A TRICKLE IRRIGATION EXPERIMENT IN THE SOUTH AFRICAN SUGAR INDUSTRY

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Abstract

A trickle irrigation experiment on sugarcane was established in October 1985 on the SASA Experiment Station farm at Shakaskraal. The objectives were to establish suitable operating procedures, to measure cane yield potential, and to study the effects of factors such as fertigation and crop row spacing on yields of trickle irrigated sugarcane. The results of the plant and first ratoon crops of this experiment are presented. Cane rows were planted either at a standard 1,3 m row spacing or in a tramline pattern with rows spaced alternately 1,8 and 0,8 m apart. Fertilizer was applied as a topdressing of granules on the soil surface to some plots and dissolved in the irrigation water and applied over a period of time to other plots. Results from plant and first ratoon crops indicate that no marked benefits can be expected from fertigation or tramline spacing. Better growth in the cane rows below the trickle irrigation lines on the slope was observed.

Introduction

Although trickle or drip irrigation has been used by cane growers and investigated by the sugar industry researchers in Hawaii since the early 1970's and in Australia in the late 1970's, it has not been used commercially in South Africa to any extent (P. A. Donovan, unpublished report). However, pilot schemes and experimental blocks have been established using trickle irrigation in Mauritius and Swaziland (Nixon & Workman;[5] Pollok & Boshua[6]) and South Africa. Virtually all irrigation of cane in Hawaii is by means of trickle irrigation, the advantages cited being savings of labour, water and energy and therefore cost reductions and increases in water use efficiency, from 30 to 85%. (P. A. Donovan, unpublished report).

The benefits of trickle irrigation have been summarised by Dasberg and Bresler.[2] They consider the main advantage to be the degree of control over water application that the system affords.

Other benefits include the possible use of low quality water, easy fertilizer and herbicide application, and better use of marginal soils. Accordingly, an experiment was designed to evaluate trickle irrigation under local conditions and, since it has been suggested that soils with poor physical characteristics should benefit to a greater extent than good soils (which have shown benefits in Hawaii from trickle irrigation), a site on a poor soil was chosen. The objectives of this experiment were:

- to assess the yield potential of the highest yielding cane varieties in the industry grown on a comparatively poor soil
- to compare the effects of fertilizers supplied through the trickle irrigation system on cane growth, yield, quality, and third leaf nutrient values, for about 3 and 6 months, with those of granular fertilizer applied in the conventional way
- to compare yields and water use efficiency of 3 sugarcane varieties grown under conventional and tramline row spacing.

Table 1

Soil characteristics and nutrient status prior to establishment of the experiment

pH	Organic matter (%)	Clay (%)	Silt (%)	Sand (%)	Nutrients (ppm)				
					P	K	Ca	Mg	S
5,8	1,56	13	13	74	45	55	570	117	27

The experiment was planted in October 1985 in randomised blocks with 5 replications. Plots comprised either 4 or 6 rows 16 m long; the 2 centre rows (except 1 m at each end) were used for crop growth measurements and harvest analysis. Measurements of crop growth were made regularly; stalks were counted in the 2 centre rows of each plot and the length of 20 stalks randomly selected from these 2 rows were measured.

For nutrient analysis samples of the third leaf, counted from the top of the stalks, were taken from each plot on 3 occasions. Selected plots in the plant crop were sampled (16 stalks per sample) 7 weeks before harvesting when sugarcane ripener was applied to most plots, and samples of 12 stalks were taken from each plot on the day of harvesting to determine sucrose content.

Irrigation

Irrigation equipment consisted of 12 mm diameter polyethylene tubing fitted with 4 ℓ h^{-1} emitters spaced 1 m apart in the line. Lines were placed in alternate interrows. The irrigation system was designed to apply 1,5 mm h^{-1} and to be able to run for 4 h per treatment per day giving an application of 6 mm d^{-1}. A TAM (total available moisture) content of 40 mm was used for this soil and scheduling was based on the long term mean monthly evaporation from a Class A pan, in conjunction with a crop canopy factor to give an estimated crop requirement. The profile was maintained at field capacity and irrigation was withheld for one day whenever there was rainfall of more than 6 mm. Rainfall was not taken into account in the design of scheme capacity.

Varieties

Three varieties were used: NCo376, the most widely grown variety in the South African sugar industry, N14, a variety suited to the conditions of the northern irrigated areas, and N12, a variety which performs well under relatively harsh conditions.

Row spacing

Two spacings were used: conventional 1,3 m spacing between rows, and a tramline arrangement with spacing of alternately 1,8 and 0,8 m. Trickle irrigation lines were placed in the centre of alternate interrows, and between the closely spaced rows in the tramline spacing treatment.

