

Analysis of aroma and yield components of aromatic rice in Malaysian tropical environment**Faruq Golam^{*1}, Y. Hui Yin¹, A. Masitah¹, N. Afnierna¹, Nazia Abdul Majid¹, Norzulaani Khalid², Mohamad Osman³.**¹Genetics and Molecular Biology, Institute of Biological Sciences, University of Malaya, 50603, Kuala Lumpur, Malaysia²UM Biotechnology and Bio-product Research Cluster, University of Malaya, 50603, Kuala Lumpur, Malaysia³Kulliyah of Science, International Islamic University Malaysia, 25200, Kuantan, Pahang, Malaysia***Corresponding author: faruq@um.edu.my****Abstract**

Low yield is a common phenomenon of aromatic rice and consequently rice breeders are trying to develop the agronomic characters to gain a better grain yield. In this study, a total of 53 rice genotypes including 12 globally popular aromatic rice cultivars and 39 advanced breeding lines were evaluated for yield and yield contributing characters in Malaysian tropical environment. Two local varieties MRQ 50 and MRQ 72 were used as check varieties. Correlation analysis revealed that the number of fertile tillers ($r = 0.69$), grain/panicle ($r = 0.86$) and fertile grain per panicle ($r = 0.65$) have the positive contribution to grain yield. Highest grain yield was observed in E36, followed by Khau Dau Mali, E26 and E13. E36 appeared with lowest plant height and it also produced highest number of fertile tillers. After evaluation of yield components four genotypes namely E36, Khau Dau Mali, E26 and E13 were selected as outstanding genotypes, which can be used as potential breeding materials for Malaysian tropical environment.

Keywords: Aromatic rice, Yield, Yield component, Tropical environment**Introduction**

Rice is the major food of most Asian countries and aromatic rice varieties are playing a vital role in global rice trading. Major feature of these aromatic rice varieties is aroma which is being appreciated by many people and represents a high value added trait (Dela Cruz and Khush, 2000). So, rice needs attention toward improvement in its cooking qualities as well as several biochemical and morphological characteristics (Golam et al., 2004). The demand for aroma rice is increasing day by day. Unfortunately, the aromatic rice often has undesirable agronomic characters, such as low yield, susceptibility to pests and diseases, and strong shedding (Bermer and Hoff, 1986). The agronomic value of a variety depends on many characteristics (Huang et al. 1991) and the most important characteristics are high yielding ability, resistance to diseases and pests, resistance to undesirable environmental factors and high quality of the products. But, the final aim is to increase the grain yield of rice (Swaminathan, 1999). Rice grain yield is determined by several agronomic characters such as heading days, days to maturity, grain filling period, number of fertile tiller, number of fertile grain per panicle, panicle length, 1000 grain weight and plant height (Halil & Necmi, 2005). The number of fertile tiller and number of grains per panicle can be determined at vegetative and reproductive phase, respectively. The weight of 1000 grain which is important trait is normally determined during the ripening phase. Larger number of tillers can be expected at longer vegetative phase. But, the space available or optimum growth will limit the

number of tillers which produce panicles. In determining the number of panicles the maximum tiller-number stage is the most important stage (Wang et al., 2007). Yield is a quantitative trait, greatly influenced by environmental fluctuations. Study on yield contributing characters assumes greater importance of fixing up characters that influence yield (Prasad et al., 2001; Kole and Hasib, 2008). A statistical analysis has been used to measure the mutual relationships between various characters and yield improvement. Genotypic evaluation of yield components can identify their relationship with grain yield in aromatic rice and the information of these relationships can be helpful to find superior aromatic rice genotypes (Tahir et al., 2002). In the present study, we tried to evaluate the extent of genetic variability of several diverse high yielding aromatic rice genotypes for yield contributing traits and to find out the correlation between yield and yield contributing traits.

Results and discussion***Genotypic variation in agronomic characters***

A significant difference (5% level) was observed in all agronomic traits among the genotypes. Highest coefficient of variation observed in grain yield/plot followed by number of fertile tillers, fertile grains/panicle and grains/panicle. Number of tillers, grain filling period, 1000 grain weight, panicle length, plant height and heading days showed

moderate values for coefficient of variation. The lowest coefficient of variation was days to maturity (Table 3).

