

## Inheritance of kernel elongation in F<sub>2</sub> rice populations crossed between Indian rice basmati 370 and selected Malaysian rice varieties

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### Article history:

Received: 22 July 2020

Received in revised form: 29 September 2020

Accepted: 9 December 2020

Available Online: 20 December 2020

### Keywords:

Basmati 370,

Grain elongation ratio,

Heritability,

Malaysian rice variety,

Physical traits

### DOI:

[https://doi.org/10.26656/fr.2017.4\(S5\).002](https://doi.org/10.26656/fr.2017.4(S5).002)

### Abstract

The speciality rice variety such as Basmati and Jasmine maybe not be very suitable to plant under the Malaysian climate because the growth may be influenced by the changes in the environmental conditions causing the changes of its physical and chemical characters and results in low yield. Thus, an attempt was made through a hybridisation program among selected Malaysian rice varieties consist of MRQ50, MRQ74, MRQ76, MR219, Mahsuri Mutant, and Mahsuri Mutant 98 with Indian traditional rice, Basmati 370 with the main objectives, to compare the kernel elongation ratio of each cross and to determine the potential and suitable combination among crosses rice for further evaluation program. The results of the study indicated that among parental lines, Basmati 370 posed the highest elongation ratio 2.00 which revealed its speciality elongation trait of cooked rice. A comparison between crosses, rice cross between Basmati 370 and Mahsuri Mutant 98 showed the highest elongation ratio with the value 2.12 and the lowest elongation ratio of about 1.96 was found in rice cross between Basmati 370 and MR219. However, all hybridised rice poses a value of elongation ratio more than 1.6 which is considered good kernel elongation. The segregation pattern of all crosses also posed a ratio 3:1 whereas three is low elongation and one is high elongation which demonstrated the Mendelian inheritance of monogenic cross. The results obtained from this study could contribute to the existing literature on speciality rice production in Malaysia and beneficial for future rice quality improvement program.

## 1. Introduction

Rice or its scientific name *Oryza sativa* belonging to the Poaceae family and is well-known as the main staple food for most of the world's populations (Savitha and Ushakumari, 2016). To meet the growing rice demand, researchers have undertaken numerous studies to produce new varieties to improve existing rice varieties. Among the studies that have been done is the production of high-quality rice (Cheng *et al.*, 2017), high yield varieties (Nirmaladevi *et al.*, 2015), agronomic traits improvements (Seth *et al.*, 2018), resistant to pest and disease such as blast (Mehta *et al.*, 2019), brown planthopper (BPH) (Mohamad Bahagia *et al.*, 2011) and adaptation to diverse environmental conditions.

Presently, due to changes in lifestyle, eating habits, income, and health concerns, consumers preferred high-quality rice with special attributes such as pleasant fragrant, long-grain, intermediate amylose, low glycemic index, and so on (Nirmaladevi *et al.*, 2015). Consumers usually classify rice quality based on the grain appearance, size, and shape of the grain, behaviour upon cooking, taste, tenderness, and flavour of cooked rice (Nadaf *et al.*, 2016). Verma *et al.* (2015) suggested that rice quality can be grouped based on physical, chemical, cooking, and nutritional quality. Physical properties include kernel size, shape, milling recovery, degree of milling, grain appearance (Dela Cruz and Khush, 2000), kernel length, kernel breadth, and kernel length/breadth ratio (Reddy *et al.*, 2012) while physicochemical

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properties refer to amylose content, gel consistency and gelatinize temperature (Chemutai *et al.*, 2016).

Grain elongation which was determined through cooked kernel is the most important quality traits which differentiate the highly valued aromatic rice from the other rice types (Golam *et al.*, 2010). However, the preferences for grain size and shape varied within different cultures and regions (Suwannaporn *et al.*, 2008). Some cultures prefer short and bold grains, while others prefer medium and long slender grains. For example, people in Asia preferred on cooking and eating rice that is determined by the properties of starch that makes up to 90% of milled rice (Nadaf *et al.*, 2016) while in Japan, short-grain with sticky texture is preferred by Japanese for making sushi (Suwannaporn *et al.*, 2008).

