

PERFORMANCE OF GRAIN QUALITY AND AROMA OF AROMATIC NEW PLANT TYPE PROMISING RICE LINES

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ABSTRACT

Grain quality and aroma are important characteristics of rice that affect consumer acceptance. This research was conducted to study the grain quality and aroma of aromatic new plant type (NPT) promising rice lines. Thirty five lines as well as Ciherang and Sintanur varieties were planted at Bogor and Pusakanagara, West Java in the dry season (DS) 2009 and wet season (WS) 2009. Three methods, i.e. leaf aroma tested with KOH, rice aroma tested in the test tube, and cooked rice aroma test, were used to evaluate the aroma of the lines. The results showed that line B11742-RS*2-3-MR-34-1-2-1 was aromatic identified using different methods. The line had long, slender, and small chalkiness grains, high percentage of head rice, high amylose, and hard texture. Lines IPB 140-F-6, B11249-9C-PN-3-3-2-2-MR-1, and B11955-MR-84-1-4 also had a high aroma score and grain yield. Testing leaf aroma with KOH can be used as early selection method in breeding program for aromatic lines. Lines derived from aromatic parents from highlands of South Sulawesi did not show consistent aroma under three testing methods. Those tested lines had good grain quality, both physical and cooked rice quality.

[**Keywords:** Rice, promising lines, new plant type, aroma, grain quality]

INTRODUCTION

Consumer acceptance of rice depends on its physical and chemical quality. New rice varieties that have better benefits than the existing ones will be more accepted if their characteristics are in accordance with consumers' preferences (Zen 2007). High quality rice, uniform shape, whiteness and translucency are major factors defining market value of rice (Fitzgerald *et al.* 2008). Therefore, rice breeders should consider the better quality of new rice varieties in addition to higher yield potential. Consumers will pay more for good quality rice and this implicate better income for farmers (Adnyana *et al.* 2008).

Rice varieties have different productivities, grain qualities, grain appearance and aroma. Many aromatic rice are produced in Thailand, India, Pakistan,

Bangladesh, Nepal, Iran, Afghanistan, Myanmar, and Indonesia. Aromatic rice cultivars that are popular in Thailand are Thai Hom Mali Rice, Jasmine Rice, and Thai Fragrant Rice. In India the famous aromatic rice is Basmati, which has medium texture with a slender shape and long grain and less chalkiness (Kamath *et al.* 2008). In Indonesia, the type of aromatic rice widely cultivated by farmers is tender texture rice, such as Pandanwangi and Rojolele. Farmers cultivate local aromatic rice in irrigated land. However, these local varieties have long maturity (more than 125 days) and susceptible to major pests and diseases.

Aroma of rice is caused by chemical compounds that can easily evaporate. There are more than 114 compounds found in aromatic rice grains (Weber *et al.* 2000). The main aromatic compound, 2-acetyl-1-pyrroline (2AP) is detected in one of the famous aromatic rice Khaw Dawk Mali-105 (Laksanalamai and Ilangantileke 1993; Bourgis *et al.* 2008). Weber *et al.* (2000) stated that 2AP content in aromatic rice is 15 times greater than that of non-aromatic rice. Gene controlling the level of 2AP expression is *OsBADH2* (Niu *et al.* 2008). Rice aroma also depends on environmental conditions and cultivation management. Basmati variety will be more aromatic if cultivated in area having relatively cool temperature in the afternoon (25-32°C) and night (20-25°C) with humidity of about 70-80% among primordial and grain filling stages (Singh 2000).

New plant types (NPTs) of rice are designed to have more efficient assimilate distribution to the grains (Khush 2000; Peng and Khush 2003). However, the yield potentials of NPTs were not as high as expected. This may be due to low biomass production and low number of filled grains, and also sensitive to major pests and diseases. Therefore, in 1995 the second generation NPTs were developed by crossing tropical japonica NPT lines with the elite indica lines to increase the number of tillers (Peng *et al.* 2008).

The Indonesian Center for Rice Research (ICRR) has developed NPT promising line, BP360E-MR-79-PN-3, having good grain quality, high percentage of head rice and strong aroma (Abdullah *et al.* 2008). ICRR and Bogor Agricultural University (IPB) also created some aromatic NPT rice lines. IPB used local aromatic upland rice originated from South Sulawesi as parents of the aroma gene source. These local rice varieties are Pulu Mandoti, Pinjan, Pare Bau and Lambau, besides Sintanur variety. ICRR has created NPT aromatic lines with source of aroma gene from Gilirang variety. Those aromatic NPTs have 90-119 cm plant height, 9-14 productive tillers, 150-300 grains/panicle, mature at 117-123 days, 25.2-31.7 cm panicle length, erect leaves, sturdy stem, thick and dark green leaves (data unpublished). It was desired as NPT characteristics according to Khush (2000), i.e. 80-100 cm plant height, sturdy stem, 8-10 productive tillers, erect leaves, thick, dark green leaves, long panicle, 200-250 grains/panicle, and mature at 100-130 days. The aroma stability at different environments and grain quality of these lines should be evaluated. The study aimed to evaluate the grain quality and aroma of aromatic NPT promising lines.

