

DRIP IRRIGATION OF SUGARCANE ON A POORLY DRAINING SALINE/SODIC SOIL

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Abstract

An observation trial was set up to test the feasibility of using drip irrigation to improve yields of sugarcane on poorly draining saline/sodic soils of the H and Z sets (Sterkspruit form). It was felt that the problems of poor infiltration rates and low TAM could be overcome by applying small quantities of water (and nutrients) daily. Drip was installed into newly planted cane, and also into an old ratoon crop (which had previously been furrow irrigated) to determine whether it could be "rejuvenated". Treatments using a dripper line in every interrow and every alternate interrow were compared with an adjacent field under furrow irrigation. In the newly planted cane, a good response was achieved using a dripper line every interrow, being about 22% in the plant crop and 11% in the 1st ratoon. Using a dripper line every alternate interrow gave less response in the plant crop and no response in the 1st ratoon. Where drip irrigation was imposed on the 4th ratoon crop, there was no response. In the 5th ratoon there was a negative response. The advantages and disadvantages of drip irrigation, together with the problems of its management on these soils are discussed. The factors responsible for the relatively poor responses achieved are explained.

The results of this purely observational trial are supported by those of fully replicated trials on similar soils at neighbouring estates.

Introduction

Since its development in Israel in the early 1960's, drip irrigation has been established as a highly successful method of water application for a wide range of crops. In the early stages, drip (or trickle) irrigation was mainly used for high value crops and orchard fruits, but in recent years has been successfully applied to lower value field crops such as cotton and sugarcane.

The advantages of drip irrigation have been summarized by Dasberg and Bresler,¹ with the principle benefit being that a high degree of control of water application can be achieved. Consequently, available moisture in the rooting zone can be maintained at an optimum level. Also, very high efficiencies of water application (up to 90%) are possible, and so drip is particularly valuable in areas where water is in short supply. In the root zone water is maintained at low tensions, and so the effects of salinity are partly negated, allowing the use of poorer quality irrigation water in some cases (Goldberg *et al.*²). One of the major reasons for the high efficiency is that the soil is only partially wetted, and that rooting proliferates in the wetted zone. An added benefit of this factor is that weed growth is generally reduced.

Labour and production costs are lowered by using drip, as both water and nutrients (and possibly herbicides and pesticides) are delivered via a highly automated system requiring only routine maintenance and supervision. Costs are further reduced by the more efficient utilization of water and fertilizer.

Due to the above factors, drip is often well suited to marginal conditions such as very sandy or shallow soils with very low moisture holding capacities. The low application rates which can be achieved would also suggest that drip should be suited to soils with very low permeabilities and infiltration rates.

One of the main factors against the use of drip is the high initial cost of installation, particularly in the case of conversion from an existing irrigation system. However, it has been shown that if all the economic factors are taken into account (including labour, housing, improved efficiencies etc), the costs of installing a drip scheme from the onset are comparable with those for sprinkler irrigation (Pollok and Bosua³).

A high level of management and maintenance are required. In particular, meticulous attention must be paid to water filtration. A lack of diligence will inevitably lead to clogging of emitters, as occurred in the early drip schemes in Hawaii (Haines⁴). Clogging may also be caused by microbial growth which can be reduced by the use of chlorine. Where dripper lines have been buried, root growth into the emitters may occur. The problem is combated by the use of a root inhibitor, such as *Treflan*.

In poorly draining soils, or if saline irrigation water is used, the application of crop water requirements only may lead to a build up of salinity due to a lack of leaching. However, this is only likely in regions of very low rainfall.

Drip irrigation in the sugar industry

Hawaii represents the only large sugar growing area where drip irrigation has taken over as the principal method of irrigation. In 1973, less than 10% of the sugarcane area was under drip, but this figure had risen to 40% by 1979 (Gillespie²). At present, more than 70 000 hectares, or 80% of the total area of irrigated cane is under drip. However, the conditions are specialised, in that relatively cheap biwall dripper lines are used, and planting is carried out in "pine-apple" fashion, with 2 cane rows 90 cm apart being fed by one dripper line between, which is either buried or laid on the surface. The dripper lines are replaced in each successive crop.

