WATER USE EFFICIENCY OF IRRIGATED SUGARCANE AS AFFECTED BY ROW SPACING AND VARIETY

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Introduction

To meet the challenge of a limited and costly water supply, South African sugarcane growers will have to find ways of increasing the efficiency of irrigation to maintain high cane and sucrose yields. The term 'water use efficiency' (WUE) is generally used as a measure of the overall effectiveness of water (either rainfall or irrigation, or both) for crop production. WUE can be defined as cane yield per unit of crop water use (evapotranspiration). Irrigation water use efficiency (IWUE) is another term commonly associated with WUE, and can be defined as the cane yield response per unit of irrigation water applied. More efficient irrigation systems, accurate irrigation scheduling and agronomic practices such as mulching, variety choice and row spacing are potential means of increasing water use efficiency. WUE and IWUE values are required for water resource planning and for the assessment of irrigation management practices. Improved water use efficiency would also reduce negative environmental impacts by reducing runoff, erosion, drainage and leaching of agricultural chemicals.

The objective of this study was to determine the WUE and IWUE of surface drip irrigated sugarcane as influenced by the amount of irrigation applied, the variety planted and the row spacing arrangement. The information obtained will be used to develop irrigation recommendations, as well as to test crop models. Preliminary results are reported here.

Keywords: sugarcane, water use efficiency, variety, row spacing, irrigation, water deficit

Methods

Experiment 1: Row spacing
Variety N25 was planted in dual rows at interrow spacings of 0.4, 0.6 and 0.9 m, with the centres of the dual rows spaced at 1.8 m in all cases. The plant crop was cut back on 4 April 2002, and the experiment was conducted on the first ratoon. Irrigation was applied with surface drip lines placed at the centre between dual rows, 1.8 m apart.

Experiment 2: Variety
Varieties N25, N22 and N14 were planted in single rows at 1.5 m spacing, and all three varieties were cut back on 6 April 2002. The experiment was conducted on the first ratoon crop. Irrigation was applied with surface drip lines placed on the row and moved to the centre of the interrow after shoot emergence.

Both experiments were conducted on the South African Sugar Association Experiment Station (SASEX) Mpumalanga research station (25°37'S, 31°52'E, 187 m), near Komatipoort on a Glenrosa soil form. Standard cultivation, fertiliser and weed control practices were followed.

Cane yield was measured at four, six and ten months of age. Four sub-samples of a 0.5 m line of cane were taken at random in each of three replicate plots. Interception of photosynthetic active radiation was measured weekly with an AccuPAR linear ceptometer (Decagon Devices Inc, WA, USA).

Irrigation scheduling and water treatments

Irrigation was scheduled using the SQR-Canesim program (Singels *et al*., 1998) and daily weather data was obtained from an on-site automatic weather station.

The following irrigation treatments were applied:

- Full treatment   Irrigated to replace 100% of potential evapotranspiration (ETp)
- Def1 treatment   Irrigated to replace 50% of ETp
- Def2 treatment   Irrigated to replace 25% of ETp during the first six months, and thereafter irrigated to replace 50% of ETp.

Experiment 1 was subjected to all the treatments, whereas Experiment 2 was subjected to treatments Full and Def1 only. In all treatments, 8 mm irrigation was applied when the respective thresholds were reached. Treatment Def1 therefore received roughly half the number of irrigations received by treatment Full.

Volumetric soil water content (SWC) was measured twice weekly using a neutron water meter, Model 503DR CPN Hydroprobe (Campbell Pacific Nuclear, CA, USA). Readings commenced at a depth of 0.25 m, and were taken at 0.15 m intervals thereafter to a maximum soil depth of 1.15 m. Aluminium access tubes were installed between the dual rows in Experiment 1, and 0.15 m from the single row in Experiment 2. Measured change in soil water content (ΔSWC), total irrigation (I), total rainfall (R) and total estimated drainage (D) for a given period was used to derive cumulative crop water use (CWU) at the end of that period, using the standard water balance equation. Drainage was estimated by the SQR-Canesim model.

