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Improving irrigation for Ord sugar cane

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Major changes are underway in irrigation practices for the Ord sugar industry as it moves to implement recent findings on improving irrigation efficiency and managing rising groundwater.

Significant improvement in efficiency is expected by more accurately matching water application with crop water requirements and by minimising drainage losses through improved water application techniques. Jim Engelke¹, Joe Sherrard², Gae Plunkett³ and Tim Triglone⁴ report.

The Ord sugar industry was established in 1995 with the commissioning of the mill, and the first full season crush was completed in 1996. It is now a major industry in Stage 1 of the Ord River Irrigation Area (ORIA), currently occupying some 4,000 hectares and producing around 55,000 tonnes of raw sugar annually for export.

Sugarcane requires irrigation throughout the year, and is supplemented by rainfall during the wet season months between December and early April. With interest in increasing Stage 1 production to 9,000 hectares, and a feasibility study under way for developing a further 29,000 hectares for sugarcane in Stage 2 of the ORIA, sugarcane has the potential to have a major impact on resource allocation and environmental issues in the region, as well as the region's economic well-being.

In particular, the prospect of rising costs for irrigation water and increasing concerns associated with the impact of rising ground water will mean that more efficient use of irrigation water will be a key to future profitability and long term production capability in the ORIA.

The project
The Department of Agriculture, in collaboration with CSIRO, CSR Ltd., the Ord sugar industry and the Sugar Research and Development Corporation, has spent the past four years examining sugarcane crop water use, irrigation scheduling requirements, and the effect of irrigation practices on water losses through surface and deep drainage.

Implementation of the research findings will assist the industry to improve profitability, as well as meet targets set through a community-developed Land and Water Management Plan, and those required to be met through licensing for water allocation.

The community developed Land and Water Management Plan addresses a range of environmental and technical issues associated with farming in the ORIA. The Ord Land and Water Board, which oversees implementation of the Land and Water Management Plan, continues to support the research findings and their implementation.

Already, research findings have increased knowledge to allow for significant improvements in managing sugarcane. These findings have been the result of the following activities undertaken since 1996.

• Initially, a benchmarking survey was undertaken to examine current irrigation practices. As well as confirming the need for the proposed research and development, the survey provided an opportunity to measure improvements made in subsequent years.

• On-farm research quantified the impact of different irrigation practices on productivity, water use efficiency and ground water management.

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Based on findings from this work, drying off may not be an appropriate strategy for the ORIA as a means of improving crop sucrose content, but could allow for some reduction in water use towards the end of the crop cycle without adversely impacting on sucrose yield.

This finding was investigated further through the subsequent irrigation scheduling trial.

Computer models using climatic, crop, soil, irrigation and drainage data assisted in developing optimum irrigation scheduling and water application requirements for sugarcane.

Best practice guidelines were developed and promoted using experimental field data and simulation modelling, which have optimised the long-term profitability and sustainability of the Ord sugar industry.

The range in irrigation practices used indicated that growers were still 'experimenting' with water management and that best practice had not been developed. A research and development program involving field experimentation and simulation modelling was initiated to address this gap in current knowledge.

**Benchmarking irrigation practices**

The first step in developing best practice management was to gain a better understanding of the range of irrigation practices being used. Accordingly, a survey was conducted to benchmark irrigation practices used on the 1995/96 sugarcane crop in the ORIA (Wood et al., 1998).

The most significant outcome from the survey was the identification of high rates of water application to crops. The average water applied per annum was 32.5 million Litres per hectare, with values ranging from 15.3 to 53.8 million Litres per hectare. High water use indicated significant losses associated with run-off and possibly deep drainage, providing a significant opportunity for improving application efficiency.

**On-farm research**

**Drying-off trials in commercial crops**

Withholding irrigation prior to crop harvest, often termed drying-off, is used in various cane growing areas to increase sucrose content, although responses can be highly variable. To examine this concept for the ORIA, treatments were imposed on three crops of sugarcane in 1997 and four in 1998 by withholding irrigation for increasing lengths of time prior to harvest.

Results indicated minimal yield response to drying off for periods of up to 80 days, with no increase in sucrose content of the cane. Sucrose yields ranged between 18 and 22 tonnes per hectare for all treatments and over all sites. Explanations for the lack of response to drying off treatments included the crop having access to larger quantities of water in the soil profile than expected and/or the water requirements of the crop being much lower than assumed.

