Saturated soil culture: a new concept for irrigated rice production in tropical Australia

A.K. Borrell, S. Fukai and A.L. Garside

Department of Primary Industries, Hermitage Research Station, Warwick QLD 4370
Department of Agriculture, The University of Queensland, QLD 4072
Department of Primary Industries, PO Box 6014, Rockhampton QLD 4702

Summary. Efficiency of water use for grain production in rice (grain dry mass/water applied) was higher with saturated soil culture (SSC) than with the traditional method of flooded production (control) in north Queensland. Leaf area development and subsequent radiation interception was similar between traditionally irrigated and SSC plants, resulting in equivalent dry matter production and grain yield in the wet and dry seasons. However, SSC plants used 34% less water than the control in both seasons. Improved water use efficiency in SSC was due primarily to reduced evaporation from the wet bed surface compared with free water in the control. Concentration of N in the organs of SSC plants was less than the control in the dry season, suggesting that N may have limited growth in this season. Since the agronomy used in these studies was developed for flooded rice, different strategies for nitrogen application and weed control may result in higher yields with SSC than those reported here.

Introduction

Water is an expensive and scarce resource in the semi-arid tropics of northern Australia. While the commercial grain yield of irrigated dry seeded rice in the Burdekin River Irrigation Area (BRIA) (20?03'S, 147?17'E) of north Queensland is relatively high in the dry (7 t/ha) and wet (5 t/ha) seasons, water use is also high in both seasons (about 12 ML/ha (1)), accounting for about 40% of all variable costs. Consequently, if water use efficiency of rice production can be increased by reducing water use while maintaining grain yield, economic returns to the growers will improve.

SSC is a technique developed for soybean in which plants are grown on 1.5 m raised beds with water maintained in the furrows, some 0.1 m below the bed surface (2,3). The production of rice with SSC was recently examined in north Queensland as part of an irrigated rice based cropping systems study (4). The objectives of the research outlined in this paper were threefold. Firstly, to examine whether SSC increases grain yield per unit of water applied over traditional irrigation. Secondly, to examine if there is any interaction between irrigation method and season. Thirdly, to compare evaporation losses between SSC and traditional irrigation.

Materials and methods

Treatments

Two experiments were conducted in consecutive seasons at Millaroo Research Station, BRIA, in the 1989 dry season (Experiment I) and the 1990 wet season (Experiment 2). The traditional method of irrigating rice (two intermittent irrigations followed by a permanent flood of depth 0.1 m at the three-leaf stage: PF-3L [control]) was compared with SSC. Plot size was 288 m2 and both irrigation treatments were replicated three times. The rice cultivar used was Lemont, a short-statured plant bred in Texas, and commercially released in north Queensland in 1987.

Sowing and fertilisation

Treatments were dry seeded at a rate of 141 kg seed/ha with a combine to a depth of 10 mm in rows 0.18 m apart on 24 August 1989 (Experiment 1) and 4 January 1990 (Experiment 2). The SSC treatment was sown into both beds (7 rows) and furrows (2 rows). Treatments were fertilised immediately prior to sowing using a mixture containing P, 18; K, 30; S, 23; Ca, 40; Zn, 6 kg/ha. A total of 210 and 190 kg N/ha as urea were applied to both irrigation treatments in Experiments I and 2, respectively. The nitrogen was split between sowing and panicle initiation (PI).

Treatment application

Water was applied to both treatments on 0, 13 and 25 (days after sowing) DAS (Experiment I), and 0, 11 and 17 DAS (Experiment 2), then each Tuesday for the remainder of crop growth (14 applications in all for both experiments). PF-3L remained unflooded and was intermittently irrigated until 25 and 17 DAS in Experiments I and 2, respectively, at which times a permanent flood of 0.1 m depth was applied.

Water was maintained in the furrows some 0.1 m below the bed surface in SSC plots from the three-leaf stage in Experiment I and after first irrigation in Experiment 2.

Harvests

Six dry matter harvests were taken at 40, 61, 75, 89, 110 and 130 DAS during Experiment I, and five dry matter harvests were taken at 39, 49, 66, 86 and 112 DAS during Experiment 2. Harvests at 61, 89 and 130 DAS (Experiment 1) and 49, 66 and 112 DAS (Experiment 2) corresponded to the phenological stages of PI. anthesis (A) and harvest maturity (M), respectively. Five rows of I m length (0.89 m^2) were cut at ground level from all plots at each harvest and immediately placed in a forced draft oven at 80?C for 48 h to determine dry masses.

The leaf area of 10-tiller sub-samples was determined at harvests corresponding to active tittering, PI and A (Experiment I) and PI and A (Experiment 2) with a planimeter (Licor). Five light interception readings were taken in Experiment I between 11 am and 2 pm in each plot at 40 and 61 DAS using a line quantum sensor (Licor).

In Experiment I, concentrations of N were determined in the root (61, 89 and 130 DAS), stem and leaf (40. 61, 89 and 130 DAS) and panicle (89 and 130 DAS) of sub-samples. In Experiment 2, concentrations of N were determined in the root, stem and leaf (39, 66 and 112 DAS) and panicle (66 and 112 DAS) of sub-samples.

