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Performance of selected aerobic rice varieties cultivated under local condition

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Abstract
Aerobic rice cultivation is a new concept of growing rice with supplemental irrigation, without the necessity for standing water in the field. IRRI has developed aerobic rice varieties and MARDI has requested some of these planting materials to be tested in the local environment. The main aim of the study was to select suitable varieties from the foreign introduction and evaluate their growth and yield performance under local aerobic condition. Variety AERON 1/05 showed superior in some yield component characteristics such as longer panicle, higher number of rachis, higher yield and heavier grains. However, this variety has no significant difference in the number of primary branches compared to AERON 49/05. All the International Network for Genetic Evaluation of Rice (INGER) varieties showed no significant difference in the number of filled grains but they were able to have significantly higher filled grains than the control varieties (MR 219, MRQ 50 and MRQ 74). Correlation analysis showed that 1000-grain weight contributed positively to the yield of the control and varieties from the INGER. Traits that are positively correlated with yield improvement of aerobic rice are very beneficial and these useful traits must be incorporated to enhance the yield of new aerobic rice varieties.

Keywords: aerobic rice, AERON varieties, yield components

Introduction

The productivity of Asia's irrigated rice is increasingly threatened by 'physical water scarcity'. Hence, there is a need to identify and develop water stress tolerant varieties which are suitable for cultivation under aerobic condition. Aerobic rice cultivation is a new concept of growing rice with supplemental irrigation, but without the necessity for standing water in the field. There are at least three challenges in aerobic rice cultivation that needs further considerations. Firstly, chemicals for weed control need to be identified urgently because of the high labour cost for manual weeding. Secondly, there is a need of proper and suitable irrigation for aerobic rice field to avoid major humidity change, which may cause fungal infection. Thirdly, the varieties are adaptable, sustainable and show good yield potential in this environment. The water requirement for aerobic rice cultivation is reported 50% lower than that required for lowland irrigated rice

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(Bouman 2001). International Rice Research Institute (IRRI) has developed aerobic rice varieties and MARDI has requested some of these planting materials to be tested in local environment. The first step in this investigation was to select suitable varieties from foreign introductions and then evaluate their growth and yield performance under local aerobic condition. This paper reports the progress made from the studies.

Materials and methods

Plant materials

Four potential varieties were selected from IRRI's First International Aerobic Rice Observational Nursery (1st AERON) 2005 set consisting of 81 rice varieties. They were known as AERON 1/05, AERON 4/05, AERON 33/05 and AERON 49/05. Similarly, two potential varieties were selected from the pool of 19 rice varieties in AERON 2006 set. These varieties were known as AERON 2/06 and AERON 26/06.

Studies were conducted to evaluate crop performance of the selected varieties from AERON set 2005 in off season (OS) of 2005 and AERON set 2006 in OS 2006. These potential lines were planted together in the main season (MS) 2007/08 for seeds multiplication and further evaluations in MARDI Seberang Perai.

Five local varieties were used as control: MRQ 50, MR 219, MRQ 74, Kuku Belang and Kurau. The MRQ 50, MR 219, MRQ 74 varieties were currently undergoing crop performance test under aerobic condition and interim agronomic package for planting these varieties under aerobic condition is being developed.

The selection process was done by focusing on seven morphological characteristics such as plant vegetative vigour, phenotypic acceptability, culm height, leaf length and shape, tillering ability, days of maturation and yield component. Vegetative vigour and phenotypic acceptability characteristics were influenced by several factors such as tillering ability, plant height, plants recovery after water and drought stress, nutrients uptakes and others. Standard descriptions and scales guidelines named SES by IRRI were used for evaluating both characteristics in genetic materials and varieties under stress and non-stress conditions (IRRI 2007).

The yield component analysis comprises panicle length, number of total spikelets, number of filled grains, number of primary branches (rachis) and 1000-grain weight. Screening for major pests and diseases were also conducted on these varieties.

