Development of Special Purpose Aromatic Rice Varieties in the United States

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Abstract

In U.S., the demand for special purpose aromatic rice has dramatically increased over the past two decades. Efforts have been devoted to develop rice varieties to fit this high value niche market. So far, eight aromatic rice varieties have been released for commercial production by three public rice breeding programs in Louisiana, Texas, and California. However, the specialty attributes such as aroma, grain appearance, and flavor of these varieties are no match for those of the imports. In order to effectively utilize limited resources, research has been conducted to develop an efficient and effective aroma screening method that can handle a large number of small samples in a timely manner, and to compare the efficiency of different cross combinations and different selection schemes on the recovery of aromatic progenies. Our results indicated that by chewing three dry dehulled rice kernels, progenies with strong aroma can be effectively detected in field selection, while by smelling a small cooked sample in a test tube, progenies, even with a weak aroma, can be detected in laboratory tests. Both methods can work with a large number of small samples. Our results also suggested that intracrossing among different aromatic breeding lines has the greatest chance to recover aroma. Selection for aroma in early generations may slightly reduce the chance of recovering aromatic genotypes; however, it is well compensated for by eliminating a majority of non-aromatic ones from later generations.

Media Summary

Progress on breeding special purpose aromatic rice varieties will help U.S. rice growers to access to the high value domestic specialty rice market.

Key Words

Rice, breeding, aromatic, variety.

Introduction

The demand for special purpose aromatic rice has dramatically increased over the past two decades in the U.S. The three major types of aromatic rice, in the order of importance, are Jasmine, Basmati, and Della types. Most of the aromatic Jasmine and elongating Basmati rice in the U.S. market is imported from other countries, and the volume of such imports is increasing every year. In 1990, about 137,000 tons of Jasmine and Basmati rice was imported, however, by 2003, that figure had increased to 375,000 tons. Imported aromatic rice makes up 12% of domestic food rice consumption (USDA, 2004). The biggest market for imported aromatic rice is among Asian-Americans, the nation’s fastest growing ethnic group. As a group, they eat about 10 times more rice than most other Americans. Based on the growth rate of the Asian-American population and the increased selective taste preference of other American consumers, the special purpose aromatic rice market is expected to expand in the future (Meullenet, et al, 2001).

Jasmine rice, which originated and is largely produced in Thailand, makes up 75% of U.S. rice imports. It is renowned for its aroma, flavor, slender kernels, and soft-cooking characteristics (Singh et al. 2000). The variety ‘Jasmine 85,’ which was released in 1988 by the Texas Agricultural Experiment Station in cooperation with USDA-ARS, is the only adapted Jasmine variety currently available in the United States (Marchetti et al. 1998). Consumer acceptability of this variety is low because of the off-white grain color, weak aroma, and flavor (Pinson, 1994). The unique kernel elongation ability of cooked Basmati rice distinguishes it from other aromatic rices. Premium Basmati rices have extremely slender grains, substantial kernel elongation after cooking, fluffy appearance, high amylose content, and low gel consistency (Singh et al. 2000). Basmati rices make up about 12% of total U.S. imports but are sold at a much higher price (USDA, 2004). The typical U.S. long-grain aromatic varieties, such as ‘Della,’ ‘Dellmont,’ and ‘Dellrose,’ have a different market, which is composed of non-ethnic American consumers who prefer the popcorn-like aroma in an otherwise typical U.S. long-grain rice (Jodon et al, 1973, Bollich et al, 1993, Jodari et al, 1996).

At present, only the Della- type and very limited quantities of the Jasmine- and Basmati- type aromatic rices are being grown in Louisiana and other southern states (Bollich & Linscombe, 1996). There are few adapted varieties available in the United States. However, specialty characteristics, such as aroma, flavor, and appearance, of these domestically produced Jasmine and Basmati rices do not match those of imported rice (Meullenet, et al, 2001). Development of improved special purpose rice varieties adapted to the southern U.S. environment with competitive grain and milling yield, superior specialty characteristics that match those of imported rice, and pest resistance will help the U.S. rice industry to obtain a sizable portion of this fast growing, high value aromatic rice market, both domestically and internationally. However, due to limited resources, only a fraction of our overall breeding efforts can be devoted to breeding for special purpose aromatic rices. In order to maintain such a small but productive program, intensive or rigorous selection for specialty traits, such as aroma and grain appearance, in the early and mid generations of well planned recombinant populations is essential. To facilitate such selection, simple, economic, and reliable testing method for aroma that can handle a great number of small samples in a timely manner is critical. A number of methods were developed for the detection of aroma in different rice genotypes both quantitatively and qualitatively (Buttery et al, 1983; Berner and Hoff, 1986; Sood and Siddiq, 1978). It is well accepted that 2-acetyl-1-pyrroline (2-AP) is the determining factor for the “popcorn” like scent in aromatic rices, while the concentration of 2-AP of a given sample can be determined by using gas chromatography and gas chromatography mass spectrometry (Buttery et al 1983). The high expense has kept it from being a preliminary screening method. Fortunately, several qualitative methods involving panel tests of detached leaves enhanced by KOH, dehulled mature seeds with or without enhancement by KOH, and smelling of test tube cooked small rice samples have also been described (Berner and Hoff, 1986; Sood and Siddiq, 1978). However, some of the above methods are too cumbersome for breeders and no comparison between quantitative and qualitative methods on the same set of samples has been reported. The objectives of this study were to identify methods for noting aroma at different stages of selection by comparing three common methods on the same set of progenies, to compare different cross combinations for their efficiency of aroma recovery, and to evaluate different selection schemes for aroma.