MATERIALS AND METHODS

Grain Quality

Thirty five rice lines which have been selected based on aroma and yield and two check varieties, Ciherang and Sintanur were studied in November 2009-March 2010. Those lines were developed by crossing high yielding and local rice varieties which have aromatic character in pedigree method and became F9 population (Table 1). The lines were selected from each generation based on their yield and aroma. The selected lines were planted at Bogor and Pusanagara, West Java, in an elevation of 200 m and 8 m above sea level (asl), respectively, in the dry season (DS) and wet season (WS) of 2009. Grain quality was evaluated in the laboratory of Muara Experimental Farm, Bogor.

About 500 g of grains of each line were milled with ST50 Yanmar rice huller to have brown rice. The brown rice was then milled in Yakatama miller machine to obtain white milled rice and bran. Evaluation was conducted on the percentage of brown rice, milled rice, and head rice, as well as length, shape, chalkiness, amylose content, gelatinization temperature and texture.

Table 1. Genetic materials for developing new plant types rice lines.

Line	Combination
IPB 113-F-1	Pare Bau*/Fatmawati
IPB 113-F-2	Pare Bau/Fatmawati
IPB 115-F-3-2	Fatmawati/Lambau*
IPB 115-F-11	Fatmawati/Lambau
IPB 116-F-3-1	Pinjan*/Fatmawati
IPB 116-F-44-1	Pinjan/Fatmawati
IPB 116-F-46-1	Pinjan/Fatmawati
IPB 117-F-1-3	Fatmawati/Pulu Mandoti*
IPB 117-F-4-1	Fatmawati/Pulu Mandoti
IPB 117-F-6-1	Fatmawati/Pulu Mandoti
IPB 117-F-14-2	Fatmawati/Pulu Mandoti
IPB 117-F-15-2	Fatmawati/Pulu Mandoti
IPB 117-F-17-4	Fatmawati/Pulu Mandoti
IPB 117-F-17-5	Fatmawati/Pulu Mandoti
IPB 117-F-18-3	Fatmawati/Pulu Mandoti
IPB 117-F-45-2	Fatmawati/Pulu Mandoti
IPB 140-F-1-1	Sintanur*/Fatmawati/IPB26-d-14j-1-1-2
IPB 140-F-2-1	Sintanur/Fatmawati/IPB26-d-14j-1-1-2
IPB 140-F-3	Sintanur/Fatmawati/IPB26-d-14j-1-1-2
IPB 140-F-4	Sintanur/Fatmawati/IPB26-d-14j-1-1-2
IPB 140-F-5	Sintanur/Fatmawati/IPB26-d-14j-1-1-2
IPB 140-F-6	Sintanur/Fatmawati/IPB26-d-14j-1-1-2
IPB 140-F-7	Sintanur/Fatmawati/IPB26-d-14j-1-1-2
IPB 149-F-1	Lambau*/Fatmawati
IPB 149-F-2	Lambau/Fatmawati
IPB 149-F-3	Lambau/Fatmawati
IPB 149-F-4	Lambau/Fatmawati
IPB 149-F-5	Lambau/Fatmawati
IPB 149-F-7	Lambau/Fatmawati
IPB 149-F-8	Lambau/Fatmawati
B11249-9C-PN-3-3-2-2-MR-1	B10589F/Memberamo/IR64
B11738-MR-1-2-Si-1-2	Gilirang*/BP342F-MR-1-3//Gilirang*
B11742-RS*2-3-MR-34-1-2-1	BP360E-MR-79-PN-2/IR71218/BP360E
B11823-MR-3-15-1	BP140F-MR-1-KN-1/Code/BP140F-MR-1
B11955-MR-84-1-4	B11738-MR-2-5/B11738-MR-6B
Ciherang	B10589FKN//Memberamo/IR64
Sintanur	Gilirang*/BP342F-MR-1-3//Gilirang*

*Parent as source of aroma.

Percentage of brown rice (BR), milled rice (MR), and head rice (HR) were calculated by the following formula:

$$\text{BR (\%)} = \frac{\text{weight of brown rice (g)}}{\text{weight of grains (500 g)}} \times 100\%$$

$$\text{MR (\%)} = \frac{\text{weight of milled rice (g)}}{\text{weight of grains (500 g)}} \times 100\%$$

$$\text{HR (\%)} = \frac{\text{weight of head rice (g)}}{\text{weight of grains (500 g)}} \times 100\%$$

Length, shape, and chalkiness

Length and width of ten head rice were measured manually using dial caliper. The scales of rice length were long (6.6-7.5 mm), medium (5.5-6.6 mm), and short (<5.5 mm). Rice shape is the ratio of length to width. Rice performance quality was determined by observing the appearance and clearness of the endosperm. Chalkiness was noted in the middle of rice (white center), front (white belly), or none at all (none). The scales of kernel area were small (<10%), medium (11-20%), and large (>20%).

Amylose content

Amylose content was analyzed using calorimetric iodide. A total of 100 mg of white rice flour from each line was put in 100 ml measuring flask, and then mixed with 1 ml of 95% alcohol and 9 ml of NaOH 1 N. The solution was kept and undisturbed at room temperature for 23 hours, then added with distillate water until line of measuring tera, and shaken. Five ml of solution was taken and placed in a 100 ml measuring flask per sample; 85 ml water was added, then distilled with 1 ml of acetate 1 N and 2 ml of 2% KI. The solution was then diluted to the tera. The value of light absorption of the solution was measured with a spectrophotometer. Amylose content was classified as high (>25%), medium (20.1-25%), low (12.1-20.0%), very low (5.1-12.0%) and waxy (0-5.0%).