Nutrition

G = granular fertilizer in the form of a single topdressing to plant cane (10 weeks after planting) and two separate applications to ratoon crops (10 days and 8 weeks after harvest in the first ratoon)

F3 = fertigation for a period of 4 months in plant cane and 3 months in ratoon cane

F6 = fertigation for a period of 7 months in plant cane and 6 months in ratoon cane.

Quantities of N, P and K for plant and first ratoon crops were: (kg ha^{-1})

	N	P	K
Plant	141	32	166
Ratoon	164	—	164

All plots in the plant crop received some granular fertilizer in the furrow, which supplied the crop's total requirement for phosphorus (P) and 30% of the crop's requirements for nitrogen (N) and potassium (K). The balance was either topdressed with granular fertilizer (G) or applied via fertigation treatments (F3, F6).

Fertigation was carried out with the same granular fertilizers dissolved in a slurry and then poured into tanks, from which injection into the irrigation lines could take place.

Ripeners

The use of ripeners was an integral part of crop management, rather than a treatment, but some conventionally spaced plots were left unsprayed to allow comparisons to be made and tramline plots were not sprayed because moving the equipment between the rows would have been difficult. The ripener was Fusilade Super applied at a rate of 412 ml ha^{-1}. The ratoon crop was not treated with a ripener.

Results and discussion

Irrigation

Details of rainfall received and irrigation applied to the plant and first ratoon crops are shown in Tables 2 and 3.

Table 2

Moisture received in each treatment in the plant crop

Month	Granular			F3			F6		
	Irrig mm	Rain mm	Total	Irrig mm	Rain mm	Total	Irrig mm	Rain mm	Total
Oct '85	0	234	234	0	234	234	0	234	234
Nov	8	55	63	8	55	63	10	55	65
Dec	25	67	92	26	67	93	26	67	93
Jan '86	39	130	169	44	130	174	49	130	179
Feb	44	77	121	48	77	125	56	77	133
Mar	47	99	146	44	99	143	58	99	157
Apr	44	67	111	43	67	110	48	67	115
May	45	0	45	44	0	44	49	0	49
Jun	31	25	56	31	25	56	30	25	55
Jul	58	7	65	62	7	69	56	7	63
Aug	65	35	100	67	35	102	60	35	95
Sep	86	32	118	92	32	124	80	32	112
Oct	26	12	38	27	12	39	23	12	35
Total	518	840	1 358	536	840	1 376	545	840	1 385

Visual observations of the plant crop suggested that the surface distribution of water from the emitters was very poor and water tended to pond near the emitters and then move down the slope. Each emitter was intended to supply moisture to the roots of sugarcane in an area of 2,6 m^2. The poor surface wetting pattern and lack of lateral movement up the slope suggested that this may not have been achieved although the subsurface moisture pattern was not studied in detail. In dry periods this may have led to a benefit to sugarcane lines below the trickle irrigation lines while in wet periods it could have been a disadvantage due to waterlogging. During the growth of both the plant and first ratoon crops heavy rainfall occurred over short periods (October '85 and September '87 — see Tables 2 and 3). For this reason and because surface water distribution was poor no attempt has been made to calculate effective water and water use efficiency.

Table 3

Moisture (mm) received in each treatment in the first ratoon crop

Month	Granular			F3			F6		
	Irrig mm	Rain mm	Total	Irrig mm	Rain mm	Total	Irrig mm	Rain mm	Total
Oct '86	9	38	47	8	38	46	7	38	45
Nov	54	88	142	49	88	137	44	88	132
Dec	75	146	221	66	146	212	58	146	204
Jan '87	22	191	213	21	191	212	20	191	211
Feb	87	82	169	81	82	163	59	82	141
Mar	41	140	181	35	140	175	25	140	165
Apr	66	46	112	64	46	110	57	46	103
May	43	69	112	49	69	118	140	69	209
Jun	23	72	95	27	72	99	58	72	130
Jul	54	8	62	57	8	65	64	8	72
Aug	53	81	134	54	81	135	43	81	124
Sep	0	495	495	0	495	495	0	495	495
Oct	0	81	81	0	81	81	0	81	81
Total	527	1 537	2 064	511	1 537	2 048	575	1 537	2 112

These results tend to support those of Nixon *et al*[5] who found that results from trickle irrigation on a Sterkspruit form soil were disappointing and associated with poor infiltration rates and poor surface water distribution. Results were better with trickle lines placed in every interrow.

Third leaf nutrients

Third leaf samples were taken from the plant crop before all the applications of fertigation had been completed. There was no indication that uptake of nutrients in the fertigation treatment was greater than in the granular fertilizer treatment. The application of 30% of the nitrogen and potassium in the furrow at planting may account for the absence of differences.

