SHORT NON-REFEREED PAPER

A SYNERGETIC SYSTEM TO PRODUCE SUGARCANE USING SURFACE IRRIGATION

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Abstract

In 2008, a novel irrigation system, named 'automated short furrow'(ASF) was developed and implemented in a 0.6 ha trial at the University of KwaZulu-Natal's Ukulinga research farm. ASF was shown to have potential to be a relatively low cost, efficient and easy to manage irrigation system. Further development and testing was required before it could be easily adopted by commercial growers. The purpose of the project described in this paper was to further develop, refine and test ASF and associated sugarcane farming systems for implementation in a commercial environment. In the current project, a unique and synergetic production system for sugarcane was developed using surface irrigation similar to ASF. The new system, as described in this paper, permitted efficient use of mechanical equipment and precise low energy surface irrigation, even on relatively shallow soils. The system was demonstrated at the Zimbabwe Sugar Association Experiment Station. At the demonstration site, water use productivity (WUP) was 2.72 tons of estimated recoverable crystal (ERC) per megalitre (ML) of irrigation water applied. This WUP was exceptionally high relative to even the better performing plant-cane fields in the surrounding area. In an industry and country where water supplies are limited, the WUP value obtained at the demonstration site showed a potential to permit a substantial reduction in water withdrawals or a major expansion of the irrigated area using existing water supplies.

Keywords: irrigation efficiency, surface irrigation, sugarcane, farming systems, energy, economics

Introduction

A novel irrigation system aimed at addressing many of the challenges with traditional irrigation options was developed and implemented in a 0.6 ha trial at the University of KwaZulu-Natal,Ukulinga research farm in 2008. Field tests and computer model simulations indicated that sequencing sets of comparatively short (±30 m) blocked furrows were ideal from an irrigation performance perspective. Relatively small amounts of water (<20 mm) could be applied at high uniformities, i.e. with low quartile distribution uniformity, DU_{lq}, above 80% for a range of conditions and with relatively low evaporative losses (Lecler *et al*., 2008). The layout of the system laterals and piping was such that, although the irrigation furrows were short, field lengths could be relatively long, which is ideal for operating machines efficiently.

Although evidence for the benefits of ASF irrigation was established during the Ukulinga field trial, the system implemented was 'embryonic' and not yet ideal for application under commercial farming conditions. The purpose of the project described in this short paper was to further develop, refine and test an irrigation system based on ASF principles and develop an associated sugarcane farming system for implementation in a commercial environment.

Materials and Methods

Development of a synergetic surface irrigation (and farming) system for sugarcane (SSIS) involved the design and development of appropriate implements, layouts and procedures to:

- plant sugarcane in layouts suited to mechanical or semi-mechanical harvesting and short furrow irrigation
- eradicate the sugarcane, plant an appropriate rotation crop, then replant sugarcane in zero-till conditions
- minimise potential compaction damage, tillage requirements and replanting costs through traffic control systems.

Advancing a SSIS also involved: (i) the development of methods and apparatus to facilitate design of the irrigation system for various field conditions, (ii) sourcing and evaluating irrigation piping and fittings suited to low pressure high flow conditions, (iii) application of the *ZIMsched* scheduling tool (Lecler, 2004) and (iv) demonstrating that all these components function and combine in a synergistic manner.

Field operations

To fit with controlled trafficking, agronomic considerations and developments in mechanical harvesting, the cane row and furrow spacing arrangement was selected whereby dual rows of cane spaced 0.9 m apart are planted with 2.4 m between the centres of each pair of dual rows. The irrigation furrow is located between the dual rows. The row spacing suits the potential introduction of dual row mechanical harvesters with a 2.4 m wheel-track. In the interim, cane can be hand cut and windrowed and loaded with mechanical loaders with minimal compaction damage, or cut and stacked and loaded with Perry self-loading trailers.

The development of implements for planting and furrow establishment was done in collaboration with equipment manufacturers. Options include:

- open planting furrows with a ‘ducks-foot’ ridger, plant cane by hand and then use a bed-and-furrow former to simultaneously open an irrigation furrow in the centre of the bed, form the bed and cover the cane-setts
- use the bed-and-furrow former then plant cane either side of the irrigation furrow using a double-disc zero-till cane planter. Both the bed-and-furrow former and cane planter are prototype implements.

Apparatus and procedures for the design of the irrigation system

A set of apparatus and associated procedures for assessing furrow irrigation performance were developed. The procedure involves making test furrows and then irrigating the test furrows under conditions where furrow dimensions, inflows, outflows, advance-front times and recession-front times are measured. The data obtained facilitates calibration of a computer simulation model which can be used to perform various what-if type analyses to develop and verify appropriate design parameters such as furrow lengths, shapes, inflows and slopes suited to a particular field. Following this the laterals and sub-mains are sized using standard hydraulic theory to ensure uniform distribution of water along the operating laterals which are sequenced using manually operated valves.

Results

Procedures, implements and materials were evaluated at a demonstration site at the Zimbabwe Sugar Association Experiment Station.