**Irrigation scheduling trial**

An irrigation scheduling trial was established in 1998. Treatments imposed at canopy closure in the first year were irrigation at 60, 120 and 180 millimetres of cumulative daily evaporation (Class A Pan). Treatments were imposed throughout the season until dry down, five weeks prior to harvest in July 1999.

Treatments in the second year of the trial were based on soil moisture deficits. The quantity of water available to sugarcane over a depth of 1.9 metres was established to be 225 millimetres. Irrigation was scheduled after the sugarcane had removed 79, 123 and 191 millimetres of the total available water. Irrigation prior to canopy closure was scheduled at 120 millimetres cumulative evaporation for both crops.
Surprisingly, there was little response to the treatments imposed, which were considered to represent irrigation scheduling extremities. There was no significant effect on sucrose yield, although a small but significant reduction in cane yield was recorded for the driest treatments in each year (see Table 1).

<table>
<thead>
<tr>
<th>Irrigation treatment (mm)</th>
<th>Cane yield (t/ha)</th>
<th>Sucrose yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998/99 (pan evaporation)</td>
<td>60</td>
<td>218</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>212</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>195</td>
</tr>
<tr>
<td>1999/00 (soil deficit)</td>
<td>79</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>123</td>
<td>173</td>
</tr>
<tr>
<td></td>
<td>191</td>
<td>153</td>
</tr>
</tbody>
</table>

Investigations of crop water use were carried out on a commercial crop throughout the 1999/00 season. The crop was planted in May 1999 with the variety Q96 and harvested in June 2000, yielding 183 tonnes per hectare of cane. Using EnviroSCAN equipment, changes in soil moisture were recorded and logged continuously throughout the season at three sites within the crop. This allowed determination of water extraction on a daily basis and for the entire crop season.

Based on these results, a significant opportunity now exists for improving water application efficiency of the sugar cane crop by ensuring that water application, particularly following the wet season, is better matched to crop water demand. Generally, this could be achieved in practice by less frequent irrigation after the end of the wet season.

Due to confounding influences of wet season rainfall with saturated profiles, soil moisture extraction was assessed between periods of rainfall and extrapolated to estimate extraction on a daily basis.

Water extraction by the cane crop varied to a maximum of 10.9 millimetres per day over the crop cycle. On this basis, total crop water use
Sugarcane crops are watered through syphons from irrigation channels on farms.

Figure 2. Soil moisture extraction by a plant crop of Q96 grown through the 1999/00 season. The crop was planted in May 1999 and was harvested in June 2000.

was assessed to be 17.3 million litres per hectare for the season. This number is likely to vary between seasons and will depend on crop circumstances.

This work supports the earlier finding of growth slow down through reduced water use in the latter stages of crop growth. The sharp decline in crop water use soon after the start of the wet season as shown in Figure 2 correlates with the timing of the growth slow down observed in the irrigation trial. This information has proved useful in the development of the Interim Water Allocation Plan for the ORIA.

Water application efficiency

In irrigated agriculture, improving water application efficiency is dependent on minimising the amount of water losses associated with run-off from irrigation bays, and/or losses due to deep drainage from irrigation bays or infrastructure such as channels and drains. Improving application efficiency will ensure better use of a limited resource, and will in some instances reduce production costs.

Many factors can contribute to the efficiency achieved. Run-off can be influenced by the duration of irrigation, the soil moisture deficit at irrigation, cross sectional profile of beds and furrows, soil infiltration characteristics, water application rate, and furrow length. Similarly, a range of factors will influence the extent of deep drainage.
Table 2. Irrigation run-off losses from a block of sugarcane and number of irrigations applied to each bay during the 1999/00 season. Irrigation bays were planted and harvested in sequence with Bay 4 planted in May 1999 and harvested in June 2000, and Bay 1 planted in August 1999 and harvested in November 2000.

