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Rice Growth and Yield under Rain Shelter House as Influenced by Different Water Regimes

WAN MOHAMMAD ZULKARNAIN, MOHD RAZI ISMAIL[1]†, M. ASHRAFUZZAMAN†, HALIMI MOHD SAUD† AND ISMAIL C. HAROUN†

Department of Agriculture, Wisma Tani, Federal Administration Centre, 62624 Putrajaya, Malaysia

†Laboratory of Food and Floriculture, Institute of Tropical Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

[1]Corresponding author's e-mail: razi@agri.upm.edu.my

ABSTRACT

A pot experiment was conducted to evaluate the effect of different water regimes on growth and yield of rice (*Oryza sativa* L.) variety MR220. Water regimes applied were flooded (5 cm above the soil surface), saturated (water given just to saturate the soil) and field capacity (periodic irrigation applied to maintain the desired level). Significantly higher values were recorded for plant height, number of tillers, shoot and root biomass in flooded rice followed by saturated and field capacity condition. Similar trends were observed for physiological parameters like stomatal conductance, SPAD values and water use efficiency. Yield and yield components were also influenced by the water regimes. Under the field capacity condition, rice plants received comparatively less water than flooded and saturated condition, which resulted in impaired rice growth that reduced grain yield and lowered harvest index.

Key Words: Growth; Yield; Water regimes; Rice; MR220

INTRODUCTION

Rice is a major food crop for the people of the world in general and Asians in particular; nearly 92% of the world's rice is produced and consumed in this region (Huke & Huke, 1997). Water for irrigation, a major factor in increased food production, is becoming scarce as the increasing pressure on water supplies for domestic and industrial purposes and in view of un-evenly distributed rainfall. To maintain food security, means must be adopted to increase the productivity of water used in agriculture. Malaysia is categorized in zone 3 in terms of water scarcity in the 20^{th} century with a need to increase water management efficiency between 25-100% to meet 2025 needs (FAO, 2006). The traditional practice of abundant water environment for rice cultivation needs to be re-examined as water is becoming increasingly scarce. As the demand for effective management of water resource increase, future rice production will therefore depend heavily on developing and adopting strategies and practices that will use efficient irrigation schemes (Guerra *et al.*, 1998). There are many approaches to improve water use efficiency in plants including regulated irrigation (Jones, 1992). Water saving measures by regulated irrigation in rice cultivation can bring impact water use efficiency and yield.

The scenario of decreasing the amount of available water for irrigation necessitates the adoption of rice production practices that reduce water inputs without impairing yield. To tackle the problem of severe water shortage for rice production, we urgently need new methods of irrigation to save water and related crop management technologies to sustain yield (Bouman & Tuong, 2001). In this study we tested three water regimes to choose one of the promising water saving technology keeping the morpho-physiological growth and yield unimpaired.

MATERIALS AND METHODS

Plant material and growth condition. An experiment was conducted at the rain shelter house of the Universiti Putra Malaysia, Serdang Malaysia. The commercial rice (*Oryza sativa* L.) variety MR220 was used in this experiment. Sandy clay loams from BERTAM, was used in this experiment. The experiment was laid out in Randomized Complete Block Design (RCBD), consisting of three treatments with four replications.

Water regime treatments. Three water regimes namely flooded, saturated and field capacity were used. For flooded treatments, the level of water in each pot was maintained at about 5 cm above the soil surface throughout the growing period of the crop until near maturity. For saturated treatment, water was applied just to saturate the soil (without flood) throughout the growing period of the crop. For maintaining field capacity, periodic irrigation was applied to maintain the soil at about field capacity from

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seeding to maturity. Irrigation was done when the water potential fell to -0.03 to -0.05 MPa, as measured with a tensiometer at the 15 cm soil depth. Tensiometers were installed in an extra pot for each replicate.

Morphological determinations. Plant height was measured from the soil surface to the tip of the tallest leaf. At maturity, the plant height was measured from the soil surface to the tip of the tallest panicle. Tillers number per pot was recorded as the tillers having at least three green leaves. At maturity, panicle bearing tillers counted only.