Gelatinization temperature

Six head rice were soaked in 10 ml of 1.7% KOH solution for 23 hours at 30°C. Rice appearance and separation were visually classified using IRRI scoring method (IRRI 2002). Rice having low-gelatinization temperature would be completely separating or disappear, while that having medium gelatinization temperature was only partially cracked or separated. Grain affected by alkaline solution indicated high temperature gelatinization. Gelatinization temperature was classified into three criteria, namely high (75-79°C), moderate (70-74°C), and low (55-69°C).

Aroma Sensory

Aroma was evaluated using three methods. The first method was leaf aroma tested with KOH according a technique developed by Berner and Hoff (1986)

which further modified by Dong *et al.* (2001). The second method was rice aroma tested in the test tube, that was a modified method of Sha and Linscombe (2004), and the third was cooked rice aroma test followed Allidawati and Kustianto (1989). Those three methods were used depending on the needs and efficiency for detecting and selecting aromatic rice lines. Leaf aroma test is used to determine the aroma of rice lines as early as possible and will be more effective applied in a large population. Testing rice aroma in test tube is needed if the rice harvest is not enough to be cooked as if using a test of cooked rice. Those three methods were used to evaluate the possibility of correlation among them in detecting rice aroma. Comparison among these methods is important for evaluation of rice aroma. The score of each sample was recorded by a panel of experts (panelists) who have experience in evaluation of aroma and quality of rice. The average scores of each method and all of the three methods were used to determine aroma of the rice lines tested.

Leaf aroma tested with KOH

Leaves tested were taken at maximum tillering until panicle initiation stages. Three to five leaves from second leaf under the flag leaf of the plant were taken. The leaf samples were cut at approximately 5 mm and then placed in sealed plastic and stored in the freezer at temperature of -20°C until frozen. The frozen leaf was weighed of about 0.8 g then placed in a test tube previously filled with 5 ml of 1.7% KOH solution. The tube was then covered with aluminum foil and put into a 50°C oven for 10 minutes. The tube was opened one by one and the leaf aroma was evaluated by four panelists to be scored at 0-3: score 0 was no aroma, 1 was faint aroma, 2 indicated aroma, and 3 represent strong aroma. The scores of each line were averaged and differentiated into three groups, namely aromatic (score > 1.0), slightly aromatic (score 0.6-1.0), and not aromatic (score < 0.5).

Rice aroma test in test tube

One gram of rice was placed in test tube of 15 mm x 150 mm previously filled with 10 ml of dH₂O. The test tube was then covered with aluminum foil and cooked in boiling water for 15 minutes. After the samples were cool, the aluminum foil was opened and aroma was smelled one by one by the panelists and scored using the same method as previously described. The

scores were averaged and classified into aromatic (score > 1.0), slightly aromatic (score of 0.5-1.0), and not aromatic (score < 0.5).

Cooked rice test

A total of 200 g of rice of each line was cooked with 300 ml of water and then steamed for 30 minutes. Cooked rice aroma and texture were tested by 10 panelists to determine the aroma level (using score). Rice texture was classified into tender, medium, and hard.

RESULTS AND DISCUSSION

Grain Quality

No grain quality data of replication 1 and 2 from Pusakanagara WS were available due to the damage caused by rats. So we analyzed data only from Bogor DS, Bogor WS, and Pusakanagara DS. Sources of variation of all rice qualities were significantly different, except for amylose and head rice in environment, also in all grain qualities and line environment interaction (Table 2). Rice qualities tested include physical quality, cooking quality, and texture of cooked rice. The physical quality include length, shape, and chalkiness, as well as percentage of broken rice, husk, milled rice and head rice. Cooking quality composed of amylose content and gelatinization temperature. Rice texture was tested manually using a score. In this discussion, grain quality used average data of both locations, Bogor DS and Pusakanagara DS.

Length, shape, and chalkiness of the grains were mostly classified into long, medium, and medium, respectively. Medium rice chalkiness was identified from the appearance of chalky rice grains that were not as clear as Ciherang and Sintanur. There were eight lines, namely IPB 117-F-1-3, IPB 117-F-18-3, IPB

117-F-45-2, IPB 140-F-1-1, IPB 140-F-2-1, IPB 140-F-4, IPB 140-F-5, and IPB 149-F-1 with length, shape, and chalkiness felt under medium. IPB 113-F-1, IPB 113-F-2, IPB 116-F-44-1, IPB 140-F-7, B11249-9C-PN-3-3-2-2-MR-1, and B11742-RS*2-3-MR-34-1-2-1 had slender shape and small chalkiness (Table 3).

The average yields of brown rice were higher than those of check varieties, ranging from 73% to 77% and mostly significantly different from Ciherang. The yield of milled rice was at an average of > 65%, while the head rice yields varied, ranging from 38.6% (IPB 140-F-5) to 74% (IPB 113-F-1). The low percentage of head rice was because the rice grains were too dry and therefore easily broken when milled. Amylose contents of the lines were 17-26%. Amylose content of IPB-117-F-1-3 was the lowest (17.0%) and B11742-RS*2-3-MR-34-1-2-1 had the highest amylose content (26.3%) with hard cooked rice texture. Most of the lines had medium to low amylose content, consequently cooked rice will have tender texture and soft when cold.