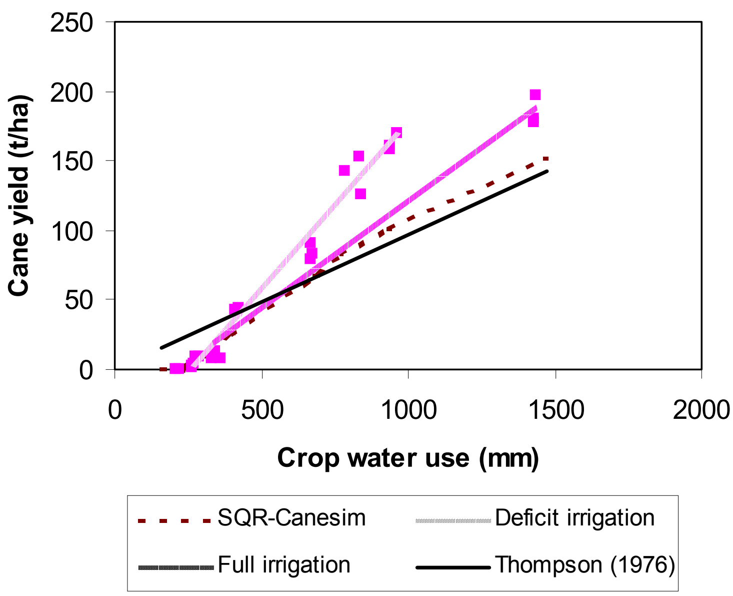

Figure 1. The relationship between estimated crop water use and cane yield. Measurements (points) are compared with SQR-Canesim simulated values and the Thompson (1976) relationship.

Results

Water status

Figure 1 illustrates the relationship between yield and water use. WUE of all deficit treatments were much higher than the values established by Thompson (1976) and used by the SQR-Canesim model (Singels *et al*., 1998). A possible reason could be that the ratio of radiation (which drives yield) to atmospheric evaporative demand (which drives evapotranspiration) was higher at the Mpumalanga research station than the conditions that existed at the experiment sites used by Thompson (1976). The Full treatment had lower WUE values, indicating possible wastage of water.

Growers and irrigation planners are interested in IWUE (Table 1) because it is closely related to irrigation efficiency and profitability. The amount of irrigation had a profound effect on IWUE. For example, IWUE of the 0.6 m row spacing increased from 13.2 t cane/100 mm irrigation in the Full treatment, to 24.7 t cane/100 mm irrigation in the Def1 treatment (Table 1). This increase was due mainly to the large reduction (50%) in irrigation, while yield declined by only 4%. Field trials at Mount Edgecombe have produced responses that vary from 22 to 48 t cane/100 mm irrigation, depending on the scheduling strategy and rainfall (Inman-Bamber *et al*., 1998). The increase in IWUE due to less irrigation could be ascribed in part to reduced evaporation from the soil resulting from the lower wetting frequency of the deficit irrigation treatments. Furthermore, considerably more drainage from the root zone was estimated for the Full treatment compared with Def1 and Def2 treatments.

Dual row spacing

Spacing of dual rows had no significant effect on WUE or IWUE, irrespective of crop water status (Table1). WUE values for the Full treatment were higher than the 9.7 t cane/100 mm irrigation found by Thompson (1976), but is in agreement with the value of 12.2 t/100 mm reported by Kingston (1994).

Table 1. Yield and water use data for Experiment 1.

Treatment: Irrigation	Treatment: Row spacing	Yield (t/ha)	CWU* (mm)	Irrigation (mm)	Rainfall (mm)	Drainage (mm)	WUE (t/100 mm)	IWUE (t/100 mm)
Full	0.4	180_{abc}	1427_{a} (1468)	1332_{a}	328	190	12.6_{a}	13.5_{a}
	0.6	177_{abc}	1426_{a} (1468)	1332_{a}	328	190	12.4_{a}	13.2_{a}
	0.9	196_{a}	1434_{a} (1468)	1332_{a}	328	190	13.7_{ab}	14.7_{a}
Def1	0.4	161_{bc}	939_{b} (934)	687_{b}	328	60	17.2_{ab}	23.4_{b}
	0.6	170_{bc}	963_{b} (934)	687_{b}	328	60	17.7_{b}	24.7_{b}
	0.9	158_{bc}	939_{b} (934)	687_{b}	328	60	16.8_{ab}	23.0_{b}
Def2	0.4	125_{c}	840_{c} (776)	551_{b}	328	60	15.0_{ab}	22.8_{b}
	0.6	142_{c}	783_{d} (776)	551_{b}	328	60	18.2_{b}	25.8_{b}
	0.9	152_{c}	833_{cd} (776)	551_{b}	328	60	18.4_{b}	27.6_{b}

*CWU = Crop water use; SQR-Canesim generated CWU values in brackets.

