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Effects of Different Water Levels on Physiology and Yield of Salinity Rice Variety

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ABSTRACT

Background: Water wise rice production is the current concern. **Objective:** To justify the water effects on production of salinity rice cultivar, plants physiological, and yield parameters were evaluated. There were four water treatments, T1: flooding at 5 cm (control), T2: flooding at 1 cm, T3: saturated condition and T4: alternative wet and dry (AWD) and five replicates were arranged according to a completely randomized design. Yield, plant and soil parameters under different irrigation conditions were measured. **Results:** Different water treatments affected plant height at secondary tillering stage, yield and yield parameters of rice plants. AWD treatment decreased chlorophyll (Chl) content and Chl fluorescence in leaves. In addition, net photosynthesis rate (Pn), relative water content (RWC) decreased gradually with decreasing water content in the soil. AWD treatment reduced soil pH but increased soil electric conductivity (EC) value. **Conclusion:** These results suggest that AWD affected plant yield through modulating plant physiological function but saturated to 1 cm flooding condition showed no effect on rice yield and plant physiology.

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INTRODUCTION

Rice provides approximately 32% of total calorie uptake (Maclean *et al*., 2002) from a 455 ton of rice production in Asia (IRRI, 2012). Sarwar (2004) stated that less water use account for almost 30% of water saving from traditional irrigation system. Currently, shrinking water availability for rice cultivation during summer season in Malaysia threatens the productivity of rice and, therefore, measures to save water as well as to sustain the productivity have to be established.

In Malaysia, increasing water demand about 4% annually and approximately 20 billion m^3 by 2020 will be needed to fulfill the water demands (Keizrul and Azuhan, 1998). Malaysia imports about 983,000 metric tons of rice in 2012, but 1.1 million metric tonnes in 2013 (Ismail, 2014). In Malaysia, water rationing during rainless season in Selangor state supply off a critical condition for fresh water (Koon and Pakiam, 2014), therefore, rice, palm oil, cocoa and rubber-tapping industries are in a pressure. It is important to cut down water supply for rice cultivation without insignificant effect on rice yield. The implementation of the rice cultivation programmes should be taken to present sustainable rice production.

Water level at lower than saturated condition reduced rice yield (Sarwar and Khanif, 2005a, 2005b, 2005c). Khairi *et al.* (2015) reported that thewater deficit affected plant growth, photosynthesis and grain yield of lowland variety.Water stress limits rice production and yield sustainability in lowland rice growing areas which depend on degree and duration of water stress (Khairi*et al*., 2015). Less water shows low tissue water potential (Kato *et al*., 2004) which may affect net photosynthesis rate (Khairi *et al*., 2015) and RWC in leaves (Chelah *et al*., 2011; Jahan *et al*., 2013a). Chlorophyll content plays an important role in plant growth and development (Jahan *et al*., 2014). Water stress affects chlorophyll content in leaves of rice (Sheela and Alexander, 1996). A chlorophyll loss is a main cause of inactivation of photosynthesis (Kura- Hotta*et al*., 1987).

Present rice production system requiresabout 1900 to 5000 liters of water to produce 1kg of rice grain. By 2025, about 10% of the land under rice production will face water scarcity (Bouman *et al*., 2007). To date, many researches have been done to reduce water use in rice cultivation. Therefore, this study was carried out to provide information on the effects of low water use on saline rice variety for sustainable rice production.

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Methodology:

Experimental setup:

Rice plants were grown in a pot measuring of 25 cm x 25 cm x 35 cm according to previous studies (Sarwar *et al*., 2004; Jahan *et al*., 2013b). Allpots were filled by soil and 5 cm spaces were kept free from the soil level to the top of the pot for irrigation facilities. Two holes were made at 0 cm and 1 cm above from the soil level in the respective pots to regulate water treatments. Four treatments,T1: 5 cm flooding, W2: 1 cm flooding, W3: saturated condition, and W4: alternative wetting and drying (AWD; irrigate 5 cm flooding when water dropped at field condition level, that is -33 Kpa), were arranged according to a completely randomized design (CRD) with five replicates. An ECHO soil moisture sensor was used to determine soil water potential value. Seeds of rice variety IRRI147 were used in this study. Pre-sprouted seeds were planted in each pot. Standard agronomic practices were maintained to control insect, disease and weeds according previous reports (Jahan *et al*., 2004; Sarwar and Khanif, 2005d).

