THE PERFORMANCE OF SUBSURFACE DRIP IRRIGATION AT ROYAL SWAZILAND SUGAR CORPORATION DURING ITS FIRST SEASON

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Abstract

The Royal Swaziland Sugar Corporation at Simunye has embarked on a project to develop and convert approximately 7000 ha of its sprinkler or overhead-irrigated area to subsurface drip irrigated sugarcane because of the advantages associated with the system. In the first year of this project 1550 ha were developed and planted to sugarcane. At the end of the season a comparison of yields from plant-cane fields on sprinkler and drip irrigation was done to review the performance of drip. Results showed that drip irrigated fields yield much higher than sprinkler fields per unit of water as well as per unit area but the cane quality was slightly lower, particularly early in the season. Although water was saved under drip irrigation, more work needs to be done to convert the bio-mass into sugar and to increase the efficiency of rainfall use. Monitoring of the performance of the system is continuing.

Introduction

Subsurface drip irrigation (SDI) offers many advantages as a method of water application and also for controlled release of nutrients into the root-zone. SDI for sugarcane is being developed and installed as rapidly as possible at Royal Swaziland Sugar Corporation (RSSC) to replace the less efficient drag-line sprinkler system which has served the industry for many years. The reasons for changing from the current sprinkler to SDI at RSSC are to:

- Increase sucrose yield
- Improve water use efficiency
- Reduce the cost of cane production
- Provide a more even power demand
- Reduce labor inputs
- Provide a more even application of water
- Make water available for expansion elsewhere
- Reduce maintenance costs
- Reduce soil water drainage
- Reduce the number of night shift operations
- Increase the level of automation
- Provide an irrigation system that can be operated by management during periods of industrial unrest.

In the first year of the project approximately 1550 ha of overhead-irrigated cane at 1.5 meter spacing was converted to SDI with the drip tape placed 1.8 meters apart and cane planted in tramlines, 0.2 meters either side of the tape. The drip line was placed 150 mm below the surface and discharged 1.6 liters/hour through emitters spaced 920 mm apart. The cane seed was placed at the same level as the drip tape.

RSSC is collecting data to provide information on the performance of SDI and drag-line sprinkler irrigation under sugarcane. The technical knowledge on management and operation of SDI, which is very limited at present at RSSC, will be enhanced through lessons learnt from this project. This report outlines the steps taken in managing SDI at RSSC during the first year, and compares its performance with overhead systems.

Materials and Methods

The data comes from forty-six commercial SDI fields in the northwestern area of the estate, and thirteen sprinkler-irrigated fields distributed throughout the estate. In these fields, the yields and water use from a plant cane-crop were compared. A conventional statistical comparison of the data was not possible because of the differences in soil types, and to some extent the varieties planted in these fields except for two fields feeding from one pump (pump station 12). The two fields feeding from pump station 12 (1209 and 1212) were on similar soils (T-sets), and planted to the same variety (N19) on tramline spacing of 1.8 meters. One field was irrigated using SDI and the other using sprinkler. The rest of the fields were either on different soil types, or different sugarcane line spacing. The spacing under the sprinkler system was 1.5 meters single rows, while 1.8 meters tramline was used in the SDI fields.

Irrigation Scheduling

Prior to planting 12 mm of irrigation was applied so that setts could be placed in moist soil, to encourage germination. After planting, water was applied to fill the profile to the field moisture capacity, based on the water holding characteristics (TAM) of the soil. The irrigation was applied in doses of 6 mm or less to encourage lateral movement, because continuous application encourages vertical movement and increases deep percolation losses.

Irrigation scheduling was based on a combined approach using the soil moisture balance calculated from atmospheric demand and augering to confirm the balance. Factors derived from a comparison of Class A pan and a sugarcane reference evaporation calculated using the Penman-Monteith equation (M. McGlinchey, 1994) were used to adjust Class A pan evaporation to an equivalent sugarcane evapotranspiration. These factors depend on the month of cut and the stage of canopy development of the cane crop. Plant cane Class-A pan adjustment factors are not available. In order to simplify irrigation scheduling RSSC opted to use ratoon cane factors, which slightly over-estimate demand. The ratoon cane factors were used to derive the demands, summaries of which are given in Table 1.

Table 1. Summary of seasonal (1998-99) evapotranspiration (mm) for all fields RSSC – Swaziland.