Grain yield per plot

The genotypes were significantly different for this trait at 1% level (Table 3). Coefficient of variation and coefficient of determination (R^2) for grain yield/plot were 3.62 % and 0.49 (Table 4). Higher coefficient of variation was recorded for grain yield/plot (Kole and Hasib 2008). Grain yield/plot ranged from 1.38 to 3.8 kg (Table 4). Minimum grain yield per plant was recorded in MRQ50, while maximum was recorded by E36.

Days to heading

A significant genetic variation was observed among genotypes in different replications (Table 3). Coefficient of variation and the coefficient of determination (R^2) for heading days were 7.26 % and 0.79, respectively (Table 4). Days to heading ranged from 75 to 94 (Table 4). The minimum days to 70 % heading were observed for genotype E15 while the maximum value was recorded in MRQ50. Weiya et al. (2008) also observed variation in heading days of several genotypes and they identified a regulatory gene responsible for this variation.

Days to maturity

For days to maturity variation was not significant among the tested genotypes (Table 3). Coefficient of variation and coefficient of determination (R^2) for days to maturity were 4.77 % and 0.84, respectively (Table 4). Days to maturity among rice genotypes ranged from 105 to 117 (Table 4). Minimum and maximum days to maturity was observed in E3 and MRQ50, respectively.

Grain filling period

Significant difference was observed for grain filling period in all genotypes. However, this variation was not significant in different replications (Table 3). Coefficient of variation and coefficient of determination (R^2) for grain filling period were 16.95 % and 0.37 (Table 4). Grain filling period ranged from 21 to 30 (Table 4). Minimum grain filling period was observed in MRQ70 while maximum were in 4 genotypes (E36, E11, E14, E15).

Plant height

Analysis of variance for plant height was significantly different among the genotypes at 1% level (Table 3). Coefficient of variation and coefficient of determination (R^2) for plant height were 8.65 % and 0.82, respectively (Table 4). Panicle length displayed moderate coefficient of variation values. Similar result was recorded by Kole and Hasib, 2008. Plant height ranged between 72 cm to 103 cm (Table 4). Minimum plant height were recorded in E36, while maximum height observed in E5.

Number of fertile tillers

Genetic differences were not significant among rice genotypes for tillers per plant (Table 3). Coefficient of variation and coefficient of determination (R^2) for number of fertile tillers were 34.32% and 0.49, respectively (Table 4). The number of tillers per plant ranged from 10 to 20 (Table 4). Minimum and maximum number of tillers observed in MRQ50 and in E36, respectively.

Panicle length

Significant variation was observed in length of panicle among the genotypes at 5% levels (Table 3). Coefficient of variation and coefficient of determination (R^2) for panicle length were 9.54 % and 0.68, respectively (Table 4). Panicle length displayed moderate values of variation coefficient. Kole and Hasib, (2008) also obtained the same results. The data for panicle length ranged 19.30 to 26.77 (Table 4). The minimum panicle length was recorded in E15 while maximum panicle length in E26. Ifftikhar et al. (2009) studied genetic variability for various traits and found that this trait is under the genetic control and could be used in the selection process of some desirable traits.

Fertile grain per panicle

Analysis of variance showed significant genetic variations among genotypes at 1% level in replications and non-significant among all varieties for fertile grains per panicle (Table 3). Coefficient of variation and coefficient of determination (R^2) for fertile grains per panicle were 26.26 % and 0.55, respectively (Table 4). Number of fertile grains/panicle ranged from 65 to 135 (Table 4). The least number of grains/panicle was observed by the genotype E3, while the maximum number for Khau Dau Mali.

1000 Grain weight

Significant variation was not observed among the tested genotypes in replications and among all varieties (Table 3). Coefficient of variation and coefficient of determination (R^2) for 1000 grain weight were 11.55 % and 0.78 (Table 4). The 1000 grain weight ranged from 15.33 g to 31.33 g (Table 4). Minimum 1000 grain weight was recorded in MRQ50, while maximum in E3.