Fertilizer and irrigation:

Nitrogen (110 kg/ha) as urea three splits (1/3 as basal + 1/3 at active tillering + 1/3 at late vegetative stage)was applied. A basal application of 60 kg/ha of P_2O_5 as triple super phosphate (TSP), and K_2O (65 kg/ha) as muriate of potash (MOP) was applied.A compound fertilizer (N: P: K= 12:12:17) was applied twice at 50 and 70 days after sowing (DAS) at the rate of 250 kg/ha. Irrigation water was applied through a plastic tube attached to the water tank and water levels were maintained according to the treatments.

Measurement of yield and yield components:

Yield and yield parameters were measured according to Jahan *et al*. (2012, Syuhada *et al*., 2014). At maturity, number of tillers and panicles per pot was recorded. Yield in each pot was recorded. The panicles were separated from the straws. The filled grains were separated from the unfilled grains by using a salt solution, then washed, dried, weighed and counted. Grains per panicleand weight of 1000-grain were recorded. Plant height and panicle length were measured using a measuring tape.

Measurement of chlorophyll content and chlorophyll fluorescence in leaves:

A portable SPAD-502 chlorophyll meter (Spectrum Technologies, USA) was used to acquire a*in situ* leaf chlorophyll content (Jahan *et al*., 2014). Data were taken from 11 am to 12 pm to avoid error from water droplets on the leaf surface (Jahan *et al*., 2013a). On the other hand, a portable Junior-PAM chlorophyll fluorescence monitoring meter (Walz, Germany) was used to quantify *in situ* chlorophyll fluorescence in leaves of rice plants (Jahan *et al*., 2014). The fully open uppermost collared-leaf was used to take reading in between 11 am to 1 pm. The minimum fluorescence (Fo), the maximum fluorescence level (Fm) and quantum yield in photosystem II (Fv/Fm) in leaves of rice plants were estimated.

Determination of net photosynthesis rate andrelative water content:

A CI-340 portable photosynthesis meter (CID Biosciences, Inc.) was used to determine Pn rate according to the previous study (Syuhada *et al*., 2014). Data were taken from 11 am to 1 pm on each operational day. The RWC was measured according to Chelah *et al*. (2011) using the following formula.
RWC (%) = (fresh weight – dry weight) / (turgid weight – dry weight) X 100

Measurement of electric conductivity and Soil pH:

Electric conductivity (EC) was determined using a portable Field Scout direct soil EC meter (Spectrum Technologies, USA). Soil pH was measured using a portable soil pH meter (HANNA Instruments, USA). Both EC and soil pH meters were calibrated before using.

Statistical analysis:

The data were analyzed for the analysis of variance (ANOVA). The means were compared by using Duncan's Multiple Range Test (DMRT) at 5% level by using the SPSS software (Version 17) and Minitab 16.

Results:

Effects of different water treatments on yield and yield parameters of rice plants:

We showed whether low input water affects yield and yield parameters of salinity rice variety. Figure 1A showed that plant height gradually increased with increasing plant age but AWD treatment affected plant height after 49 days after planting. The panicle numbers decreased with decreasing water status in soil (Fig. 1B). Plants grown under AWD condition produced significantly lower panicle numbers than other plants. A weight of 1000-seed was found insignificantly different (Fig. 1C). Alternative wet and dry treatment significantly reduced total grains per panicle compared than that of other treatments (Fig. 1D). Filled grain per panicle was found to be similar trend with total grain per panicle (Fig. 1E). In addition, the AWD treatment significantly ($P<0.04$) reduced rice yield (Fig. 1F).

