Identifying the Potential to Apply Deficit Irrigation Strategies in Cotton Using Large Mobile Irrigation Machines

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Abstract

Irrigation water restrictions in the cotton industry have increased the focus on improving water use efficiency. Regulated deficit irrigation (RDI) has been found to improve the water use of efficiency of cotton under drip irrigation. Partial rootzone drying (PRD) has been commercially implemented in grapevines and found to increase the water use efficiency for a variety of crops. This paper investigates the potential to improve cotton water use efficiency using RDI and PRD strategies applied with lateral move machines. A range of RDI treatments (71 % - 100 % evapotranspiration replaced) and a PRD and non-PRD treatment were applied to a crop of Sicot 180 during the 2002/2003 cotton season. No yield reduction was found between the fully irrigated and the 50% RDI treatment that received 1.05 ML/ha less water. Crop WUE was found to increase from 0.94 bales/ha to 1.17 bales/ha as the irrigation water applied was reduced from 100% to 79 % of evapotranspiration replacement. No difference in physiological growth and yield was found due to the implementation of the PRD treatment. Further work is required to confirm the RDI results, further explore the application of PRD strategies using these machines, and to more fully understand the physiological response of cotton to imposed soil moisture deficits applied either by volume (RDI) or space (PRD).

Media Summary

Water use efficiency benefits in cotton have been achieved with a regulated deficit irrigation strategy used under a lateral move irrigator fitted with LEPA socks.

Introduction

Current climatic conditions and reduced irrigation allocations have resulted in irrigation water now becoming the most limiting resource in many cotton growing regions. Reductions in irrigation losses and improvements in whole farm water use efficiency (WUE) is now a major aim for producers. Potential areas for improvement in WUE include a reduction in storage and conveyance losses and an increase in irrigation uniformity and crop WUE. Irrigation systems in cotton including centre pivots and lateral moves, collectively known as large mobile irrigation machines (LMIMs), have received interest in recent times as an alternative to furrow irrigation (Foley, 2001). Due to their flexibility in being able to easily vary the frequency, volume and placement of irrigation water with low energy precision application (LEPA socks), it may be possible to implement alternative irrigation strategies such as regulated deficit irrigation and partial rootzone drying to increase crop WUE.

Regulated deficit irrigation (RDI) occurs when irrigation is applied which maintains plant water status within prescribed limits of deficit (with respect to maximum water potential) for a prescribed part or parts of the seasonal cycle of plant development, normally when fruit growth is least sensitive to water reductions (Kang, Shi & Zhang 2000; Kirda et al 1999; Kriedemann & Goodwin 2002; Marsal et al 2002). Previous cotton research applying RDI using drip irrigation found no significant difference in yield when 100 % and 67 % of cumulative Class-A-pan evaporation was applied. Partial rootzone drying (PRD) results by applying at least two alternatively wet and drying rootzones. PRD acts to simultaneously maintain plant water status at maximum water potential while regulating stomatal behavior and vegetative growth for a prescribed part/s of the seasonal cycle of a plant’s development (Kriedemann & Goodwin 2002). Regulation of vegetative growth and stomatal behavior occurs via the elevation of the stress/growth hormone abscisic acid which originates from the plants roots. Research into grapes has found improvements in WUE ranging from 86 % for Shiraz to 90 % for Riesling (Kriedemann & Goodwin

2002). The objective of this research was to investigate improvements in crop WUE from the application of RDI and PRD in cotton under a lateral move irrigator.

Materials and Methods

A 4.3 ha field trial was conducted during the 2002/2003 cotton season. The trial site was located on a black Vertosol soil located on the eastern Darling Downs (S270 54.176', E1510 30.871') within a commercial crop of Sicot 180. The crop was planted on the 25 October 2002 after pre-irrigation totaling 98 mm was applied. Irrigation water was applied with a lateral move irrigator fitted with double-ended low energy precision application (LEPA) socks.

A total of 45 plots were established within the trial area. The trial consisted of 3 columns of plots across the irrigator span by 15 rows of plots down the field (or travel path of the machine). A factorial row/column field trial design consisting of 5 RDI treatments by 3 PRD treatments replicated across 3 blocks was used. Each plot consisted of 8 crop rows each of 52 m long, with 8 rows of buffer being managed as commercial practice between the columns of plots. Alternative levels of irrigation volume applied under RDI treatments were controlled by a PLC which operated a combination of solenoid operated sub-mains. This enabled alternative flow rates to be automatically regulated for each plot. RDI treatments were applied as 25, 50, 75, 100 and 125 % of commercially applied irrigation amounts. All irrigations where implemented when the 100% (ie. commercial practice) treatment had reached the desired re-irrigation deficit. PRD treatments were applied by alternating the LEPA socks to the opposite side of the crop row after the second and forth irrigation events. PRD treatments were applied by linear actuators that enabled the sub-main for each plot to be moved sideways automatically.