Shoot and root biomass. For the shoot biomass, samples were harvested by cutting about 2 cm above the soil surface at 20, 40, 60 and 80 DAT. The shoots were separated into grain and straw at maturity. The shoots were oven dried at 70^{o}C for 72 h and weighed. The remaining root mass of each section was washed to remove soil and then oven dried at 70^{o}C for 72 h and weighed again for root dry weight.

At maturity, the plants in each pot were harvested for the determination of yield and yield components. The panicles in each pot were counted to determine the panicle number per plant. All spikelets were separated from the panicle, weighed and counted to determine the number of spikelets per panicle. Grain yield per plant was obtained from the weight of filled grains calculated at 14% moisture. Filled grains were separated from un-filled and partially filled grains by using salt solution with a specific gravity of 1.06. The filled grains were dried, counted and the percentage of filled grains determined. The straw from each pot was cut at 2 cm above the soil surface, oven dried at 70^{o}C for 72 h and weighed.

Physiological determinations. Stomatal conductance of leaves was determined using a portable porometer (Delta-T AP4, Delta-T Devices, Cambridge, UK). The measurements were taken on the abaxial surface of the leaf once a week between 11.00 h and 14.00 h. The readings were accomplished during one-hour to avoid the diurnal pattern of variation of the leaves. The terminal part of the main leaf lobe was placed into the cup on the head unit that was positioned normal to the sun. Measurements were conducted during cloudless periods on exposed leaves between 10.00 h and 14.00 h.

Chlorophyll or SPAD meter (Minolta SPAD-502) was used to measure the greenness or relative chlorophyll content of leaves (Inada, 1985). SPAD values were taken at 15, 30, 45, 60 and 75 DAT. The youngest fully expanded leaf of a plant was used for SPAD measurement. Readings were taken on one side of the midrib of the leaf blade. In the early growth stage when leaves were too narrow to allow SPAD measurements on one side of the midrib, the leaf tips were used for measuring SPAD values. A mean of 10 values per plant was taken as the measured SPAD value.

Statistical analysis. The collected data were analyzed for variance using statistical analysis system (SAS) computer software and the significance of differences among the treatments was analyzed using the Duncan's Multiple Range Test (DMRT).

RESULTS

Morphological parameters. Plant height increased gradually with the advancement of growth under different water regimes. The tallest plant was observed in the rice grown under flooded condition. However, rice growth under saturated and flooded conditions was comparable. On the other hand, the growth of rice under field capacity was limited as indicated by shorter plants especially during active tillering stage through maturity when compared to rice grown under flooded and saturated conditions (Fig. 1). At maturity stage, rice grown under field capacity was about 20% shorter than rice plant grown under normal flooded condition.

Tiller production was also influenced by water regimes (Fig. 1). More tillers were observed under flooded and saturated conditions than field capacity condition. As rice growth advanced, the reduced amount of water under field capacity condition had limited tiller production of only 18 tillers per pot during panicle initiation stage (PI) as compared to 23 and 22 tillers for flooded and saturated treatments, respectively (Fig. 1).

Water regimes also affected dry shoot biomass (Fig. 2). There were no significant differences in producing shoot biomass by water regimes. However, shoot dry mass was reduced under field capacity as compared to saturated and flooding condition. During active tillering stage, more tillers were produced under saturated and flooding condition, resulting in a higher dry shoot biomass, compared to field capacity condition. About 40% shoot biomass was reduced under field capacity compare to under flooded condition.

Dry root biomass of rice at various growth stages was significantly affected by water regimes (Fig. 2). The dry root biomass for rice subjected to field capacity condition was lower at all the sampling dates as compared to flooded and saturated conditions. The root dry mass for rice grown under field capacity was only a half of the amount observed under flooded or saturated condition, at all growth stages except at maturity. A greater reduction in root dry mass was observed at maturity whereby only 25% of root biomass was recorded for rice subjected to field capacity when compared to flooded and saturated conditions. The shoot-root ratio at maturity was significantly affected by water management and rice variety (Table II). Higher root biomass at maturity from flooded and saturated conditions resulted in a lower shoot-root ratio under these water management treatments. On the other hand, a much smaller amount of roots under field capacity produced a higher shoot-root ratio.