Comparison of agronomic characters

The DMRT comparison of the data presented in Table 4, suggests that aroma rice genotypes show considerable variations in growth and yield characters. The E36, Khau Dau Mali, E26 and E13 were observed as the four top yielders, respectively. The yield potential of these genotypes can be explained based on the higher number of fertile tillers (E36), fertile grain per panicle (Khau Dau Mali and E13) and increased panicle length (E26). Khau Dau Mali is a popular and a well accepted Thai aromatic rice variety. Comparison of agronomic characters of 4 selected outstanding lines along with E11 (with good aroma and kernel elongation ratio), E2 (highest aroma) and two local checks MRQ50 and MRQ72 are presented in Fig 1.

Table 1. Description of 53 rice genotypes

Entry No.	Designation	Cross	Origin
1	E1 (88023-RE)	Unknown	CIAT
2	E2 (CT9882-16-4-2-3-2P-M)	Unknown	CIAT
3	E3 (H013-5-3-B4)	Unknown	ARGENTINA
4	E4 (H014-1-1-B2)	Unknown	ARGENTINA
5	E5 (IR 60080-46A)	IR 47686-08-4-3/CT 6516-21-4-4	IRRI
6	E6 (IR 74)	IR 19661-131-1-2/IR 15795-199-3-3	IRRI
7	E7 (IR 77734-93-2-3-2)	NSIC RC 148/PSB RC 18//NSIC RC 148	IRRI
8	E8 (IR 77736-54-3-1-2)	NSIC RC 148/PSB RC 64//NSIC RC 148	IRRI
9	E9 (IR 78006-55-2-3-3)	IR 67406-6-3-2-3/IR 72860-80-3-3-3	IRRI
10	E10 (IR 78537-32-1-2-10)	IR 65610-38-2-4-2-6-3/IR 60912-93-3-2-3-3	IRRI
11	E11 (IR 78554-145-1-3-2)	IR 72861-13-2-1-2/IR 68450-36-3-2-2-3	IRRI
12	E12 (IR 77298-14-1-2)	IR 64 (WH)/ADAY SEL//3*IR64	IRRI
13	E13 (IR 77512-2-1-2-2)	IR 68726-3-3-1-2/IR 71730-51-2	IRRI
14	E14 (IR 77629-72-2-1-3)	IR 71730-51-2/IR 71742-267-3-2	IRRI
15	E15 (M1-10-29 UL)	Unknown	MYANMAR
16	E16 (TOX 3226-5-2-2-2-2)	ITA 235/IR 9828-91-2-3//CT 19	IITA
17	E17 (TOX 3867-19-1-2-3-3)	Unknown	WARDA
18	E18 (WAB 272-B-B-5-H5)	3290/WASC165	WARDA
19	E19 (WAB 99-84)	ITA257/WABUKA	WARDA
20	E20 (WAB 337-B-B-15-H1)	ITA 135/WABC 165	WARDA
21	E21 (WAB 515-B-10 A 1-4)	Unknown	WARDA
22	E22 (WAS 169-B-B-4-2-7)	Jaya / Basmati 370	SENEGAL
23	E23 (WAS 169-B-B-4-2-9)	Jaya / Basmati 370	SENEGAL
24	E24 (WAS 197-B-4-1-22)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
25	E25 (WAS 197-B-4-1-25)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
26	E25 (WAS 197-B-5-2-16)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
27	E27 (WAS 197-B-5-2-5)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
28	E28 (WAS 197-B-6-3-12)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
29	E29 (WAS 197-B-6-3-16)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
30	E30 (WAS 197-B-6-3-2)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
31	E31 (WAS 197-B-6-3-4)	IR 31851-96-2-3-2-1 / IR 66231-37-1-2	SENEGAL
32	E32 (WITA 7=TOX 3440-171-1-1-1-1)	TOX891-212-1-201-1-105/TOX3056-5-1	WARDA
33	E33 (BASMATI 370)	Unknown	PAKISTAN
34	E34 (IR 50)	IR 2153-14-1-6-2/IR 2061-214-3-8-2//IR 2071-625-1-252	IRRI
35	E35 (IR 64)	IR 5657-33-2-1/IR 2061-465-1-5-5	IRRI
36	E36 (IR 72)	IR 19661-9-2-3/IR 15795-199-3-3//IR 9129-209-2-2-2-1	IRRI
37	E37 (PSB RC2= IR 32809-26-3-3)	IR 4215-301-2-2-6/BG90-2//IR 19661-131-1-2	IRRI
38	E38 (PSB RC18=IR51672-62-2-1-1-2-3)	IR 24594-204-1-3-2-6-2/IR 28222-9-2-2-2-2	IRRI
39	E39 (PSB RC64=IR 59552-21-3-2-2)	IR 32809-26-3-3/IR 39292-142-3-2-3	IRRI
40	Ratani Pagal	Land race	Bangladesh
41	Katari Bog	Land race	Bangladesh
42	Khau Dau Mali	Land race	Thailand
43	Gharib	Land race	India/Pakistan
44	Sadri	Land race	Iran
45	Chini Gura	Land race	Bangladesh
46	Kasturi	Land race	India/Pakistan
47	Paheale	Land race	India/Pakistan
48	Tamahonami	Land race	Japan
49	Rambir Basmati	Land race	India
50	Rato Basmati	Land race	India
51	MRQ70	Variety	Malaysia
52	Q50	Variety	Malaysia
53	Q72	Advance line	Malaysia