A weather station was installed approximately 1 km from the trial site. Crop Et was estimated using WaterSCHED (Kennedy 2002). Within each plot, 4 m^2 of crop were marked for hand harvesting. Six hand harvests where conducted between 139-165 days after planting (DAP). All harvested cotton was oven-dried at 320?C for 24 hours. Individual boll number and dry lint weight for each row was recorded. Data analysis was conducted using SPSS (SPSS Inc 2002).

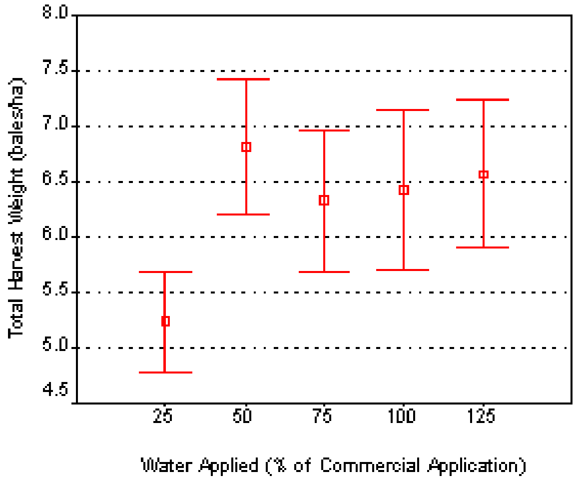
Results

A total of 210 mm of in-crop irrigation was applied in the 100% RDI treatment. Total in-crop rainfall was 298 mm and potential evapotranspiration (ET) calculated for the 100% control treatment was 740 mm for the season. Conversion of RDI treatments to percentage ET replaced, showed the RDI treatments implemented ranged from 71% to 100% potential ET replaced (Table 1).

Grower control over irrigation resulted in one end of the trial area being un-irrigated after the first two irrigations. Consequently, 9 plots were removed from the trial area. Limitations in irrigations applied also resulted in only 2 PRD treatments being applied. PRD treatments applied were (a) no alternation and (b) alternate every second irrigation. Exclusion of 9 plots from the trial area did not reduce the replication desired in the trial area, as there was an increase in the number of replications due to the application of only two PRD treatments instead of three.

Analysis of total harvested cotton lint found no significant difference between alternated (PRD) and non alternated treatments or any interaction between the PRD and RDI treatments imposed. A significant yield difference (P=0.05) was found between the 25% RDI treatment and all other RDI treatments, which were not significantly different from each other (Figure 1). Conversion of harvested lint weight to bales/ha assumed a nominal 40% gin turnout and 20% picker losses.

Grouping of harvest weights for RDI treatments was also carried out to investigate earliness of crop maturity. Lower RDI treatments (less total water applied) were found to have a greater proportion of their total harvested cotton lint maturing earlier than higher RDI treatments (Figure 2). Calculation of WUE (bales/ML) found a range in water use efficiency from 0.88 to 1.17 bales/ML (Table 1). WUE was calculated by dividing the harvest yield by the total water applied to the plant (sum of irrigations, rainfall and starting soil moisture).



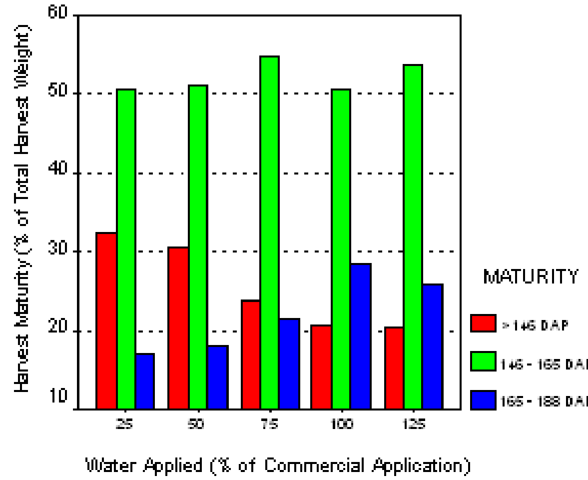


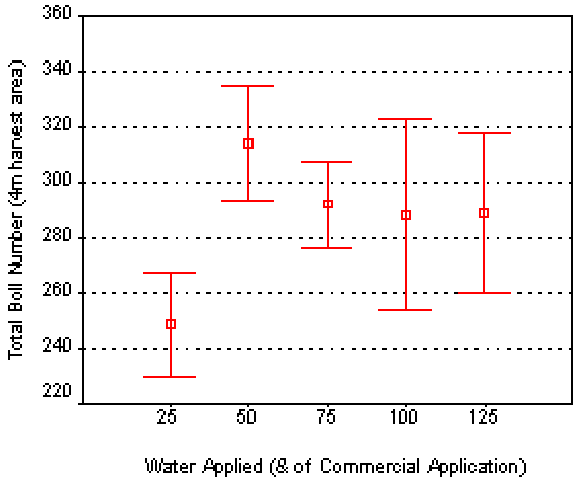
Figure 1. Effect of irrigation applied on average cotton yield (bars indicate 95% confidence interval)