In other sugar growing areas, tentative investigations have been made into the use of drip. In Australia, a number of small trials have led to the conclusion that drip is not suited to the industry, for the following reasons (SASA Experiment Station¹⁰):

- The majority of cane is grown by small scale farmers working almost single handed, and so the high costs of drip cannot be justified, as it would not reduce production costs significantly, albeit reducing the grower's own workload.
- The trials which were conducted indicated the yield benefit would be relatively small.
- Damage to drip equipment by rats would be a major problem.

In Mauritius, the use of drip irrigation is currently being investigated (Mauritius Sugar Industry Research Institute^{5,6}), but the results are of limited use, as the various drip treatments are compared with rainfed cane only, and not with other irrigation systems.

In South Africa and Swaziland a number of trials and pilot schemes have been installed to investigate drip irrigation. At Simunye Sugar Estate (Swaziland), a 560 hectare drip irrigation scheme has recently been installed for the cultivation of cotton and dry beans, with the provision for the conversion to sugarcane (Pollok and Bosua⁹).

Investigation of drip irrigation at Mhlume Sugar Company

The problems of the soils at Mhlume have been previously documented by Workman *et al.*¹¹ The poorest soils are of the H, Z and E sets (Murdoch⁷), which correlate to the Sterkspruit, Katspruit and Kroonstad forms (Nixon *et al.*⁸). They are duplex in character, have inherent saline/sodic properties, and have been further degraded by more than 20 years of continuous cultivation. Cane growth is mainly limited by:

- Shallow rooting, giving low values of total available moisture (TAM).
- Poor soil structure, leading to slow intake of water, low available moisture capacity (AMC) and rapid degradation of the tilth created prior to planting by irrigation practices.
- Poorly draining subsoils, leading to waterlogging and subsequent build-up of salinity in the soil profile.

Drip irrigation was seen as a possible method of overcoming these problems. By using a slow, constant delivery of water the soil is kept at field capacity, maintaining available moisture at a maximum. In addition, the water is applied in a much more moderate manner than by either furrow or sprinkler irrigation, and so the rate of structural degradation should be reduced. The combination of these 2 factors should therefore lead to increased yields and ratoon longevity. Also, nutrients can be delivered more accurately and efficiently via fertigation, which should also contribute to enhancement of yields.

In July 1984 a trial was initiated to investigate the use of drip irrigation. In order that both the agronomic and managerial aspects of the system could be investigated, it was decided to carry out a whole field trial. Two adjacent fields of very similar soils (mainly H and Z sets) were chosen, for which field records showed the yields to have been fairly similar over a number of years. The slightly poorer field was put under drip irrigation so that any improvements over and above the field remaining under furrow irrigation (for comparison) could be positively attributed to drip. The decision to establish a management – orientated trial was also taken in the knowledge that fully replicated drip trials were being installed on similar soils at neighbouring estates.

Aims

- To test yields and length of crop cycle under drip compared with furrow irrigation.
- To compare the performance of drip irrigation installed into an old ratoon crop, which had previously been furrow irrigated, with that installed in a newly planted crop, and thus determine whether the old crop could be “rejuvenated” under drip.
- To test the feasibility of using a dripper line in every alternate interrow compared with every interrow. In economic terms, this is an important factor.

- To determine whether burying the dripper lines would be feasible. This has the advantage that once installed the pipes can remain in the field throughout the crop cycle.
- To experience the management of field scale drip irrigation.

Experimental details

Layout

Figure 1 shows the overall layout of the trial, at block 403 on Mhlume's main estate.