Irrigation system performance

Pressure versus flow tests were done with various irrigation emitter options. Emitters selected consisted of different sized 'layflat start connectors'. Using these as emitters and a suitably designed layflat lateral, the emitter flow variation measured along the laterals was less than 5%, with a pressure of only 1.5 m at the field edge. This is well within design norms and helps ensure highly uniform low energy irrigation applications.

For the infield irrigation laterals and sub-mains, low pressure vinyl layflat piping, which is more cost effective than large diameter uPVC piping, was obtained. The piping was observed to be very durable and can be buried in shallow trenches to give further protection. After 17 months there were no signs that the piping had degenerated.

Data and information collected to assess irrigation performance permitted a sensitivity analysis to be undertaken with the WinSRFR furrow irrigation simulation model (Bautista, *et al*. 2009). It was found that for relatively small irrigation application amounts of only 16 to 20 mm, the DU_{lq} remained above 80% for a range of slopes, inflows and furrow lengths indicating robust performance. The optimum set of design parameters did vary according to soil conditions and there were thresholds, for example, minimum inflow rates, below which performance degenerated markedly. Extending furrow lengths beyond a certain limit, dependent on particular soil conditions, also resulted in performance degenerating rapidly.

Farming operations

Initial planting was done by opening planting furrows with a ducks-foot ridger, planting cane setts by hand and then the 'bed-and-furrow former' was used to simultaneously open the irrigation furrow, form the bed and cover the cane setts. This procedure was effective although it was noted that exact matching of the centre of the ridger and the bed-and-furrow former was needed to ensure that the irrigation furrow was located in the centre of the planted cane. The wetting pattern of the irrigation system was similar to drip irrigation and there was a limit to the lateral distribution of water. This resulted in germination delays in the cane most distant from the furrow in places where the furrow was not well centred.

After harvesting the plant crop the plan was to prematurely kill the cane in order to test equipment and procedures for incorporating a rotation crop and re-establishing a cane crop. The cane was killed effectively by spraying it with glyphosate. Sunn hemp (*Crotalaria juncea*) was then drilled directly into the dying cane stools using a direct drill seeder. This worked well and germination and growth of the sunn hemp crop was good. At the time of writing it remains to knock over the sunn hemp crop and plant cane into the resulting stubble. The option of using the prototype mechanical cane planter will be tested as an option when replanting.

Water use productivity (WUP)

In plots treated with fungicide, estimated recoverable crystal (ERC) yields for the plant crop at the demonstration site averaged 19 t/ha using only 7 ML of water. Typically, plant-cane fields in the industry yield approximately 15 t ERC/ha and use approximately 15 ML of water.

Discussion and Conclusions

The system has been named synergetic surface irrigation for sugarcane (SSIS) due to the inherent synergies. SSIS can be used to apply small amounts of water per application with minimal losses, great flexibility and a high degree of uniformity. This permits effective and efficient irrigation even on shallow soils, when combined with an appropriate scheduling tool such as *ZIMsched*. While 30 m long furrows can perform well for a range of soil conditions, optimum furrow lengths should be determined for specific soil types as part of the design process. Procedures to do this were developed. The low pressure requirements and efficient water use result in energy requirements and operational costs being relatively low compared with most other types of irrigation.

In the controlled traffic farming system crops are harvested at 14 months of age to ensure mature cane and associated benefits in terms of harvest, haulage and milling costs per ton sugar (or ethanol/biobutanol). This means that the plant crop is harvested in April/May and the third ratoon is harvested in October/November when the cycle of eradicating the cane, planting a rotation crop and then replanting cane in the January to March period is repeated. In the Zimbabwe Lowveld, the likelihood of rain falling in the January to March period is high and this will help alleviate any risks of poor germination. The 0.9 m spacing between the dual rows of cane could be reduced slightly if the lateral distribution of water is a concern and the furrow shape can be modified so that it is wider.

Many synergistic benefits accrue with the associated controlled traffic farming (CTF) system. Amongst other things, the CTF system permits a range of mechanised operations while at the same time limiting compaction. This, together with appropriate implements, permits relatively low cost planting and harvesting and more frequent rotation crops. Rotation crops benefit soil productivity, reduce pest and disease pressure and help to sustain higher crop yields, water use productivity and overall profitability.

The WUP for the plant crop at the demonstration site was exceptionally high relative to even the better performing plant-cane fields in the surrounding area. In an industry and country where water supplies are limited, attaining higher WUP values over large areas should permit a substantial reduction in water withdrawals or an expansion of the irrigated area using existing water supplies. Further development and commercial adoption of SSIS is recommended.

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REFERENCES

Bautista E, Clemmens AJ, Strelkoff TS and Schlegel J (2009).Modern analysis of surface irrigation systems with WinSRFR. *Agricultural Water Management* 96: 1146–1154.

Lecler NL (2004). Performance of irrigation and water management systems in the Lowveld of Zimbabwe. PhD thesis, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, South Africa, 181 pp.

Lecler NL, Mills DD and Smithers JC (2008). Automated short furrow irrigation. *Proc S Afr Sug Technol Ass* 81: 470-473.