Gelatinization temperature of the grains of the lines tested mostly belonged to intermediate class (70-74°C) and some were relatively low (55-69°C). It determines the length of cooking. Rice with low gelatinization temperature takes shorter cooking time compared with that having high gelatinization temperature.

Rice texture is classified into tender, medium, and hard. Most of the lines had tender rice texture, five had moderate, and one hard. Rice texture was comparable its amylose content. The low the amylose content the tender the cooked rice texture. The cooked rice texture of B11742-RS*2-3-MR-34-1-2-1 was hard as it had high amylose content (26.3%).

Aroma Sensory

There were high significant differences between lines and environment interaction, except for leaf aroma (Table 4).

Table 2. Mean square values for combined analysis of variance for grain quality of aromatic new plant type promising rice lines.

Source of variation	df	Amylose	Brown rice	Milled rice	Head rice
Environment	2	79.015ns	397.221*	325.810*	8434.009ns
Replication (environment)	6	29.181	44.580	34.839	2623.808
Line	36	40.451**	9.067*	14.184**	1022.695**
Line x environment	72	2.298ns	6.046ns	6.310ns	341.049ns
Error	216	2.891	5.350	6.301	270.082

ns = not significant, * and ** = significant at 5% and 1%, respectively.

Table 3. Grain quality of new plant type rice lines.

Lines	Physical quality						Amylose (%)	Gelatinization temperature (°C)	Rice texture
	Length	Shape	Chalkiness	Brown rice (%)	Milled rice (%)	Head rice (%)			
IPB 113-F-1	Long	Slender	Small	76.1a	66.3ab	74.0b	23.1ab	70-74	Tender
IPB 113-F-2	Long	Slender	Small	76.1ab	66.1ab	66.8b	23.6ab	70-74	Tender
IPB 115-F-3-2	Medium	Medium	Small	74.6ab	64.9ab	59.3b	22.1b	70-74	Tender
IPB 115-F-11	Long	Medium	Small	74.6a	64.6b	50.4ab	21.3b	70-74	Tender
IPB 116-F-3-1	Long	Medium	Small	75.2a	65.3ab	59.9b	23.1ab	70-74	Medium
IPB 116-F-44-1	Long	Slender	Small	76.4ab	65.5ab	66.3b	23.0ab	70-74	Medium
IPB 116-F-46-1	Long	Medium	Small	73.8ab	64.0b	65.1b	23.1ab	70-74	Tender
IPB 117-F-1-3	Medium	Medium	Medium	74.8a	64.9ab	71.3b	17.0ab	70-74	Tender
IPB 117-F-4-1	Long	Medium	Medium	75.5ab	64.8ab	68.3b	23.0ab	70-74	Tender
IPB 117-F-6-1	Long	Medium	Small	74.6ab	64.1b	66.6b	21.1b	70-74	Tender
IPB 117-F-14-2	Long	Medium	Medium	74.4a	64.3b	47.7a	22.0b	70-74	Tender
IPB 117-F-15-2	Long	Medium	Medium	75.3ab	65.1ab	63.9b	23.0ab	70-74	Tender
IPB 117-F-17-4	Long	Medium	Medium	75.5ab	64.5b	49.3ab	22.5b	70-74	Tender
IPB 117-F-17-5	Long	Medium	Medium	75.0ab	63.9b	45.8a	22.2b	70-74	Tender
IPB 117-F-18-3	Medium	Medium	Medium	75.4ab	65.2ab	63.7b	23.0ab	70-74	Tender
IPB 117-F-45-2	Medium	Medium	Medium	76.2b	63.3c	56.8b	23.4ab	70-74	Tender
IPB 140-F-1-1	Medium	Medium	Medium	77.0a	67.8a	72.0b	22.7ab	70-74	Tender
IPB 140-F-2-1	Medium	Medium	Medium	74.9ab	66.2ab	68.0b	23.3ab	70-74	Tender
IPB 140-F-3	Long	Medium	Medium	75.5ab	64.1b	64.8b	22.5b	70-74	Tender
IPB 140-F-4	Medium	Medium	Medium	74.0a	62.9c	55.4b	20.7a	70-74	Tender
IPB 140-F-5	Medium	Medium	Medium	75.4ab	64.9ab	38.6a	21.9b	55-69	Medium
IPB 140-F-6	Long	Medium	Small	75.4ab	66.2ab	68.8b	23.8ab	55-69	Medium
IPB 140-F-7	Long	Slender	Small	76.3ab	67.2ab	65.7b	24.0ab	70-74	Tender
IPB 149-F-1	Medium	Medium	Medium	76.4ab	63.3c	50.7ab	21.9b	70-74	Tender
IPB 149-F-2	Long	Medium	Medium	75.7a	64.4b	50.7ab	22.5b	70-74	Tender
IPB 149-F-3	Long	Medium	Small	74.7a	64.7b	48.5a	22.2b	70-74	Tender
IPB 149-F-4	Long	Medium	Medium	75.0a	63.1c	56.8b	23.3ab	70-74	Medium
IPB 149-F-5	Long	Medium	Medium	74.6a	63.8b	44.2a	22.8ab	70-74	Tender
IPB 149-F-7	Long	Medium	Medium	76.6ab	66.2ab	60.9a	22.6b	70-74	Tender
IPB 149-F-8	Long	Medium	Medium	75.2a	64.3b	53.3a	21.7b	70-74	Tender
B11249-9C-PN-3-3-2-2-MR-1	Long	Slender	Small	75.2ab	65.7ab	72.2b	17.1ab	55-69	Tender
B11738-MR-1-2-Si-1-2	Long	Medium	Small	73.3a	63.8b	41.2a	17.7a	55-69	Tender
B11742-RS*2-3-MR-34-1-2-1	Long	Slender	Small	73.8a	64.0b	66.3ab	26.3ab	55-69	Hard
B11823-MR-3-15-1	Long	Medium	Small	75.4ab	66.1ab	68.5b	17.3ab	55-69	Tender
B11955-MR-84-1-4	Medium	Medium	Small	73.6ab	64.0b	60.9b	17.6a	55-69	Tender
Ciherang	Long	Medium	Small	74.8b	65.1b	58.4b	21.0b	70-74	Tender
Sintanur	Medium	Medium	Small	75.0a	66.2a	52.6a	19.2a	55-69	Tender
LSD 5%				2.15	2.33	15.27	1.58		