After the third ratoon had been harvested, a portion in the centre of field 2 (3,2 ha) was selected, in which to impose drip irrigation on the existing crop. The adjacent portion of field 1 (4,4 ha) was designated to be ratooned under furrow irrigation for comparison.

The remaining top and bottom portions of both fields were then ploughed out and replanted. In field 1 a total of 10,1 ha was planted for inrow furrow irrigation, to be converted to interrow at 1st ratoon (this is the standard practice at Mhlume). In field 2, a total of 9,4 hectares was planted in a similar manner for drip irrigation but using a less pronounced furrow shape, which, it was thought, would assist lateral movement to the rows. In both cases the row spacing and furrow gradients were standardized at 1,5 m and 1 : 250 respectively. Prior to planting 5 t gypsum ha⁻¹ was applied as a standard soil amelioration treatment.

Drip treatments

Field 2 was split into 7 panels, each receiving water from an individual field valve (see Figure 1). The initial treatments applied to each panel are shown in Table 1.

Table 1
Details of drip irrigation treatments

Drip treatment	Panel/s
Plant cane; dripper lines every interrow	2, 5, 7
Plant cane; dripper lines every alternate interrow	1
Plant cane; dripper lines buried beneath the cane row	6
Ratoon cane; randomised plots (12 lines × 4 replicates) with dripper lines every interrow versus dripper lines every alternate interrow.	3,4

In the plant crop, only 1 panel was laid down with dripper lines every alternate interrow, as it was uncertain how successful the germination and growth of cane under this system would be. In the 1st ratoon crop panel 5 was converted to drip every alternate interrow to increase the area under this treatment. For similar reasons only a small area was laid down to buried lines because it would be very difficult to rectify any problems that might develop. Recovery of the dripper lines intact following the experiment would not be possible.

Irrigation and filtration system

A pump draws water by flooded suction from the storage dam, which then passes through a pair of Conn sand-bed filters, which remove the bulk of the sediment load. A pair of Amiad 120 mesh ring filters remove any fine clay particles remaining, and the filtered water passes through a main valve and water meter. An air release valve on the main line ensures there is no “suck back” of air into the filtration system and pump. Finally, fertilizer is injected by an Amiad pump.

