EVALUATION OF WATER PRODUCTIVITY FOR LOWLAND RICE UNDER SENSOR BASED DEFICIT IRRIGATION SYSTEM

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Abstract: *Rice, as the main food produced in Asia, requires more water than the other cereals. Flooded irrigation, the most common method of irrigation in rice, results high water losses and emits more greenhouse gases. Changes in climate, decrease in water resources and arable lands, necessitates the water productivity increasing strategies for rice. Soil matric potential based irrigation is such a strategy to irrigate rice under these conditions. This paper presents an experiment carried out inside a climate chamber to assess the water productivity of Bg300 rice variety using above approach. Three irrigation treatments; flooded treatment with a ponding water depth of 3cm and treatments with soil matric potentials at -150mbar and -300mbar were imposed in three large containers. Soil matric potentials were maintained using tensiometers installed at a depth of 20cm. Treatment at -150mbar showed best performance in terms of yield, water productivity and water savings. This strategy is transferable to a wide range of locations under different climates and reduces time for many field experiments.*

Keywords*: SOIL MATRIC POTENTIAL, IRRIGATION, RICE, WATER PRODUCTIVITY, YIELD, BG300*

1. Introduction

Food security to sustain growing world population is one of the key challenges in 21st century with the existing water scarcity and degradation in arable land. Agriculture as a major component of the economy of Sri Lanka, and rice as a major food crop cultivated, faces many challenges due to increasing population demand.

Irrigated land in Sri Lanka is mainly developed for paddy cultivation and accounts for 80% of rice production. Rice being a semi-aquatic crop requires 2–3 times more water than other cereals (Bouman et al. 2007). Besides, the looming water demand for domestic and industrial sectors, conflicts between these sectors, climate change and low economic viability of agriculture are restricting the expansion of irrigated agriculture.

Therefore, increasing crop water productivity or the amount of agricultural output produced per unit amount of water used, is a viable solution to overcome the above mentioned challenges.

About 90% of the world's rice production is harvested from irrigated or rain-fed lowland rice fields. Lowland rice is raised in a nursery bed and transplanted into a main field which is kept mostly under continuous or intermittent ponded water conditions to help weed and pests (GRiSP (Global Science Partnership) 2013). Water for lowland rice is required for land preparation, to fulfill the crop water demand and to match seepage and percolation losses (Allen et al. 1998). The water required to produce 1 kg of rice varies from 1-3 tons of water (FAO 2000). Usually one third of it is used in the land preparation prior to cultivation.

Although the rice plant is unique in its ability to grow and yield in a wide range of agro ecological conditions such as flooded lowlands, drought-prone uplands, humid tropics and cool temperate climates, yield declines when soil dries below saturation.

However, lowland rice fields have large amounts of water losses and less fertilizer use efficiency apart from heavy emissions of methane, ammonia and nitrous oxide gases. Water saving irrigation strategies such as aerobic rice cultivation could save significant amount of water.

Therefore, improved irrigation management techniques for aerobic and flooded rice systems concerning uncertainties in soil, climate and management practices are important in near future.

Deficit irrigation, defined as the application of water below full crop-water requirements is an important tool to achieve the goal of reducing irrigation water use (Fereres & Soriano 2007).

The objective of this study was to evaluate water productivity of a lowland Sri Lankan rice variety (Bg300) under deficit irrigation conditions with a view of reducing water input and ensuring minimum yield losses.

2. Materials and Methodology

Experiment was conducted in a constructed climate chamber (2m x 2m x 4m), within the laboratory premises of Dresden University of Technology, from 08th of May till 19th of September, 2015. Three irrigation treatments, T1, T2 and T3 were imposed, based on soil matric potential levels. Each treatment was imposed in a separate large PVC container (1m x 0.6m x 0.8m) as shown in Figure 1. Treatment T1 was maintained with a 3cm of ponding water level throughout the treatment period. Other two treatments were maintained with soil matric potential levels at -150mbar (T2) and -300mbar (T3) respectively throughout the treatment period. Irrigation treatments duration was from two weeks after seed establishment up to two weeks before physiological maturity.

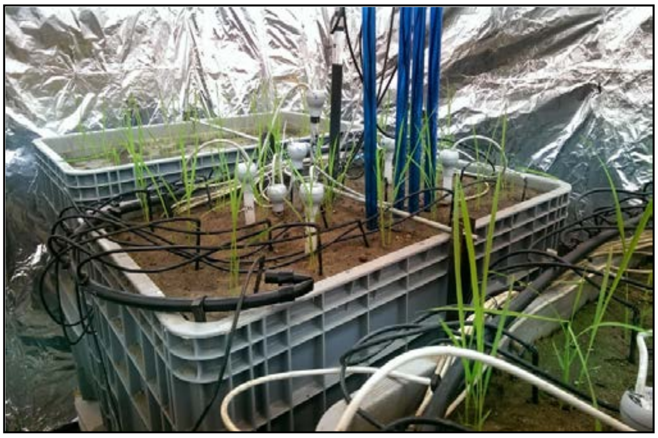

Figure 1: *Experimental set up*

Containers of treatments T2 and T3 were placed on fabricated weighing balances. They were connected to a data logger (DT80) for frequent water balance measurements. However, treatment T1 was not placed on a weighing balance but placed at the same vertical position with other containers.