Numbers in a column followed with letter *a* were not significantly different from Sintanur, those followed by letter *b* were not significantly different from Ciherang, and those followed by letter *c* were significantly different from Ciherang and Sintanur at 5% level of LSD test.

Table 4. Mean square values for combined analysis of variance of three methods used for evaluating rice aroma.

Source of variation	df	Leaf aroma	Rice aroma	Cooked rice aroma
Environment	3	0.1017ns	0.0208ns	0.2701*
Replication (environment)	8	0.0633	0.0201	0.0235
Line	36	0.1217**	0.0904**	0.1151**
Line x environment	108	0.0154ns	0.0142**	0.0215**
Error	288	0.0152	0.0080	0.0118

ns = not significant, * and ** = significant at 5% and 1%, respectively.

Leaf aroma

Leaf aroma scores of NPT promising rice lines ranged from 0.1 to 2.1 (Table 5). Several lines had light aroma or having score of > 0.5. Based on leaf aroma, four lines had average score of >1 (aromatic), i.e. IPB 140-F-6 (1.2), B11249-9C-PN-3-3-2-2-MR-1 (1.6), B11742-RS*2-3-MR-34-1-2-1 (1.6), and B11955-MR-84-1-4 (1.3), while Sintanur variety had aroma score of 1.6. Among those lines, IPB 140-F-6 showed low score (0.7) in Bogor in 2009 WS, unlike in other environ-

Table 5. Aroma of new plant type rice lines based on leaf aroma method in four environments.

Lines	Leaf aroma score				Average	Aroma (from avg.)
	Bogor 2009 DS	Bogor 2009 WS	Pusakanagara 2009 DS	Pusakanagara 2009 WS		
IPB 113-F-1	0.7	0.5	0.6	0.7	0.6b	Light
IPB 113-F-2	0.6	0.4	0.5b	0.6	0.5b	None
IPB 115-F-3-2	0.8	0.3	0.3	0.9	0.6b	Light
IPB 115-F-11	0.6	0.6	0.4	0.7	0.6b	Light
IPB 116-F-3-1	0.8	0.2	0.5	0.7	0.6b	Light
IPB 116-F-44-1	0.5	0.4	0.7	0.8	0.6b	Light
IPB 116-F-46-1	0.8	0.8	0.7	1.2	0.9b	Light
IPB 117-F-1-3	0.4	0.5	0.7	1.1	0.7b	Light
IPB 117-F-4-1	0.5	0.6	0.3	1.1	0.7b	Light
IPB 117-F-6-1	0.9	0.6	0.3	0.7	0.6b	Light
IPB 117-F-14-2	0.5	0.3	0.5	0.8	0.5b	None
IPB 117-F-15-2	0.5	0.5	0.5	0.7	0.5b	None
IPB 117-F-17-4	0.6	0.4	0.8	0.5	0.6b	Light
IPB 117-F-17-5	0.6	0.4	0.7	0.9	0.7b	Light
IPB 117-F-18-3	0.9	0.5	0.7	1.1	0.8b	Light
IPB 117-F-45-2	0.7	0.6	0.6	0.9	0.7b	Light
IPB 140-F-1-1	0.5	0.6	0.8	0.5	0.6b	Light
IPB 140-F-2-1	0.5	0.3	0.6	0.7	0.5b	None
IPB 140-F-3	0.9	0.7	0.8	0.9	0.8b	Light
IPB 140-F-4	0.6	0.4	0.6	1.1	0.6b	Light
IPB 140-F-5	0.5	0.3	0.6	0.8	0.6b	Light
IPB 140-F-6	1.3	0.7	1.4	1.1	1.2a	Aromatic
IPB 140-F-7	0.9	0.6	0.4	0.6	0.6b	Light
IPB 149-F-1	1.0	0.1	0.4	0.7	0.5b	None
IPB 149-F-2	0.7	0.2	0.5	0.8	0.6b	Light
IPB 149-F-3	0.8	1.0	0.5	0.6	0.7b	Light
IPB 149-F-4	0.4	0.3	0.6	0.8	0.5b	None
IPB 149-F-5	0.1	0.2	0.5	0.6	0.3b	None
IPB 149-F-7	0.6	0.2	0.5	0.6	0.5b	None
IPB 149-F-8	0.6	0.7	0.8	0.9	0.7b	Light
B11249-9C-PN-3-3-2-2-MR-1	1.6	1.5	2.1	1.1	1.6a	Aromatic
B11738-MR-1-2-Si-1-2	0.5	1.0	1.0	0.6	0.8b	Light
B11742-RS*2-3-MR-34-1-2-1	1.7	1.6	1.7	1.2	1.6a	Aromatic
B11823-MR-3-15-1	0.8	0.2	0.4	0.7	0.5b	None
B11955-MR-84-1-4	1.1	1.1	1.8	1.1	1.3a	Aromatic
Ciherang	0.9	0.3	0.5	0.7	0.6b	Light
Sintanur	1.8	1.5	1.6	1.4	1.6a	Aromatic
LSD 5%	0.17	0.17	0.20	0.25	0.09	