Preliminary yield trial

The experiment was conducted in MS 2007/08 and OS 2008 under aerobic cultivation in non-puddle soil with supplementary irrigation. Dry rice seeds from each accession were drilled into the soil in row with three seeds per point. The planting distance was 20 cm spacing within rows; and 25 cm spacing between rows in 5 m x 5 m plot. A total of nine treatments using Randomised Complete Block Design with three replicates were used.

Pre-emergence herbicide was sprayed in blanket to control weeds before seed sowing. The field was irrigated 10 – 15 days after planting and selective herbicides were again applied to reduce weeds in the field. Compound fertilisers (N; P_2O_5; K_2O; 12:12:17+TE) at the total rate of 150 kg/ha were split into four times and applied at 15, 30 – 35, 55 – 60 and 70 – 75 days after sowing and additional fertiliser of urea 46% at the total rate of 100 kg/ha were split applied at 15 and 45 days. Fungicide and insecticide were sprayed to control foliar blast, neck rot and rice bugs when infestation occurred.

Rainfall was the main source of water for the crop and furrow irrigation was utilised to provide supplementary irrigation. Water supplement was given at least twice a week during vegetative stage and four times a week during productive stage, from panicle initiation stage to the grain ripening stage. Tensiometer readings indicated that

the water potential in these plots ranged between 30 – 60 centibars. Various crop data such as plant morphology and other traits were observed and recorded at weekly intervals. Based on 3-day-old panicle emergence, 50% flowering were recorded.

All plants within each plot were harvested for yield estimation. A total of 15 plants from all varieties and every replicate were also sampled for yield component analysis. The mean data from every observed variety were subjected to Pearson correlation by using SAS program (SAS Inst. 1993) to determine the relationship between selected morphology and yield characteristics between control and INGER varieties.

Results and discussion

Five wetland rice varieties (MRQ 50, MRQ 74, MR 219, Kuku Belang and Kurau) were used as control under aerobic soil conditions since MARDI has not released any local aerobic rice variety yet. However, two control varieties, Kuku Belang and Kurau were discarded during evaluation because no panicle emergence was observed at 115 days after sowing due to photo period sensitive. MR 219 was used as control because it is a popular variety and is widely grown in the country. MRQ 50 and MRQ 74 are local high quality rice which are planted in the east coast of Malaysia especially in rainfed fields and in water shortage areas with supplementary irrigation. The varieties mentioned above were bred from different crosses, identified and selected under a breeding programme suitable for irrigated fields only.

AERON 1/05, 4/05, 33/05, 49/05, 2/06 and 26/06 were identified and selected from aerobic rice breeding lines under INGER programme from IRRI. These varieties were chosen for this study after undergoing the preliminary selection process in local aerobic environment together with many varieties received from IRRI under INGER programme. The designations of selected varieties in this study are shown in *Table 1*.

Comparatively, variety AERON 1/05 showed superior values in some yield component characteristic such as longer panicle, higher number of rachis, higher yield and heavier grains. However, there was no significant difference in the number of primary branches compared to AERON 49/05 (*Table 2*).

Selected morphology characteristics were also evaluated in this study and are shown in *Table* 3. AERON 1/05 was identified as having the best plant vigor character and good phenotype acceptability in aerobic condition. AERON 1/05 and AERON 4/05 had a similar characteristic in tillering ability trait and significantly higher compared to the other varieties.