Methods

Two hundred and ninety-six specialty progeny rows harvested in 2000 were tested for aroma by chewing dehulled kernels and test tube cooking methods. Out of these,, 41 randomly selected samples, including the non-aromatic check Cypress and aromatic check Dellmati, were tested for 2-acetyl-1-pyrroline (2-AP) concentration at the USDA-ARS Rice Quality Laboratory at Beaumont, TX. By directly chewing three dried and dehulled kernels, each sample was rated either strongly aromatic, aromatic, weakly aromatic, trace or not decisive, or non aromatic. For the test tube cooking method, 1 gram of milled rice was put into a 16x150 mm test tube containing 10 ml dH_2O, covered with a stainless steel cap, and cooked in a boiling water bath for 15 minutes. After the sample cooled down, it was evaluated and rated as either aromatic, weak aromatic, or no aroma. These methods were modified from the ones reported by Berner and Hoff, and IRRI (Berner and Hoff, 1986; IRRI, 1971).

A total of 1024 progeny rows of 2003 field selections, which ranged from F_3 to F_8 and derived from 63 different crosses, were analyzed for aroma by the test tube cooking method. Data generated from this study were used to compare the effectiveness of different parental combinations and different selection schemes.

Results

Ratings from the chewing method had an 88% overall match with corresponding 2-AP content. However, samples rated strongly aromatic or aromatic and non aromatic by the chewing method had 100% match with those by 2-AP tests (Table 1). Ratings from test tube cooking of 1 gram of milled rice had a perfect match with 2-AP contents (Table 2). By comparing ratings from all 296 samples tested with both chewing and test tube cooking methods, it was found that both methods had an 81% overall match, with the highest matches occurring on samples with strongly aromatic or aromatic ratings by the chewing method. Results from this test suggest that the chewing method is effective in detecting strong aromatic progenies and is suitable for field selection, while the test tube method is more sensitive and accurate and works well in laboratory tests. Both methods can work with a large number of small samples. Significant difference for 2-AP content (ranging from 5.4 ppb to 100 ppb) among different aromatic progenies was also observed.

Single crosses between two aromatic breeding lines and three-way crosses involving two aromatic parents yielded the highest aromatic progenies (about 82%), while single crosses between aromatic germplasm and conventional non-aromatic varieties only yielded 42% of the aromatic progenies (Table 3). Development, collection, and utilization of improved aromatic breeding lines adapted to the U.S. environment is the key to breed special purpose aromatic rices. Marginal reduction of aromatic progeny recovery was observed when pedigree selection and testing for aroma started at an early generation such as F_3 compared with a later generation such as F_5, however, over 56% of non-aromatic progenies can be eliminated from that generation (Table 4).

Table 1. Ability of detecting aroma by chewing dehulled rice kernels as compared to the estimated 2-acetyl-1-pyrroline (2-AP) contents, 2000

Aroma determined by chewing		Match with 2-AP content	
Rating†	No. of Samples	No. of Matches	Match %
A+	1	1	100
A	20	20	100
A-	9	6	67
A?	2	0	0
Non	9	9	100
Total	41	36	88

†Subjective rating, A+ = strong aroma, A = aroma, A- = weak aroma, A? = trace or not decisive, and Non = no aroma.

Table 2. Ability of detecting aroma by test tube cooking of one gram milled rice kernels as compared to the estimated 2-acetyl-1-pyrroline (2-AP) contents, 2000

Aroma determined by test tube cooking		Match with 2-AP content	
Rating†	No. of Samples	No. of Matches	Match %
A	26	26	100
A-	1	1	100
Non	14	14	100
Total	41	41	100

†Subjective rating, A = aroma, A- = weak aroma, and Non = no aroma.

Table 3. Effects of different cross combinations on the recovery of aromatic progenies in breeding aromatic rice, Crowley, LA, 2003.

Combination	No. of Breeding Lines (% of total)			No. crosses
	Aromatic (A)	Weak-aromatic	Non-aromatic (Non)	
A x Non	169 (29%)	72 (12%)	346 (59%)	39
A x A	42 (75%)	4 (7%)	10 (18%)	10
(A x Non) x A	60 (66%)	15 (16%)	16 (18%)	6
(A x Non) x Non	23 (35%)	10 (15%)	32 (49%)	5
Others	10 (32%)	4 (13%)	17 (55%)	3
Total	304 (37%)	105 (13%)	421 (51%)	63

Table 4. Effects of different selection schemes on the recovery of aromatic progenies in breeding aromatic specialty rice, Crowley, LA, 2003.

Generation†	Aromatic	Weak-aromatic	Non-aromatic	No. of crosses
F_3	107 (26%)	56 (14%)	241 (60%)	19

F_4	29 (33%)	9 (10%)	49 (56%)	6
F_{5+}	33 (34%)	7 (7%)	56 (58%)	14
Total	169 (29%)	72 (12%)	346 (59%)	39

†Generation when the pedigree selection and progeny test starts.

Conclusion

By chewing three dry dehulled rice kernels, progenies with strong aroma can be effectively detected in field selection, while by evaluating a cooked small rice sample in a test tube, progenies even with a weak aroma can be detected in laboratory tests. Both methods can work with a large number of small samples. Our results also suggested that intracrossing among different aromatic breeding lines creates the greatest chance to recover aroma. Selection for aroma in early generation may slightly reduce the chance of recovering aromatic genotypes, however, it is well compensated for by eliminating a majority of non-aromatic ones from later generations.

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