Numbers in a column followed with letter *a* were not significantly different from Sintanur, and those followed by letter *b* were not significantly different from Ciherang at 5% level of LSD test.

ments, while the three others tended to be stable in all environments.

In Pusakanagara in 2009 WS, 10 lines, included Sintanur variety, had high score of aroma, although the average score (0.8) was not much different from average score in other environments (0.6-0.8). Most of the lines had light aroma (medium score, 0.6-1.0). Lines are classified as aromatic if they have high concentration of aromatic compound 2AP after testing using gas chromatography-mass spectrometry (GC-

MS) method (Widjaja *et al.* 1996). Sarhadi *et al.* (2009) reported that the correlation among 1.7% KOH sensory test, GC-MS method and PCR analysis was high enough, and will allow selecting the Afghan native aromatic cultivars. The 1.7% KOH sensory test was useful for distinguishing aromatic and non-aromatic rice. GC-MS and PCR methods will be useful for breeders to streamline the breeding process and reduce the time for new cultivar development in the future.

Rice aroma

Lines detected as aromatic or had high score of aroma using leaf method did not show the same score if tested using rice aroma test. There was an interaction effect between line and environment. The aroma scores of the lines tested ranged from 0.1 to 1.6 (Table 6).

IPB 140-F-6, B11249-9C-PN-3-3-2-2-MR-1, B11742-RS*2-3-MR-34-1-2-1, and B11955-MR-84-1-4 had a high aroma score (>1.0) and did not significantly differ from Sintanur as aromatic check variety in Bogor in 2009 DS. Line B11742-RS*2-3-MR-34-1-2-1 had high aroma score in Bogor 2009 WS and Pusakanagara 2009 DS, while in Pusakanagara 2009 WS the aromatic aroma which turned to light aroma. On the average, those lines had medium score (0.7-1.0) which meant that they were considered as aromatic. The aroma of the other lines was not detected in all environments.

Cooked rice aroma

The aroma of cooked rice in this experiment was not tested in environmental condition of Pusakanagara in 2009 WS (Table 7) due to insufficient amount of milled rice to be cooked as testing requires 200 g of milled rice. The amount of milled rice adequate for testing derived only from one replication. Therefore, no data were available from the two other replication. In Pusakanagara 2009 DS, aroma score of lines B11742-RS*2-3-MR-34-1-2-1 and B11955-MR-84-1-4 were significantly higher than that of Sintanur. Lines IPB 140-F-6 and B11742-RS*2-3-MR-34-1-2-1 had the same aroma score in Bogor DS and Pusakanagara DS (> 1.0), except in Bogor WS (score < 0.5). It indicated that location affected leaf aroma of both lines. Data showed that lines which had high average aroma score (> 1.0) using leaf testing, gave the same score with cooked rice testing.

All of the lines tested had a high score of cooked rice aroma, except in Bogor of 2009 DS with 0.6 as the highest score (Table 8). Sintanur as aromatic check variety turned to be light aroma, such as B11249-9C-PN-3-3-2-2-MR-1 and B11955-MR-84-1-4. This might be due to environmental factors, such as temperature, weather, or disease during the growing period. However, cooked rice aroma of those lines was high in Pusakanagara 2009 DS. Those lines, except B11742-RS*2-3-MR-34-1-2-1, also had high grain yield, which was not significantly different from check varieties, Ciherang and Sintanur. B11742-RS*2-3-MR-34-1-2-1

Table 6. Aroma of new plant type rice lines based on test tube method in four environments.