There are variations in leaf length, culm height and days of maturation among the varieties shown in *Figure 1*. AERON 5/06 is taller and AERON 33/05 has longer leaf compared to others. All the INGER varieties matured earlier and showed no

Table 1. Designation of selected varieties

Variety	Designation	Cross	Origin
AERON 1/05	IR76569-259-1-2-1	IR76569-259-1-2-1	IRRI
AERON 4/05	IR76569-166-4-2-2 – I	IR76569-166-4-2-2 – I	IRRI
AERON 33/05	IR76569-166-4-2-2 – I	WAB 56-50/CG 14	WRDA
AERON 49/05	YUNLU NO. 34	YUNLU NO. 34	China
AERON 2/06	B6149F-MR-7	ITA117/B1050C-MR-18-2	Indonesia
AERON 26/06	IR 78877-208-B-1-1	APO/IR 72	IRRI
Control 1	MRQ 50	Q34/KDML	MARDI
Control 2	MRQ 74	Q34/KDML//KASTURI///Q34	MARDI
Control 3	MR 219	MR151/MR137	MARDI

Table 2. Yield component analyses of the selected rice varieties grown under aerobic soil condition

Variety	Panicle length (cm)	1000-grain wt. (g)	Yield/ha (kg)	No. of primary branches
AERON 1/05	27.1a	26.9a	6378a	10.7a
AERON 4/05	26.4c	26.2b	6011b	9.7bcd
AERON 33/05	26.8ab	25.1d	5466d	9.7bcd
AERON 49/05	26.5bc	25.7c	5719c	10.7a
AERON 2/06	25.7d	25.1d	6104b	10.0abc
AERON 26/06	24.8e	24.9e	5838c	9.7bc
MRQ 50	22.17h	23.8g	4561f	9.3cd
MRQ 74	22.5g	23.4h	4721e	9.0d
MR 219	23.6f	24.5f	4468f	10.3ab
Mean	25.06	25.05	4129	9.88
CV	20.89	10.37	16.44	15.14

Means in a column followed by the same letter are not significantly at 5% DMRT

Table 3. Morphological characteristic of selected rice varieties grown under aerobic soil condition

Variety	Plant vigour	Phenotype acceptability	Tillering ability
AERON 1/05	2.0a	2.0a	10.3a
AERON 4/05	2.6b	2.6ab	10.3a
AERON 33/05	3.3c	3.0b	9.0b
AERON 49/05	3.0cd	3.0b	9.3b
AERON 2/06	3.0cd	3.33b	9.0b
AERON 26/06	3.0cd	3.0b	9.0b
MRQ 50	5.3d	5.0c	8.0c
MRQ 74	5.0d	5.0c	9.0b
MR 219	5.0d	6.3d	9.7ab
Mean	3.39	3.70	9.29
CV	19.27	12.72	15.47

Means in a column followed by the same letter are not significantly at 5% DMRT

significant difference among them in days to maturation but were significantly different compared to control varieties that needed more days to mature.

Variety AERON 49/05 produced higher total number of spikelet compared to others and this character also indicated that all the INGER varieties had more spikelets compared to control varieties under aerobic condition (*Figure 2*). Varying sterility rates were observed in this study with MR 219 scored the highest. All the INGER varieties showed no significant differences in number of filled grains and these varieties were able to produce more filled grains and significantly different than the control varieties (*Figure 2*).

Panicle length and total spikelet characteristics indicated significant positive correlation among the varieties, but there are different trends of relationship of this character between INGER varieties and control varieties as shown in *Figure* 3. The correlation results showed 1000-grain weight has significant positive relation to grain yields for controls and INGER varieties at $p < 0.01$ level, but the correlation was negative for total spikelet to grain

