# Rice and sweet corn response to high levels of water supply

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## Abstract

As water resources become scarce and costly, there is an increasing need to improve the water use efficiency of crops. Aerobic rice has been advocated as potential water saving production system. In this paper we examine the sensitivity of rice to water availability (at high levels of water supply) compared to sweet corn in a glasshouse experiment utilizing the pot-in-bucket (PIB) watering system to adjust the water supply. By using different size floats we were able to maintain a constant water table at either 1.5 or 3.5 cm in base of bucket, and by adjusting the width of the capillary mat or the height of the top pot we established six levels of water availability in the pot. Water use in sweet corn varied from 3.7 to 5.8 liters per plant depending on the water table depth and position in the bucket, while in rice water use ranged from 1.9 to 11.4 liters per plant. The water use efficiency of sweet corn was a mean of 8.20 g/l while rice averaged 4.44 g/l. The effect of reducing water supply in rice from flooded to aerobic conditions and the importance of air temperature in relation to plant performance under aerobic conditions is discussed.

## Key word

*Oryza sativa*, Water-saving technology, Root biomass**,**

## Introduction

Rice is traditionally grown under flooded conditions. Recently aerobic rice where soil water content is maintained mostly at around field capacity has been advocated as a potential water saving production system. However, relative to other crop species, rice is considered highly sensitive to low soil water (Fukai and Inthapan, 1988; Kondo et al 2000b) this has been partly attributed to its shallow root system (Angus *et al.* 1983). A large number of studies have been conducted examining rice growth under flooded conditions and severe water deficit under aerobic conditions. However, few studies have examined the response of rice grown under aerobic but relatively high soil water availability conditions. Kato et al (2009) in field studies suggested that there was no yield penalty in growing aerobic rice. However, Fukai and Inthapan (1988) noted that even when soil water content was high, that leaf water potential was consistently lower in rice than in maize and sorghum, indicating that rice had a higher internal resistance to water flow. High internal plant resistance (axial resistance) to the flow of water in rice plants was also noted by Yoshida and Hasegawa (1982). However, this should not be a major factor when water levels are high in the top soil layers. In a glasshouse study, utilising pots whose soil was entirely colonized by roots (thereby buffering genetic differences in root systems and in their ability to take up water), Parent et al. (2010) compared a diverse set of rice lines and concluded that the sensitivity to soil water deficit of leaf elongation rate of rice and maize was similar. These results again suggest that the sensitivity of rice to decline in water is related to root system. This experiment examined the growth response of rice and sweet corn to high levels of water supply maintained above field capacity.

## Methods

Seed of sweet corn (cv. Terrific F1) and rice (cv. Shepra) were sown in a glasshouse experiment on 28/07/2011 at The University of Queensland, St Lucia. For the first two weeks, all pots were grown in glasshouse with non-water limiting conditions to ensure the optimum environment for germination and establishment. Plants were thinned to leave 1 plant per pot, and water treatments were imposed 14 days after sowing (DAS) on 11$^{th}$ August 2011. Sweet corn was harvested on the12$^{th}$ September (46 DAS) and rice on the 4$^{th}$ October 2011 (68 DAS). A sandy loam with soil pH (1:5 Water) of 7.8 was used to fill ANOVApot® (20 x 20 cm). The air-dry soil was mixed with 20 grams of slow release fertilizer Osmocote® Exact Mini 3-4M (16N + 8P2O5 + 11K2O + 2MgO + Trace elements) and each pot filled with 4600 g of soil. After a 4 cm layer of soil was placed in the bottom of the ANOVApot® an upturned Petrie dish was placed into the soil directly above the meshed hole in the base of the ANOVApot® to reduce the likelihood of root escape. All ANOVApot®s were set up in a pot-in-bucket system (PIB- described in detail in Hunter et al (2012) these proceedings) fitted with a float value that maintained a constant water table in the lower bucket allowing accurate measurement of water use and calculation of water use efficiency (WUE). The experiment was a randomized complete block design with 6 water treatments and 4 replications for each species.

*Treatments*

The water treatments consisted of 6 levels of water supply achieved by using variations in the pot-in-bucket system. The 6 treatments will be grouped based on constant level of water supply, thus group 1 was flooded; group 2 had aerobic conditions with a constant high water table of 3.5cm in the base of bucket (treatment 2, 3, and 4); while group 3 had aerobic conditions with a constant low water table of 1.5cm (treatment 5 and 6) in the base of bucket. All soil and water surfaces were covered with impervious plastic to minimize evaporation.

In the flooded treatment (treatment 1) the ANOVApot® was placed directly inside a large bucket and water level was constantly maintained at 3.5 cm above the soil surface for rice and 22.5 cm below soil surface for sweet corn (i.e. 3.5cm depth within base of bucket).

