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Traits Performance and Heterosis Estimation in F_1 Rice Generations Crossed between Basmati 370 and Selected Malaysian Rice Varieties

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ABSTRACT

The assessment in 13 rice genotypes that consisted of MR219, Mahsuri Mutant, Basmati 370, MRQ76, MRQ74, MRQ50, and Mahsuri Mutant 98 as parental lines, and six rice combinations were conducted in MARDI Seberang Perai, Penang. This assessment analyzed the variability among parental lines and F_1 generations, including heterosis mechanism in rice combinations for the identification of better traits related to grain quality and yield. The parental lines, Basmati 370, MRQ50, MRQ74, MR219 and Mahsuri Mutan have long and slender grains. This characteristic is desired in breeding for grain quality traits. It was found that cross Basmati 370 × MR219 showed the best performances in most of the grain quality traits with grain shape >3 mm. Besides that, it also showed significant differences as compared to other. The findings included that the cross had the highest value in plant height (120.2 cm), panicle length (30.4 cm), thousand grain weight (26 g), and flag leaves length (42.4 cm). Pearson correlation analysis showed that strong positive relationship and a significant association were found between traits panicle fertility and tiller number (0.843), and traits milled grain length and length/breadth ratio (0.768). Heterosis analysis showed that RU14387 posed positive heterosis value in most of the traits studied except for the panicle fertility and filled grain per panicle traits when compared with better parent. RU14387 also recorded

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positive heterosis over standard check variety in length/breadth ratio and milled grain length compared to standard check variety. The information gained from this study can be a great foundation for future rice development study of rice lines with better grain quality and high yield.

Keywords: Basmati 370, grain quality, heterosis, rice breeding

INTRODUCTION

Rice is the most important food crop consumed by more than four billion people throughout the world and the demand has been increased continuously in the world population (Bouman & Reyes, 2017). Currently, changes in lifestyle, education, income, eating habits, healthy diets concerns, and taste preferences have caused the trend in rice production and consumption to change and most of the rice producers and consumers have also demanded on rice with higher-quality traits. According to Nirmaladewi, Padmavathi, Suneetha and Babu (2015), to meet consumer and industry preferences as well as market demand; improving milling, cooking, eating, and processing qualities is crucial in rice breeding for quality as well as high-yielding performance. Sran, Pandey and Kumar (2016) stated that the improvement of rice quality could be achieved through heterosis breeding.

Heterosis is defined as the superiority of the first generation (F_1) hybrids over its parents (Virmani et al., 1997) and the occurrence of heterosis is determined as a success and a great achievement in rice breeding program (Tiwari, Pandey, Giri, & Dwivedi, 2011). Heterosis in rice was first discovered by Jones in 1926 who found the great performances of grain yield and culm in F_1 population compared to their parental lines. The values of heterosis can be observed through hybrid performances over their mid-parents' (MPH), better parents (BPH), and standard check variety (STH) (Rahimi, Rabiei, Samizadeh, & Kafi Ghasemi, 2010; Yildrim, Gezginc, Paksoy, 2014). The value of heterosis either positive or negative depends on the degree of selected parental lines (Rahimi et al., 2010; Bhatti, Pandey, & Singh, 2015) and both indicate significant information of preferred traits for quality and gene action that is beneficial for rice development program (Raju, Kumar, Raju, & Srijan, 2014; Reddy, Raju, Srayani, Reddy, & Reddy, 2012). Rahimi et al. (2010) reported significant heterosis in all traits studied as compared to standard check variety Dorfak, and the highest heterosis value was found in grain yield. High degree of heterosis over standard check variety in different quality traits of some cross combinations have been claimed by Sran et al. (2016). The finding showed the highest value in general combining ability (GCA) and served as a guidance in the determination of suitable parents as good combiners for quality traits. Venkanna, Raju, Lingaiah and Rao (2014) have revealed significant positive heterosis for yield and grain quality traits in crosses JGL 3844 × JGL 11690, Erramallelu × LGL 11690, BPT 5204 × JGL 11690, and MTU 1001 × JGL 1798. The same findings were also claimed by Krishna et al. (2016) in crosses NLR 145 × Sumathi, Akshyadhan × Pusa 1122, and RNR 2354 × Basmati 370. In contrast, Faiz, Sabar, Awan, Tjaz and Manzoor (2006) revealed negative value in heterobeltiosis in plant height and spikelets sterility that is desirable for those particular traits. However, the study also reported positive heterobeltiosis and in desirable traits such as grain yield, number of productive tillers and number of filled panicles. The highly significant negative value also was found by Ariful, Khaleque, Golam, Khaliq and Mannan (2015) in plant height of five male plants that were important for developing dwarfing characters.