Correlations analysis

Correlation analysis of characters can be used as tool for indirect selection. Correlation studies help the plant breeder during selection and provide the understanding of yield components. From the result in Table 5, out of eleven characters, only three variables such as number of fertile tillers, grains/panicle and fertile grain/panicle, show positive correlation with the most important character yield. Although negative trend was observed between heading date (HD), days to maturity (DM) and plant height (PH) but they were not correlated. Direct effect of days to flowering and positive indirect effect via days to maturity on grain yield was reported by Prasad et al. (2001), which is against with the present findings. Plant height has no significant correlation with yield. This is in contrast with the previous study of Bai et al. (1992) that presented the positive and significant correlation between plant height and yield. Usually, it is desired that a high yielding type of rice should be of short stature (Singh et al., 2000). However, number of tiller (NT), panicle length (PL) and thousand grain weight (TGW) suppose to show positive correlation with yield. However, no significant correlation observed between the above mentioned characters and yield in this study although their trend was positive. We suggest infertility of grains for lack of correlation. Zia-ul-qwamar et al. (2005) observed negative correlation between productive tillers per plant and fertility percentage. The indirect effects via total grain/panicle and 1000-grain weight were positive but low as compared to other traits. Positive correlation was observed between grain yield per plot (GYP) with grain/panicle (GP), fertile grain/panicle (FGP) and number of fertile tiller (NFT). Fertile tillers per plant exhibited a positive direct effect on grain yield/plot. Positive association of grain yield with productive tillers/plant was also studied by Meenakshi et al. (1999). Total grain per panicle also exhibited a positive direct effect and correlation coefficient with grain yield per plant. Kim et al. (1999) reported positive contribution of total grain towards grain yield, which supports the present finding. Correlation coefficients between different agronomic traits and grain yield have shown in Fig 2.

Association analysis of aroma-kernel elongation ratio

In the present investigation, genotype E11 and Garib performed excellent in aroma (score 3.5-4.0) as well as in kernel elongation ratio (1.2-1.35). In addition, within the total 53 aromatic genotypes, 17 did not produce any aroma. In addition, a significant number of genotypes showed relatively low kernel elongation ratio in this sub-tropical environment. Aroma score such as Rambir Basmati or Rato Basmati is always more than 4.0 in Indian subcontinent (in sub-tropical environment; day night average temperature 22-23°C) and in Malaysian tropical environment (day night average 28 - 30°C) and the score was 2.5 in both genotypes (Faruq et al., 2010). Similar observations were also observed in kernel elongation ratio. In subtropical environment kernel elongation ratio was always observed to be more than 2.0 in Rambir Basmati or Rato Basmati in Malaysian tropical environment. It was 1.1 and 1.05 for Rambir basmati and Rato basmati, respectively (Faruq et al., 2010). This investigation indicated that association of aroma and kernel elongation ratio can be highly influenced by tropical environment.