Mean Annual Demand (mm)	1221.5
Maximum Annual Demand (mm)	1431.0
Minimum Annual Demand (mm)	931.0

The annual demand was higher later in the season because the sugarcane crop planted later took a short time to develop to full canopy when compared to the crop planted earlier.

The contribution from daily rainfall amount to the soil moisture balance was calculated using the following equation:

$$P_e = 0.9*(P-2) \qquad \text{Equation 1}$$

Where P_e is the daily effective rainfall and P is the daily amount of rainfall collected in a raingauge. The net contribution then becomes a portion of the effective amount that can be stored in the root-zone. Any effective precipitation in excess of storage is assumed to be lost to deep percolation or runoff. Raingauges are available at each of the pump stations. All fields getting their irrigation water from a pump station were assumed to have received the same amount of rainfall as that at the pump station. On each rainy day, the P_e for each field is then calculated and used in the soil moisture balance calculation. Daily soil moisture balances were calculated throughout the growing season.

A daily irrigation strategy, i.e. daily replenishment, for SDI was adopted. For overhead systems a deficit strategy was used based on the system's capacity (20 or 27 mm) or 50 percent of TAM depending on which was most critical.

Crop Management

Fertilizer applications earlier in the season were based on soil samples taken prior to planting. Fields included in this report received 120 kg/ha Nitrogen, 40 kg/ha Phosphorus with Potassium applied as stillage at about 4 tons per ha (about 200 kg/ha). At planting all fields received only half the Nitrogen and all of the Phosphorus and Potassium. The rest of the Nitrogen was applied as a top-dressing at 14 to 20 weeks after planting. The SDI fields received the top-dressing Nitrogen from UAN30 as fertigation while Urea was applied in granular form for the sprinkler-irrigated fields.

Weeds were controlled with herbicides applied using tractor-mounted booms, followed by hand weeding. A combination of any three of the following herbicides, Gramoxone, Harness, Gesapax and Actril DS was used in different mixtures and applied post emergent twice on the SDI fields and once to the sprinkler irrigated fields. This was then followed by hand weeding (hoeing) under both systems to eliminate all weeds that may have survived the effects of the herbicide. Weed control on the field verges was mainly achieved with herbicide for both sprinkler and drip fields.

Before the beginning of the drying-off period all the early season fields (to be harvested in April to July) were ripened using Fusilade and/or Ethrel combined with Downright. Drying-off was restricted to the period needed to avoid damage from in-field transport. The period of drying-off was determined from the total available moisture in the soil and rate of expected evaporation as recommended by Swaziland Sugar Association Extension Services.

Results and Discussion

At the end of the first season, water use and yield data were gathered from 59 plant fields (46 SDI and 13 Overhead) harvested at about the same time for purposes of comparing the performance of SDI and overhead irrigated fields. The field data were grouped and analyzed according to RSSC definition of the harvesting season, i.e., early (April-July), mid (August-September), late (October-November).

Crop Growth

Data collection on stalk population and height was undertaken by the Crops Section of the Agronomy department on fields that were planted in July and August of 1998. Data from six overhead fields at pump stations 2, 3, 5, and 6 as well as 10 SDI fields at pump stations 10 and 16 were obtained. Table 2 shows stalk measurements and population counts of NCo376 for tramline (SDI) and 1.5 meter (overhead) spacings, as a function of planting dates.

Table 2. Stalk measurements and population counts for NCo376 under SDI and Overhead Irrigation Systems as a function of planting date.

Irrigation Type	Plant Month	Average Population per ha	Average Stalk Height (mm)	Average Stalk Diameter (mm)
Overhead	July	127,289	2,162	22.12
SDI	July	141,889	2,569	22.20
Differences		**14,600**	**407**	**0.08**
Percentage difference		**+11**	**+19**	**0**
Overhead	August	133,156	2,068	21.91
SDI	August	138,222	2,559	22.16
Differences		**5,066**	**491**	**0.25**
Percentage difference		**+4**	**+24**	**+1**

Table 3. Average gross effective rainfall and irrigation for SDI and Overhead systems

