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Performance and heterosis estimation on yield and yield components of several rice hybrid lines

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Abstract

An experiment was conducted to study the heterosis of 12 F_1 rice hybrids derived from crosses between three CMS lines (IR79126A, IR78374A and 0025A) and four local restorers (001R, 002R, 003R and 004R). The popular rice variety MR 219 was used as standard check. Estimation of standard and better-parent heterosis of the F_1 hybrid lines was evaluated on yield and yield components. The heterosis for days to 50% heading and culm height of the F_1 hybrids were mostly in negative direction for both standard and better-parent heterosis. This indicated that the F_1 hybrids have shorter maturation and culm height compared to the MR 219 or to their better-parents. Four F_1 hybrids, namely HY011H, HY009H, HY006H and HY012H have higher yield/plant than MR 219 and have standard and better-parent heterosis range from 24.8% to 48.0%. Plant yield is positively correlated to the number of panicles/plant, total spikelets/panicle and percentage of filled spikelets/panicle. These promising F_1 hybrid lines are recommended for further evaluation in preliminary and advance yield trials.

Keywords: CMS lines, F_1 hybrid, hybrid rice, standard heterosis, better-parent heterosis

Introduction

Heterosis or hybrid vigour is the phenomenon of superiority of F_1 generation over its two genetically dissimilar parents (Virmani 1994). Heterosis has been exploited in diverse system including mammal, human and plant kingdom (Shawn 2012). In rice hybrids, outstanding heterosis of their F_1 has been reported on their morphological, physiological and biochemical traits such as bigger and heavier panicle, more tiller production and more efficient root system (Virmani 1994). The expression of heterosis for yield in hybrid rice was 20 – 30% over the best high yielding inbred varieties. Virmani and Edwards (1983) reviewed the prospects of hybrid rice breeding and concluded that exploitation of heterosis would offer an alternative approach towards increasing yield potential of rice.

The heterosis phenomenon can be explained by dominance, over dominance and epistasis effects (Reif et al. 2012). Meanwhile, the magnitude of heterosis is expressed in three criteria, namely standard heterosis (SH) which measures an increase or decrease in the perfomance of hybrid compared to a standard check or popular variety in the region, mid-parents heterosis, a measure of hybrid performance in comparison to the average-parental value

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and better-parent heterosis or heterobeltiosis (BP) which measures the increase or decrease in performance of hybrid in comparison with its better-parent of cross combination (Virmani et al. 2003). Among the three, SH is considered as the most important measurement in the identification of superior hybrids over the existing high yielding inbred varieties.

China was the first country that exploits the phenomenon of heterosis in rice. About 50% of rice area in China were planted with hybrid rice varieties with yield average around 6.9 t/ha as compared to the inbred yield of about 5.4 t/ha (Virmani 2004). Inspiring from China experience, IRRI and other countries including India, Vietnam and Philippines had established their own hybrid rice breeding programmes to exploit heterosis (Parvez 2006).

Exploitation of heterosis may also increase rice productivity in Malaysia. Local rice production contributed about 70% of self-sufficiency level (SSL) for rice and the balance had to be imported from Thailand, Vietnam and other countries. Experience from food crisis in 2008 has made rice cultivation to become one of the national priorities and to be classified as a security crop. The country is now aiming to reduce import bills by setting up a national rice policy to sustain the current SSL at 70% through increasing farm productivity. One of the promising approaches towards rising productivity is by planting hybrid rice variety.

MARDI's hybrid rice breeding programme has three strategies, namely through the introduction of imported rice hybrids, production of half-Malaysian rice hybrids through crossing of imported CMS (cytoplasmic male sterile) lines with local restorers and finally to produce Malaysian own rice hybrids derived from crosses of locally developed CMS and local restorer lines (Othman et al. 2008).

Through collaborations with IRRI and other local-based companies such as RB Biotech and Puncak Kaji, MARDI had evaluated several imported hybrids, mainly from China, India and Philippines. However, most of these imported hybrids were inferior in grain quality, low yielder, susceptible to local pests and diseases, and not well adapted to local environments, except for a few selected potential hybrid lines. A hybrid variety named as SIRAJ was released for commercialisation in 2011 at MARDI Tambun Tulang, Perlis.