Effects of different water treatments on chlorophyll-dependent parameters in leaves:

Chlorophyll related parameters (Chl contents and Chl fluorescence, and quantum yield in photo system II) in leaves of rice plants were determined to justify if different water treatments affect Chl related parameters. Chl content increased gradually with increasing plant age. But chlorophyll content in leaves of the rice plant was not affected by different water levels in the first few weeks then affected thereafter (Fig. 2A). Where, AWD treatment significantly decreased Chl content after week-7. Similar results were observed in case of Chl fluorescence (Maximum and minimum Chl fluorescence) in leaves of rice plants (Fig. 2B and C). In addition, quantum yields (Fv/Fm) in leaves of rice plants showed similar results as Chl content under different water treatments in the first few weeks but decreased thereafter (Fig. 2D).

Effects of different water treatments on net photosynthesis rate (Pn) and relative water content in leaves:

Figure 3A showed that different water treatments significantly affected Pn rate (mmol/m^2/s) in leaves of rice plants. Pn rate decreased with decreasing water input in soil where AWD treatment showed significantly effect on Pn rate in leaves of rice plants compared to other treatments. Figure 3B showed that RWC in leaves of rice plants under different water treatments. However, RWC data was similar Pn rate data in leaves of rice plants. However, AWD treatment significantly affected RWC in leaves of rice plants compared than other treatments.

Effects of different water treatments on soil pH, Soil EC value in soil:

Figure 4A shows the effects of different water treatments on soil pH.AWD treatment significantly decreased soil pH compared than other treatments (Fig. 4A). Different water treatments except AWD treatment did not affect soil EC value (Fig. 4B). But AWD significantly increased EC value than other treatments.

Discussion:

Rice can grow in a wide range of hydrological situations, e.g. soil types and climates. In Malaysia, rice produced through conventional flooded rice cultivation system which made higher quantity of fresh water used and less water productivity (Sariam *et al*., 2004). In this study, we showed that saturated or above soil water condition did not affect yield and yield parameters (Fig. 1). This result suggests that AWD condition-induced water scarcity might induced a degree of water stress to plants and reduce rice yield. This was supported by Sariam *et al*. (2002) that saturated condition did not affect plant parameters. In addition Jahan *et al*. (2004) also stated that soil water condition at 1 cm flooding did not affect yield compared to the traditional flooding. These results suggest that salinity variety might suffer for water scarcity under AWD treatment therefore produced less yield.

Water stress affected chlorophyll content in leaves of the rice plant might control crop productivity through CO_2 assimilation (Sheela and Alexander, 1996; Awal and Ikeda, 2002). This study reveals that plants accumulated less Chl content under AWD condition (Fig. 2A) which was supported by maximum Chl fluorescence (Fig. 2B) and minimum Chl fluorescence data (Fig. 2C). These results suggest that a water stress might affect light-related plant growth, development and production. Recently, Jahan *et al*. (2014) stated that Chl content affected leaf, plant growth and production plant. Therefore, it is suggested that AWD treatment might Chl content through modulation of plant physiological function. In this phenomenon Chl content might works as a factor of Chl content and glutathione correlation in plants (Jahan *et al*., 2011) infers to affect glutathione in plants. Previous study also stated that proper management of water while rice was grown on sandy soil did not affect Chl content (Chelah *et al*., 2011). A reduction Fv/Fm ratio in plant under AWD condition reflects potential quantum yield of PSII, which specifies the photosynthetic apparatus in leaves in plant (Pereira *et al*., 2004). Environmental stresses, e.g. drought, affect PSII efficiency and reduce the Fv/Fm values (Pospisil*et al*., 1998) and majority of Chl loss is due to water deficit (Nadler and Bruvia, 1998). According to Kurra-Hotta *et al*.(1987) that water stress affects photosynthesis ratewhich support that AWD condition decreased Pn rate (Fig. 3A).