Season	*Irrigation Type*	*Average Gross Effective Rainfall (mm)*	*Average Gross Irrigation (mm)*	*Total Water (mm)*
Early (Apr-Jul)	Overhead	830.0	676	1,506.0
	SDI	822.4	528	1,305.4
	Percentage difference	**-0.9**	**-22**	**-13**
Mid (Aug-Sep)	Overhead	811.6	808.2	1,619.8
	SDI	734.7	672.0	1,406.7
	Percentage difference	**9.5**	**16.9**	**-13**
Late (Oct-Nov)	Overhead	710.6	710.0	1,420.6
	SDI	893.8	481.8	1,375.6
	Percentage difference	**20.5**	**32.1**	**-3**

Depending on the planting month of the crop, preliminary observations on the plant crop show an increase in populations of 4- 11 % for 1.8 tramlines compared with 1.5 single row. The cane height was found on average to be substantially taller under SDI, while the stalk diameter was similar to that of sprinkler irrigated cane.

Water Use

Records of seasonal gross irrigation and effective rainfall at each of the pump stations where yield was to be compared were obtained. Table 3 shows the average gross effective precipitation and irrigation for SDI and overhead.

The data showing supply and demand at each of the fields were also plotted to observe any trends. Typical graphs for overhead and SDI systems are shown in Figures 1 and 2.

The seasonal average effective rainfall for the overhead fields was about the same as that for SDI yet the amount of gross irrigation on average was 22 percent less for the SDI early season fields. For the mid and late season fields, the gross effective rainfall was 9.5 and 20.5 percent different, respectively, and the gross irrigation was 16.9 and 32.1 percent less for SDI, respectively. The total water was 13 % lower for SDI fields for the early and mid season sugarcane and 3 % lower during the late season. Earlier in the season most SDI fields were over-irrigated because of commissioning and fault identification for repairs. Filling up the soil profile earlier in the season on both systems accounted for some of the over-irrigation seen. Some of the oversupply during the season was where the combined rainfall and irrigation was higher than demand when rainfall occurred just after an irrigation.

Cane and Sucrose Yields

The yield data analysis does not take into account the differences that could be attributed to sugarcane varieties and soil types, because of the complexity of including such with commercial field data. The most common variety was NCo376 which accounts for 31 of the SDI fields and 9 of the overhead fields. The other varieties in the rest of the fields include N14, N19, N25, N30. Results for the other varieties were combined with those of NCo376. As commonly observed in Swaziland, the SDI and overhead-irrigated fields planted earlier in the year gave higher yields than those planted late, as shown in Figure 3.

Table 4 shows the averages and ranges of yields as well as the percent differences between the SDI and the overhead fields.

Through all seasons, the mean cane yield of SDI fields were higher than overhead fields. The mean tons cane per hectare per month ranged from 5 to 24.6 percent above overhead fields. The pol yield was lower during the early season for the SDI fields. At pump station 12 the SDI yields (tons cane per ha) were more than 30 percent higher than long-term means. SDI yield in tons cane per 100 mm of water was 11.9-42 percent

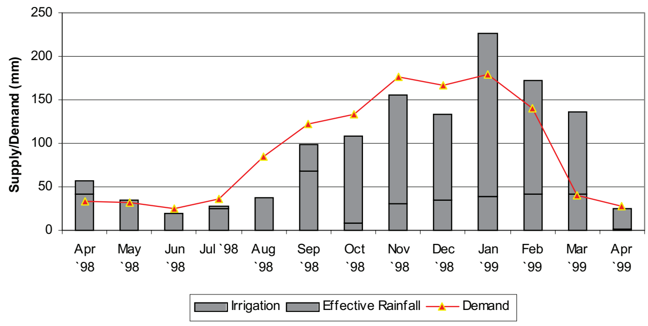

Figure 1. Typical SDI system supply and demand curve at pump station 12 at RSSC during the cropping season 98-99.

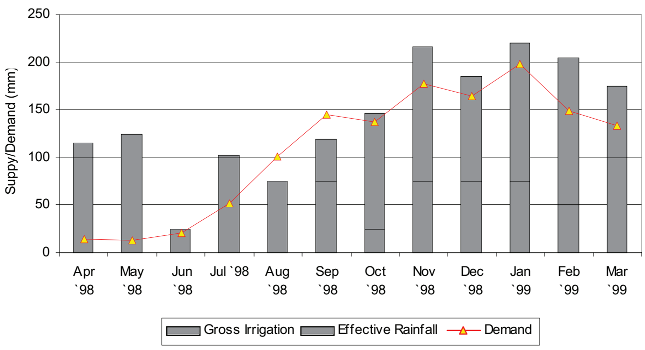

Figure 2. Typical overhead irrigation supply and demand curve at pump stations 13 and 14 at RSSC during the cropping season 98-99.

higher than that for overhead system, as anticipated in the motivations justifying the move to SDI.