The current emphasis of MARDI hybrid rice breeding programme is to identify and develop local hybrid parental lines. MARDI has developed its own local CMS lines and several potential local restorer lines had also been identified. These potential lines were used in hybrid rice breeding programme (Elixon et al. 2013). The objective of this study was to evaluate the magnitude of heterosis of several locally developed rice hybrids in order to identify desirable local hybrid rice lines for commercial release.

Materials and methods

The experiment was carried out at MARDI Seberang Perai during main season 2011 – 2012. The experimental materials involved three CMS lines namely IR79126A and IR78374A from IRRI and 0025A, previously developed by MARDI. Four local restorer lines coded as 001R, 002R, 003R and 004R were used as male parents. Crosses were made during off-season 2011 and 12 F_1 hybrid lines were produced, coded as HY001H, HY002H, HY003H, HY004H, HY005H, HY006H, HY007H, HY008H, HY009H, HY010H, HY011H and HY012H. All F_1 hybrids together with their parents were planted in the experimental field in a randomised complete block design (RCBD) with three replications. Rice variety MR 219 was used as standard check variety. The crops were fertilised with 100:80:90 NPK. Seedlings at the age of 15 – 20 days old were planted in the field, single plant per point with a planting distance of 25 cm x 25 cm.

The following data were taken from five randomly selected hills/line/replicate. Data on the days to 50% heading, culm height (cm), number of panicles/plant, panicle length (cm), number of spikelets/panicle, filled spikelets/panicle (%), 1,000-grain weight (g) and plant yield (g) were recorded. Data were analysed according to analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). Heterosis was recorded as SH and BP by using the following formula of Fehr (1987):

$$SH = \frac{(F_1 - \text{Check variety}) \times 100}{\text{Check variety}}$$

$$BP = \frac{(F_1 - \text{Better-parent}) \times 100}{\text{Better-parent}}$$

The test of significance for heterosis was carried out by comparing the calculated to the tabulated value of 't' at 5% and 1% levels of significance. Phenotypic coefficients of correlation were computed using Pearson's linear correlation as outlined by Steel and Torrie (1984).

Results and discussion

There was significant variation among rice genotypes for yield and other yield component traits (*Table 1*). No significant effects of replicates were observed on variations between means of treatments. Days to 50% heading of the rice genotypes ranged from 56 to 68 days (*Table 2*). Most of the hybrid lines significantly maturated 1 – 4 days earlier than the check variety MR 219 (66 days) except for the hybrid lines HY002H, HY005H and HY011H. All maintainer lines, including IR79126B were also matured earlier than MR 219, while three out of four restorer lines matured simultaneously with the check variety.

Most of the hybrid lines evaluated had significantly shorter culm height (54.6 – 63.1 cm) than MR 219 (68.8 cm) except for HY008H (64.2 cm), HY007H (65.1 cm), HY004H (66.7 cm) and HY005H

Table 1. Analysis of Variance (ANOVA) of yield and yield component traits

Sources	DF	Days to 50% heading (days)	Culm height (cm)	No. panicles/plant	Panicle length (cm)	Filled spikelets/panicle (%)	Total spikelets/panicle	1,000-grain weight (g)	Yield (g/plants)
Replication	2	3.4667	9.7407	9.3167	1.1711	4.3782	467.4500	0.6740	80.0312
Genotype	19	22.8246**	83.7113**	14.8167**	4.000**	91.9348**	2081.0342**	6.2468**	123.8106**
Error	38	71.7333	7.4482	2.4746	0.5206	21.1200	218.1342	0.8740	31.4447
Total	59	512.3333	1893.0273	394.1833	98.1293	2558.0818	48763.6500	153.2500	3707.3618

**Significant at $p < 0.01$

Table 2. Mean value of check variety, parents and F_1 hybrids on yield and yield component traits