Consumers mostly described high-quality rice based on grain appearance, shape, size, cooking properties, flavor, and taste. Rice with pleasant aroma, short or long slender grain normally fetched higher prices in market. Kernel length, kernel width, and kernel length/breadth ratio are among the important components in physical quality traits (Reddy et al., 2012). Based on the standard rice classification system by the International Rice Research Institute (IRRI), length of rice grain ranges from 5.51-6.60 mm is considered as medium grain, while a range of 6.61-7.5 mm is considered as long grain (Cruz & Khush, 2002). Likewise, rice with grain shape less than two mm (<2 mm) is considered as bold grain while grain-shaped rice ranged from 2.1-3.0 mm and more than 3 mm (>3.0 mm) are classified as medium and slender shape. Grain shape is determined from the proportion of length to width of grain (Graham, 2002). Although Malaysia has released more than 40 rice varieties including special variety with characteristic pleasant aroma, long grain, high yield and resistance to pest and diseases (Jamal, Kamarulzaman, Abdullah, Ismail, & Hashim, 2014), but some of the variety, such as aromatic rice is reported to have undesirable agronomic characters such as low yield and susceptible to pest and disease (Golam et al., 2011). Thus, exploitation through heterosis breeding is one of the alternatives to improve crop performances. Nevertheless, the studies on heterosis breeding for grain quality improvement among Malaysian rice varieties with other specialty variety are still lacking. Therefore, by means to provide significant information and essential knowledge for future grain quality and yield traits improvements as well as varietal development, the breeding and study on heterosis were conducted among selected Malaysian rice varieties with Indian traditional rice, Basmati 370. Basmati 370 was selected as parent due to its pleasant aroma and elongation of cooked rice. The main objective of this study was to analyze the variability in grain quality and yield traits among parental lines and F_1 generations including heterosis mechanism in rice combinations for identification of better traits related to grain quality and yield.

MATERIALS AND METHODS

Plant Materials and Hybridisation

The experiment was conducted over two seasons (main season and off season) at Malaysian Agricultural Research and

Development Institute (MARDI), Seberang Perai, Penang (Latitude 05° 21'N and Longitude 100° 24'E). Parental lines consist of local Malaysian rice varieties: MR219, MRQ76, MRQ74, MRQ50, Mahsuri Mutant 98, Mahsuri Mutant, and traditional Indian rice Basmati 370 (B370) were used in this study. The hybridization among selected varieties was conducted under closed area according to the method described by Jenning, Coffman and Kauffman (1979). Crosses plants were kept under glasshouse with good exposure to sunlight. The F_1 seeds were harvested when the flag leaves turned yellowish and reached maturity stage, and the seeds were kept in a cool temperature 4°C to maintain its viability before use for the next experiment. Hybridization programs produced six F_1 rice combinations named as RU14701, RU14702, RU14703, RU14704, RU14705, and RU14387 (Table 1).