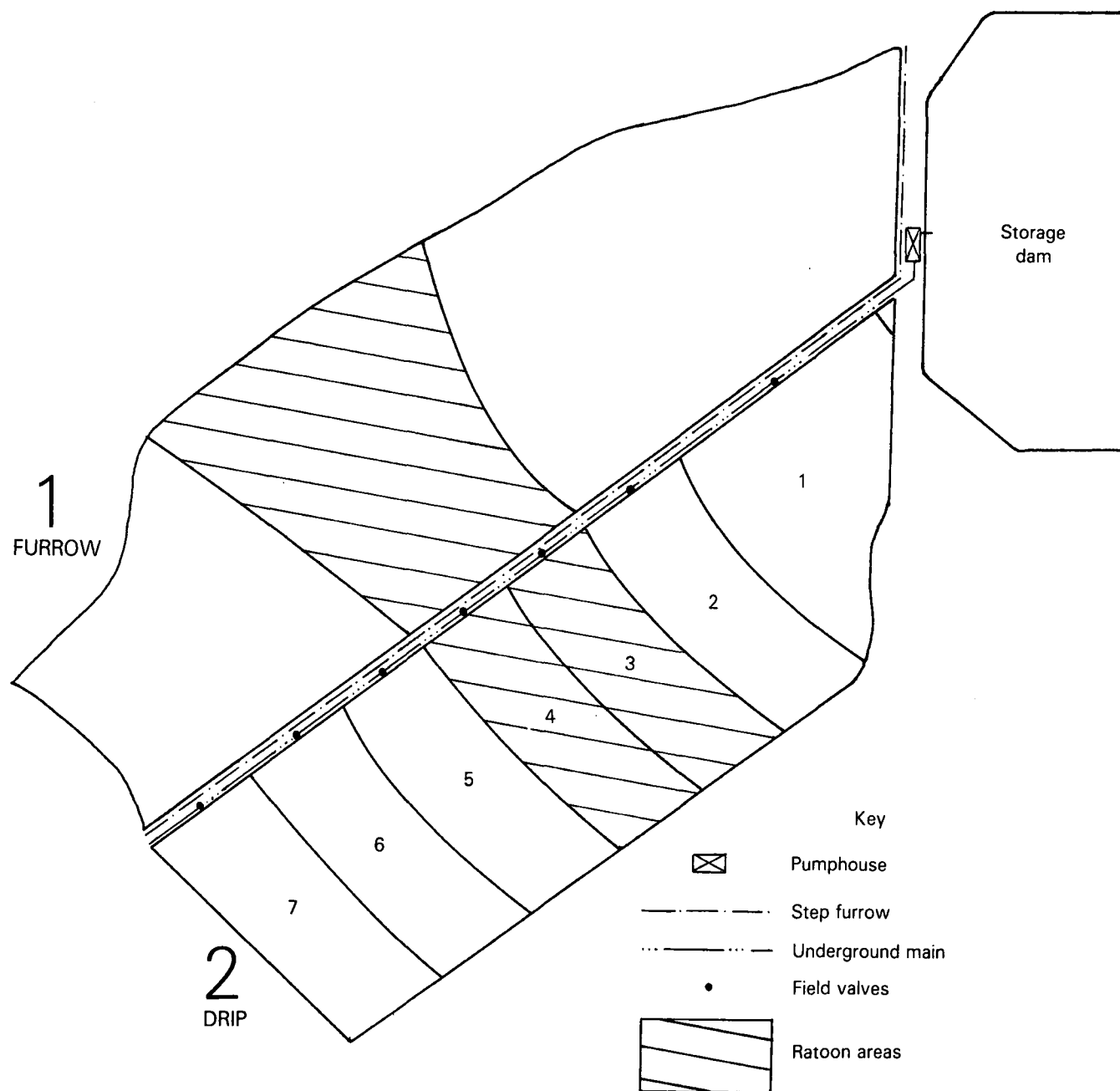


FIGURE 1 Trial layout.

The main line then travels underground to the field, where 7 valves take off water for each panel. Water is fed through 50 mm aluminium surface laterals to the head of the cane rows, where the individual dripper lines are attached via a saddle connection. These are Ra'am multi-seasonal pressure compensating drip lines of 17 mm external diameter. The emitters are spaced at 1 m intervals down the line, and a compressible labyrinth system contained wholly within the pipe ensures that the flow rate from the emitters remains constant over a wide range of pressures (0,5 to 4 bars). Thus there is no change in flow due to increasing head down the lines, allowing lengths of up to 300 m, although the longest lines in the trial were about 220 m. The flow rate of each dripper is set at $2,3\text{l/h}^{-1}$. With a spacing of 1,5 m, this gives an overall average application rate of $1,5\text{ mm/h}^{-1}$, being half of this if a dripper line is used in every alternate interrow. The system was designed with the capacity to apply up to 9 mm gross per day.

The system is run by a Motorola MIR 2000 Matarol computerized controller. All quantities of water and fertilizer are programmed, and the computer runs the irrigation in a series of schedules according to requirements. The opening and closing of field valves is controlled hydraulically via a series of solenoid relays, as are fertilizer injection and automatic backflushing of the sand filters.

The furrow field was irrigated via a concrete step furrow, using 50 mm spiles.

Irrigation

Furrow

Irrigation was carried out using a standard profit and loss system, with a fixed TAM (45 mm), calculating daily losses using a combination of pan evaporation data and a canopy factor. The field was irrigated when available moisture had fallen to within 15 mm of the TAM value.

