161. KDM 105 and LA2125 were harvested from the winter nursery in Lajas, Puerto Rico, in November 2006, while the three other varieties were harvested in Crowley, LA, in August 2006.

Cultivar/Line	2-AP (ng/g)	% Amylose	Alkali Spread	Whiteness
KDM 105	581	11.8	6.9	32.5
LA2125	647	14.5	6.1	41.1
Toro-2	N/A	15.4	6.0	41.2
Della	527	21.0	3.8	46.9
CL161	N/A	21.0	4.0	42.8

Summary and Conclusions

In order to define its specialty attributes, Thai Jasmine cultivar KDM 105 was grown, along with the U.S. bred Jasmine-type line LA2125, in Lajas, Puerto Rico, in the fall of 2006. The freshly harvested rice of these two genotypes, two U.S. developed specialty cultivars, Della and Toro-2, and two conventional cultivars, Cypress and CL161, were compared for their grain dimensions, aroma, physiochemical, and RVA properties. Our results indicate that both brown and milled KDM 105 rice are slightly slenderer, longer, and narrower but lighter than LA2125. LA2125 has the higher 2-AP concentration and is whiter than KDM 105, but the latter has somewhat lower AC and GT. This finding contradicts to the fact that imported Thai Jasmine has much stronger aroma and much whiter grain than the U.S. grown Jasmine. The only explanation for such a difference is the area dependency of quality Thai Jasmine, which has been reported by others (Narula and Chaudhary, 2001; Yoshihashi et al. 2004). This may undermine our breeding efforts for the adapted Jasmine cultivar with the same quality as the imports. Instead, we can only develop generic Jasmine because of such genotype x environment interaction. KDM 105 has the higher peak and breakdown viscosity but lower setback viscosity than LA2125. Nevertheless, both Toro-2 and KDM 105 have the similar RVA profiles.

Five different cross schemes were proposed and compared, which involved different parental genotypes. The most common crosses between Thai Jasmine or its derived lines and elite U.S. long-grain genotypes have the least chance to produce new Jasmine-type recombinants, thus have the lowest efficiency. Using the single seed descent in early generations (F_2-F_4) and followed by pedigree selection will improve the efficiency. The chance of recovery can be further increased by the inclusion of U.S. specialty rices, such as Della and Toro-2, as parents, which have some of the specialty traits but are agronomically acceptable. However, the best cross to generate novel Jasmine-type recombinants is that among different partially improved Jasmine lines. Thus, development and stepwise improvement of specialty germplasm are the keys for the success of breeding for Jasmine-type rice.

Table 3. Rapid Visco Analyser (RVA) profiles of Khao Dawk Mali 105 (KDM 105), LA2125, Toro-2, Della, and CL161. KDM 105 and LA2125 were harvested from the winter nursery in Lajas, Puerto Rico in November 2006, while the three other varieties were harvested in Crowley, LA, in August 2006.

Cultivar/Line	Peak	Trgh	Brkdn	Final V	Stbk	Peak T	Pasting T	Consist V
KDM 105	328	145	183	241	-87.4	5.7	72.8	96
LA2125	289	160	130	253	-36.6	6.1	73.6	93
Toro-2	337	169	168	271	-65.6	5.9	75.6	102
Della	324	185	138	333	9.3	6.1	80.4	147
CL161	277	145	132	290	12.4	5.6	80.8	145

†Peak V, peak viscosity; Trgh, trough; Brkdn, breakdown viscosity; Final V, final viscosity; Stbk, setback viscosity; Peak T, time to reach peak viscosity; Pasting T, pasting temperature; Consist V, consistency value. Brkdn, Stbk, and Consist V are relative values. Brkdn = peak V – Trgh; Stbk = Final V – Peak V; and Consist V = Final V- Trgh.

Table 4. Comparison of different parents and cross schemes for the effectiveness in recovery of Jasmine-type recombinants. The single monogenic model was assumed for aroma (*fgr* for aromatic), amylose content (*wx* for low amylose content), and gelatinization temperature (*alk* for low gelatinization temperature). Genotypes of the Jasmine-type (J), U.S. long-grain (LG), Della (D), and Toro-type (T) is expressed as *fgrfgrwxwxalkalk*, *FgrFgrWxWxAlkAlk*, *fgrfgrWxWxAlkAlk*, and *FgrFgrwxwxalkalk*, respectively.

Cross Scheme	Genotype	Chance of recovery of Jasmine-type recombinants if selection starts at F_2	F_3	F_4
J x LG	*fgrfgrwxwxalkalk* x *FgrFgrWxWxAlkAlk*	1/64 (1.6%)	27/712 (3.8%)	343/4096 (8.4%)
J x D	*fgrfgrwxwxalkalk* x *fgrfgrWxWxAlkAlk*	1/16 (6.3%)	9/64 (14.1%)	49/256 (19.1%)
J x T	*fgrfgrwxwxalkalk* x *FgrFgrwxwxalkalk*	1/4 (25%)	3/8 (37.5%)	7/16 (43.8%)
J x J	*fgrfgrwxwxalkalk* x *fgrfgrwxwxalkalk*	~1 (100%)	~1 (100%)	~1 (100%)
D x T	*fgrfgrWxWxAlkAlk* x *FgrFgrwxwxalkalk*	1/64 (1.6%)	27/712 (3.8%)	343/4096 (8.4%)

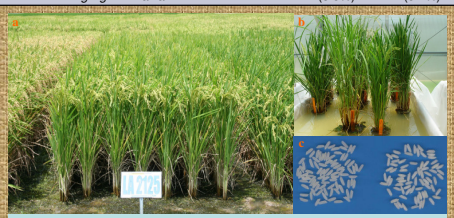

Figure 1. Appearance of LA2125, a Louisiana bred Jasmine line, as compared with Khao Dawk Mali 105 (KDM 105), and Jasmine 85. (a) LA2125 plot grown in Crowley, LA. (b) In the front, the left plant is KDM 105 and the right is LA2125. (c) Milled rice of LA2125 is in the left, and Jasmine 85 in the right.

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