Table 1
Rice combinations and its F_1 generation

Female		Male	F_1 Generation
Basmati 370	×	MRQ50	RU14701
Basmati 370	×	MRQ76	RU14702
Basmati 370	×	MRQ74	RU14703
Basmati 370	×	Mahsuri Mutan	RU14704
Basmati 370	×	Mahsuri Mutan 98	RU14705
Basmati 370	×	MR219	RU14387

Raising of F_1 Generations

The F_1 seeds were placed in petri dishes and heated in an oven for 24 h at a temperature of 37.5°C. Then, distilled water with a few drops of fungicide was added and the seeds were kept for 48 h. After that, distilled water was removed and seeds were allowed to germinate under room temperature. Germinated seeds were then sown in the glasshouse. Rice seedling at 25 days old was then transplanted into field plots with a total area 101.31 m^2 at a spacing of 0.3 m × 0.3 m between rows and plants, and 0.5 m between plots and replicated in a randomized complete block design with three replicates. Fifty seedlings of each parental lines and F_1 plants were planted with single seedling per hill in each row. Fertilizers were applied in experimental plot according to the standards rates stated by MARDI (2002) whereas NPK (17.5:15.5:10) and urea (46% N) were applied at 15 days and 30 days after planting at the rates of 2.55 kg and 0.85 kg, respectively. NPK (17:3:20:2:0.8 S+TE) was applied at 45 days and 70 days at the rates of 1.6 kg, respectively.

Grain quality traits consisted of milled grain length (MGL), milled grain width (GW), length/breadth ratio (LB), and filled grain per panicle (FGP) and selected yield component, such as heading days at 70% (HD), plant height (PL), panicle length (PL), fertile panicle per plant (FP), tiller number per plant (TN), flag leaf length (FLL), flag leaf width (FLW), weight of thousand rice grains (TGW) on 10 randomly selected plants were evaluated according to standard evaluation system rice described by Scshu

(1988) and IRRI (Cruz & Khush, 2002). The harvested seeds that represent F_2 generation were kept under 4°C for future analysis.

Statistical Analysis

The data was analyzed 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 $P<0.05$. Interrelationships among traits studied were made using Pearson correlation coefficient at level 0.01 and 0.05 while the coefficient of variation was calculated by divided value of standard deviation with a mean of each trait. Heterosis was expressed as an increase or decrease of percentage in the performances of F_1 generations and was calculated based on the differences of F_1 generations from mid-parent (MPH), better parents (BPH), and standard variety (STH) following the method described by Virmani et al. (1997). MRQ76 was used as a standard check variety for quality traits studied in this research.

Mid parent heterosis (MPH)
$= [(F_1 - M.P)/M.P] \times 100$

Better parent heterosis (BPH)
$= [(F_1 - B.P) / B.P] \times 100$

Standard heterosis (STH)
$= [(F_1 - S.T) / S.T] \times 100$

Where,
F_1 = Mean value of F_1 progeny
M.P = Mean value of parents
B.P = Mean value of better parent
S.T = Mean value of standard check variety

RESULTS AND DISCUSSION

Mean performances of grain quality traits and selected yield components of parental lines and F_1 generations were summarized in Table 2. The results of the study indicated that parental lines consisting of Basmati 370 (6.8 mm), MRQ50 (6.9 mm), MRQ74 (6.7 mm), MR219 (6.7 mm), and Mahsuri Mutan (6.6 mm) showed long grain length while another two parents consisting of MRQ76 (6.5 mm) and Mahsuri Mutan 98 (6.6 mm) showed medium grain length. Among six crosses, three crosses consisting of RU14701 (Basmati 370 × MRQ50), RU14703 (Basmati 370 × MRQ74), and RU14387 (Basmati 370 × MR219) showed long grain length with value 6.9 mm, 6.6 mm, and 6.8 mm, respectively. However, there was no significant differences recorded when compared with their parental lines. In contrast, cross RU14704 (Basmati 370 × Mahsuri Mutan) showed the lowest grain length (6.1 mm) and it differed significantly with their parental lines. Grain width of parental lines ranged from 1.6 mm to 2.0 mm, while in crosses ranged from 1.7-2.0 mm. Among the six crosses plants, three combinations consisting of RU14701, RU14703, and RU14387 showed the best performances in grain shape.