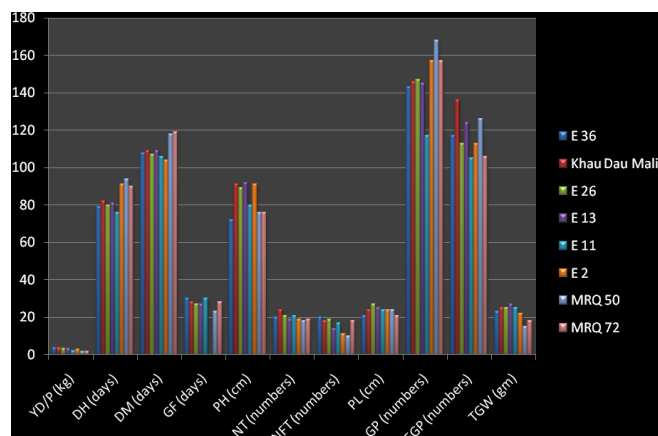


Fig 1. Comparison of agronomic characters of 4 selected outstanding lines along with E11 (with good aroma and kernel elongation ratio), E2 (highest aroma) and two local checks MRQ50 and MRQ72. Indicators: YD/P= Yield/plot, DH= Heading days, DM= Days to maturity, GF= Grain filling period, PH= Plant height, NT=Number of tillers, NFT=Number of fertile tillers, PL= Panicle length, GP= Grain/panicle, FGP= Fertile grain/panicle, TGW=1000 grain weight .

Interestingly, two genotypes (Garib and E11) produced their normal aromatic and Kernel elongation ratio and aromatic expression even in tropical Malaysian Environment. It can be concluded that this expression might be as a result of the influence of dominant nature of some associated genes in these two traits. However, both Garib and E11 were not placed in top 4 yielders, because of their low yield performance in Malaysian tropical environment.

Materials and methods

Plant Materials

A total of 53 rice genotypes including two local check varieties (MRQ50 and MRQ72) were used in this investigation. Twelve of them were globally popular aromatic rice cultivar such as Radhuni Pagal, Katari Bhog, Khau Dau Mali, Gharib, Sadri, Chini Gura, Kasturi, Paheale, Tamahonami, Rambir Basmati, Rato Basmati, Rato basmati. In addition, 39 advanced breeding lines plus 2 local check varieties (MRQ 50 and MRQ 72) were collected from International Rice Research Institute (IRRI) and Malaysia Agricultural Research and Development Institute (MARDI), respectively. A brief description of these 53 genotypes has been provided in Table 1.

Experimental design and growing condition

All of 53 genotypes raised in small plots (1 × 3 m) in three replications with Randomized Complete Block Design (RCBD) at the experimental field at Genetic and Molecular Biology, Institute of Biological Science, Faculty of Science University of Malaya situated at Latitude 3° 06' N and Longitude 101° 39' N with elevation of 60.8 m from sea level in October 2009. The climatic condition was hot and humid with frequent rain (Table 2). Recommended rice production practice of Malaysian Agricultural Research Institute was followed.

Table 2. Meteorological data recorded at the experimental site during the study period.

Months	Average temperature (°C)	Rainfall (mm)	Relative Humidity (%)	Sunshine (h day ⁻¹)
October 09	27.7	64.5 (2.1 mm/day)	75.7	7.4
November 09	26.8	239.1 (8 mm/day)	82.0	6.7
December 09	25.2	242.3 (11 mm/day)	74.9	6.3
January 10	27.4	202.2 (6.5 mm/day)	78.0	6.9
February 10	27.5	192.3 (6.9 mm/day)	73.8	7.0

