ABSTRACT

There is currently a shortage of irrigation water available for cotton production in Australia due to recent climatic and legislative conditions. Some growers have responded to this water shortage by changing from traditional furrow irrigation to alternative irrigation systems such as centre pivots and lateral move irrigations (collectively known as large mobile irrigation machines – LMIMs). Improved efficiency of irrigation application, as well as labour savings, have been the main reasons for the increased adoption of LMIMs. The use of LMIMs also enables a higher level of control in water application in terms of irrigation volume, timing and placement. As a result, growers now have much greater control over soil moisture conditions which enables the implementation of improved irrigation management strategies that have the potential for improved crop water use efficiency (WUE).

Two irrigation strategies which have been demonstrated to achieve benefits in terms of crop WUE are partial rootzone drying (PRD) and deficit irrigation (DI). PRD and DI involve manipulating the placement of irrigation water and the moisture deficit maintained in the root zone, respectively. Neither PRD nor DI is able to be applied easily under furrow irrigation. However, both PRD and DI may be able to be implemented under LMIMs within the cotton industry. Deficit irrigation has been shown to be effective at improving WUE in cotton, although it is not widely used within the Australian cotton industry. Similarly, there has been little research conducted to identify whether cotton responds to partial rootzone drying and there is currently little understanding of the way in which DI and PRD strategies could be implemented commercially using LMIMs.

This research investigated the response of cotton to a range of PRD and deficit irrigation strategies under LMIMs. Assessment of the biochemical and physiological response of cotton to irrigation strategies were conducted under glasshouse conditions. Field trials conducted under a commercial centre pivot and lateral move assessed the crop response, soil moisture movement, yield and WUE associated with the implementation of a range of PRD and deficit treatments. Modelling of rainfall probability and soil moisture movement were also undertaken to quantify constraints to the successful commercial implementation of irrigation management strategies such as PRD within the Australian cotton industry.

PRD applied to cotton grown in split-pot containers under glasshouse conditions was found to produce a biochemical response in the form of a four fold increase in xylem Abscisic Acid concentration. The application of alternated PRD strategies was generally found to reduce both vegetative (i.e. height, leaf area) and reproductive (i.e. fruiting sites) plant growth compared to Control treatments irrigated on both sides of the plant. Increasing the period between PRD alternations from 5 to 15 days when the soil moisture potential in the wet root zone was maintained between 30 and 60 kPa also reduced the plant height and the number of fruiting sites. However, where the soil moisture in the wetted root zone was maintained at <3 kPa and alternation was based on the dry root zone moisture levels 16% (~350 kPa) and 10% (>1500 kPa) there was no difference in the major plant growth indicators (i.e. height, fruiting branches, fruiting sites, leaf area) between the various alternated PRD treatments. This suggests that the level of moisture availability in the wet root zone area is a key factor influencing water uptake and crop stress under alternated PRD conditions.

No significant difference in crop growth or yield was found as a result of the PRD treatments implemented under commercial field conditions. However, this may have been attributed to the inability to apply and maintain a sufficient soil moisture gradient across the root zone to successfully induce biochemical signalling from PRD. Practical limitations in the successful application of PRD in cotton production are attributed to the soil hydraulic properties, current irrigation practices (i.e. volume and frequency of water applied) and the occurrence of in-season rainfall events.

Rainfall probability and soil moisture modelling were used to evaluate the practical application of PRD within the Australian cotton industry. This work suggested that the creation of a soil moisture gradient across the plant root zone large enough to trigger a PRD response is most likely to be achieved on light textured soils located in semi-arid regions which experience minimal in-season rainfall events. However, the conditions are only met for a relatively small proportion of the current Australian cotton industry. Hence, it would seem that further research into the benefits of implementing PRD in cotton under LMIMs is not warranted.

Deficit irrigation applied under glasshouse conditions was found to have a controlling influence over partitioning between vegetative and reproductive growth. Improved physiological and crop WUE benefits were measured as a result of deficit irrigation under both field and glasshouse conditions. Deficit irrigation (79% of predicted ET) under field conditions produced a 31.5% improvement in crop water use productivity over commercial practice (i.e. applying 100% of predicted ET). However, the largest benefits derived from deficit irrigation were associated with the management of crop agronomics (i.e. vegetative growth, retention rate and crop earliness) and the increased ability for capture of in-crop rainfall. Hence, deficit irrigation may provide substantial benefits in terms of improved crop WUE for the cotton industry.

The ability to implement a suitable deficit irrigation strategy is regionally and seasonally dependent as the uncertainty over the timing of rainfall events and irrigation allocation both within and between seasons makes the optimal use of water resources difficult. Hence, future research should aim to enhance current crop production models to predict crop growth and response to a range of deficit irrigation treatments. Greater knowledge and adoption in the use of climatic predictors (such as SOI) are required to improve the volume and timing of deficit irrigations applied. An economics framework should be developed which encompasses resource costs and constraints on a farm basis to enable the identification of optimal management practices based on the risk profiles of the various deficit irrigation strategies. Irrigation scheduling under LMIMs is also currently limited by the use of point scale soil moisture measurements (especially under LEPA) and this may be improved by the use of plant based sensors.