Tropical climate conditions were simulated by installing two growing lamps (Osram power star HQI-BT 400 W/D PRO) above each container. They were connected to a timer to automatically switch on lamps to create 12 hours of day and 12 hours of night cycles. Additionally, climate chamber inner walls and roof were covered with aluminium foils to provide homogeneous lighting conditions.

In order to maintain required soil matric potentials in T2 and T3, tensiometers (T4 and Bambach digital tensiometers) were installed at 10cm interval up to 40cm depth. Twelve tensiometers were installed in each container. Control tensiometer was installed at 20cm depth to maintain soil matric potential at threshold level and to trigger the irrigation system.

Soil moisture content was measured using time domain reflectometry (Campbell Scientific, TDR100) probes installed at same depths. Both tensiometers and TDR probes were connected separately to two data loggers.

Sub-surface drip irrigation system (Netafim NMC-pro) was installed to irrigate treatments T2 and T3 (see Figure 2). Irrigation system was triggered upon reaching relevant soil matric potential thresholds at 20cm depth.

Each drip emits 1.2 l/hr of water to plants. Single irrigation event was set to 5 minutes and allowed to distribute water for 2 hours. After 2 hours, if required threshold level is not achieved then it re-irrigates to bring down the soil tensions.

Figure 2: *dripper installed next to a planting hill*

Rice seeds were soaked in water for 24 hours and incubated in a cloth bag for 48 hours to germinate. Germinated seeds were established in soil at a planting space of 20cm x 15cm in all containers. This allowed each container to grow 18 planting hills.

After seed establishment, basal fertilizer (N P K) was applied at a rate of 5 kg/ha, 50 kg/ha and 20 kg/ha respectively to all three containers. All fertilizer applications were carried out according to the fertilizer recommendations issued in 2001 by the Department of Agriculture, Sri Lanka.

Soil in all containers were kept at saturation for two weeks in order to establish homogeneous plant density. At two weeks additional plants were removed by leaving 3 plants per planting hill.

Air temperature, soil surface temperature, temperature at weighing balance (to account for changes in resistance in load bearing cells) were logged using temperature sensors. Other climate data such as radiation, relative humidity were measured periodically.

Plant growth measurements, leaf area, leaf nitrogen content, stomatal conductance, leaf rolling and phenology were measured weekly. At physiological maturity, grain yield, total above ground and below ground biomass and root growth were measured.

3. Results and Discussion

Under Sri Lankan climate and irrigation conditions, rice requires 900-1200 mm of water per season.

According to the experimental results, highest grain yield was observed in treatment T1 in comparison to the average yield observed under flooded field conditions in Sri Lanka, where ponding water depth is usually 5-10cm.

Amount of yield gained in three irrigation treatments were linearly related to the soil moisture stress. Lowest yield was obtained in most dry treatment. For this particular rice variety yield reduction in T1 is non-significant as shown in Table 1. Considering the water productivity, highest water productivity was obtained in drier treatment, T3.

Even though highest water saving is achieved in Treatment T3 yield reduction is significant compared to the reference yield. However, comparing yield, water productivity and water savings of each treatment, treatment T2 shows the best performance.

Table 1: *Summary of the experimental results*

Treatment	Yield [t/ha]	Water productivity [kg/m^3]	Yield reduction [%]	Water Savings [%]
T1	4.93	1.08	5.7	56.8
T2	4.33	1.49	17.2	72.4
T3	3.15	1.78	39.7	83.1
Reference	5.23	0.58	-	-

4. Conclusions

According to the above results, T1 and T2 had no significant difference in yield compared to the reference yield, which is a long term average value for Bg 300 rice variety under Sri Lankan tropical climate and flooded conditions.

However, all three irrigation treatments resulted comparatively higher water productivities. Water productivity is expressed in terms of total irrigation amount. If this is expressed in terms of crop evapotranspiration, much higher water productivities could be expected.

Considering overall results; yield, water productivity and irrigation water savings are high in T2. Sensor based automatic irrigation provides reliable results and feasible in irrigation scheduling for rice under field conditions. This strategy can be applied to a wide range of locations under different climates, is transferable and reduces time for many field experiments.

Main disadvantage of this kind of experiments is the high expenses for electricity to operate growing lamps for a long time period. As a solution white colour LED lamps could be used at a low cost.

5. References

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