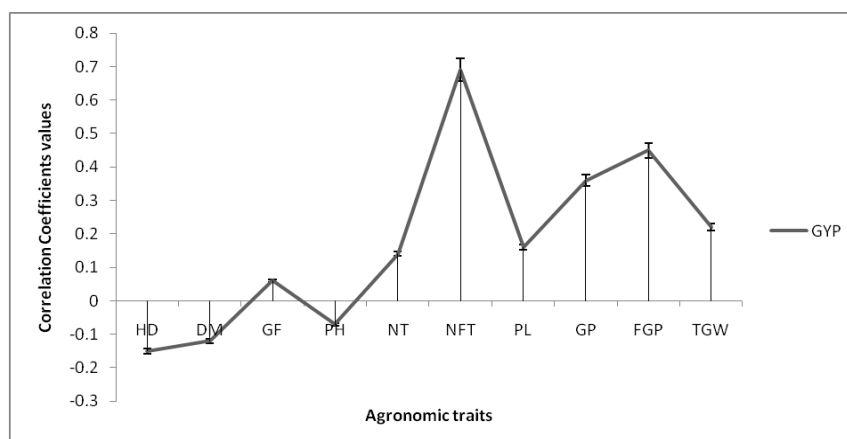


Fig 2. Correlation coefficients between different agronomic traits and grain yield. Indicators: HD= Heading days, DM= Days to maturity, GF= Grain filling period, PH= Plant height, NT= Number of tillers, NFT= Number of fertile tillers, PL= Panicle length, GP= Grain/panicle, FGP= Fertile grain/panicle, TGW= 1000 grain weight, GYP= Grain yield/plot

Data collection of agronomic traits

Data were collected at 70% flowering or heading stages (HD), days to maturity (DM), plant height (PH), number of total tillers (NT), number of fertile tillers (NFT), panicle length (PL), number of grain/panicle (GP), fertile grain/panicle (FGP), 1000 grain-weight and grain yield/plot (TGW). Days to flowering have been recorded as soon as 70% of the panicles appeared. Number of tillers were recorded when grain has set and the total number of fertile panicles emerged by each plant. The plant height was measured from ground level to the top the node (just below the panicle). Panicles were harvested at maturity and individually placed in an envelope. All panicles were taken out of the envelopes and air-dried at room temperature for one week. After that fertility of panicle, 1000 grain-weight and grain yield/plot were estimated.

Aromatic Test (Sensory Test)

Leaf Aromatic Test

To know the level of aromatic nature of each rice genotypes Leaf Aromatic Test (LAT) was conducted. An amount of 0.2 g of leaf samples was taken from each genotype. Leaves were cut into tiny pieces and put into glass petri-plates. 10ml of 1.7% potassium hydroxide (KOH) was added to each of the petri-plates containing the sample and was covered immediately. These petri-plates were left under room temperature for 10 minutes and then opened one by one for aroma test. The contents in each petri-plates was smelt and were scored on 1-4 scale with 1, 2, 3 and 4 corresponding to absence of aroma, slight aroma, moderate aroma, and strong aroma, respectively. Four panels of students and staffs from

Division of Genetics and Molecular Biology, Institute of Biological Science, Faculty of Science University of Malaya were invited to score the aroma in each genotype.

Grain Aromatic Test

Fourty grains of each genotype were soaked in 10ml 1.7% KOH solution at room temperature in a covered glass Petri-plate for about 1 hour. The sample was scored on 1-4 scale with 1, 2, 3 and 4 corresponding to absence of aroma, slight aroma, moderate aroma, and strong aroma, respectively. The same four panels of students and staffs from Division of Genetics and Molecular Biology, Institute of Biological Science, Faculty of Science University of Malaya were invited to score the aroma in each genotype.

Measurement of elongation ratio, proportionate change and actual elongation

Ten measured (length and width) rice grain took into 20 ml glass test tube and soaked for 20 minutes in 5 ml of tap water. After soaking, the test tubes were put into the boil water for around 30 min. When the grains cooked properly test tubes were taken out from boiled water and water inside the test tubes removed. After that cooked grain were kept on a glass plate for few minutes to evaporate extra moisture and then measured the length and width of the cooked grain. Measurements were done through a digital slide calipers. Kernel elongation ratio means the proportionate change of rice grain after cooking. But different research group define it in different way. However, we followed the protocol described by Golam et al. (2004). Length and breadth of 10 kernels were measured before cooking and after cooking also length and width of these same 10 kernels were measured for calculation of actual elongation kernel ratio using the formula