In the 5 remaining aerobic treatments the upper ANOVApot® was supported inside the lower 2.2L bucket by an upturned 80mm tall pot over which was draped a capillary tape (60 x 300mm) to cover the width of the grid (in the base of the ANOVApot®) with both ends of the tape extending to the bottom of the bucket. In the second group of aerobic with high water table, treatments 2, 3 and 4 a constant high (3.5cm) water table was maintained in the lower bucket (which was equivalent to 22.5 cm (or 28.5 cm in treatment 4) below the soil surface of the top ANOVApot®). In treatment 2, the upper ANOVApot® was placed on two capillary tapes which were crossed over the support pot at 90º angle (ie potentially supplying more water more rapidly to the upper pot); treatments 3 was supported by one capillary tape (standard arrangement) while treatment 4 was stacked inside a further 2 ANOVApot®s thereby raising the top pot by an extra 6cm in height (thus 3.5 and 1.5 cm water table was 28.5 and 30.5 cm below the soil surface of upper pot).

In the third group of aerobic with low water table, treatments 5, and 6, maintained a constant low (1.5cm) water table in the lower bucket (or respectively 24.5 and 30.5 cm below the soil surface of the top ANOVApot®). The standard arrangement in treatment 5 was the same as in treatment 3, and the stacked arrangement in treatment 6 the same as in treatment 4, with the low water table. Additionally treatment 6 was supported by a 30 mm width capillary tape (covering only about half the grid at the base of the ANOVApot®).

*Measurements*

At harvest 46 DAS (Sweet corn) and 68 DAS (Rice) the plant was cut at the base of the stem and samples were oven dried at 65 °C for 4 days and weighed to determine the above ground dry matter. The soil and root mass in the anova pots were removed from the pot and cut into three equal horizontal layers, each layer averaging a height of 5 cm. Each of the three layers in the aerobic treatments were then halved. One half of the sample was weighed immediately after harvest and then again after drying at 105°C for 8 days to determine gravimetric water content for each layer. While the second half was used to determine root dry weight in each layer. This second half was placed into plastic bags and kept in the cold room for three days, after which the soil was washed off the roots using a gentle water spray. The root samples were oven dried at 65 °C for 4 days and dry weights determined (RDW). Root and above ground dry weights were summed to determine total dry matter (TDM). Water use efficiency (transpiration efficiency) was determined from the ratio of total dry weight and total water used over the experimental period.

## Results and discussion

During the experiment the average maximum and minimum air temperature in the glasshouse ranged between 28-48 ºC and 11-18 ºC respectively. There was a two week period from 28Aug to 18 Sept in which the maximum temperature was above 40 ºC, with four days (30 Aug, 1, 8 and 15 Sept) the temperature reaching 47-48 ºC for about 1 hr between 12-2pm.

Significant treatment differences existed in total dry matter and water use per plant (Table 1). Total dry matter of 46 day old sweet corn ranged between 34.9 and 55.2 g/ plant and rice produced between 9.5 and 59.4 g/ plant, 68 days after sowing. Under aerobic conditions with a high water table (3.5cm), which maintained greater soil water availability in the upper sections of the pot, but raised pots (i.e. no

waterlogging in base of top pot), Sweet corn produced the highest total dry matter (55.2 g/plant), while the low water table (1.5cm) produced visually stressed (wilted) plants (40.5 and 34.9 g/ plant). Sweet corn with 3.5cm flooded condition at the base of the pot also produced relatively poor total dry matter (38.1 g/ plant). In contrast, total dry matter in rice was greatest in the flooded condition (59.4 g/ plant) and below 23 g/ plant under aerobic conditions. However, similar to sweet corn, rice grew relatively poorly under the low water table (9.5 and 13.4 g/plant) compared to the high (17.1-23.1g/plant) water table.
When the plants were small and had relatively low demand for water (young sweet corn and rice) the PIB system maintained moist conditions (what would be considered around field capacity (i.e. watered up and drained for 24 hours) throughout the soil volume. As demand increased, particularly for sweet corn the ability of the low water table to maintain wet soil at the surface reduced. However, in contrast to other experiments we have conducted in rice under aerobic conditions, this experiment was exposed to extremely hot days and the ability of the plant to maintain the transpiration stream would have been compromised. This was particularly evident in rice which had chlorotic leaf burn in small leaf sections after particular events despite having relatively wet soil. This leaf burning was not evident in the flooded rice condition, nor to the same extent in sweet corn. In terms of total dry matter production the rice was better adapted to flooded conditions, and more susceptible to reductions in water supply compared to sweet corn which seemed less sensitive to reductions in water supply and did not tolerate the flooded condition. In previous PIB experiments when aerobic rice was not exposed to extreme temperature events, biomass of aerobic rice has been within 90% of that of flooded rice.