Yield and yield contributing characters. There was a yield reduction of 10% when grown in saturated as compared to flooded condition. However, grain yield of rice grown under field capacity condition was significantly lower as compared to saturated and flooded condition. The grain yield under field capacity condition was 46% and 41% lower than flooded and saturated conditions, respectively

Fig. 1. Influence of different water regimes on plant height and number of tillers, Bars represent means of 4 replicates ± SE

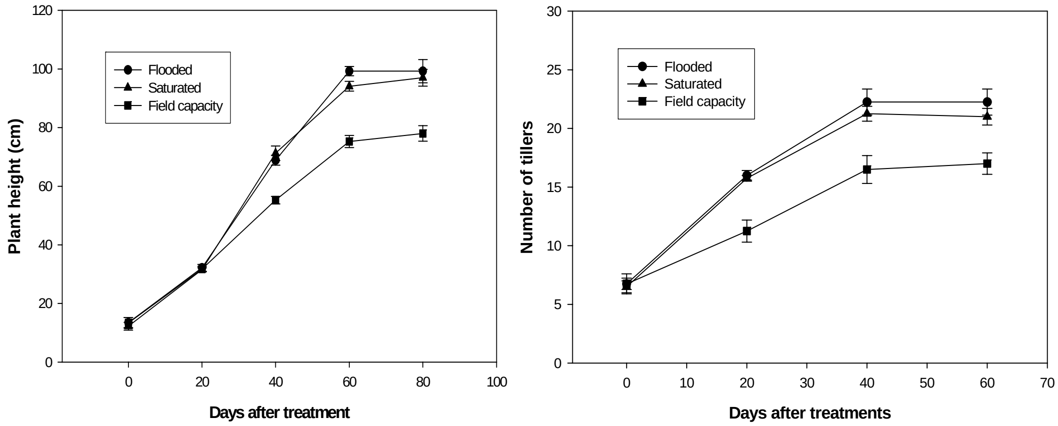


Fig. 2. Changes in shoot and root biomass under different water regimes, Bars represent means of 4 replicates ± SE

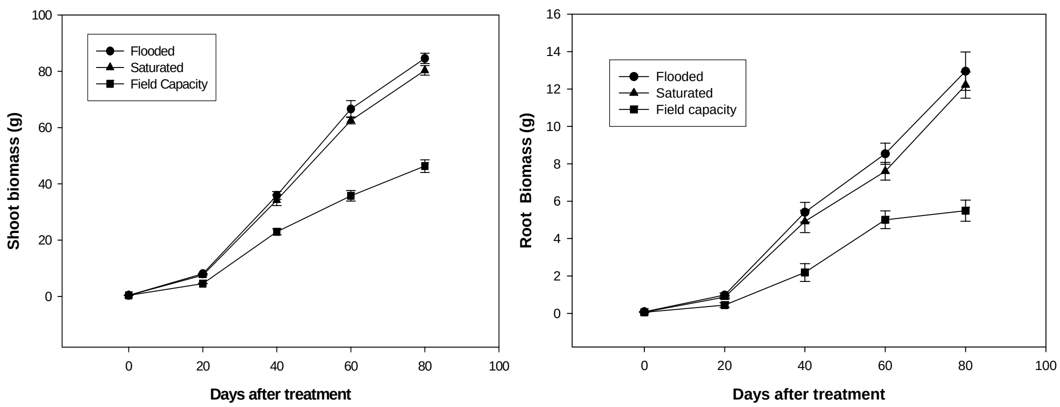
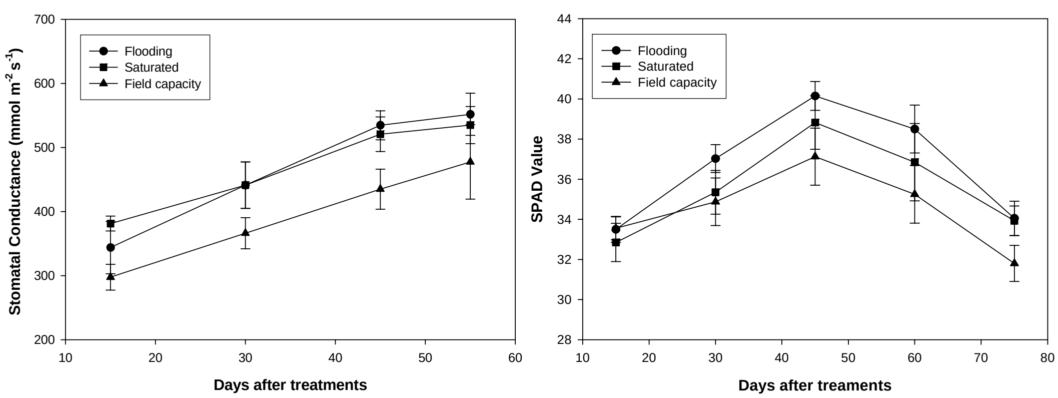