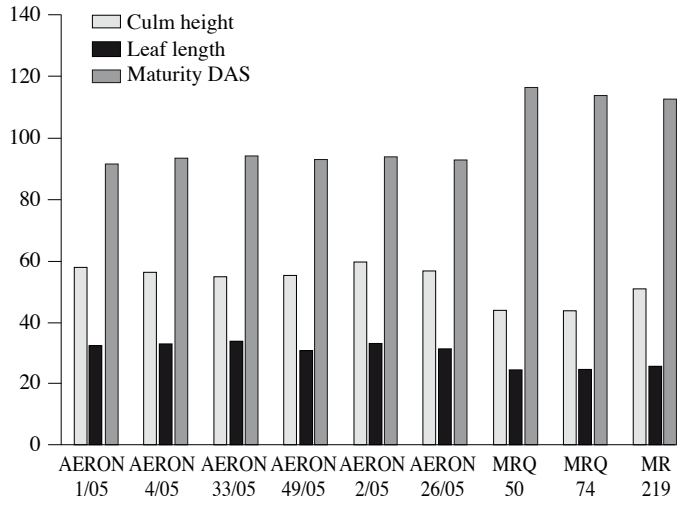

Figure 1. Selected morphology characteristics of observed rice varieties

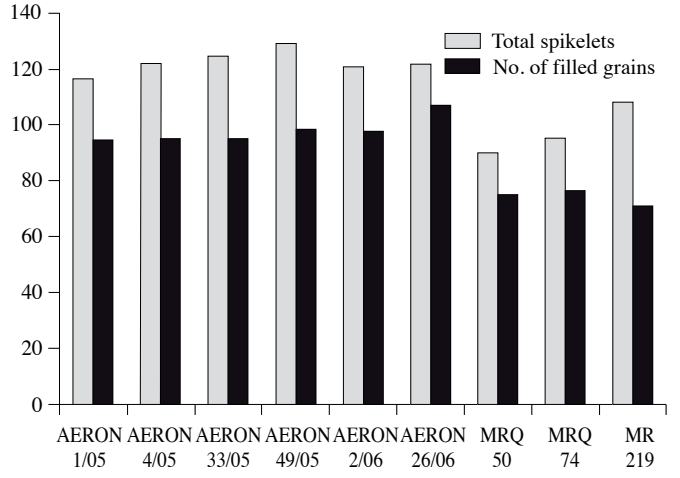

Figure 2. Total number of spikelets and filled grains of observed rice varieties

yields (*Table 4*). The relationship to panicle length is positive but non-significant with number of primary branches on panicle and negatively correlated with number of total spikelets.

The plot yield of the three control varieties ranged from 3.3 to 3.5 t/ha under aerobic soil condition. These yields were very much lower compared to the yield when they are grown under flooded condition. However, the yield of all the AERON lines studied were higher than the control variety MR 219. The increase in yield ranged from 18.1% to 28.9% (*Table 2*). This suggested that aerobic lines developed from the INGER breeding programme were able to adapt and perform under water stress condition in non-puddle soil.

In addition to yield, number of filled grains per panicle, 1000-grain weight, the number of spikelets per panicle and the length of panicles, were all higher for the aerobic than the control varieties. The results suggested that under aerobic soil condition,

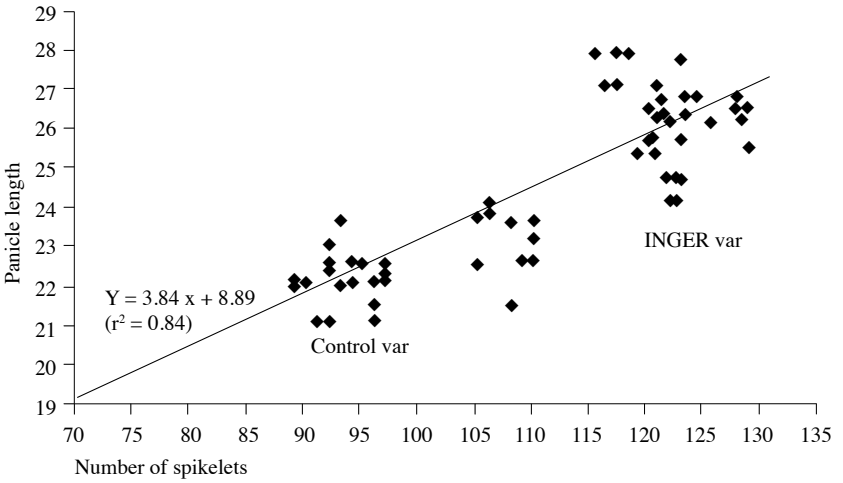

Figure 3. Relationship between the length of panicles and the number of spikelets of control and INGER varieties