Entries	Pedigree	Days to 50% heading (days)	Culm height (cm)	No. panicles/ plant	Panicle length (cm)	Filled spikelets/ panicle (%)	Total spikelets/ panicle	1,000-grain weight (g)	Yield (g/plant)
F_1 Hybrids									
HY001H	IR79126A/001R	61d	62.6defgh	16ab	28.2abcde	75.6cdef	199bc	25.1ef	37.8abcde
HY002H	IR78374A/001R	65ab	63.1cdefgh	12bcde	27.6defgh	70.2f	182cd	26.5abcd	31.2def
HY003H	0025A/001R	61d	54.6lm	13bcd	26.8fgh	73.2def	194bc	25.9cde	35.6bcde
HY004H	IR79126A/002R	64cd	66.7abc	13bcd	29.4a	79.9bcde	228a	27.7ab	40.3abc
HY005H	IR78374A/002R	63bcd	67.8abc	15ab	29.2a	69.8f	219ab	26.9abcd	38.6abcde
HY006H	0025A/002R	62cd	59.9fghjjk	13bcd	28.1abcde	81.9bcd	210abc	27.3abc	43.7ab
HY007H	IR79126A/003R	61d	65.1abcde	11def	29.0abc	77.5bcdef	219ab	27.0abcd	34.8bcde
HY008H	IR78374A/003R	61d	64.2bcdefg	12cdef	28.9abcd	74.3cdef	199abc	27.3abc	33.5bcde
HY009H	0025A/003R	62cd	61.6defghi	14bc	28.4abcde	82.6bc	219ab	28.0ab	46.5a
HY010H	IR79126A/004R	62cd	62.1defghi	13bcd	29.1ab	77.4bcdef	192bc	25.6cde	33.3bcde
HY011H	IR78374A/004R	65b	61.2efghij	17a	28.5abcde	75.6cdef	203abc	26.9abcd	47.4a
HY012H	0025A/004R	61d	56.3jkl	14bc	27.8abcdef	81.2bcd	204abc	27.1abcd	42.4abc
Parents									
001R	–	61d	57.3ijkl	11def	26.3hi	78.8bcdef	146ef	25.0ef	22.2f
002R	–	67a	70.7a	10ef	27.7cdfg	77.0bcdef	207abc	27.9ab	33.3bcde
003R	–	66ab	66.2abcde	9f	26.7ghi	71.8ef	206abc	28.7a	28.2ef
004R	–	68a	58.0hijkl	12bcde	26.5ghi	75.4cdef	166de	26.5bcde	32.0cdef
IR79126B	–	56e	59.5ghijkl	17a	27.1efghi	85.5ab	156def	23.9fg	32.7cdef
IR78374B	–	62cd	55.0kl	14bc	25.8i	83.1bc	135f	22.9g	27.6ef
0025B	–	64bc	50.2m	11def	26.5ghi	92.8a	158df	25.7cde	30.8def
MR 219 (check)	–	66ab	68.8ab	13bcde	26.0i	75.0cdef	200abc	25.4def	34.0bcde
CV (%)		2.19	4.44	11.90	2.61	5.90	7.69	3.55	15.90

Means with the same letter are not significantly different at $p \leq 0.05$, *Data for the CMS rice parents were corresponding to its respective maintainers

(67.8 cm) which might be due to the height of their parents which were also shorter than MR 219, except that of the restorer 002R (70.7 cm). Only one hybrid HY011H produced more number of panicles (17) than that of MR 219 (13), while the others produced less or equivalent number of panicles to MR 219. Meanwhile, 003R produced the least number of panicles per plant (9) while, the maintainer line IR79126B produced more (17). The panicles of all hybrid lines were significantly longer (27.6 – 29.4 cm) than that of MR 219 (26.0 cm). One of the restorers, 002R had significantly long panicle (27.7 cm) as compared to MR 219 (*Table 2*).

Results on the total number of spikelets/panicle showed that, none of the hybrid lines significantly have more spikelet numbers than that of MR 219 (200), even though in magnitudes there are small variations among lines (*Table 2*). Their percentages of filled spikelets/panicle were also comparable to that of MR 219 (75.0%), which ranged from 69.8% to 82.6%. Among the parents, only IR79126B and 0025B produced higher percentages filled spikelets/panicle (85.5 and 92.8% respectively). Results on 1,000-grain weight showed that hybrid lines HY004H and HY009H had heavier grains (27.7 and 28.0 g respectively) than that of MR 219 (25.4 g). Most of the hybrid lines mean yield were lower or not significantly different from that of MR 219 (34.0 g/plant) except HY009H (46.5 g/plant) and HY011H (47.4 g/plant). The yield of HY006H and HY012H are high in magnitudes (43.7 and 42.4 g/plant respectively) than MR 219, even though their differences are not significant. Similarly, none of their parents, had higher mean yield than MR 219, and in fact the panicle yield of 001R was significantly lower at 22.2 g/plant.