Fig. 3. Changes in stomatal conductance and SPAD values under different water regimes, Bars represent means of 4 replicates ± SE



(Table I). Rice grown under field capacity condition produced lower number of panicles than under flooded and saturated condition. A reduction of 45% in the number of panicles was observed to the rice grown under field capacity as compared to rice grown under flooded and saturated conditions (Table I). Profuse tillering under flooded and saturated condition resulted in significantly higher number of panicles at maturity (24 panicles per pot). On the other hand, rice plants produced significantly lower number of tillers (14 panicles per pot).

The number of spikelets per panicle was significantly lower under field capacity condition than flooded and saturated conditions. However no significant difference in the number of spikelets per panicle was observed between flooded and saturated conditions. The percentage of filled grain was significantly affected by water regimes (Table I). A significantly higher percentage of filled grain was observed under flooded and saturated conditions compared to under field capacity. The percentage of filled grain was, however comparable between flooded and saturated conditions.

A higher straw yield was obtained under normal flooded and saturated conditions. The amount of straw produced under field capacity was a half the amount produced under flooded and saturated water conditions. The harvest index (HI) was higher under flooded condition but significantly low under field capacity. HI of rice grown under saturated condition was comparable to HI of flooded as well as field capacity conditions (Table II).

Physiological parameters. Stomatal conductance gradually increased with the increase in plant ages irrespective water regime treatments. Stomatal conductance was significantly higher in both flooding and saturated condition and it was comparable between this two treatments. Under field capacity condition the stomatal conductance was consistent and increased by days but still lower than under saturated and flooding condition (Fig. 3).

The SPAD value indicating the greenness or relative chlorophyll content of leaves, differed significantly due to different water regimes. The maximum values were recorded in the flooded rice leaves followed by saturated condition and it was significantly low under field capacity condition. This trend was observed throughout the whole study period. Irrespective of water regimes SPAD values gradually increased with the advancement of plant age until 45 DAT and then declined gradually (Fig. 3).

Water use efficiency significantly differed over the applied water regimes and it was greater under field capacity (Table II). There were no significant differences between saturated and field capacity water regimes. On the other hand, water use efficiency was lower under flooding condition because water supply was more, whereas production of yield was comparable with saturated condition.

DISCUSSION

Plant height during early tillering stage was not much affected by different water regimes. This might be due to few and small tillers being produced up to this growth stage, which minimized competition for available water for growth even under field capacity condition (Khaliq & Cheema, 2005). With advancing plant age, water requirement increased and reducing water to field capacity condition significantly reduced plant height especially at maturity as well as tiller production during later growth stages. Beyrouty *et al.* (1994) also observed reduction in plant height but not tiller production when flood was delayed.

A lower shoot dry mass at all growth stages for rice subjected to field capacity treatment was expected, which corroborated the previous findings (Prasertsak & Fukai, 1997). On the other hand, a significantly higher shoot dry mass observed under flooded and saturated conditions might have been attributed to increased nutrient availability due to physico-chemical and biological reactions in soils (Choudhary & McLean, 1963).