Drought adversely affects rice plants and reduces relative water content in leaves (Fig. 3B). Therefore, less water condition in leaves might play an important role in keeping cells functioning. Garg (2003) stated that water availability in soil affects acquisition of nutrients by the root and transport to the shoots. Instead, soil pH plays an important role on availability of nutrient in the soil. In dry condition, less downward nutrient leaching might increase salt concentration (Donohue, 1998). Therefore, EC value increased in soil under AWD water condition indicates increased salt concentration in soil (Fig. 4B) but might not affected yield of IRRI147 variety which is less sensitive to saline condition. Under saturated or flooding condition, the anaerobic condition and bio-chemical reaction might increase soil pH (Fig. 4A) which might be a "temporary" pH fluctuation due to water condition in soil.

In conclusion, alternative wet and dry soil condition might affect plant growth and production, plant physiology of salinity variety but it might also save larger of fresh water to be used by other sectors. Farmers could adopt irrigation 1 cm to saturated soil water condition for sustainable rice production.

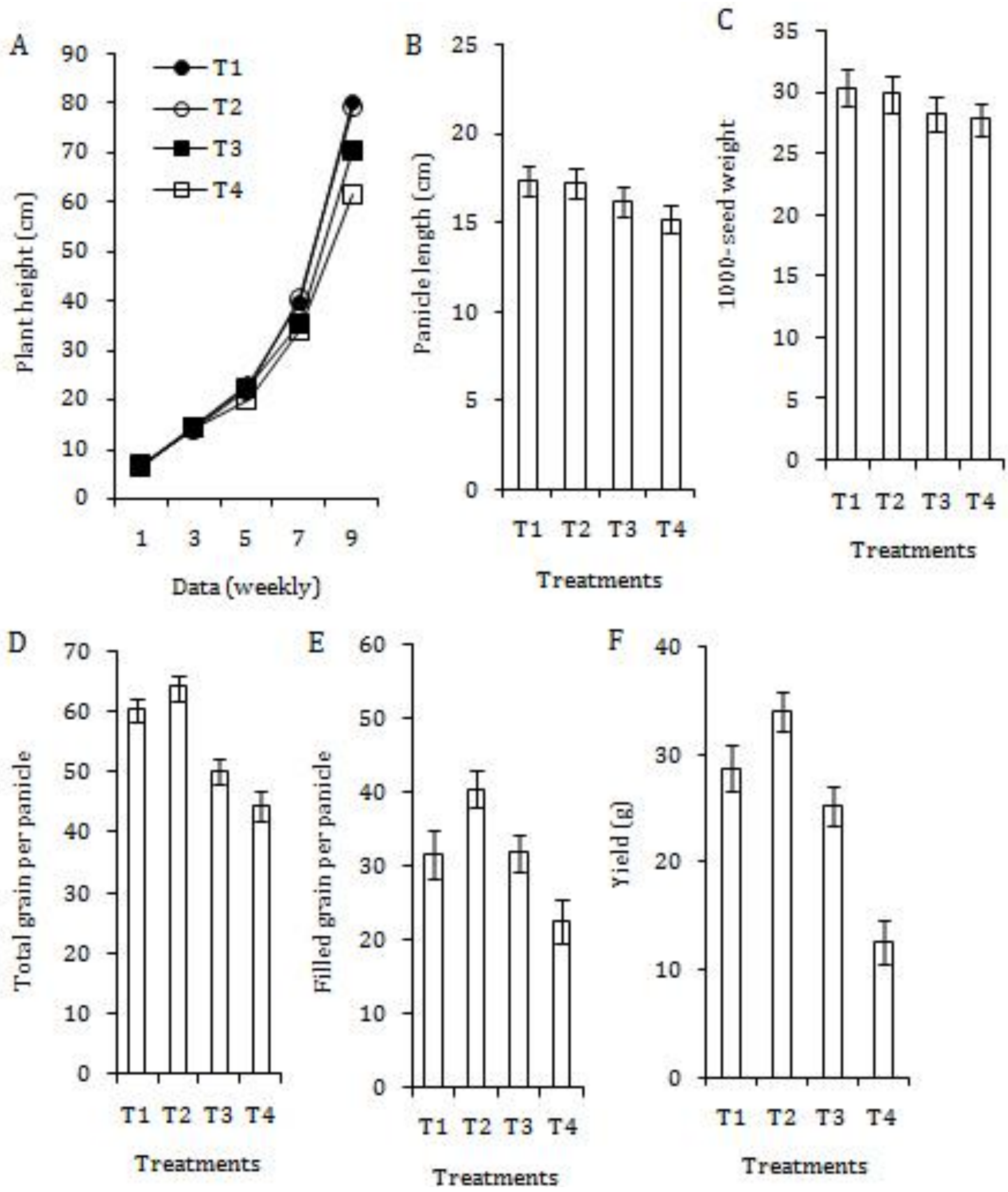

Fig. 1: Effects of different water treatments on yield and yield parameters. A, Plant height under different flooding levels, T1 (close round), T2 (open round), T3 (close square) and T4 (open square) showed different water conditions. Plant produced panicle length (B), 1000-seed weight (C), total grains per panicle (D), filled grains per panicle (E) and yield (F) per panicle.

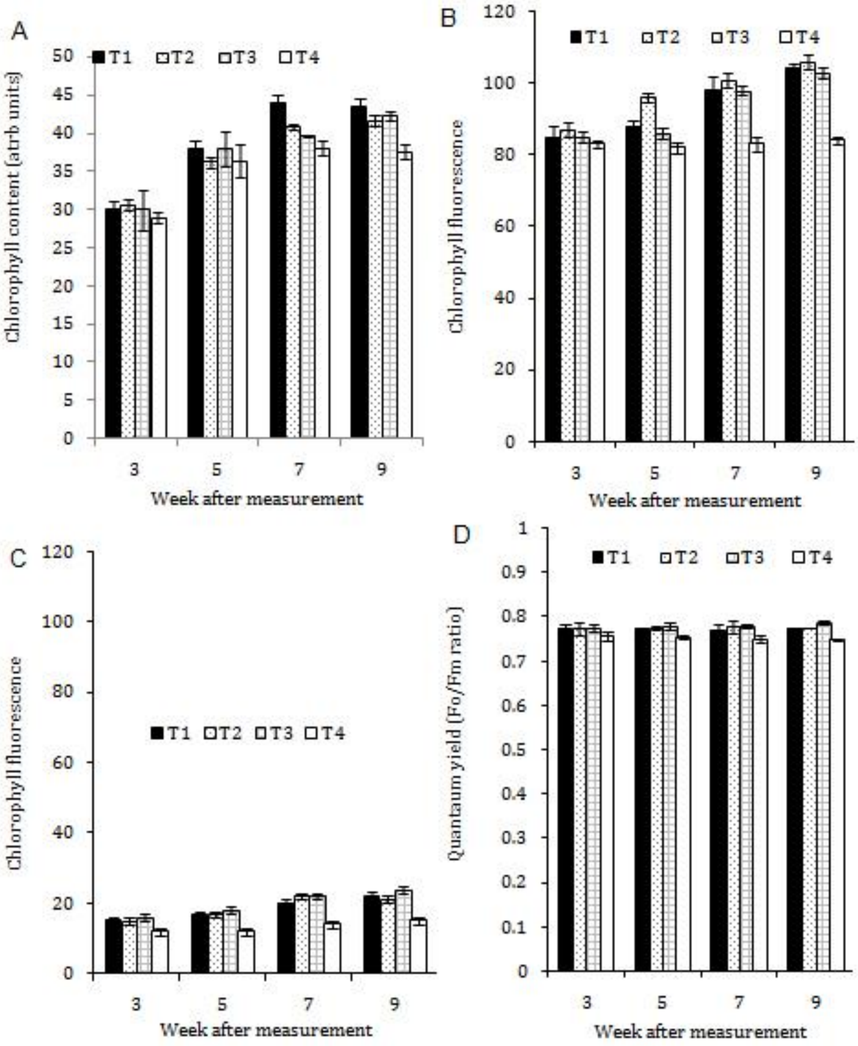

Fig. 2: Effects of different water levels on chlorophyll related data.