The character of grain elongation is a major component of the grain quality which can be found in Basmati rice types. The world price for Basmati rice showed the highest value in the year 2008 at USD1,077/metric ton (FAO, 2012). Basmati rice is important in economics of India, Pakistan and Thailand and also preferred by people in India, Pakistan and the Middle East (Shahzadi *et al.*, 2018). In Malaysia, there is an increasing demand for quality rice in domestic markets. Nowadays, Malaysia has released more than 40 rice varieties including aromatic rice such as MRQ50, MRQ74, MRQ76 and MRQ88. Most of the released varieties have special characteristics such as high yield and resistance to pest and disease (Jamal *et al.*, 2014) and so on. However, some of the aromatic rice in Malaysian reported has undesirable agronomic characters such as low yield and susceptible to pest and disease (Golam *et al.*, 2011). Introducing other speciality rice varieties under the Malaysian climate may not be very suitable because some growth of the speciality rice may be influenced by the changes in the environmental conditions thus would result in low yields. Besides that, crop improvement in rice depends on the magnitude of genetic variability and the extent to which the desirable genes are heritable (Savitha and Ushakumari, 2014). Moreover, grain size and shape are also among the main important quality trait considered by breeders before releasing new varieties (Shamim *et al.*, 2017). Both private and government industries are always working together to ensure a continuous supply of high-quality rice for farmer use although sometimes they have to face problems related to unpredictable weather conditions which may reduce the quality seed supplied (Mohd Shukor *et al.*, 2018).

Cheng *et al.* (2014) stated that the development of rice is quite challenging without considering grain

quality improvement especially to meet preferences of wealthier consumers living in well-developed countries. To meet consumer and industry preferences as well as market demand, improving milling, cooking, eating and processing qualities is crucial in quality rice breeding instead of yield performance (Nirmaladevi *et al.*, 2015). Therefore, an investigation has been conducted to observe the segregation pattern of cooked kernel elongation in F<sub>2</sub> generation of six Basmati rice crosses. The information gathered from this study is beneficial for future rice quality improvement and varietal development as well as to ensure the Malaysians achieve a 100% target of rice self-sufficiency level (SSL).

## 2. Materials and method

### 2.1 Source of plant materials

The study on thirteen rice genotypes comprised of seven varieties viz. Basmati 370, MR219, Mahsuri Mutant, Mahsuri Mutant 98, MRQ50, MRQ74, MRQ76 and six F<sub>2</sub> rice generation has been conducted at the Malaysian Agricultural Research and Development Institute (MARDI). Two hundred plant representing F<sub>2</sub> generation of each cross were analyzed to evaluate segregation pattern of grain elongation in the cooked kernel.

### 2.2 Sample preparation

About 135 g of paddy at moisture content 13-14% were weighed using an analytical balance. Then, it was passed through Satake Rice Dehusker (Satake Co. Ltd. Tokyo, Japan) for milling process and after that were polished using Satake Rice Polisher (Satake Co. Ltd. Tokyo, Japan) to obtain milled rice. Unbroken polished rice grains were used for grain quality evaluation (Bhattacharya, 2011).

### 2.3 Determination of elongation ratio in F<sub>2</sub> rice population

Randomly, 200 pieces of head rice from each cross were selected and individually measured its length and width using Mitoyo Digital Caliper. The length/width ratio was recorded and classified based on the Standard Rice Evaluation System described by IRRI (2002) for comparisons of physical properties. The kernel elongation ratio of F<sub>2</sub> seeds was determined according to the procedures described by Sood and Siddiq (1980) with some minor modification.

### 2.4 Statistical analysis

The data were analysed by analysis of variance (ANOVA) using SPSS software version 23. Mean comparisons were made using Duncan New Multiple

Range Test (DNMRT) and means were statistically significant when  $P < 0.05$ . Frequency distribution was calculated from the data recorded and the chi-square analysis for elongation ratio among  $F_2$  populations was calculated at 95% of a confidence interval.