Figure 2. Effect of irrigation applied on harvest maturity

Table 1. Conversion of RDI treatments to percentage potential ET replaced and estimated WUE

RDI Treatments	% Potential ET replaced	WUE (bales/ML)
25%	71 %	0.99
50%	79 %	1.17
75%	86 %	1.00
100%	93 %	0.94
125%	100 %	0.88

Boll weight was found to increase with irrigation water applied (Figure 3). However, the only significant difference in average boll weight was found between the 25% and 125% RDI treatments. A trend of decreasing boll number with increased water above 50% RDI was present. The only significant difference in harvested boll number was found between the 25% and 50% RDI treatment (Figure 3).



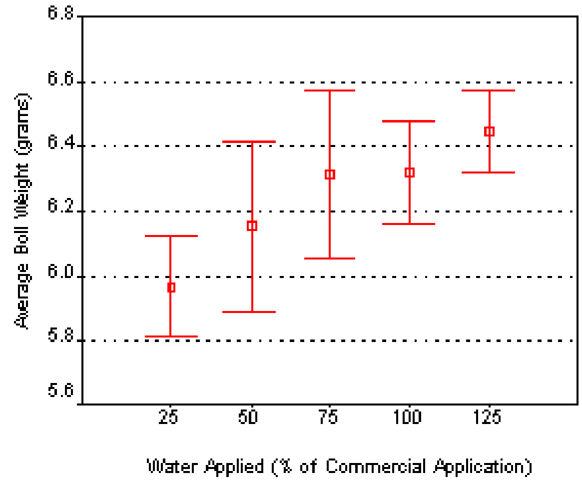


Figure 3. Effect of irrigation applied on average harvested lint weight per boll (bars indicate 95% confidence interval)

Figure 4. Effect of irrigation applied on average boll weight (bars indicate 95% confidence interval)

Discussion

An increase in crop WUE and earlier crop maturity was associated with the implementation of an RDI treatment equivalent to replacing 78% ET. This is consistent with previous work conducted on RDI using drip irrigation (Yazar, Sezen & Sesveren 2002). The trend towards greater boll retention in RDI treatments (down to 78% ET replaced) is consistent with the supply and demand of assimilates and the occurrence of nutritional priority to vegetative organs and is associated with a higher water potential and turgor in these organs than in leaves and stem (Hearn 1994).

This work has found that the implementation of RDI in cotton grown under large mobile irrigators can provide WUE improvements. Due to the low number of irrigation events which occurred in this trial, comprehensive implementation and evaluation of PRD could not be achieved. No conclusion can therefore be made on the potential for WUE benefits from PRD in cotton. However, the RDI treatments applied did increase WUE. However, additional benefit may have been achieved if the treatments had been irrigated at their target deficit and not when the 100% RDI (ie. commercial practice treatment) reached its target irrigation deficit.

The application of irrigation strategies which improve WUE are keenly sort within industries facing water limited scenarios. Implementation of RDI and/or PRD is easily achievable under centre pivots and lateral moves with little capital expenditure and additional labour. Further work is required to evaluate the application of RDI in a wider range of cotton growing locations and seasonal climates. The occurrence of in-crop rain could be expected to have a substantial influence on the amount of irrigation water applied and the maintenance of any given soil moisture deficit. Benefits from reduced vegetative growth under RDI (eg. reduced boll rot, increased spray penetration and therefore efficacy of pesticides and reduced fertilizer requirements) also need confirming and quantifying in cotton under RDI. The increased earliness of crop maturity under RDI may also have an effect on lint quality and should also be assessed in any future work.

The success of implementing PRD in cotton, traditional grown on heavy cracking clays will be dependent on the ability to create a sufficient soil moisture gradient across the plants rootzone. Further investigation of PRD in cotton under LMIMs needs to investigate the ability to induce the moisture gradients under commercial conditions and the frequency of irrigation alternation required to elevate abscisic acid levels. The resulting change in vegetative growth, stomatal aperture and consequent effect on crop WUE will also be dependent on the response of the crop to elevated abscisic acid levels and requires further research.

Conclusion

This preliminary study has demonstrated that RDI benefits can be achieved in cotton grown under LMIMs. Due to the low frequency of irrigations which were applied and the incursion of in-crop rain, the potential for PRD to improve crop water use efficiency in cotton could not be evaluated. Further research is required to fully evaluate the potential for both RDI and PRD in cotton grown under LMIMs.

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