Ratoon drip

Following harvesting, these panels were initially furrow irrigated whilst the drip equipment was being installed. Once irrigation by the drip system had been established, scheduling was carried out using a combination of pan evaporation figures, canopy factor and field observations by auger. Following rainfall, irrigation was cancelled until the soil had returned to field capacity.

It was soon apparent that infiltration rates were very poor, with ponding occurring around the drippers, and runoff after 1,5 to 2 hours of irrigation. Lateral spread of water to the cane rows was also poor. These problems were more marked in the plots with a dripper line every alternate interrow, where the volume applied by each line is doubled. In an attempt to improve the situation, the dripper lines were temporarily removed, and gypsum at 5 t ha⁻¹ was applied and incorporated by a shallow cultivation. Initially infiltration was better, but as the application volumes increased (due to higher crop demand) ponding and runoff again became a problem. Some improvements were achieved by increasing the number of irrigation cycles per day, and thereby reducing the volume applied at any one time.

In the following crop (5th ratoon) the problems of ponding and runoff were acute.

Plant drip

The dripper lines were initially placed on the rows to allow thorough wetting of the setts. In panel 1 the lines were alternated at 24 hour intervals between the 2 rows until thorough wetting had been achieved. The dripper lines were then placed in the interrows and the soil wetted to TAM. Irrigation scheduling was then carried out as for the ratoon panels.

In the plant crop, no infiltration problems were encountered, and there was good lateral spread to the rows. In the 1st ratoon however, problems of ponding and runoff began to occur in the plots with a dripper line every alternate interrow. In the present 2nd ratoon crop, these problems are occurring under all drip treatments, except for the buried lines, which are continuing to function well.

Fertilization

It is generally accepted that efficiency of nutrient usage is improved by use of fertigation, compared with conventional application methods (Goldberg *et al*³). Therefore, less fertilizer was applied to the drip irrigated cane, compared with the quantities applied to the furrow irrigated areas by granular broadcasting. The overall quantities of nutrients applied are shown in Table 2.

Fertigation was carried out daily, with small quantities being injected into every irrigation cycle. A 10 : 1 : 6 mixture

Table 2

Rates of fertilizer applied				
Crop	Irrigation	N kg/ha	P kg/ha	K kg/ha
Plant	Furrow	120	66	100
	Drip	105	58	88
Ratoon	Furrow	160	20	125
	Drip	140	18	110

was used over the first 5 months, followed by a 0 : 1 : 6 mixture for the remainder of the season. In the furrow field, the bulk of the application was carried out at planting/ratooning, with the N being split once.

Results

Yields

Yield assessment was carried out by small plot harvest (4 rows by 10 m, 16 per treatment). The results are shown in Table 3.

Due to variations in age at harvest, the results have been expressed on a monthly basis, (the average age was 11 months, cut in July/August). The performance of the main drip treatments, compared with the corresponding furrow areas is shown in Figure 2, expressed as a percentage in terms of t cane ha⁻¹ mth⁻¹.

From these results, the following overall conclusions can be drawn:

Drip every interrow

There was a very good response in the plant crop of about 22%, but this response decreased to 11% in the 1st ratoon. Where drip was imposed on the 4th ratoon there was no response. In the 5th ratoon there was a marked negative response to drip.

Drip every alternate interrow

There was a reasonable response in the plant crop, being about 6%. However, there was no response in the 1st ratoon. In the 4th ratoon, there was a small negative response, whilst in the 5th ratoon there was again a marked negative response to drip.

Buried lines

In the plant crop, these gave the best response of all treatments. In the 1st ratoon the response was similar to that of the surface drip every interrow treatment.

