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SHORT COMMUNICATION

AUTOMATED SHORT-FURROW IRRIGATION

LECLER NL[1], MILLS DC[2] and SMITHERS JC[2]

[1]*South African Sugarcane Research Institute, Private Bag X02, Mount Edgecombe, 4300, South Africa*
[2]*School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal,*
Private Bag X01, Scottsville, 3209, South Africa
Neil.Lecler@sugar.org.za

Abstract

Automated short-furrow (ASF) irrigation is a prototype irrigation system aimed at providing farmers with a robust, relatively low cost but highly effective and efficient irrigation system option. ASF uses substantially less energy than conventional systems requiring a pressure of only 70 kPa at the field edge compared to 150 kPa for drip irrigation and 400 kPa for dragline systems. With ASF, water is applied sequentially to sets of relatively small and short furrows, typically approximately 30 m in length. By automating the sequencing of the short furrow sets, and controlling the flow of water into the furrows, operational and labour overheads are minimal and system performance is enhanced. With the relatively short furrows, the distribution uniformity of applied water is very high under a wide range of conditions and, since only a very small proportion of the soil surface is wetted, there are relatively low evaporation losses. The configuration of the system piping and emitters is such that, although the irrigation furrows are short, relatively high machine operating efficiencies are possible. The development and potential advantages of a prototype ASF irrigation system are detailed and discussed in this communication.

Keywords: irrigation, sugarcane, economics, energy conservation, water conservation, efficiency

Introduction

The provision of a low cost, efficient and flexible irrigation system option could enhance the viability of irrigation projects. Farmers, especially emerging and small scale farmers in South Africa, are facing increasing pressure to use water and energy more effectively whilst boosting and sustaining profits. The adoption of improved technologies such as drip irrigation is, however, often constrained by available finances and prohibitive management and/or maintenance requirements. The automated short-furrow (ASF) irrigation system described in this communication is a prototype irrigation system aimed at providing farmers with a robust, relatively low cost but highly effective and efficient irrigation system option.

Methodology

A novel system to implement ASF irrigation was developed and installed in a trial at the University of KwaZulu-Natal Ukulinga research farm near Pietermaritzburg. The engineering, economic, agronomic and practical performance/suitability of ASF is being compared to sub-surface drip (SSD) irrigation by taking measurements and keeping records of sugarcane yields, water use, soil water energy levels, system overhead and operating costs and assessments of the uniformity of irrigation water applications. The two treatments used in the trial, namely ASF irrigation and SSD irrigation, were arranged in a randomised block design with four replications on a total trial area of 0.5 hectares. Both treatments have received nearly identical amounts of water. The irrigation scheduling tool, *SAsched* (Lecler, 2004) was used to schedule the irrigation water applications using weather data from a nearby automatic weather station.

Description of the ASF irrigation system

The novelty of the system begins at the field edge. From the field edge water is conveyed in a sub-main pipe consisting of low class polyethylene or PVC piping. Polyethylene laterals join into the sub-main via a 'boot and piston valve'. The laterals (running downhill) convey water to emitters typically made of 10 mm diameter lengths of polypipe, spaced at a distance to suit the row spacing of the crop and connected to the lateral using standard fittings. The emitters convey water into short furrows. The furrows are approximately 30 m in length and are typically 'U' shaped, with a top width of approximately 0.15 m and a depth of 0.15 m. The ends of the furrows are blocked and coincide/intersect with the position of the next downstream lateral. The furrows should be land-planed so that they are relatively smooth. In the Ukulinga trial, sugarcane was planted on either side of the short furrows in a tramline arrangement, so that controlled-trafficking could take place, i.e. 0.6 m between cane plants and 1.8 m between furrows.

When an irrigation application is initiated the most upstream boot and piston valve allows water into the most upstream lateral and, via the emitters, into the first set of 24 short furrows. The boot and piston valve also prevents flow to the remaining downstream laterals. After approximately 40 minutes, the 'boot valve' automatically stops the flow to the first set of furrows and allows water to flow to the next downstream lateral and set of furrows. This sequence continues automatically until a whole field has been irrigated. Typically all the lateral and sub-main piping would be buried, so that only the emitters are visible and trafficking can take place in the field without disturbing the irrigation system and *vice versa*.