Conclusions

From the preliminary results obtained it seems that there are substantial benefits to be realized from SDI in terms sugarcane yield. The cane quality was lower during the early part of the season under drip when compared to overhead systems. The water-savings obtained under SDI imply a saving in power costs because the water delivery to the fields is through pumping. These preliminary conclusions need to be substantiated with further studies of plant cane, and it needs to be observed whether the trends continue in ratoon crops.

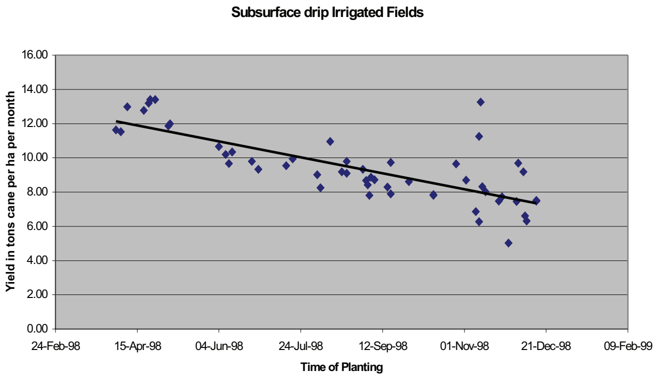

Figure 3. Yield (tons cane /ha/month) versus the time of harvest for subsurface drip irrigated fields planted in 1998 for harvest in 1999.

Lessons learnt

- Improvements on irrigation scheduling are necessary in order to maximize the benefits from SDI. Soil reservoir concepts need to be redefined to refine scheduling techniques and increase rainfall efficiency. Augering and digging observation pits are also necessary.
- A flow-meter is an indispensable tool and set times are not a substitute for establishing volumes.
- Routine observations in the field are essential to detect irregularities (e.g. broken and/or leaking pipes or connections).
- Routine inspection of all system components, including the filter station, is essential.
- Preventative maintenance and trouble shooting are an integral part of SDI management.
- Pulsing the early-season irrigation is necessary to achieve lateral movement.
- There were labour savings because there was no need for irrigators to move system components.
- There is a high potential for automation of the system.

Challenges are to:

- Convert the bio-mass into sucrose.
- Maintain the yields at high levels.
- Increase rainfall efficiency through making maximum use of rainfall.

Table 4. Mean Yield for Subsurface Drip and Overhead Fields.

	Yield Mean Tc/ha/month (Range)		Percentage Difference
Season	**Subsurface Drip**	**Overhead**	
Early	12.35 (11.53-13.41)	9.91 (9.05-10.05)	+24.6 (+16-+35)
Mid	9.64 (8.26-10.95)	7.98 (7.64-8.58)	+20.8 (+8.11-+27.62)
Late	8.27 (5.02-13.22)	7.87 (7.27-8.48)	+5.1 (-30.95-+55.90)
	Mean Pol %		
Early	12.48	13.46	-8
Mid	14.98	14.39	+4.1
Late	14.76	13.82	+6.8
	Mean Pol % /ha/month (Range)		
Early	1.54 (1.44-1.66)	1.29 (1.25-1.37)	+19.4 (+11.6-+28.7)
Mid	1.12 (1.0-1.3)	1.11 (1.02-1.18)	+1 (-1.96-+10.16)
Late	1.24 (1.04-1.44)	1.03 (1.00-1.05)	+20.39 (+4-+37.14)
	Tons cane/100 mm (Ml)		
Early	11.9 (11.1-13.9)	8.4 (8.2-8.6)	+42 (+32.1-+65.5)
Mid	8.5 (5.95-12.7)	6.8 (5.4-8.9)	+25.22 (+11-+43.33)
Late	8.4 (5.1 -11.84)	7.3 (4.03-7.4)	+11.9 (-24.3-+60)

- Maintain the system to receive maximum gains from it.
- Quickly detect instrumentation malfunction in case of automation.
- Increase the ratooning ability of the crop.

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REFERENCES

McGlinchey M. (1994) Table to convert Class A pan evaporation to Penman-Monteith evaporation. South African Sugar Experiment Station Specialist Advisory Report to Swaziland Sugar Association.