In the ratoon crop there was a tendency for N, P and K contents of leaves of both NCo376 and N12 to be higher in fertigation treatments. However, the differences were relatively small, and far less than varietal differences, which were marked.

Responses of plant and ratoon cane to treatment

Crop measurements: stalks were taller and populations lower in the plant crop where tramline spacing and fertigation were practised. Spacing treatments were confounded with the use of ripeners so any differential effect due to these factors on stalk height and number at harvest could not be determined.

In the first ratoon crop the residual effects of ripening the plant crop caused populations to be slightly higher and stalks shorter. This is likely to have exaggerated the differences between tramline and conventional spacing (stalks were taller and populations lower in tramline than in conventional spacings where ripener had not been applied).

Table 4

Third leaf nutrient (dm%) analysis of the plant and first ratoon crops sampled at 5,4 months and 5,1 months respectively

Treatments	Plant crop			1st ratoon crop		
	NCo376	N12	N14	NCo376	N12	N14
dm % N						
Granular	1,95	1,71	1,92	1,89	1,57	1,75
F3:*3 or 4 mths fertigation	1,95	1,68	1,90	1,90	1,67	1,82
F6: 6 or 7 mths fertigation	1,93	1,70	1,89	2,01	1,76	1,80
dm % P						
Granular	0,23	0,20	0,20	0,25	0,18	0,20
F3: 3 or 4 mths fertigation	0,24	0,19	0,21	0,24	0,19	0,20
F6: 6 or 7 mths fertigation	0,25	0,19	0,21	0,26	0,20	0,21
dm % K						
Granular	1,17	1,09	0,92	1,23	1,16	1,05
F3: 3 or 4 mths fertigation	1,16	1,06	0,91	1,25	1,19	0,99
F6: 6 or 7 mths fertigation	1,18	1,04	0,87	1,27	1,30	1,02
dm % S						
Granular	0,16	0,14	0,14	0,14	0,10	0,11
F3: 3 or 4 mths fertigation	0,16	0,14	0,14	0,14	0,12	0,12
F6: 6 or 7 mths fertigation	0,16	0,14	0,14	0,14	0,11	0,11

* 4 months in plant and 3 months in ratoon

Spacing and ripener effects on cane yield: visual symptoms were severe in varieties NCo376 and N12 and to a lesser extent in N14 after treatment with the ripener Fusilade Super. Stalks were stunted and black constrictions or 'ringbarking' occurred on many stalks. The effects on yield may have been exaggerated by a tendency to cut the tops of unripened stalks at a higher point. Although spacing effects were confounded with ripener effects, the calculations (Table 5) indicate that yields in conventionally spaced plots were greater than those in plots with tramline spacing.

Response to Fusilade Super: in the plant crop all varieties showed improved cane quality as a result of spraying with ripeners but cane yields were smaller after ripening, which result in reduced sucrose yields in NCo376 and N12, and only a very small increase in N14 (Table 6).

The residual effects of ripener applied to the plant crop were evident in lower cane yields in the ratoon crops of NCo376 and N12. No improvement in cane quality occurred and sucrose yields were significantly reduced.

Table 6

Response to Fusilade Super (conventional spacing only)

Cane yields and quality	NCo376	N12	N14	SE* diff
Plant crop				
Cane (t ha^{-1})	−10,20	−14,30	−9,00	± 7,80
Sucrose % cane	1,04	1,52	1,42	± 0,50
Sucrose (t ha^{-1})	− 0,20	− 0,30	0,70	± 0,83
1st ratoon crop				
Cane (t ha^{-1})	−17,00	−10,00	5,00	±12,60
Sucrose % cane	0,04	0,06	−0,25	± 0,49
Sucrose (t ha^{-1})	− 2,20	− 1,50	0,50	± 1,83

* Standard error of the difference between varieties

Fertilizer: no significant responses to fertigation were obtained in terms of either cane or sucrose yields, but there was a slightly higher sucrose % cane content in plots of N12 and N14 when they received fertilizer through the irrigation water for three or four months. However, this did not occur in NCo376. (Tables 7 & 8).