$_{abc}$ = Values that have the same subscripts do not differ significantly.

Variety

N14 had higher yield, WUE and IWUE than N22 and N25 (Table 2). Under water stress conditions, N22 had significantly lower yield, WUE and IWUE than the other two varieties. The reduction in yield as a result of deficit irrigation is a measure of drought susceptibility. Yields of N25 declined by only 3% compared with 17% for N14 and 30% for N22. These results confirm the classification of N22 as a drought susceptible variety.

Table 2. Yield and water balance data for Experiment 2.

Treatment		Yield (t/ha)	CWU* (mm)	Irrigation (mm)	Rainfall (mm)	Drainage (mm)	WUE (t/100 mm)	IWUE (t/100 mm)
Irrigation	Row spacing							
Full	N25	136_{ab}	1447_{a} (1475)	1319_{a}	328	200	9.4_{a}	10.3_{a}
	N22	139_{ab}	1465_{a} (1475)	1319_{a}	328	200	9.5_{a}	10.6_{a}
	N14	151_{a}	1468_{a} (1475)	1319_{a}	328	200	10.3_{a}	11.4_{a}
Def1	N25	131_{b}	939_{b} (941)	675_{b}	328	70	14.0_{b}	19.5_{b}
	N22	99_{c}	952_{b} (941)	675_{b}	328	70	10.4_{a}	14.6_{a}
	N14	126_{b}	940_{b} (941)	675_{b}	328	70	13.4_{b}	18.6_{b}

*CWU = Water use; SQR-Canesim generated CWU values in brackets.

$_{abc}$ = Values that have the same subscripts do not differ significantly.

General

It is interesting that the yield of N25 obtained with dual rows at 1.8 m (Table 1) was 23% higher than that obtained in single rows at 1.5 m (Table 2). The yield response of 58% per 1 m reduction in row spacing is much higher than the value of 13% reported by Boyce (1968) and Singels and Smit (2002). WUE and IWUE were therefore also much higher for dual rows than for single rows. This result can be explained by the increased interception of radiation by the dual rows because of quicker canopy development. Dual rows required 90 days to reach 80% canopy cover, whereas the 1.5 m single rows required 120 days.

Plant crop results from trials conducted recently in Swaziland ([1]personal communication) showed that 1.8 m spaced dual rows (0.4 m apart) produced higher yields than the standard 1.5 m single rows. However, these results could not always be repeated in the ratoon crops. Results from trials conducted in Zimbabwe ([2]personal communication) were also inconclusive.

Another interesting aspect of these experiments was the high cane yields obtained at 10 months on the dual row spacing. Another two months of stalk growth and proper ripening could, theoretically, have lead to sucrose yields of more than 28 t/ha. Although this was achieved on soil that is relatively new to cultivation, it is nevertheless an indication of the high climatic potential of the Mpumalanga area. There is considerable scope for cane growers to increase yields and IWUE through improved agronomic management.

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[1]DWF Butler, Swaziland Sugar Association Technical Services.

[2]NL Lecler, South African Sugar Association Experiment Station.

Conclusions

Key findings from this work were:

- Under well-watered conditions, N14 had slightly higher WUE and IWUE values than N22 and N25.
- Yield, WUE and IWUE of N25 was significantly higher in dual rows spaced 1.8 m apart than in single rows spaced 1.5 m apart. There appears to be a clear yield advantage to planting cane in dual rows where drip irrigation is practised. The configuration of the dual row spacing does not affect yield or WUE.
- Increases in WUE and IWUE can be achieved by reducing irrigation in drought tolerant varieties without causing severe yield loss. N22 was confirmed as being susceptible to drought, whereas N25 appeared to be drought tolerant.

The data from these experiments will be further analysed to develop practical irrigation recommendations. Further investigation into the optimal use of limited irrigation water is required. Efficiencies need to be expressed in terms of ERC yield per unit of water use or water applied. The data will also be used to refine and test crop models for use as irrigation management support tools.

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