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Growth and Physiological Performance of Aerobic and Lowland Rice as Affected by Water Stress at Selected Growth Stages

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Abstract: Aerobic rice technology is still new in Malaysia, and information regarding MARDI Aerob 1 (MA1), the first local aerobic rice variety, is still lacking. Therefore, comparative studies were carried out to determine the physiological performance of aerobic rice variety MA1 and lowland rice variety MR253 under water stress given at the panicle initiation, flowering and ripening stages. This experiment was arranged in a randomized complete block design. Stomatal conductance (g_s), chlorophyll a fluorescence (F_v/F_m), leaf relative water content (leaf RWC), and soil moisture content (SMC) as well as yield component parameters such as panicle number, grain yield and 100-grain weight were measured. Results revealed that g_s and leaf RWC for both varieties decreased with depletion of SMC. The correlation study between the physiological parameters and SMC indicated that F_v/F_m was not affected by water stress, regardless of varieties. The yield components (panicle number, grain yield and 100-grain weight) for both varieties greatly decreased when water stress was imposed at the panicle initiation stage. This study showed that the panicle initiation period was the most sensitive stage to water stress that contributed to a substantial reduction in yield for both varieties. Under the aerobic condition (control), MR253 produced higher panicle number, 100-grain weight and yield than MA1. Although MR253 is bred for lowland, it is well adapted to aerobic condition.

Key words: water stress; stomatal conductance; chlorophyll a fluorescence; leaf relative water content; yield component; aerobic rice

Rice industry in Malaysia is still depending on irrigated lowland rice (Sariam et al, 2014). Lowland rice can produce high yield but with high water input since it is grown in puddled lowland field that requires continuous flooding (Chan et al, 2012). Generally, 3 000 to 5 000 L water is needed to produce 1 kg rice (Bouman et al, 2002). Limited water availability in the future coupled with climate change effects may reduce the capacity of farmers to irrigate their fields, which may result in increased incidence to crop water stress (Chauhan and Abugho, 2013). Hence, aerobic rice is developed to maintain the sustainability of rice production under water scarce environment (Govindarasu et al, 2015). It can be a replacement to lowland rice where available water is insufficient for lowland but sufficient for aerobic rice production. Aerobic rice can save as much as 50% of irrigation water in comparison to lowland rice (Chan et al, 2012; Parthasarathi et al, 2012). In Malaysia, MARDI Aerob 1 (MA1) is the first aerobic rice variety developed by Malaysian Agricultural Research and Development Institute (MARDI), characterised with a short maturation period of 79 to 88 d with attainable grain yield of 4 to 5 t/hm^2 under optimum condition (Sariam et al, 2015).

In general, the sensitivity of rice to drought or water stress varies with timing, duration, severity of drought stress, variety and the growth stage of rice (Bakul et al, 2009; Anjum et al, 2011; Sokoto and Muhammad, 2014).

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Drought sensitivity has been determined on several Malaysian local rice varieties namely MR220, Muda, MR84, MR219 and Jawi Lanjut, and MR220 is the most drought sensitive, followed by Muda, MR84, MR219 and Jawi Lanjut (Zulkarnain et al, 2009). The crop water requirement depends on growth stages, field condition and cropping season (MARDI, 2009). Under Malaysian local environment, about 560 and 1 200 mm water is required for a single cropping season for aerobic and wetland rice, respectively (Chan et al, 2012). For many annual crops, the productions are greatly affected when drought occurs at the flowering and yield formation stages (Pandey and Bhandari, 2007). According to Saragih et al (2013), drought or water stress at the early reproductive stage greatly affects the grain yield of rice. The variation in rice yield component is associated with variability in water availability at different growth stages (Boonjung and Fukai, 1996). The reduction in leaf water potential adversely affects the reproductive growth and canopy expansion, leading to significant yield loss (Kato and Okami, 2011). Drought also adversely affects plant physiological performance through reduction in gas exchange in particular stomatal conductance, photosynthetic pigments and overall crop water relations (Anjum et al, 2011). Regardless of varieties, chlorophyll content, photochemical efficiency (F_v/F_m) and leaf relative water content (leaf RWC) are also affected when drought occurs at the vegetative, flowering or grain-filling stages (Pirdashti et al, 2009).

Periodic water stress seems to increase rice tolerance to drought stress besides improving its water use efficiency (Zain et al, 2014). Wopereis et al (1996) found that the occurrence of water stress during transplanting and two weeks after transplanting results in no yield reduction compared to drought stress that occurs at the reproductive stage in rice. The incidence of water stress at the full heading stage results in lower grain yield as compared to water stress at 10 to 25 d after the full heading stage (Abou-Khalifa, 2010). Stunted or delayed growth due to drought during the vegetative stage may not necessarily bring negative effects on yield if rice plants are re-watered and recovered before the flowering stage (Yoshida, 1981). As water scarcity increases with the changing climate, there is a need to improve irrigation water management to minimise incidence of severe water stress at critical growth stages for yield maximisation (Davatgar et al, 2009).

MA1 is a newly developed aerobic rice variety, but its information on physiological characterisation and growth performance under various environmental conditions is still lacking. More crop water relation studies are needed to be carried out since water will be the main limiting factor particularly under irrigated rice cultivation system. This study aimed at characterising the physiological performance of this variety under water stress given at selected growth stages and subsequent effects on grain yield and yield components. The performance of this variety was compared to MR253, an established lowland variety that can be grown under aerobic condition (Mahmod et al, 2014). The understanding of physiological and morphological adaptations of these varieties to water stress at selected growth stages is crucial in minimising water wastage, future improvement of water use efficiency and maximizing rice productivity.

MATERIALS AND METHODS

Description of the study area

The field experiment was carried out in the experimental farm of the Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA (UITM), Melaka Jasin (2º22′N, 102º45′E), Malaysia, from August in 2015 until January in 2016. The field was formerly cultivated with oil palm and has been planted with aerobic rice at small scale for several cropping seasons since 2014. The soil is of Gajah Mati soil series with average pH of about 6.0, N of 0.15% (nitrogen), P_2O_5 of 0.01% (phosphate) and K_2O of 0.068% (potash). The monthly means for temperature, rainfall and relative humidity recorded during the field study is shown in Table 1.

Planting materials

Two local varieties, MA1 (an aerobic rice variety) and MR253 (a lowland variety), were used in this study. Both varieties were obtained from MARDI. The maturation periods of MA1 and MR253 are from 79 to 88 d and from 100 to 104 d, respectively, and vary

Table 1. Climatic factors during experimental period.

Month	Temperature (ºC)		Rainfall	Relative
	Minimum	Maximum	(mm)	humidity (%)
August 2015	24.7	31.8	410.2	82.8
September 2015	24.6	31.8	113.0	83.9
October 2015	24.4	32.6	244.0	82.7
November 2015	24.6	32.4	217.0	85.9
December 2015	24.5	32.4	275.6	83.5
January 2016	25.2	33.3	122.4	81.0

Data were obtained from the Meteorological Department for Melaka Station.