Filled grain per panicle also contributed to the good quality of rice. The highest filled grain per panicle was found in parent MRQ76 followed by MR219 and MRQ74. The lowest filled grain was recorded in

MRQ50. In crosses rice plant, the highest filled grain (136) was recorded in cross RU14387 from the combination of parents Basmati 370 and MR219 followed by cross RU14702 (110.3) from the combination of Basmati 370 and MRQ76. The lowest filled grain per panicle was recorded in cross RU14701, from the combination of Basmati 370 and MRQ50. Juliano (1993) stated that grain length and width were considered as important traits compared to other traits. Rafii et al. (2014) mentioned that the value of grain length and width determined the grain shape of rice. The results indicated that all parental lines and cross combinations showed grain shape more than 3 mm (>3.0 mm) that is categorized as slender grain shape. All crosses plants also differed significantly with parents Basmati 370 and MRQ50 that have grain shape values of 4.05 and 4.25, respectively. Grain size and shape are among the most important criteria in determining grain quality and yield (Wang et al., 2012). Moreover, the characteristics of long and slender grain as found in parents Basmati 370, MRQ50, MRQ74, MR219 and Mahsuri Mutan are the main focus on selecting breeding material (Rafii et al., 2014).

Besides quality traits, the observation of some characters contributed to grain yield performances can also be used in selection of promising high yield variety. The shortest heading days was found in variety Mahsuri Mutan 98 (79 days) and cross RU14705 (75 days), while Basmati 370 and cross RU14703 recorded the longest heading days, 97 days and 94 days, respectively. Among all yield traits studied, cross RU14387 showed significant differences and highest in plant height (120.2 cm), panicle length (30.4 cm), thousand grain weight (26.0 g), and flag leaves length (42.4 cm) compared to other crosses in plants. In contrary, cross RU14703 showed significant difference in panicle fertility (13.7) and tiller number (14.0) compared with its male parent, MRQ74. The yield and quality traits of the plant are related to each other. Grain filling of the plant is usually influenced by the photosynthesis process that occurred on uppermost leaf below the panicle, which is known as flag leaf. Flag leaf plays an important role in providing food for grain development (Rahman, Haque, Sikdar, Islam, & Matin, 2013) while grain filling contributes to grain weight (Wang et. al., 2008) and grain quality (Wei et al., 2017). Rahimi et al. (2010) reported that rice varieties with higher grain weight and more panicles per plant could be selected for the purpose of breeding for grain yield. Coefficient of variation was found to be 7.29% in 79% heading days, 10.4% in plant height, 8.5% in panicle length, 15.8% in tiller number, 18.0% in panicle fertility, 16.6% in flag leaf length, 13.78% in flag leaf width, and 7.43% in thousand grain weight. For grain quality traits, coefficient of variation was 3.19% in milled grain length, 7.82% in milled grain width, 10.45% in length/breadth ratio, and 20.55% in filled grain per panicle.

The analysis of correlation coefficients between all pairs of studied traits is presented in Table 3. Positive strong relationship and

Table 2
Genotypes mean for grain quality and selected yield traits of parental lines and F_1 generation