The increased yield of those several hybrid lines could possibly due to the contribution from various yield component traits. The result of correlation analysis as shown in *Table 3* reveals that the obtained

Table 3. The phenotypic correlations among the traits

	Yield (g/plant)	Days to 50% heading (day)	Culm height (cm)	No. panicles/plant	Panicle length (cm)	Filled spikelets/panicle (%)	Total spikelets/panicle	1,000-grain weight (g)
Yield (g/plant)	1.00	–0.17	0.08	0.72**	0.08	0.42**	0.36*	0.19
Days to 50% heading (day)		1.00	0.15	0.13	0.06	–0.38*	–0.15	–0.05
Culm height (cm)			1.00	0.08	0.54**	–0.13	0.36*	0.27
No. of panicles/plant				1.00	0.09	0.07	0.08	–0.01
Panicle length (cm)					1.00	0.11	0.55**	0.25
Filled spikelets/panicle (%)						1.00	0.30	0.10
Total spikelets/panicle							1.00	0.11
1,000-grain weight (g)								1.00

*Significant at $p < 0.05$, **Significant at $p < 0.01$

yield/plant is highly correlated with the number of panicles/plant (r = 0.72), total spikelets/panicle (r = 0.36) and percentage of filled spikelets/panicle (r = 0.42). Results also showed that the total spikelet number/panicle is significantly correlated with panicle length (r = 0.55) and culm height (r = 0.36), while panicle length is significantly correlated with culm height (r = 0.54). These results indicated that yielding ability of a plant could be achieved through manipulation of these major traits, namely the number of panicles/plant, total spikelets/panicle and percentages of filled spikelets/panicle and as well as contribution from the other secondary traits such as panicle length, plant height and 1,000-grain weight as mentioned by Duan et al. (2013).

The number of panicles produced per plant is an important trait and is closely associated with high yield potential either for both hybrid or inbred varieties. Previously, Muhammed et al. (2007) have also reported that grain yield has positive correlation with the number of panicles/plant, while Ramakrishman et al. (2006) observed that yield obtained is positively correlated with the number of spikelets/panicle.

The range of heterosis for days to 50% heading was –7.6 to –2.0% for SH and –5.2 to 10.7% for BP heterosis (*Table 4*). The magnitude of heterosis for all hibrids showed negative effect for SH which is highest from five hybrids, HY001H, HY003H, HY007H, HY008H and HY012H. This indicated that these hybrid lines matured earlier than MR 219. The magnitudes of BP heterosis for days to 50% heading were also negative for HY012H, HY009H, HY006H and HY008H which also indicated that these lines matured earlier than their best parents. Negative heterosis for days to heading in rice hybrids had also been reported previously by Kumar et al. (2012).

SH for culm height showed negative direction (–20.7% to 1.5%), but positive direction (4.3 – 23.2%) for BP heterosis (*Table 4*). Most of the hybrid lines showed significant negative SH except HY004H, HY005H and HY007H. The maximum negative effect for SH was shown by HY003H, followed by HY012H and HY006H. BP heterosis for all hybrid lines showed significant positive effect for culm height except for HY010H. Negative heterosis for plant height has also been reported by Kumar et al. (2012). Its shorter plant statue is desired for preventing lodging. Lodging in rice crop is closely related to the tallness of the plant (Takayuki et al. 2005), that could decrease the photosynthesis activities and photo-assimilation, thus resulted in poor grain filling and yield reduction. On the other hand, if lodging is a non-issue, strong positive SH could be desirable because culm height is associated with culm length and indirectly could contribute to better yield (*Table 3*).