Lines	Rice aroma score			
	Bogor 2009 DS	Bogor 2009 WS	Pusaka- nagara 2009 DS	Pusaka- nagara 2009 WS
IPB 113-F-1	0.2b	0.2b	0.2b	0.3b
IPB 113-F-2	0.3b	0.1b	0.2b	0.3b
IPB 115-F-3-2	0.1b	0.1b	0.4b	0.3b
IPB 115-F-11	0.3b	0.7b	0.2b	0.2b
IPB 116-F-3-1	0.1b	0.1b	0.1b	0.3b
IPB 116-F-44-1	0.0c	0.3b	0.4b	0.3b
IPB 116-F-46-1	0.4b	0.4b	0.1b	0.7ab
IPB 117-F-1-3	0.1b	0.0b	0.1b	0.2b
IPB 117-F-4-1	0.0c	0.2b	0.3b	0.0ab
IPB 117-F-6-1	0.1b	0.1b	0.1b	0.6b
IPB 117-F-14-2	0.3b	0.2b	0.1b	0.7ab
IPB 117-F-15-2	0.2b	0.4b	0.1b	0.3b
IPB 117-F-17-4	0.1b	0.3b	0.4b	0.3b
IPB 117-F-17-5	0.2b	0.3b	0.3b	0.0ab
IPB 117-F-18-3	0.3b	0.3b	0.2b	0.0ab
IPB 117-F-45-2	0.4b	0.0b	0.0b	0.2b
IPB 140-F-1-1	0.2b	0.2b	0.1b	0.7ab
IPB 140-F-2-1	0.3b	0.2b	0.3b	0.3b
IPB 140-F-3	0.5b	0.5b	0.0b	0.0ab
IPB 140-F-4	0.0c	0.5b	0.3b	0.3b
IPB 140-F-5	0.3b	0.1b	0.1b	0.3b
IPB 140-F-6	1.2a	1.0a	0.8a	0.4b
IPB 140-F-7	0.1bb	0.1b	0.3b	0.3b
IPB 149-F-1	0.1b	0.1b	0.3b	0.3b
IPB 149-F-2	0.4b	0.2b	0.1b	0.5b
IPB 149-F-3	0.5b	0.3b	0.2b	0.4b
IPB 149-F-4	0.2b	0.2b	0.1b	0.3b
IPB 149-F-5	0.3b	0.2b	0.2b	0.2b
IPB 149-F-7	0.0ab	0.2b	0.6ab	0.7ab
IPB 149-F-8	0.3b	0.3b	0.2b	0.6b
B11249-9C-PN-3-3-2-2-MR-1	1.6a	1.0a	0.9a	0.7ab
B11738-MR-1-2-Si-1-2	0.1ab	0.2b	0.4b	0.3b
B11742-RS*2-3-MR-34-1-2-1	1.2a	1.3a	1.2a	0.9a
B11823-MR-3-15-1	0.2b	0.1b	0.1b	0.4b
B11955-MR-84-1-4	1.3a	0.2b	0.9a	0.3b
Ciherang	0.7b	0.2b	0.1b	0.3b
Sintanur	1.1a	1.1a	1.1a	1.1a
LSD 5%	0.19	0.15	0.15	0.08

Numbers in a column followed with letter *a* were not significantly different from Sintanur, those followed by letter *b* were not significantly different from Ciherang, and those followed by letter *c* were significantly different from Ciherang and Sintanur at 5% level of LSD test.

had the lowest grain yield because the line was highly susceptible to bacterial leaf blight disease.

Cooked rice method was significantly correlated positively with the test tube ($r = 0.5285$) and leaf method ($r = 0.5223$). Thus, leaf method can be used as

Table 7. Cooked rice aroma of new plant type rice lines in three environments.

Lines	Cooked rice aroma score		
	Bogor 2009 DS	Bogor 2009 WS	Pusakanagara 2009 DS
IPB 113-F-1	0.2b	0.0b	0.3b
IPB 113-F-2	0.0b	0.1b	0.1b
IPB 115-F-3-2	0.2b	0.0b	0.1b
IPB 115-F-11	0.1b	0.5a	0.4b
IPB 116-F-3-1	0.2b	0.0b	0.2b
IPB 116-F-44-1	0.2b	0.0b	0.1b
IPB 116-F-46-1	0.6c	0.1b	0.4b
IPB 117-F-1-3	0.2b	0.1b	0.1b
IPB 117-F-4-1	0.3c	0.1b	0.3b
IPB 117-F-6-1	0.3c	0.0b	0.0b
IPB 117-F-14-2	0.4c	0.0b	0.3b
IPB 117-F-15-2	0.1b	0.0b	0.4b
IPB 117-F-17-4	0.2b	0.1b	0.2b
IPB 117-F-17-5	0.2b	0.0b	0.1b
IPB 117-F-18-3	0.2b	0.0b	0.2b
IPB 117-F-45-2	0.2b	0.0b	0.1b
IPB 140-F-1-1	0.4c	0.0b	0.1b
IPB 140-F-2-1	0.2b	0.1b	0.3b
IPB 140-F-3	0.1b	0.0b	0.3b
IPB 140-F-4	0.1b	0.1b	0.2b
IPB 140-F-5	0.2b	0.0b	0.1b
IPB 140-F-6	1.8a	0.3b	1.3a
IPB 140-F-7	0.4c	0.2b	0.3b
IPB 149-F-1	0.2b	0.1b	0.0b
IPB 149-F-2	0.0b	0.0b	0.1b
IPB 149-F-3	0.3c	0.1b	0.4b
IPB 149-F-4	0.1b	0.0b	0.0b
IPB 149-F-5	0.1b	0.0b	0.0b
IPB 149-F-7	0.1b	0.0b	0.5b
IPB 149-F-8	0.4	0.0b	0.0b
B11249-9C-PN-3-3-2-2-MR-1	1.7a	1.0c	0.6b
B11738-MR-1-2-Si-1-2	0.3c	0.0b	0.0b
B11742-RS*2-3-MR-34-1-2-1	1.1a	0.3b	1.8a
B11823-MR-3-15-1	0.1b	0.0b	0.4b
B11955-MR-84-1-4	1.1a	0.6b	2.0c
Ciherang	0.7b	0.0b	0.1b
Sintanur	1.5a	0.6a	1.1a
LSD 5%	0.22	0.09	0.19