### 3. Results and discussion

Table 1 presents the physical characteristics of parental lines and Table 2 shows the mean and range of kernel elongation of parental lines and six rice crosses used in the study. Among all varieties, Basmati 370 exhibited the best in grain length (7.05 mm) and grain length after cooked (14.07 mm). Four types of Malaysian rice genotypes consist of three aromatic rice MRQ50, MRQ74, MRQ76 and non-aromatic rice MRQ219 showed grain length more than 6.61 mm which is considered as long-grain while Mahsuri Mutant and Mahsuri Mutant 98 showed grain lengths of 6.31 mm and 6.22 mm respectively which indicated medium in size. The elongation ratio (ER) in all rice genotypes consist of aromatic and non-aromatic rice ranged from 1.68 to 2.00. The highest ER was found in Basmati 370 with a value 2.00 and length to width ratio (LBAC) with a value 3.72. The lowest ER was found in Mahsuri Mutant 98 and MRQ74 with value 1.68 respectively. A study conducted by Srivastava and Jaiswal (2013) also reported high ER in Basmati 370 (1.90) with LBAC ratio value 3.7 and they concluded that Basmati rice types exhibited excellent grain and physico-quality characteristics after cooking. Rosniyana *et al.* (2010) found that Maswangi rice or MRQ74 showed ER value of 1.67 and they stated that ER of rice below than two showed that the rice did not elongate during cooking.

Among all crosses, B70/MM showed the highest ER (2.12) while the lowest ER was found in cross B370/219 (1.96). A study conducted by Golam *et al.* (2004) showed that Mahsuri mutant possessed the highest mean ER (2.14) as compared to Mahsuri (1.7) and 9192 (1.92). However, the hybridisation between Mahsuri Mutant

with Mahsuri and 9192 produced  $F_2$  generation with the mean elongation ratio more than two. The Mendelian ratio of six crosses was presented in Table 3. The results indicated that segregation pattern in grain elongation present and absent in  $F_2$  is 3:1. The chi-square value in all crosses lesser than critical chi-square value at a degree of freedom one.

Table 2. Mean and kernel elongation range of parents and  $F_2$  segregation

Parent / crosses	Mean	Range	Variance	CV (%)
MRQ50	1.76	1.75 - 1.77	0.00	0.4
MRQ74	1.68	1.67 - 1.69	0.00	0.42
MRQ76	1.84	1.83 - 1.88	0.00	1.13
MR219	1.78	1.76 - 1.80	0.00	0.85
MM	1.76	1.68 - 1.79	0.00	2.44
MM98	1.68	1.68 - 1.69	0.00	0.27
B370	2	1.98 - 2.02	0.00	0.9
B370/MRQ50	2.01	1.69 - 2.33	0.02	6.52
B370/MRQ74	2.1	1.73 - 2.53	0.02	7.3
B370/MRQ76	1.99	1.54 - 2.37	0.03	8.25
B370/MR219	1.96	1.55 - 2.44	0.03	8.9
B370/MM	2.12	1.63 - 2.61	0.03	8.65
B370/MM98	2.04	1.54 - 2.53	0.05	10.77

The study indicated that Basmati 370 exhibits its special features compared to other rice genotypes even though it is planted in the Malaysian environment. Rice grain elongation typically influenced by the environmental conditions, especially during ripening. The temperature of 25°C at day time and 21°C at night during ripening stage has been found to have a favourable effect in the aroma as well as kernel elongation where the maximum elongation in matured grains was reported at this temperature (Singh *et al.*, 2000). Nevertheless, Golam *et al.* (2010) found that two global popular aromatic rice, E11 and Garib possess its normal aromatic and kernel elongation ratio even planting in Malaysian environment and this may be due to the presence of the dominant gene in these two traits. Basmati 370 was recognized as traditional rice and its special characteristics become the benchmark in