Ranges of heterosis for the number of panicles/plant was –17.9% to 33.3% for SH and –38.5% to 30.3% for BP. The highest and significant SH heterosis was obtained with HY011H followed by HY001H and HY005H (*Table 4*). The highest and significantly different of BP heterosis was obtained with hybrids HY009H, followed by HY003H, HY006H and HY011H.

Generally, positive heterosis for panicle length is desirable in breeding of rice hybrid because it is associated with more spikelets in the panicle that contribute to higher production. The magnitude of heterosis for panicle length was positive for all hybrids (*Table 4*). Range of heterosis for panicle length was 3.1 – 12.8% for SH and 1.1 – 8.2% for BP. Results showed that HY004H, HY005H, HY010H and HY007H gave the higher positive SH heterosis for panicle length. Meanwhile, HY008H showed higher positive for BP heterosis. The significant positive heterotic effect indicates that those hybrid lines had increased panicle length. Significant SH for panicle length also have been reported by Banumathy et al. (2003). Dey et al. (2013) observed a range of BP

Table 4. Heterosis estimation on days to 50% flowering, culm height, number of panicles/plant and panicle length

Entries	Pedigree	Days to 50% heading (%)		Culm height (%)		Number of panicles/plant (%)		Panicle length (%)	
		SH	BP	SH	BP	SH	BP	SH	BP
HY001H	IR79126A/001R	−7.6**	8.9**	−9.1**	9.2**	20.5*	−9.6	8.3**	4.1
HY002H	IR78374A/001R	−1.0	7.1**	−8.3*	14.7**	−2.6	−11.6	6.0**	5.1*
HY003H	0025A/001R	−7.6**	0.0	−20.7**	8.6*	2.6	21.2*	3.1	1.1
HY004H	IR79126A/002R	−6.1**	10.7**	−3.1	12.0**	5.1	−21.0*	12.8**	5.3**
HY005H	IR78374A/002R	−3.5*	4.4**	−1.5	23.2**	17.9*	7.0	12.3**	4.8*
HY006H	0025A/002R	−6.1**	−3.6*	−12.9**	19.2**	2.6	21.2*	7.9**	1.4
HY007H	IR79126A/003R	−7.6**	8.9**	−5.4	9.4**	−17.9*	−38.5**	11.5**	7.1**
HY008H	IR78374A/003R	−7.6**	−1.6	−6.6*	16.8**	−7.7	−16.3*	10.9**	8.2**
HY009H	0025A/003R	−6.1**	−3.6*	−10.5**	22.6**	10.3	30.3**	9.1**	6.5**
HY010H	IR79126A/004R	−6.1**	10.7**	−9.7*	4.3	2.6	−23.1**	11.9**	7.5**
HY011H	IR78374A/004R	−2.0	6.0**	−11.0**	11.3**	33.3**	20.9**	9.3**	7.6**
HY012H	0025A/004R	−7.6**	−5.2**	−18.1**	12.1**	10.3	13.2	6.9**	5.2*
CV (%)		2.0	0.9	4.6	2.8	11.7	11.0	2.1	3.1

SH = Standard heterosis, BP = Better-parent heterosis, **Significant at 1% probability levels, *Significant at 5% probability levels based on t-test

heterosis of panicle length from –4.49% to 9.89% from his studies.

The percentage of filled spikelets/panicle is very important due to its direct contribution to yield potential. The study showed that the range of heterosis for filled spikelets/panicle was –6.8% to 10.2% for SH and –21.1% to –6.5% for BP (*Table 5*). Results of *Table 5* showed that SH for percentage of filled spikelets/panicle was significantly higher for HY009H, HY006H and HY012H.

However, all hybrid lines showed negative BP heterosis for percentage of filled spikelets/panicle, which indicate that the hybrid parents were greater in their grain filling capability as compared to offspring. Similarly, Ammar et al. (2014) also observed that 47 out of 50 F_1 hybrids have negative BP heterosis for filled spikelets/panicle trait. Tiwari et al. (2011) also reported that out of 60 crosses generated, 47 crosses have positive BP heterosis, while 35 crosses resulted with positive SH in a study involving three rice CMS and 20 elite restorers. The fertiliser rate applied during crop growth was 100:80:90 of NPK, a rate most probably was not suitable for those tested hybrids. Hybrids varieties have been known to be more responsive to nitrogen. Therefore, an appropriate fertiliser packages could probably improve this weakness and better grain filling capability among the lines. According to Sahar et al. (2012), the yield of hybrid GRH1 was significantly increased from 6,989.8 kg/ha to 8,611.9 kg/ha with an increasing of nitrogen levels from 100 to 300 kg/ha.