Numbers in a column followed with letter *a* were not significantly different from Sintanur, those followed by letter *b* were not significantly different from Ciherang, and those followed by letter *c* were significantly different from Ciherang and Sintanur at 5% level of LSD test.

early selection technique in breeding program to select candidates of aromatic rice lines.

Gene source of aroma of IPB 140-F-6 was Sintanur variety, B11955-MR-84-1-4 was from Gilirang variety that has aroma and delicious taste (Imran 2003), while

Table 8. Cooked rice aroma score under three environments and average of grain yield of four lines compared with check varieties Ciherang and Sintanur.

Lines	Bogor 2009 DS	Bogor 2009 WS	Pusakanagara 2009 DS	Grain yield (t ha ⁻¹)
IPB 140-F-6	1.8a	0.3b	1.3a	7.18ab
B11249-9C-PN-3-3-2-2-MR-1	1.7a	1.0c	0.6a	6.34ab
B11742-RS*2-3-MR-34-1-2-1	1.1a	0.3b	1.8c	5.55c
B11955-MR-84-1-4	1.1a	0.6a	2.0c	6.61ab
Ciherang	0.7b	0.0b	0.1b	6.69b
Sintanur	1.5a	0.6a	1.1a	7.26a

Numbers in each column followed with letter *a* were not significantly different from Sintanur, those followed by letter *b* were not significantly different from Ciherang, and those followed by letter *c* were significantly different from Ciherang and Sintanur at 5% level of LSD test.

B11249-9C-PN-3-3-2-2-MR-1 and B11742-RS*2-3-MR-34-1-2-1 was from aromatic local varieties. Therefore, aroma of the lines derived from aromatic parents from highlands, of South Sulawesi, i.e. Lambau, Pare Bau, Pinjan, and Pulu Mandoti, was not consistent under various testing methods. This might be because the lines were grown at different altitudes as the origin of those parents. Therefore, further study on the influence of altitude on aroma of those lines was necessary. Differences in aroma in various environments might be due to the differences in altitudes and temperatures. Bogor (200 m asl) has rainfall pattern without dry months. Meanwhile, Pusakanagara (8 m asl) has dry month in June-October 2010. On the average, leaf aroma test gave higher scores than two other methods because the leaves were collected at precise temperature (28-32°C) and humidity (77-80%) in all environments, so that the aroma was stronger. Meanwhile, at the grain filling stage, temperature and humidity were high, more than 32°C and 80%, respectively. This affected the concentration of aromatic compounds which have volatile character.

Singh (2000) explained that the strength of aroma or the concentration of 2AP compound might be influenced by environmental condition. For instance, Basmati variety will be more aromatic if the temperature is relatively cool during the growing period in the day (25-32°C) and night (20-25°C) with humidity of 70-80% during primordial and grain filling stages. Outside its narrow native area, Basmati loses its aroma (Oad *et al.* 2006). Therefore, aroma strength in some aromatic rice cultivars might decrease and or

absent because they were grown outside the original cultivated area (Hien *et al.* 2006; Sarhadi *et al.* 2009). Tava and Bocchi (1999) also reported that 2AP compound significantly presents in Basmati and Italian rice line B5-3. The higher content is more likely due to the differences in genotype, environment, and climate condition. Another possibility is that the key compound forming aroma in rice is not 2AP alone. Aroma in rice may be produced by integrated expression of more than one volatile compound, among which 2AP is a major component (Weber *et al.* 2000; Hien *et al.* 2006).

CONCLUSION

Grain qualities of NPT promising rice lines varied. Most of the lines had long grain with medium shape, small chalkiness, medium to low amylose contents, and tender texture of cooked rice.

B11742-RS*2-3-MR-34-1-2-1 had stable aromatic fragrance under various testing methods, while IPB 140-F-6, B11249-9C-PN-3-3-2-2-MR-1, and B11955-MR-84-1-4 not only had a high aroma score, but also high yield that was not significantly different from check varieties, Ciherang and Sintanur.

Three methods used to identify aroma of rice lines give inconsistent results. Aroma of rice lines was more easily detected and stronger using leaf test with KOH than that using test tube and cooked rice methods. Aroma of lines derived from local aromatic parents from highlands of South Sulawesi was not consistent under various testing methods, and did not show aromatic character in altitude of 8 m (Pusakanagara) and 200 m (Bogor) asl.

Rice aroma is influenced by both genetic and environmental factors. Thus, it is important to elucidate both genetic and environmental factors that may influence aroma for production and breeding of aromatic rice varieties. It was considered necessary to further study the altitude influence on aroma and yields of those aromatic lines.

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