Table 3. Variations of agronomic characters in 53 aromatic rice genotypes

Source of variation	DF	Mean square										
		HD	DM	GF	PH	NT	NFT	PL	GP	FGP	TGW	GYP
Replications	2	167**	172 ^{ns}	6.32 ^{ns}	62*	150 ^{ns}	46**	15*	839*	736*	3 ^{ns}	56.75**
Varieties	53	267 ^{ns}	275 ^{ns}	24.83*	502 ^{ns}	56 ^{ns}	42 ^{ns}	21 ^{ns}	2281 ^{ns}	1651 ^{ns}	48 ^{ns}	30.86 ^{ns}
Mean		83	110	26.99	87	20	14	24	123	100	23	3.38

*indicate significantly different at 5%, **significantly different at 1%, ns: not significant

(Indicators: HD= Heading days, DM= Days to maturity, GF= Grain filling period, PH= Plant height, NT= Number of tillers, NFT= Number of fertile tillers, PL= Panicle length, GP= Grain/panicle, FGP= Fertile grain/panicle, TGW= 1000 grain weight, GYP= Grain yield/plot)

Table 4. Mean comparison of four selected aromatic rice along with another 7 with the best Kernel elongation ratio and aroma performing including 2 local checks through Duncan Multiple Range Test (DMRT)

Genotypes	GYP (kg)	HD (days)	DM (days)	GF (days)	PH (cm)	NFT (number)	PL (cm)	FGP (number)	TGW (gm)
E36	3.80 a	79 f-o	108 e-o	30 a-d	72 o-q	20 a-c	21.37 g-n	117 a-g	22.67 e-i
Khau Dau Mali	3.56 ab	82 d-o	109 e-m	28 a-d	91 e-m	18 a-f	24.23 b-i	135 a	25.33 c-g
E26	3.40 a-c	80 e-o	107 g-o	27 a-d	89 f-n	19 a-e	26.77 b-d	113 a-g	24.67 c-h
E13	3.32 a-c	81 d-o	109 e-n	27 a-d	92 e-l	14 a-h	25.07 b-h	124 a-c	26.67 b-f
E15	3.24 a-d	75 j-o	105 j-p	30 a-d	85 h-o	18 a-f	19.30 k-n	98 a-g	22.00 e-i
E14	3.16 a-d	77 h-o	107 g-o	30 a-d	83 h-o	19 a-d	25.53 b-g	104 a-g	24.67 c-h
E11	2.92 a-e	76 i-o	106 i-p	30 a-d	80 j-q	17 a-g	23.73 d-l	105 a-g	24.67 c-h
E38	2.91 a-f	88 b-h	116 c-h	29 a-d	78 j-q	16 a-g	26.03 b-f	133 ab	22.00 e-i
E3	2.90 a-f	79 f-o	105 j-p	26 a-d	96 c-i	15 a-h	20.73 h-n	65 g-i	31.33 ab
E5	2.84 a-f	78 g-o	107 h-p	29 a-d	103 a-e	12 b-h	22.59 d-n	127 a-c	28.00 a-d
E37	2.82 a-f	88 b-h	114 e-j	26 a-d	73 o-q	14 a-h	22.27 d-n	119 a-e	22.00 e-i
MRQ 50	1.94 a-h	94 bc	117 c-g	23 b-d	76 m-q	10 c-h	24.83 b-h	126 a-c	15.33 kl
Q72	1.38 d-h	87 b-k	108 f-o	21 d	75 n-q	11 b-h	24.23 b-i	80 b-h	18.33 i-k
Range	1.38-3.8	75-94	105-117	21-30	72-103	10-20	19.30-26.77	65-135	15.33-31.33
R ²	0.49	0.79	0.84	0.37	0.82	0.49	0.68	0.55	0.78
CV	3.62	7.26	4.77	16.95	8.65	34.32	9.54	26.26	11.55
F-value	10.02	1.19	8.88	3.72	1.88	2.49	2.41	1.79	7.36

Mean followed by the same letter in a column are not significantly different from each other at 0.05 % probability level. Indicators: HD= Heading days, DM= Days to maturity, GF= Grain filling period, GYP= Grain yield/plot, PH= Plant height, NFT= Number of fertile tillers, PL= Panicle length, FGP= Fertile grain/panicle, TGW= 1000 grain weight

formula described by Sood et al., (1983).

$$PC = \frac{L_f/B_f - L_o/B_o}{L_o/B_o}$$

where, L_f, B_f are mean length and width of the 10 kernel after cooking; L_o, B_o: mean length and breadth of the 10kernel before cooking.