<table>
<thead>
<tr>
<th>Bay</th>
<th>No.</th>
<th>% run-off</th>
<th>No.</th>
<th>% run-off</th>
<th>No.</th>
<th>% run-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay 1</td>
<td>63</td>
<td>38</td>
<td>2</td>
<td>57</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Bay 2</td>
<td>47</td>
<td>41</td>
<td>6</td>
<td>55</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Bay 3</td>
<td>38</td>
<td>40</td>
<td>6</td>
<td>51</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Bay 4</td>
<td>44</td>
<td>30</td>
<td>7</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

To assess efficiency and to identify opportunities for improvement, run-off was measured during the 1999/00 crop season for a commercial block of sugarcane comprising four irrigation bays. Both flow of irrigation water onto the block and drainage were measured, and rainfall coincided with a small number of irrigations. When run-off losses were assessed for only those irrigations that occurred in the absence of rainfall, it was found that 47 per cent of the irrigation water applied had drained off the block.

A more detailed assessment of run-off throughout the season showed that losses were greatest at the start of the season, particularly when pre-irrigation was used (Bay 1), and towards the end of the season, where it appears likely that the crop was using less water than expected and more water than required was being applied (see Table 2).

Simulation modeling with APSIM and SIRMOD

APSIM

The Agricultural Production Systems Simulator (APSIM) model has been developed for the ORIA sugar industry to assist in providing guidelines for scheduling irrigation. The model uses climatic data and other inputs associated with sugarcane growth to estimate daily crop water use, and based on inputs of available soil moisture, estimates the optimum intervals at which to irrigate.

Simulations conducted by Muchow and Keating (1998) using the APSIM model developed for other cane growing areas estimated that evapotranspiration (crop water use), under non-limiting growth over a range of different seasonal conditions, would range from 29.4 to 35.0 million Litres per hectare for the ORIA.

In this situation, by irrigating less frequently following the wet season or by reducing the duration of irrigation, it is likely that deep drainage beyond the root system could be reduced. This would allow greater drying of the soil profile between irrigations, and assist in better matching of water application with crop demand.

These results also support the finding of reduced water use by the crop later in the season. Despite similar frequency and duration of irrigation before and after the wet season, drying of the soil profile at 60 centimetres depth, between irrigations, was greater prior to the wet season when compared with post-wet season results.

Checking the EnvironSCAN equipment, which played an important role in measuring soil moisture and crop water use.
Special thanks to the ORIA sugar industry and growers for cooperation in providing research sites and farm information, and for research support provided by CSIRO and CSR Ltd. Funding provided by the ORIA sugar industry and the Sugar Research and Development Corporation is also gratefully acknowledged.

After further development of the model for ORIA conditions, this estimate has been reduced significantly, due largely to the recently recognised phenomenon of growth slow down and reduced water use in the latter part of the crop season.

SIRMOD

Surface Irrigation Model (SIRMOD) has been used to simulate requirements for achieving optimum water application efficiency for furrow irrigation of the cane crop. The model has been developed and tested using information obtained from cane crops in the ORIA. The model will simulate the optimum combination of a range of parameters associated with irrigation, within management constraints imposed. Parameters most likely to influence application efficiency, and which can be adjusted include soil moisture deficit at irrigation, irrigation duration, furrow length, and rate of water application during irrigation. The model can also be used to simulate optimum requirements where deep drainage occurs and where water infiltration rates vary.

Generally, run-off can be reduced by irrigating at higher soil water deficits with longer furrow lengths, provided that deep drainage is minimal, duration of irrigation is shorter, and flow rates are lower.

Implementation by industry

Key findings from the current research have included the lower than expected cane water use in the latter stages of crop development immediately following the wet season. The supporting data have come from a number of different sources including an irrigation trial, crop water use measurements using EnviroSCAN equipment, and application efficiency measurements for specific irrigation events.

The ORIA Sugar Industry has been kept informed of research progress through regular research reviews. In April 2001, an irrigation workshop was held to discuss the opportunities and issues raised by the research to date. Participants assisted in developing best practice guidelines and defined a range of implementation strategies for the current research. These included:

- a farm ute 'quick reference' guide to cane irrigation;

- development of irrigation scheduling tables for crops at different stages of growth, using either a daily irrigation interval or pan factors; and

- on-farm demonstrations of irrigation scheduling and application efficiency findings.

The Department of Agriculture is expecting rapid adoption of the research findings by ORIA sugar growers due to their demonstrated willingness to embrace new ideas and technology, and their involvement with and support for these research and development activities.

Future research will focus on establishing the water use of crops harvested late in the year, as well as more accurately defining crop water use for a range of seasonal conditions. Research to examine the growth slow down phenomenon will improve knowledge of crop physiology, and allow further improvement in commercial cane production management practices.

References