Table 4. Correlation coefficients (r^2) of selected characteristics in control and INGER

	Panicle length	Total spikelets	No. of filled grains	1000-grain wt.	Yield/ha 20 m x 5 m (kg)
Control varieties					
No. of filled grains	–0.406	–0.245			
1000-grain wt.	0.804**	0.821**	–0.448		
Yield/ha 20 m x 5 m (kg)	0.469	–0.419	0.661	0.809**	
No. of rachis	0.785	0.869**	–0.113	0.927	–0.591
INGER varieties					
No. of filled grains	–0.475	0.559			
1000-grain wt	0.661*	–0.323	–0.376		
Yield/ha 20 m x 5 m (kg)	–0.161	–0.519**	0.017	0.688**	
No. of rachis	0.391	0.223	–0.149	0.431	0.356

*, ** = Significant at $p < 0.05$ and $p < 0.01$ levels

yield is very much determined by the number of branches that contributed to grain filling, thus increasing the number of filled grains.

These results implied that improvement of grain yield in aerobic rice is directly associated to those characteristics mentioned above. Thus, selections on breeding varieties need to focus in these characteristic to identify high yielding aerobic rice varieties. Research in other crops (Sasahara et al. 1992; Yang et al. 2000) also reported similar results.

The differences in the height of the rice plants, length of leaves, early senescence and high percentage of sterility was possibly due to competition for nutrient and sunlight, water stress, and heterosis's pressure in plant (Gealy et al. 2006; Zainudin et al. 2010). Analyses on correlation for yield components were generally positive such as correlation between panicle length and 1000-grain weight, panicle length and number of primary branches, total spikelets and number of filled grains and also for number of filled grains and plot yield. The

results showed some negative correlation in other characters.

Positive correlation between panicle length and number of primary branches indicated that more spikelets produced in the primary branches may affect the good seeds setting ability by increasing grain filling resulting in heavier grain. These phenomena enabled the crop to increase the 1000-grain weight. These correlation analyses showed similar results to studies conducted by Malik et al. (2000) and Sajid et al. (2008).

Conclusion

Generally, the morphological and physiological characteristic performances of the aerobic rice varieties were better under aerobic soil condition compared to wetland rice varieties. Some of these traits are useful for yield improvement of the varieties. These results suggested that selection process must incorporate these useful traits to enhance yield in new aerobic rice varieties.

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Abstrak

Penanaman padi aerob ialah satu kaedah baharu penanaman padi dengan bantuan pengairan, tanpa memerlukan air bertakung di dalam petak sawah. IRRI telah pun membangunkan varieti padi aerob dan MARDI telah menjalankan kajian penyesuaian baka tersebut di persekitaran tempatan. Tujuan utama kajian adalah untuk menyaring baka dari luar negara dan menilai pertumbuhan dan prestasi hasilnya di persekitaran tempatan untuk penanaman secara aerob. Varieti AERON 1/05 merupakan baka terbaik berdasarkan beberapa ciri komponen hasil seperti panjang tangkai, bilangan cabang terbanyak, hasil dan berat biji padi. Namun baka ini tidak mempunyai perbezaan yang signifikan pada ciri bilangan cabang dengan baka AERON 49/05. Semua baka dari *International Network for Genetic Evaluation of Rice* (INGER) mempunyai bilangan biji bernas yang tidak berbeza tetapi bilangan biji bernas ketara lebih tinggi berbanding dengan varieti kawalan (MR 219, MRQ 50 dan MRQ 74). Analisis korelasi menunjukkan bahawa berat 1000 biji menyumbang secara positif terhadap jumlah hasil bagi dua varieti kawalan dan baka INGER. Ciri-ciri yang mempunyai pertalian positif pada potensi hasil baka padi aerob amat berguna dan ciri-ciri tersebut perlu digabungkan untuk meningkatkan hasil varieti baru padi aerob.