Table 3

Yield results, expressed in terms of tons cane per hectare per month (TCHM), tons sucrose per hectare per month (TSHM) and sucrose percentage (suc %)

Treatment		Plant			1st ratoon			4th ratoon			5th ratoon		
		TCHM	TSHM	Suc %	TCHM	TSHM	Suc %	TCHM	TSHM	Suc %	TCHM	TSHM	Suc %
Drip	Every interrow	8,08	1,14	14,04	9,66	1,29	13,44	7,73	1,15	14,92	6,86	0,94	13,63
	Every alternate interrow	7,04	1,06	15,08	8,63	1,19	13,78	7,43	1,10	14,77	6,62	0,91	13,80
	Buried	8,23	1,28	15,61	9,17	1,30	14,16	-	-	-	-	-	-
Furrow		6,63	0,95	14,22	8,70	1,16	13,36	7,62	1,16	15,23	7,87	1,12	14,21

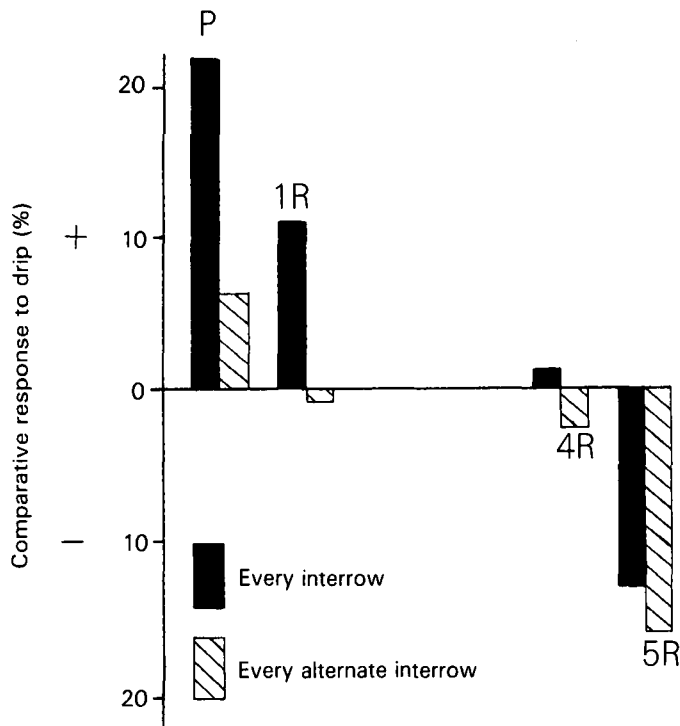


FIGURE 2 Response of drip compared with furrow irrigation, expressed as a percentage.

The results and findings of this purely observational trial are backed up by 2 fully replicated trials on neighbouring estates conducted on Z set soils, and using similar methods of crop management.

At Inyoni Yami Swaziland Irrigation Scheme (IYSIS), a trial was installed in July 1984. Conditions are similar to those at Mhlume, in that the soils have been continually cropped for more than 20 years, firstly under rice and more recently under sugarcane. Drip irrigation was imposed on a 5th ratoon crop which had previously been furrow irrigated. Treatments of drip every interrow and every alternate interrow were compared with furrow irrigation over 2 seasons. In the 5th ratoon, a small but statistically significant response was achieved to both drip treatments, being slightly better using a drip line every interrow. In the 6th ratoon there was no significant response. (Rhebergen, W. Personal communication.)

At Simunye Sugar Estate (SSE), a trial was installed in December 1983, comparing drip every alternate interrow against furrow in newly planted cane. In the first season, there was a 15% response to drip, but in the 1st ratoon there was no response. (Sweet, CPM. Personal communication.)

Nutrition

In order to monitor that nutrition was not a limiting factor to growth under furrow or drip, 3rd leaf sampling and analysis for the major nutrients was carried out at 5 months in all crops. The results are shown in Table 4.