Number of spikelets produced per panicle is one of the important criteria for higher yield. Large panicle is associated with more number of grains per panicle, thus resulting in higher productivity (Tiwari et al. 2011). Hybrids with positive heterosis are desirable. The positive heterotic effect also contributed in increasing the production of spikelets/panicle due to hybrid vigour (Jarwar et al. 2013).

Results showed that the range of SH was –8.7% to 14.2%. Only HY004H showed significant and high SH for number of spikelets/panicle (*Table 5*), followed by HY005H and HY007H. All except one hybrid (HY008H) showed positive BP heterosis. Ammar et al. (2014) have reported that 23 out of 50 of F_1 hybrids used in his studies showed positive SH with the highest value of 39.79%, while only 2 out of 50 F_1 hybrid resulted positive BP heterosis with the highest value of 13.56%.

The range of SH for 1,000-grain weight was –1.3% to 10.2% (*Table 5)*. Hybrids HY009H and HY004H have highly significant SH while HY005H, HY011, HY007H, HY012H, HY006H and HY008H also have significant positive SH with values ranged from 5.8% to 7.6%. Meanwhile, the range of BP heterosis was between –5.8 and 6.1%, which the highest was HY002H, while HY008H and HY007H showed negative BP heterosis. Significant positive heterosis effect indicates that the heavier weight of the rice grains would contribute to hybrid yield potential (Jarwar et al. 2013).

The magnitude of SH for yield/plant was significantly highest on HY011H and HY009H (*Table 5*), followed by HY006H and HY012H,which indicate that they are potentially high yielders and better than MR 219. Their BP heterosis were significantly different from their better parents. This study obtained SH values comparable to those obtained by other researchers including Latha et al. (2013), where the BP (57.35%) and SH (25.51%) were observed over the check hybrids used in their studies.

Conclusion

Hybrid lines HY011H and HY009H produced significantly higher yield than the check popular variety MR 219 or their parents. When based on heterotic estimation, it can be concluded that hybrid lines HY011H, HY009H, HY006H and HY012H showed oustanding yield/plant, estimated based on both standard heterosis,

Table 5. Heterosis estimation on filled spikelets/panicle, number of spikelets/panicle, 1,000-grain weight and yield

Entries	Pedigree	Filled spikelets/panicle (%)		No. spikelets/panicle (%)		1,000-grain weight (%)		Yield/plant (%)	
		SH	BP	SH	BP	SH	BP	SH	BP
HY001H	IR79126A/001R	0.9	–11.5**	–0.5	27.1**	–1.3	0.3	11.2	15.6
HY002H	IR78374A/001R	–6.4	–15.5**	–8.7	24.6**	4.5	6.1*	–8.3	12.9
HY003H	0025A/001R	–2.3	–21.1**	–2.7	23.3**	1.8	3.5	4.6	15.4
HY004H	IR79126A/002R	6.6	–6.5**	14.2*	10.1*	9.2**	–0.5	18.6	21.2
HY005H	IR78374A/002R	–6.8	–15.9**	9.8	6.0	5.8*	–3.6	13.6	16.1
HY006H	0025A/002R	9.2*	–11.7**	5.0	1.3	7.3*	–2.2	28.4*	31.3*
HY007H	IR79126A/003R	3.4	–9.3**	9.8	6.6	6.3*	–5.8*	2.4	6.5
HY008H	IR78374A/003R	–0.9	–10.6**	–0.2	–3.1	7.6*	–4.7*	–1.6	8.5
HY009H	0025A/003R	10.2*	–10.9**	9.7	6.5	10.2**	–2.3	36.8**	42.3**
HY010H	IR79126A/004R	3.3	–9.4**	–3.7	15.9*	0.8	–3.3	–2.1	4.1
HY011H	IR78374A/004R	0.9	–8.9**	1.5	22.1**	5.8*	1.5	39.3**	48.0**
HY012H	0025A/004R	8.4*	–12.4**	2.2	22.9**	6.6*	2.3	24.8*	32.6*
CV (%)		5.3	2.8	7.1	7.3	3.6	2.7	12.4	22.2