Description of the boot and piston valve

The boot and piston valve was manufactured from low cost PVC piping, a rubber boot, and some metal, rubber and polyethylene fittings. Essentially, when an irrigation application is initiated, water is directed from the sub-main to the lateral. Some of the water flowing in the lateral is diverted into a timing container. When the timing container is full, water starts flowing into the rubber boot, causing an internal piston to move upwards. As a result of the piston movement, an opening directing water flow to the lateral is blocked and an opening directing water flow back into the sub-main and on to the next downstream boot and piston valve is opened. The valve remains in this position, i.e. preventing water flow to the lateral and directing it downstream in the sub-main, until the system is depressurised. When the system is de-pressurised, as would happen once an irrigation application to a field is complete, a weight causes the piston to move down, thus closing the opening to the downstream sub-main and re-opening the opening to the lateral in preparation for the start of a subsequent irrigation application.

Results

The main focus of the engineering evaluations was to evaluate the distribution uniformity of applied water for a specified depth of application, and investigate the factors affecting the uniformity of water applications. In addition, system flexibility and ease of management were assessed. Irrigation uniformity is important because it can have significant effects on irrigation performance. Even if the timing and average magnitude of water applications is well matched to crop water demand and soil water storage capacity, non-uniformity results in some areas receiving relatively higher water applications and other areas receiving relatively lower water applications. Excessive runoff and deep percolation losses are likely on the areas receiving the relatively higher water applications, and reductions in crop yield can be expected on the areas receiving the relatively lower water applications. Depending on how well an area is drained, reductions in crop yields can also occur on the areas receiving excess water (Lecler, 2004). The ability to control the depth and timing of irrigation water applications is important because, when the amount of water applied per irrigation applicationis not well matched to soil water holding characteristics, performance will be poor because of either:

- excessive crop stressing if the soil is depleted to a level coinciding with larger irrigation applications, or
- inefficient irrigation with excessive runoff and deep percolation losses and associated drainage problems, if large irrigation applications are applied at relatively low soil water depletion levels to avoid excessive drying of the soil and crop water stress.

Both of these are typical problems with conventional furrow irrigation, especially on soils with low water holding capacities.

Infield measurements of various surface irrigation performance parameters were undertaken based on procedures described in Koegelenberg and Breedt (2003). The data from the field measurements were then used together with a surface irrigation simulation programme, SIRMOD III, to assess the performance of the furrows in terms of low quarter distribution uniformities, DU_{lq} (Walker, 2004). The DU_{lq} for the six furrows evaluated in the trial ranged from 71% to 81% for application depths of only 10 mm. These DU_{lq} values are considered to be very good even though the slopes at the trial site (1:40) were steeper than optimum , and many of the system parameters were not optimised because of constraints related to the prototype system. Many of these initial constraints have since been overcome as the developers have grown in knowledge of the system.

Theoretical simulations undertaken using SIRMOD III have since shown that DU_{lq} values above 85% can be obtained for a range of slopes and soil types, and that the DU_{lq} values are relatively insensitive to variations in slope, soil characteristics, and flow rates compared with typical (long) furrow irrigation. For most soils optimum furrow lengths are between 20 m and 40 m; however, for heavy clay soils, the furrow lengths can be considerably extended to>200 m, with a concurrent reduction in system cost. The application depth of 10 mm per irrigation water application means that even poor soils with low water holding capacities can be effectively irrigated without excessive losses or crop stress. Because only a small portion of the total field surface area is wetted, losses due to evaporation from the soil surface are relatively low, especially when compared with overhead sprinkler/centre pivot irrigation systems.

The system was considered to be easy to manage, highly flexible from an operational perspective and had minimal maintenance requirements. A fertigation system was developed to apply nutrients. No system problems or deterioration in components, for example clogging of emitters, has been observed. The system operated at a relatively low pressure head of 70 kPa at the field edge compared to 150 kPa for the drip system and 400 kPa for a typical dragline system. Thus operating costs can be substantially reduced. Whilst a full economic assessment is still under investigation, preliminary capital costs for the system are expected to be approximately R13 000 per hectare, compared to approximately R20 000 per hectare for an equivalent drip irrigation system.

Visual observations of sugarcane grown under the the drip and ASF treatments have not shown any obvious differences. However, yield data are required to confirm any differences in agronomic performance. The trial will be harvested in mid-March 2008.

Conclusions

ASF may offer the desired combination of low cost, high efficiency and, importantly for small growers, allow independent operation of an irrigation system. The wider community would benefit from ASF facilitating efficient production utilising less water. This is vitally important given South Africa's limited water resources and the increasing competition for them.

A key aspect of the system is the boot and piston valve which allows the use of buried piping, provides good flow control and renders the system relatively robust without requiring electronics, electric power and associated communication systems. Although the furrows are short, machinery run lengths can be long, resulting in high machinery field operating efficiencies.

While ASF has many potential advantages, the system needs to be evaluated under commercial farming conditions. The knowledge and systems required to implement a commercial scale system trial have been developed during this project.

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