Table 4
Third leaf nutrient analyses at 5 months of age

Treatment	N %		P %		K %	
	Drip	Furrow	Drip	Furrow	Drip	Furrow
Plant	2,68	2,43	0,26	0,25	1,26	1,25
1st ratoon	2,13	2,17	0,23	0,22	1,05	0,91
4th ratoon	2,08	1,79	0,22	0,27	1,18	0,96
5th ratoon	1,96	2,05	0,23	0,21	0,94	0,99

It can be seen that leaf levels are adequate in all cases, and on the whole are fairly similar under drip and furrow.

Discussion

The disappointing response to drip irrigation can be attributed mainly to the poor infiltration and hydraulic conductivity characteristics of the soils under investigation. Initially, there appears to be an anomaly, in that the very low application rates under drip should be suited to these conditions. However, a closer examination of the situation in the vicinity of each emitter reveals the source of the problem. In the field, the wetting pattern of drippers was measured to be a circle with a radius of up to 30 cm (see Figure 3).



FIGURE 3 Wetting pattern of drippers in the field

Infiltration is thus occurring over an area of 0,28 m². With a dripper flow rate of 2,3 l/h⁻¹, the average application rate within this area is therefore about 8 mm h⁻¹, although it will vary greatly within the zone, being much greater adjacent to the emitter and gradually decreasing to zero at the edge of the wetted area. Measurements of infiltration rates on these soil at Mhlume under ratoon conditions have shown the initial rate on a dry soil to be 5 mm h⁻¹. However, this decreased to less than 1 mm h⁻¹ after 2 hours. Thus where drip was installed in ratoon cane, the soil was simply unable

to take in the water at the rate applied under the conditions created by the system. In the plant cane, where land preparation had created a good tilth, infiltration rates were higher initially, and hence the soil could take in all the water applied. However, in the 1st and 2nd ratoons, the gradual deterioration of this tilth, and the consequent effects on infiltration meant that problems slowly developed. These problems were augmented by using a dripper every alternate interrow, as the application volumes from each emitter are then doubled. The poor lateral movement of water meant that the side of the stool adjacent to the dry row was consistently underwatered, and preferential canopied over the irrigated interrow. The row downslope of the dripper line received more water, and hence growth was better than the row upslope.

From a management aspect, drip irrigation requires a high level of control and monitoring. The equipment must be regularly checked for leaks from joints or damaged pipes, which becomes problematical once the crop has canopied. The dripper lines are relatively fragile and prone to damage during installation and removal, as well as by infield operations such as hand weeding. From the results of this experiment, the burying of dripper lines is a viable practice.

Conclusions

Drip irrigation would appear to be an unsuitable method of irrigation for sugarcane on these soils. The rejuvenation of old ratoons by drip irrigation is not possible. The rapid deterioration of soil structure even under drip suggests that yield benefits can only be gained in the plant crop and early ratoons, and the length of crop cycle is unlikely to be increased. However, the results and experience gained during this trial have led to a number of useful conclusions:

- In the knowledge of the problems which occurred, better results with drip could have been achieved by the use of more closely spaced emitters with correspondingly lower flow rates. Using a dripper line every alternate interrow, pineapple spacing would be advantageous. In general, all the agronomic parameters involved should be fully assessed, and the system designed to suit their needs as closely as possible.
- The poor soil structure and its rapid deterioration under irrigation suggest that structural amelioration is required

prior to planting. This need is underlined by the fact that the rate of ratoon yield decline is increasing at Mhlume (Workman *et al*¹¹). In this respect, the effects of fallowing/green manuring are currently being investigated, and the initial results are very encouraging.

- The poor infiltration rates and lateral water movement characteristics of these soils suggests that the yields and number of ratoons under furrow irrigation could be increased by irrigating in-row throughout the crop cycle. These factors also point towards the importance of identifying possible improvements which can be made to the present system of irrigation to increase yields before considering changing to a system such as drip.

Acknowledgements

We would like to thank the staff of IYSIS and SSE concerned for allowing access to trials data for use in this paper, and Peter Scott, who was largely responsible for the installation and maintenance of the drip irrigation system.

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