Table 1. Physical characteristics of parental lines

Variety	GL (mm)	GW (mm)	LWBC	GLAC (mm)	GWAC (mm)	LWAC
MRQ 50	6.71 <sup>cd</sup>	1.65 <sup>a</sup>	4.07	11.82 <sup>c</sup>	2.24 <sup>a</sup>	5.29
MRQ74	6.60 <sup>b</sup>	1.77 <sup>b</sup>	3.72	11.09 <sup>b</sup>	2.37 <sup>c</sup>	4.69
MRQ76	6.68 <sup>bc</sup>	1.94 <sup>de</sup>	3.44	12.34 <sup>c</sup>	2.63 <sup>d</sup>	4.69
MR219	6.78 <sup>d</sup>	1.90 <sup>c</sup>	3.56	12.04 <sup>d</sup>	2.88 <sup>f</sup>	4.18
MM	6.31 <sup>a</sup>	2.02 <sup>d</sup>	3.13	11.08 <sup>b</sup>	2.84 <sup>ef</sup>	3.90
MM98	6.22 <sup>a</sup>	2.02 <sup>d</sup>	3.09	10.46 <sup>a</sup>	2.82 <sup>c</sup>	3.77
B370	7.05 <sup>e</sup>	1.90 <sup>c</sup>	3.72	14.07 <sup>f</sup>	2.29 <sup>b</sup>	6.14
CV (%)	4.09	7.00		9.34	10.19	

Values of mean with the same superscript within the column are not significantly different at 0.05 level according to Duncan's New Multiple Range Test (DNMRT).

GL: Grain length; GW: Grain width, LWBC: Length to width ratio of rice before cooked, GLAC: Grain length after cooked, GWAC: Grain width after cooked, LWAC: Length to width ratio of cooked rice.

Table 3. The segregation in F<sub>2</sub> populations of six crosses.

Cross	Observed			Expected ratio	Expected		$\chi^2$
	Total	Low	High		Low	High	
Basmati 370 x MRQ50	200	150	50	3:01	157	43	1.31
Basmati 370 x MRQ74	200	150	50	3:01	152	48	0.11
Basmati 370 x MRQ76	200	150	50	3:01	142	58	1.71
Basmati 370 x MR219	200	150	50	3:01	153	47	0.24
Basmati 370 x MM	200	150	50	3:01	147	53	0.24
Basmati 370 x MM98	200	150	50	3:01	161	39	3.23

Note: The data were subjected to chi square goodness of fit test against the Mendelian ratio 3:1.

breeding for quality trait improvement. Basmati 370 has been widely used in hybridization program India and resulted in the release of some promising varieties with improved traits such as Haryana Basmati-1 (Panwar *et al.*, 1991), Ranbir Basmati, Kusuma, Basmati 385 and many more. Breeding Basmati 370 with other types of rice varieties are capable of producing new varieties that inherit the special characteristics of basmati (Bradshaw, 2016). Besides quality traits, the consideration towards various characteristics contributed to yield performances are also very important in selecting high yield promising variety (Nur Suraya *et al.*, 2018). The mechanism of the specific varieties also needs to be fully understood to achieve the breeding objective. Besides that, to meet sustainable manner in rice production, the collaboration between breeders and governments is needed to meet consumer preferences in the twenty-first century (Hanafiah *et al.*, 2020).

#### 4. Conclusion

The study had provided beneficial knowledge and information on the characteristics of F<sub>2</sub> populations that can be used for future rice improvement programs. Among the crosses, it can be concluded that the characteristics of long and slender grain found in parents Basmati 370, MRQ50, MRQ74, MR219, and Mahsuri Mutant showed that they can be used as parental lines in producing rice with long grain. The progenies of each crosses can be further evaluated to understand the mechanism of heritability

#### Conflict of interest

The authors declare no conflict of interest.

#### Acknowledgments

The authors wish to acknowledge the Malaysian Agricultural Research and Development Institute (MARDI) Seberang Perai, Penang for the facilities provided for this research and Ministry of Higher Education (MOHE) for funded through Fundamental Research Grant Scheme (FRGS/1/2016/ WAB01/UITM/03/2).

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