Total water use in sweet corn varied from 3.7 to 5.8 liters per plant depending on the water table depth and position in the bucket, while in rice water use ranged from 1.9 to 4.2 under aerobic conditions but as high as 11.4 liters per plant under flooded conditions. While differences in water use were significant, there was no treatment difference in water use efficiency (WUE) except that flooded sweet corn had significantly lower WUE (7.63 g/ l) than all the aerobic treatments which did not differ from each other (avg. 9.21 g/l). On average, sweet corn (8.95 g/ l) had nearly twice the efficiency of rice (5.39 g/ l). Water use efficiency of C4 species is known to be higher than that of C3 species and maize is approximately double that of C3 crops grown at the same sites (Ripley et al 2008; Huang et al 2006). For each species, a strong highly significant ($p<0.01$) phenotypic association existed between the amount of water used and the biomass produced (Sweet corn: $y=8.83x$; $r=0.89$, $n=6$; and Rice: $y=5.27x$; $r=0.99$, $n=6$). Thus, the plant biomass produced was proportional to the amount of water used indicating that all water used was effective, even at the higher water use levels. This is because the evaporation and deep percolation components, which are major components of field water loss, were nil when utilising the PIB system and as such the water use component was only that utilised by transpiration.

Table1. Total dry matter (TDM, g/ plant), root dry weight (RDW, g/ plant), water use (WU, litres/ plant) and water use efficiency (WUE g/litre) for sweet corn and rice grown under 6 levels of water supply (1. Flooded; aerobic conditions with a constant high (3.5cm) water table (treatments 2, 3 & 4); and low (1.5cm) water table (treatments 5& 6) in the base of bucket .

| | Flooded/aerobic | TDM | | RDW | | WU | | WUE | |
|---|---|---|---|---|---|---|---|---|---|
| | Water table | Sweet corn | Rice | Sweet corn | Rice | Sweet corn | Rice | Sweet corn | Rice |
| 1 | Flooded | 38.1 | 59.4 | 4.31 | 27.69 | 5.0 | 11.4 | 7.63 | 5.13 |
| 2 | Aerobic High# | 50.3 | 17.1 | 7.39 | 5.92 | 5.7 | 3.5 | 8.84 | 4.93 |
| 3 | Aerobic High | 47.1 | 22.4 | 6.74 | 9.2 | 5.5 | 3.7 | 8.67 | 6.29 |
| 4 | Aerobic High & raised | 55.2 | 23.1 | 9.59 | 8.31 | 5.8 | 4.2 | 9.47 | 5.68 |
| 5 | Aerobic Low | 40.5 | 9.5 | 6.9 | 3.1 | 4.4 | 1.9 | 9.44 | 5.07 |
| 6 | Aerobic Low & raised | 34.9 | 13.4 | 6.04 | 3.61 | 3.7 | 2.6 | 9.64 | 5.24 |
| | Mean | 44.3* | 24.1** | 6.83* | 9.64** | 5.0* | 4.5** | 8.95* | 5.39 |
| | LSD(5%) | 10.9 | 14.4 | 2.8 | 8.72 | 1.32 | 2.31 | 1 | ns |
| | CV(%) | 16.4 | 39.6 | 27.2 | 60 | 17.5 | 33.7 | 7.4 | 14.2 |

# treatment 2 had double capillary tape; * indicates significance at $p<0.05$, and ** indicates significance at $p<0.01$.

Differences in total root dry weight were significant ($p < 0.05$) and the proportion in different layers also varied between treatments. In sweet corn, total root dry weights were higher under aerobic conditions ranging from 6.04 to 9.59 g/ plant compared to flooded condition which produced only 4.31g/ plant. As the result of water logging in bottom layer of the pot in the flooded treatment, sweet corn had root damage. Rice however, produced the highest root dry weight (27.69 g/ plant) under flooded condition compared with aerobic condition which ranged between 5.92 and 9.20 g/ plant at high and 3.10-3.61g/ plant at low water levels respectively. Root dry weight produced by rice declined with the decline in water table and root/shoot ratio declined significantly, but this was not the case within sweet corn aerobic treatments. The sensitivity of rice appears to be related to large reduction in root biomass with small reductions in soil water. In general researchers consider that rice tends to have a poor root system compared with other species (Serraj et al. 2009).

Over 92 % of rice root occurred in top 10 cm layer and the proportion of roots in the bottom layer (11-15cm) was regularly low for all treatments (6.4 to 8.4%). In sweet corn the proportion of root in the top 10cm layer ranged from 67 to 84% while under flooded conditions this went up to 90%. For both sweet corn and rice there was a difference in root distribution in the raised treatments (4 and 6) with the low water table in which there was 13% of roots in the bottom two layers for rice and 72% in top layer while for sweet corn there was close to 33% in each layer. Thus, in the least moist environment root exploration was more evenly distributed throughout the soil volume in sweet corn, with considerably more rice roots in lower portion of soil volume compared to the wetter treatments.

## Conclusion

This study was conducted to observe the responsiveness of rice to water availability compared to sweet corn in a glasshouse experiment where water accessibility was adjusted by using the PIB watering system. Rice tolerated more saturated conditions while sweet corn tolerated drier conditions in terms of biomass production. We found that the water use efficiency of sweet corn was consistently higher than rice 8.95 vs. 5.39 g/ l. Under aerobic conditions water use per plant in rice was low (1.9 to 4.2 l/ plant) compared with sweet corn (3.7 to 5.8 l/ plant), however under flooded conditions rice used as much as 11.4 l/ plant. The results herein also point out the adverse effect of high temperature when rice is grown under aerobic conditions and this needs careful consideration in relation to developing an aerobic rice industry.

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