Parent / Cross	Traits											
	HD (70%)	**PH (cm)**	**PL (cm)**	**TN**	**PF**	**FLL (cm)**	**FLW (cm)**	**TGW (g)**	**MGL (mm)**	**MGW (mm)**	**L/B ratio**	**FGP**
Parents												
B370	97.0^{e}	127.6^{g}	26.7^{d}	12.0^{abcd}	10.0^{a}	27.5^{ab}	1.2^{a}	21.0^{b}	6.8^{fg}	1.7^{ab}	4.1^{f}	93.0^{b}
MRQ50	93.3^{cde}	93.7^{b}	24.4^{b}	13.0^{bcde}	12.7^{ab}	37.8^{f}	1.5^{cd}	20.2^{a}	6.9^{g}	1.6^{a}	4.3^{f}	77.7^{a}
MRQ74	88.0^{b}	85.0^{a}	25.0^{bc}	17.3^{f}	16.7^{d}	26.8^{a}	1.5^{cd}	21.4^{b}	6.7^{ef}	1.8^{c}	3.6^{d}	134.7^{de}
MRQ76	87.0^{b}	101.4^{c}	25.7^{c}	14.3^{e}	13.7^{c}	31.2^{d}	1.9^{g}	24.4^{f}	6.5^{bc}	2.0^{de}	3.3^{bc}	140.7^{e}
MR 219	86.3^{b}	100.5^{c}	27.7^{d}	12.0^{abcd}	12.0^{abc}	30.0^{cd}	1.6^{de}	25.8^{h}	6.7^{ef}	1.9^{de}	3.5^{cd}	138.7^{e}
MM	96.3^{e}	107.8^{d}	25.4^{bc}	11.7^{abc}	11.0^{ab}	28.5^{abc}	1.6^{de}	22.8^{c}	6.6^{def}	1.9^{cd}	3.5^{cd}	127.0^{d}
MM98	79.0^{a}	107.8^{d}	21.9^{a}	11.0^{ab}	10.0^{a}	27.0^{a}	1.8^{f}	25.0^{g}	6.6^{cde}	1.9^{cd}	3.5^{cd}	125.3^{d}
F_1 Generation												
RU14701	87.0^{b}	119.0^{ef}	27.5^{d}	11.7^{abc}	11.7^{abc}	40.3^{g}	1.6^{de}	24.1^{ef}	6.9^{g}	1.7^{b}	4.0^{e}	88.7^{b}
RU14702	91.0^{bcd}	118.6^{e}	29.3^{e}	12.3^{abcd}	11.0^{ab}	34.7^{e}	1.7^{ef}	23.5^{d}	6.4^{b}	2.0^{e}	4.0^{e}	110.3^{c}
RU14703	94.0^{de}	107.9^{d}	29.5^{ef}	14.0^{de}	13.7^{c}	35.8^{e}	1.3^{ab}	22.5^{c}	6.6^{cdef}	1.7^{ab}	3.2^{ab}	91.0^{b}
RU14387	89.0^{bc}	120.2^{f}	30.4^{f}	13.7^{cde}	12.0^{abc}	42.4^{h}	1.7^{ef}	26.0^{h}	6.8^{fg}	2.0^{de}	3.5^{cd}	136.0^{de}
RU14704	88.3^{b}	108.7^{d}	26.8^{d}	11.3^{ab}	10.3^{ab}	27.2^{a}	1.6^{cde}	21.0^{b}	6.1^{a}	2.0^{e}	3.0^{a}	93.3^{b}
RU14705	75.3^{a}	108.7^{d}	27.1^{d}	10.3^{a}	10.0^{a}	29.1^{bc}	1.4^{bc}	23.6^{de}	6.5^{bcd}	1.9^{cd}	3.4^{c}	91.3^{b}
CV (%)	7.3	10.4	8.5	15.8	18.0	16.6	13.8	7.4	3.2	7.8	10.5	20.6

Note: Mean in a column for each parent and crosses followed by the same uppercase letters are not significantly different at 0.05 level according to Duncan's New Multiple Range Test (DNMRT); HD: Heading days at stage 70%; PH: Plant height; PL: Panicle length; TN: Tiller number; PF: Panicle fertility; FLL: Flag leaf length; FLW:Flag leaf width and TGW: Thousand grain weight; MGL: Milled grain length; MGW: Milled grain width; L/B: Length to breadth ratio; FGP: Filled grain per panicle; CV %: Percentage of coefficient of variation, B370: Basmati 370, MM: Mahsuri Mutan, MM98: Mahsuri Mutan 98.