Chlorophyll content (A), maximum chlorophyll fluorescence (B), minimum chlorophyll fluorescence (C), and Quantum yield in PSII (D) in leaves of rice plants grown on different water treatments, T1 (closed bars), T2 (dotted bars), T3 (grid bars) and T4 (open bars).

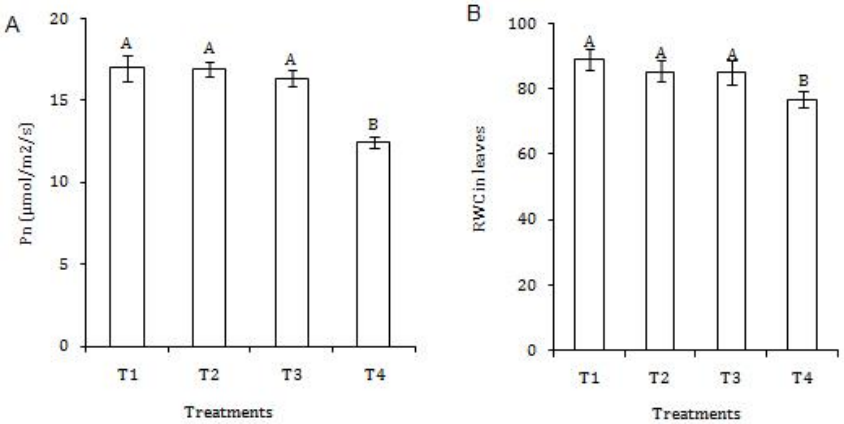

Fig 3: Effects of different water levels on photosynthesis rate (A) and relative water content (B).

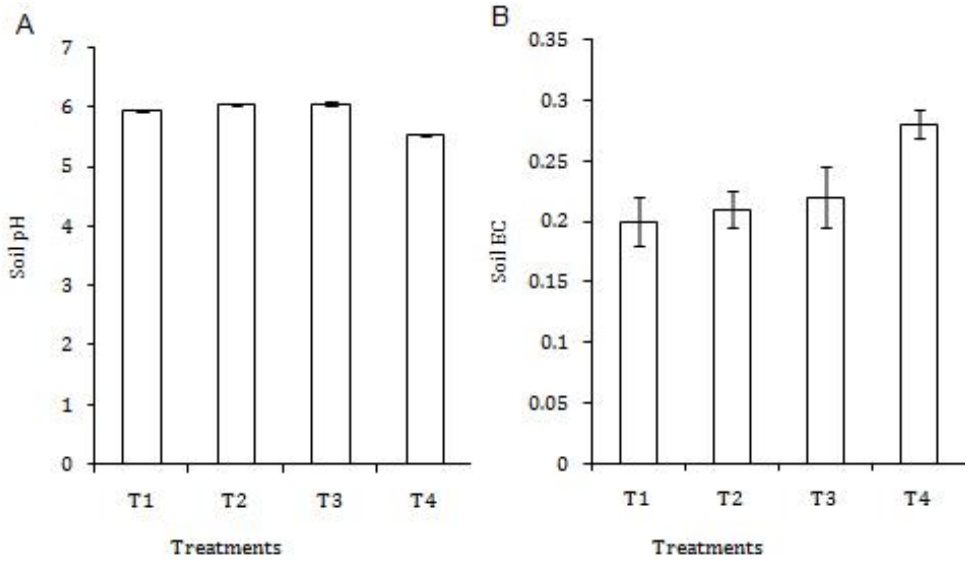

Fig. 4: Effects of different water levels on soil pH (A) and soil electric conductivity (B).

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