SH = Standard heterosis, BP = Better-parent heterosis, **Significant at 1% probability levels, *Significant at 5% probability levels based on t-test and better-parent, heterosis values as compared to other hybrid lines evaluated, and this is an important criteria used in selecting promising hybrids. The four hybrid lines have positive direction standard and better-parent heterosis values for the major yield component traits. Even though these hybrid lines showed negative better-parent heterosis values for percentage of filled spikelets/panicle, but this limitation could be improved through application of appropriate agronomic package to improve the grain filling efficiency. These four promising hybrids are recommended for further evaluation in preliminary and advance yield trials. For commercial advantages, yield potential of 15 – 30% higher than the current popular local inbred varieties should be promoted to encourage adoption and acceptability by the farmers.

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References

Ammar, G.G., Ghorbanali, N., Nadali, B., Morteza, O. and Asghar, B. (2014). Heritability and heterosis of agronomic traits in rice lines. *Intl. J. Farm and Alli Sci*. 3(1): 66 – 70

Banumathy, S., Thiyagarajan, K. and Vaidyanathan, P. (2003). Study on magnitude of heterosis of rice hybrids for yield and its components. *Crop Res*. 25: 287 – 293

Dey, S.R., Bhuyan, M.S.R., Maniruzzaman, M., Islam, M.A. and Begum, S. (2013). Heterosis in inter-ecotypic classes of rice (*Oryza sativa* L.). *J. Agrofor. Environ*. 7(1): 111 – 114

Duan, M., Zhizhong, S., Liping S., Yanning, T., Dong Y., Xuewu, S., Ruifen, Liu., Yujie, Li., Siyu, G. and Dingyang, Y. (2013). Genetic analysis of an elite super-hybrid rice parent using high-density SNP markers. *Rice* 6(21): 2 – 15

Elixon, S., Mohd Solehin, J., Asfaliza, R., Othman, O., Marzukhi, H., Allicia, J. and Maisarah, M.S. (2013). Penilaian ciri morfologi dan fisiko-kimia ke atas titisan CMS (cytoplasmic male sterile) 0025A/B dan 0047A/B. *Prosiding persidangan padi kebangsaan*, 10 – 12 Dec. 2013, Seberang Perai, P. Pinang, p. 347 – 353. Serdang: MARDI

Fehr, W.R. (1987). Heterosis. In: *Principles of cultivar development: Theory and techniques* Vol. 1, 115 p. New York: Macmillan Publishing Company

Gomez, K.A. and Gomez, A.A. (1984). *Statistical procedures for agricultural research*, p. 7 – 83. Los Banos: IRRI

Jarwar, A.D., Dela Cruz, Q.D. and Junejo, G.S. (2013). Heterosis of some yield and its related characters in aromatic rice (*Oryza sativa* L.) varieties and their F_1 hybrids under lowland and upland environments. *Pak. J. Agri. Agril. Engg. Vet. Sci*. 29(1): 13 – 23

Kumar, A., Surendra, S. and Sumer, P.S. (2012). Heterosis for yield and yield components in Basmati rice. *Asian J. Agric. Res*. 6(1): 21 – 29

Latha, S., Sharma, D. and Sanghera, S. (2013). Combining ability and heterosis for grain yield and its component traits in rice (*Oryza sativa* L.). *Not Sci. Biol*. 5(1): 90 – 97

Mishra, M. and Pandey, M.P. (1998). Heterosis breeding in rice for irrigated sub-humid tropics in North India. *Oryza* 35: 8 – 14

Muhammed, B., Asif, A.K., Anjuman A., Yusuf, Z. and Muhammad, A. (2007). Path analysis of some leaf and panicle traits affecting grain yield in doubled haploid lines of rice (*Oryza sativa* L.). *J. Agric. Res*. 45(4): 245 – 252