a significant association at $P < 0.05$ were found between traits panicle fertility and tiller number (0.843) and traits milled grain length and length/breadth ratio (0.768). Positive intermediate relationships with significant association at $P < 0.05$ were also found between panicle length and flag leaf length (0.538), thousand grain weight and flag leaf width (0.591), flag leaf width and milled grain width (0.643) include thousand grain weight and filled grain per panicle (0.587). Two of the lowest positive relationships were found between milled grain width and filled grain per panicle (0.413); and panicle fertility with filled grain per panicle (0.327) at significant association $P < 0.05$ and $P < 0.01$ respectively. In contrast, the highest negative relationship with the significant association at $P < 0.05$ was recorded between milled grain width and length/breadth ratio (−0.975). Milled grain length with milled grain width (−0.617), plant height and panicle fertility (−0.625) and traits length/breadth ratio and flag leaf width (−0.591) recorded intermediate negative relationship with significant associations at $P < 0.05$. The lowest negative relationship with significant association was recorded between heading days and flag leaf width (−0.338); and plant height with tiller number (−0.484) at significant association $P < 0.01$ and $P < 0.05$, respectively. Positive correlation among flag leaves and panicle length, panicle length and plant height, thousand grain weight and flag leaf width also have been reported in previous studies (Rahman et al., 2013; Ratna, Begum, Husna, Dey, & Hossain, 2015).

Table 4 presents the heterosis value of grain quality and selected yield traits in all six rice combinations. The results indicated

Table 3
Pearson correlation analysis of grain quality and selected yield traits of parental lines and F_1 generation

	HD	PH	PL	PF	TN	FLL	FLW	TGW	MGL	MGW	L/B	FGP
HD	1											
PH	.192	1										
PL	.200	.466**	1									
PF	.108	−.625**	-.053	1								
TN	.208	−.484**	.048	.843**	1							
FLL	.170	.278	.538**	.069	.077	1						
FLW	−.338*	−.198	−.183	−.014	−.066	.051	1					
TGW	.441**	.198	.237	−.222	−.162	.225	.604**	1				
MGL	.184	−.006	−.027	.127	.160	.458**	−.264	.053	1			
MGW	−.267	.002	.140	−.238	−.136	−.276	.643**	.483**	−.617**	1		
L/B	.286	.001	.110	.221	.150	.365*	−.591**	−.393*	.768**	-.975**	1	
FGP	−.116	−.308	.060	.327*	.400*	−.191	.433**	.587**	.010	.413**	−.357*	1

Note: *, ** Significant at the 0.01 level and 0.05 levels, respectively

Table 4
Heterosis value of grain quality traits and selected yield traits in F_1 generation among both parents, better parent and standard check variety

Crosses	Het	Traits											
		HD (70%)	**PH (cm)**	**PL (cm)**	**TN**	**PF**	**FLL (cm)**	**FLW (cm)**	**TGW (g)**	**MGL (mm)**	**MGW (mm)**	**L/B ratio**	**FGP**
RU14701	MPH	−41.25	−24.43	−27.06	−38.42	−16.31	−21.98	−26.18	−21.56	−33.11	−29.94	−36.41	−28.28
	BPH	−10.71	27.05	12.86	−10.00	22.92	6.38	3.08	19.13	−0.29	6.17	−6.12	14.16
	STH	−4.21	17.32	7.00	−18.18	−14.63	29.00	−17.89	−1.23	5.86	−13.13	21.65	−36.96
RU14702	MPH	−0.90	−33.49	−25.77	−26.89	−26.62	−19.54	−20.93	−29.24	−33.83	−37.97	−44.29	−44.29
12	BPH	4.17	16.92	14.14	−28.90	4.08	11.15	−10.53	−3.76	2.01	−16.67	−3.35	−35.32
	STH	5.36	39.47	17.18	−2.10	−34.00	29.19	15.65	9.60	2.01	−16.67	−3.35	−35.32
RU14703	MPH	−33.10	1.49	14.12	−16.04	7.92	31.66	−2.62	5.85	−4.70	14.53	5.22	−3.12
	BPH	8.05	26.89	17.84	−2.10	−2.68	33.29	−11.56	4.76	−4.05	9.24	11.63	−18.11
	STH	6.82	6.38	14.79	−13.99	0.00	14.64	−31.58	−8.01	−1.39	1.52	22.87	−21.61
RU14387	MPH	−2.91	5.44	11.78	14.17	2.08	47.48	20.24	11.14	0.45	8.03	−7.73	17.39
	BPH	3.09	19.67	9.76	14.17	−3.92	41.33	5.21	0.78	0.90	0.52	0.29	−1.95
	STH	2.30	18.53	18.16	−4.20	−12.20	35.90	−11.40	6.56	4.17	−1.52	5.49	−3.34
RU14704	MPH	−8.62	-7.61	2.88	−4.64	−0.52	−2.98	10.71	−3.94	−8.59	12.85	−19.52	−15.18
	BPH	−8.30	0.90	5.52	−3.42	−6.80	−4.68	−3.13	−7.74	−7.83	5.76	−12.93	−26.54
	STH	1.53	7.20	4.15	−20.98	−24.39	−12.93	−18.42	−13.84	−5.56	2.02	−7.62	−33.69
RU14705	MPH	−14.40	−7.65	11.46	−10.43	−4.71	6.91	−7.18	2.79	−2.33	7.00	−9.07	−16.35
	BPH	−4.65	0.83	23.59	−6.36	−9.90	7.9	−22.94	−5.42	−0.91	0.53	−1.16	−27.13
	STH	−13.41	7.16	5.32	−27.27	−26.83	−6.62	−26.32	−3.18	0.31	3.97	−6.65	−35.11