Weed control

Propanil[?] (a.i. dichloropropionanilide; Farmco) was applied to all treatments at a rate of II L/ha to control barnyard grass *(Echinochloa colonuni)* and sedges *(Cyperus iria* and C. *difformis) at* 21 DAS (Experiment 1). A second application of herbicide (Saturn/Propanil ratio of 3.5:4.0 Uha) was applied at 43 DAS to control the above weed species in SSC plots. SaturnR (a.i. thiobencarb; Schering) was included because of its residual activity. In Experiment 2, Propanil was applied to both treatments at a rate of 11 1./ha at 27 DAS.

Water balance components

The change in soil water status (AW; i.e. change in depth of floodwater in PF-3L and change in volumetric soil water content in SSC) and evaporation (E) were measured directly in SSC and control plots between 26 and 31 DAS. Sloping gauges and a neutron moisture meter were used to measure ANN/ in PF-3L and SSC plots, respectively. Mini evaporation pans and mini lysimeters were used to measure evaporation in PF-3L and SSC plots, respectively.

Results and discussion

In general, leaf area development, and hence radiation interception, were similar in SSC and traditionally irrigated plants, resulting in equivalent dry matter production in these treatments (Fig. I a) in both seasons. Since HI was slightly higher in PF-3L in both seasons, grain dry mass was about 10% higher (n.s.) in traditionally irrigated compared with SSC plants. In PF-3L and SSC respectively, dry season grain yields were 8.2 and 7.3 t/ha. and wet season grain yields were 4.6 and 4.0 t/ha. Higher grain dry masses in the dry season can be attributed to increased solar radiation during the grain filling period (25.9 $MJ/m^2/d$) compared with the wet season (14.5 $MJ/m^2/d$). Moaned over seasons, the water use of SSC as a proportion of PF-3L was 66%. Water use of the flooded PF-3L plots was higher than that of SSC due to the application of a permanent flood at the three-leaf stage (Fig. I b), resulting in a sudden increase in water use of traditionally irrigated plots at 25 and 17 DAS in the dry and wet seasons, respectively. In addition, the greater slope of the water use curve in PF-3L indicates that variation existed in water balance components. Evaporation was the critical component of the water balance which differed between flooded (PF-3L) and unflooded treatments (SSC), and was significantly less in the latter during the vegetative period prior to canopy closure. The efficiency of water use for grain production in SSC was higher than the control in the wet ($P<0.05$) and dry (n.s.) seasons.

Within SSC, there was a positive relationship between water use and dry matter production. Dry matter production was generally higher in the furrows (flooded) than on the beds (unflooded) in both seasons, indicating that the relative production from the furrows was higher than that from the beds. While this may indicate the benefit of increasing furrow area compared with that of the bed, any increase in furrow area will lead to higher evaporation losses prior to canopy closure. Further research is needed to examine the bed/furrow architecture within SSC in order to optimise the relative size of these components and hence achieve optimal efficiency of water use for grain production in this system.

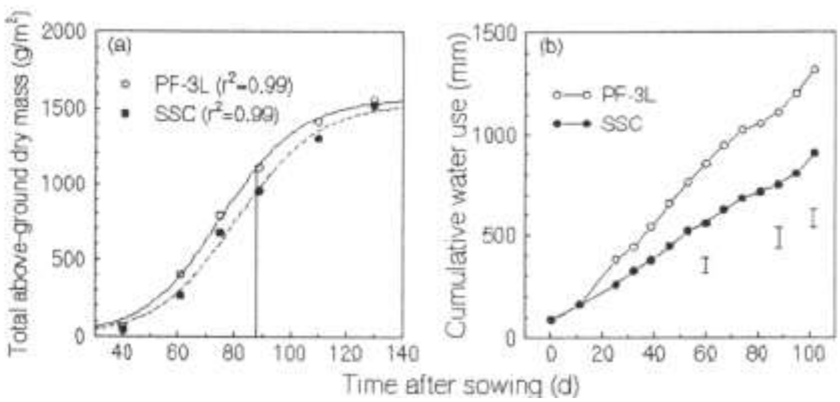

Figure 1. The relation between time after sowing and (a) total above-ground dry mass, and (b) cumulative water use in the 1989 dry season in rice (cv. Lemont) grown with two methods of irrigation: PF-3L and SSC. In Fig (a), anthesis is marked with a vertical line and logistic functions were fitted to the data. In Fig. (b), no water was applied after about 100 DAS and vertical bars at panicle initiation, anthesis and grain filling denote l.s.d. (P=0.05).

Leaf N concentration of SSC plants at panicle initiation in the dry season (3.18%) was above the critical N concentration of 2.4% (5). However, the concentration of nitrogen in the stems, leaves and panicles of SSC plants were 29%, 32% and 18% lower, respectively, than control plants at maturity, indicating that SSC plants may have been N deficient during the grain filling period. In the wet season, however, the N concentration of organs in SSC plants was comparable with the control. This may reflect the deep placement of N fertiliser in all treatments in the wet season. In addition, SSC furrows were flooded from sowing in the wet season, but not until the three-leaf stage in the dry season, possibly resulting in reduced denitrification in the wet season. Therefore dry matter production and yield in SSC were limited by N nutrition. Further research is required to improve the recovery of N fertilisers in SSC.

There were no significant differences between SSC and the control in any grain quality components, indicating that this method of irrigation was not detrimental to the attainment of high grain quality. Weed growth in SSC plots was not higher than control plots provided adequate herbicides were used.

Acknowledgements

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