Othman, O., Abdul Rahman, B., Asfaliza, R., Abu Hassan, D., Saad, A., Guok, H.P. and Elixon, S. (2008). Potential of hybrid rice in Malaysia. *Proceeding of 5th national seed symposium,* (Theme: Current trends toward quality planting materials), 11– 12 Mar. 2008, Putrajaya, p. 77 – 89

Parvez, S. (2006). Recent advances in understanding genetic basis of heterosis in rice (*Oryza sativa* L.). *Revista UDO Agricola* 6(1): 1 – 10

Ramakrishman, S.H., Amandakumar, C.R., Saravanan, S. and Malini, N. (2006). Association analysis of some yield traits in rice (*Oryza sativa* L.). *J. App. Sci. Res*. 2(7): 402 – 404

Reif, J.C., Hahn, V. and Melchinger, A.E. (2012). Genetic basis of heterosis and prediction of hybrid performance. *Helia* 35(57): 1 – 8

Sahar, Y., Allahyar, F. and Jahanfar, D. (2012). Effect of split application af nitrogen fertilizer an Spad value in hybrid rice (Grh1). *Intl. J. Agri. Crop Sci*. 4(10): 647 – 651

Shawn, K. (2012). Heterosis: Many genes, many mechanisms - end the search for an undiscovered unifying theory. Review article. In: *International Scholarly Research Network,* p. 1 – 12

Steel, R.G. and Torrie, J.H. (1984). *Principal and procedures of statistics,* p. 137 – 167. New York: McGraw Hill Book Co.

Takayuki, K., Haruto, S. and Ken, I. (2005). Factor responsible for decrease sturdiness of the lower part in lodging of rice (*Oryza sativa* L.). *Plant Prod. Sci*. 8(2): 166 – 172

Tiwari, D.K., Pandey, P., Giri, S.P. and Dwivedi, J.L. (2011). Heterosis study for yield and its components in rice hybrids using CMS. *Asian J. Plant Sci*. 10(1): 29 – 42

Virmani, S. (2004). Opportunity and challenges of developing and disseminating hybrid rice. In: *Extended summaries of international symposium on rice from green revolution to gene revolution*, 4 – 6 Oct. 2004, DRR, Hyderabad India

Virmani, S.S. (1994). Heterosis and hybrid rice breeding. In: *Monographs on theoretical and applied genetic 22,* p. 1 – 14. Los Banos: IRRI

Virmani, S.S. and Edwards, I.B. (1983). Current status and future prospects for breeding hybrid rice. *Agron. Abst*. 119

Virmani, S.S., Sun, Z.X., Mou, T.M., Jauhar Ali, A. and Mao, C.X. (2003). *Two-line hybrid rice breeding manual*, p. 1 – 3. Los Banos: IRRI

Abstrak

Satu kajian telah dijalankan untuk menguji heterosis terhadap 12 titisan padi hibrid F_1 yang diperoleh hasil daripada kacukan antara tiga titisan CMS padi (IR79126A, IR78374A dan 0025A) dengan empat titisan padi pemulih (restorer) tempatan (001R, 002R, 003R dan 004R). MR 219 telah digunakan sebagai varieti kawalan. Anggaran heterosis piawai (SH) dan heterosis induk-lebih baik (BP) terhadap titisan hibrid F_1 telah dilakukan untuk menilai potensi hasil dan komponen hasil, sama ada peratus heterosis bersifat positif atau negatif. Kebanyakan titisan hibrid F_1 menunjukkan heterosis negatif bagi ciri 50% hari berbunga dan tinggi batang, yang menunjukkan titisan padi hibrid F_1 ini mempunyai jangka masa matang yang singkat dan ketinggian pokok yang lebih rendah berbanding dengan MR 219 dan varieti induk terbaiknya. Empat titisan padi hibrid F_1 iaitu HY011H, HY009H, HY006H dan HY012H memberikan hasil (g/pokok) yang lebih baik daripada varieti pembeza, MR 219 dan mempunyai julat nilai heterosis 24.8 – 48.0%. Hasil (g/pokok) pokok berkorelasi secara positif dengan bilangan tangkai/pokok, jumlah biji/tangkai dan peratusan biji bernas/tangkai. Titisan hibrid berpotensi dicadangkan untuk dimajukan ke ujian hasil awal dan ujian hasil lanjutan.