Table I. Effect of water regimes on panicle number/plant, spiklets/panicle, filled grain (%) and grain yield/plant

Treatments	Panicles/ plant	Spikelets/panicle	Filled grain (%)	Grain yield/plant
Flooded	25a	75a	80.4	39.2a
Saturated	23a	70a	78.0	35.4ab
Field capacity	16b	64b	77.5	21.2c

Table II. Changes in water use efficiency (WUE), straw yield, harvest index and shoot-root ratio as influenced by different water regimes

Treatments	Straw yield (g)	Harvest index	Shoot-Root Ratio	WUE (kg/L)
Flooded	44.6a	0.45a	6.37b	0.08b
Saturated	44.8a	0.42ab	6.35b	0.12ab
Field capacity	22.8b	0.40b	12.49b	0.14a

Grain yield was comparable when rice was grown under flooded and saturated conditions (Table I). Results suggest that it is not necessary to flood rice to obtain high grain yield as maintaining a saturated soil throughout the growing season resulted in a non-significant reduction in rice yield. Grain yield, however decreased significantly when water was reduced to field capacity condition and this is in agreement with previous findings (Beyrouty *et al.*, 1994; Grigg *et al.*, 2000). The low grain yield for rice subjected to field capacity condition was attributed to few panicles and less spikelets per panicle. Water regimes did not only affect grain but also straw yield (Table II). The amount of straw produced under field capacity was about a half of the amount produced under flooded and saturated conditions. Shorter plants and less tillers would have attributed to the lower straw yield under field capacity condition.

Stomatal conductance (g_s) was always higher under flooding condition followed by saturated condition and was lowest at field capacity. A stomatal response has been associated with chemical signals, particularly ABA, produced by roots in drying soil and transported to leaves in the transpiration stream (Davies & Zhang, 1991; Gaff & Loveys, 1992; Bano *et al.*, 1993; Stoll *et al.*, 2000; Hartung *et al.*, 2002; Ismail *et al.*, 2002). Besides chemical signaling, soil and plant water relations (hydraulic signal) may also play an important role in stomatal regulation (Jensen *et al.*, 1989; Tardieu & Davies, 1993; Auge & Moore, 2002; Ahmadi & Siosemardeh, 2005). In the present study, rice growth under saturated and flooding condition, showed a consistent increase in g_s, because water availability was high around the root and influenced rice root for producing chemical signaling to g.

SPAD was slightly above the set critical or threshold value of 32 (Dobermann & Fairhurst, 2000) during early tillering and flowering stages and were much lower than at other growth stages. This is probable because of N fertilizer has not been applied at early tillering stage and the last N application was made during panicle initiation stage, which resulted in less N available during flowering stage.

Water use efficiency under saturated condition was higher than flooding and half the amount of water was saved and yield production was comparable. This showed that saturated condition can replace a flooding condition as normal growth condition. The application of saturated condition on lowland rice also showed a successful finding by Tabbal *et al.* (2002). Rice growth and yield was high under flooding condition but half the amount of water was wasted without being used by rice plant. Flooding condition reduced water use efficiency of rice plant. Rice only needs some level of water to maximise their growth and yield. Saturation technique still showed decreasing water use efficiency than under field capacity condition but it can maximise rice growth and yield. The reduction of g_s under field capacity reduced water lost from the leaf. It could be one of the factors, which influence rice water use efficiency under field capacity condition. This finding was quiet agreeable with Fukai *et al.* (1985) and Turner *et al.* (1986). High water use efficiency under limited water does not mean rice will produce good yield, because some of the rice activity, for example photosynthesis was limited, because of closure of the stomatal.

In conclusion, changing soil water contents affected rice growth and development. The g_s, plant height, tiller production and shoot dry mass were reduced when rice was subjected to the field capacity condition throughout the growth period but water use efficiency was high under field capacity condition. However, crop growth was not affected when rice was grown under saturated condition and performed as good as the normal flooded rice. These results suggest that it is not necessary to flood rice to obtain high yield as maintaining a saturated soil throughout the growing season without a significant reduction in yield and can even reduce water input.

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