Table 7

Differences in yield between responses to fertigation compared with those to granular applications of fertilizer (F3–G*)

Cane yields and quality	NCo376	N12	N14	SE**
Plant crop				
Cane (t ha^{-1})	5,20	−3,90	1,20	±5,20
Sucrose % cane	−0,53	0,32	0,36	±0,11
Sucrose (t ha^{-1})	0,00	−0,20	0,40	±0,60
1st ratoon crop				
Cane (t ha^{-1})	−3,00	7,00	0,50	±4,30
Sucrose % cane	0,30	0,14	0,29	±0,16
Sucrose (t ha^{-1})	−0,15	0,55	0,35	±0,47

* F3 = fertigation for 4 mths in plant and 3 mths in ratoon;
G = granular;
** SE = standard error of the mean

Table 5

Responses to ripeners and spacing in yields of plant and ratoon cane

Treatment details	Cane (t ha^{-1})			Mean and standard errors		
	NCo376	N12	N14	Mean	Single variety	Difference between varieites
Plant crop						
Conventional + ripener	− 6,4	3,4	−8,6	− 3,9±3,1	± 3,6	± 3,3
Ripener	−10,2	−14,3	−9,0	−11,2±4,3	± 5,1	± 4,7
Conventional spacing*	3,8	17,7	0,4	7,3±5,3	± 6,3	± 5,8
1st ratoon crop						
Conventional + ripener	− 9,0	1,0	8,5	0,2±4,3	± 6,7	± 8,9
Ripener	−17,0	−10,0	5,0	− 7,7±6,1	± 9,5	±12,6
Conventional spacing*	8,0	11,0	3,5	7,5±7,4	±11,6	±15,4

* These values represent an estimated effect of spacing by eliminating the measured effects of ripeners where this could be measured directly in conventionally spaced plots

Table 8

Responses to fertigation for 6 to 7 months (F6*-F3)

Cane yields and quality	NCo376	N12	N14	SE**
Plant crop				
Cane (t ha-1)	4,10	3,70	10,70	±7,40
Sucrose % cane	0,03	0,11	– 0,50	±0,15
Sucrose (t ha-1)	0,60	0,70	0,90	±0,86
1st ratoon crop				
Cane (t ha-1)	4,00	–2,00	– 8,00	±6,10
Sucrose % cane	–0,05	–0,06	– 0,93	±0,22
Sucrose (t ha-1)	0,50	–0,40	– 1,90	±0,66

*F6 = fertigation for 6 mths in plant and 7 mths in ratoon;
F3 = fertigation for 3 mths in plant and 4 mths in ratoon;
**SE = standard error of the mean

In the plant crop particularly, there was a tendency, in plots with conventional spacing, for sugarcane rows below the trickle irrigation lines to produce higher yields than those above the irrigation lines. (Table 9). In plots with tramline spacing these effects were not apparent.

Table 9

Differences in yield (tc ha-1) between cane lines above and below the trickle irrigation lines

Spacing	Treatment	NCo376	N12	N14	Mean
Plant crop					
Conventional spacing	Granular	–26,5	–18,7	–25,0	–23,4
	Fertigation 4 mths	–26,7	–24,4	–32,4	–27,8
	7 mths	–29,1	–15,4	–26,1	–23,5
Tramline spacing	Granular	– 1,2	5,6	– 3,0	0,5
	Fertigation 4 mths	–14,1	6,1	9,0	0,3
SE difference (means)*					± 3,8
1st ratoon crop					
Conventional spacing	Granular	– 7,0	– 2,5	2,3	– 2,4
	Fertigation 3 mths	– 3,6	– 8,3	–13,7	– 8,5
	6 mths	–11,4	–29,1	– 9,9	–16,8
Tramline spacing	Granular	6,8	– 1,1	18,0	7,9
	Fertigation 3 mths	–21,5	– 9,7	– 0,5	–10,6
SE difference (means)					± 6,2

* SE = standard error of the difference between means

In the first ratoon crop the benefit to sugarcane rows below the trickle irrigation lines occurred in plots with conventional spacing and in those with tramline spacing.

The effect was more evident in plots which received fertilizer through the irrigation water, and this could have been because in these plots, a relatively greater proportion of fertilizer was received by sugarcane lines below the irrigation lines. The greater benefit to rows below the irrigation lines in fertigation plots was not apparent in the plant crop, which may be explained by the furrow application to all plots of 30% of N and K requirements. This made plant crops less dependent on water distribution patterns for fertilizer uptake.

Conclusions

Results from this experiment suggest that with trickle irrigation in these soils, a closer in-line emitter spacing and trickle irrigation lines in every sugarcane interrow would be needed to approach an acceptable surface and subsurface water distribution pattern. Emitters with lower delivery rates would be an advantage.

In this experiment no significant advantage was evident from fertilisers applied through the irrigation system in spite of small increases in nutrient uptake and cane quality.

The effects of tramline row spacing and ripener application were confounded in the plant crop and first ratoon, due to the residual effects of ripener application. However, there was no increase in yield from the use of tramline spacing in this experiment.

A detailed study of the soil moisture distribution patterns in this soil under trickle irrigation would be required before a realistic assessment could be made with regard to yield potential and water use efficiency.

It appears possible that economic constraints are likely to limit the use of trickle irrigation on marginal soils.

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