Statistical analysis

Data were analyzed using SAS 9.2 (2008) software and Microsoft Excel. Analysis of variance was used to test the significance of variance sources, while DMRT test (p=0.05) employed to compare the differences among treatment means. The correlation coefficient analysis was conducted to find the relationship of different attributes.

Conclusion

In this investigation several basmati type rice genotypes were studied. None of them performed better in term of aroma score, kernel elongation and yield related traits. It might be due high temperature during their grain filling and ripening stage. All of the 4 selected top yield genotypes such as E36 and E13 had been developed at IRRRI, Philippines in the tropical environment. Also, E26 developed in Senegal and Khau Dau Mali is a cultivar originated from Thailand. However, their aroma performance and kernel elongation were moderate. Correlation analysis revealed that three agronomic traits such as number of fertile tillers (0.69), grain per panicle (0.86) and fertile grain per panicle (0.65) have the positive contribution to grain yield. Penicle length, 1000-grain weight, grain filling period suppose to have positive correlation with yield, but in this investigation superior

Table 5. Correlation coefficients among the agronomic traits using genotypes means

	HD	DM	GF	PH	NT	NFT	PL	GP	FGP	TGW	GYP
HD	1.00										
DM	0.90**	1.00									
GF	-0.25 ^{nc}	0.19 ^{nc}	1.00								
PH	-0.01 ^{nc}	-0.05 ^{nc}	-0.10 ^{nc}	1.00							
NT	0.15 ^{nc}	0.17 ^{nc}	0.03 ^{nc}	0.04 ^{nc}	1.00						
NFT	-0.24 ^{nc}	-0.16 ^{nc}	0.17 ^{nc}	-0.09 ^{nc}	0.34*	1.00					
PL	0.31*	0.18 ^{nc}	-0.29 ^{nc}	0.30 ^{nc}	0.18 ^{nc}	0.06 ^{nc}	1.00				
GP	0.32*	0.32 ^{nc}	-0.02 ^{nc}	-0.03 ^{nc}	0.07 ^{nc}	0.13 ^{nc}	0.38*	1.00			
FGP	0.22 ^{nc}	0.21 ^{nc}	-0.03 ^{nc}	0.03 ^{nc}	0.12 ^{nc}	0.18 ^{nc}	0.37*	0.86**	1.00		
TGW	-0.22 ^{nc}	-0.20 ^{nc}	0.05 ^{nc}	0.04 ^{nc}	-0.22 ^{nc}	-0.08 ^{nc}	-0.12 ^{nc}	-0.15 ^{nc}	-0.04 ^{nc}	1.00	
GYP	-0.15 ^{nc}	-0.12 ^{nc}	0.06 ^{nc}	-0.07 ^{nc}	0.14 ^{nc}	0.69*	0.16 ^{nc}	0.36*	0.45*	0.22 ^{nc}	1.00

*=positive correlation, **=highly positive correlation, ^{nc}= no correlation

Indicators: HD= Heading days, DM= Days to maturity, GF= Grain filling period, PH= Plant height, NT= Number of tillers, NFT= Number of fertile tillers, PL= Panicle length, GP= Grain/panicle, FGP= Fertile grain/panicle, TGW= 1000 grain weight, GYP= Grain yield/plot

genotypes with these traits did not show reliable number of tillers, appeared with slack panicle and sterility. So they did not show any positive correlation with. In term of yield amount, E36, Khau Dau Mali, E26 and E13 were identified as outstanding genotypes. The gathered information can be useful for rice improvement research and the selected rice genotypes can be used as a potential breeding materials in the future rice research in Malaysia as well as other tropical countries.

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