Note: Het: Heterosis; MPH: Mid parent heterosis; BPH: Better parent heterosis; STH: Standard heterosis that crosses RU14701 and RU14702 posed negative values in all grain quality and yield traits studied when compared with both parents. However, when comparing with better parents, RU14387 showed a positive heterosis value in most of the traits studied except for traits panicle fertility and filled grain per panicle. The results indicated that crosses RU14701, RU14703, and RU14387 recorded positive heterosis over standard check variety in length/breadth ratio. Positive heterosis values in milled grain length were also found in crosses RU14701, RU14702, RU14387, and RU14705 as compared to standard check variety, MRQ76. The positive or negative heterosis value gives significant information on preferred traits for the development of better rice quality and yield. Jelodar (2010) reported negative heterosis value in plant height and this information is desired for breeding of short stature hybrids and varieties. Rahimi et al. (2010) stated that plant height that posed negative heterosis value is used for the development of dwarf varieties. The same result is also reported by Kumar, Surendra and Sumer (2012) who agrees that short plant is needed to prevent lodging during planting and taller plants are usually vulnerable to disease infection that may then reduce quantity and quality of the grain. On the other hand, positive heterosis value also provides significant information for a variety of development. Nurruzzaman et al. (2010) have reported positive heterosis values in panicle length, grain length, and flag leaves of rice that are among the important traits for the development of high yield variety. Rahimi et al. (2010) also agrees that hybrids rice with more panicle and high grain weight is important for improving crop yield. The length of panicle is also one of the important traits in rice breeding as it is related with spikelets number that contributes to high yield production (Elixon, Asfaliza, Othman, & Mohd Solehin, 2015). Perera, Bentota, Ratnasekara and Senanayake (2013) mentioned that heterosis value was important in determining the successful production of hybrid varieties and both value, either negative or positive, were important in crop improvements.

CONCLUSION

The important outcome of this study is the knowledge and information on various genetic variations in grain quality and selected yield traits in parental lines and F_1 generations of rice that can be used for future rice breeding programs. It can be concluded that the characteristics of long and slender grain found in parents Basmati 370, MRQ50, MRQ74, MR219, and Mahsuri Mutan showed that they can be used in breeding rice for production of long grain rice. The study also observed good performances in grain shape of crosses RU14387, RU14701, and RU14702. Cross RU14387 also showed high performances in some yield traits and information on heterosis value can be further evaluated for the development of rice lines with good quality traits as well as yield related traits. In future, rice production and quality improvements, evaluation of selected lines can be conducted followed by the implementation of molecular study to characterize specific desired genes for grain quality trait improvements.

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