CANE AND ERC YIELDS OF TEN SUGARCANE VARIETIES IRRIGATED BY SUBSURFACE DRIP AT THE ZIMBABWE SUGAR ASSOCIATION EXPERIMENT STATION

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Abstract

In 1995, when drip irrigation was introduced into the Zimbabwe sugar industry, there were no guidelines on layouts of drip systems. An experiment was thus set up to assess cane and sugar yields and longevity of 10 sugarcane varieties that were planted using the standard and tramline layouts and irrigated by subsurface drip. In the standard layout, cane rows were spaced 1.5 m apart, and each cane row had a drip tape below. In the tramline layout, the drip tape was placed between two cane rows that were 0.42 m apart. The drip tape was laid out at 1.8 m apart. Cane and sugar yields differed between varieties and ratoons. There was a general decline in stalk populations in all varieties. Stool mortality was high in most varieties, while NCo376, ZN3L, ZN8 and N14 had a normal decline in stalk population. In the standard layout ERC % cane and cane yield were higher than in the tramline layout. Gross sugar yield was considered in a cost-to-benefit analysis that showed that ZN8 in the standard layout and N14 in the tramline layout were the most economic to grow using subsurface drip in Zimbabwe.

Keywords: sugarcane, irrigation, subsurface drip, tramline, standard, layout, stool mortality, cost benefit

Introduction

The long term average yield of 12-month old sugarcane crops of variety NCo376, irrigated using impact sprinklers or furrows in the lowveld of Zimbabwe, is ±110 tons cane/ha (Chigaro and Masokovere, 2001). During the dry years in the 1990s, Zimbabwean farmers wanted ways of using less irrigation water for sugarcane production. Several irrigation methods including drip, centre pivot, floppy sprinkler and leaflat were tested. Nyati (1996) reported that cane and sugar yields could be maintained with reduced irrigation.

Subsurface drip irrigation (SDI) offers many advantages as a method of applying water and also for the controlled release of nutrients into the root zone (Ndlovu, 2000). SDI used in commercial fields in Swaziland saved water and labour, and produced high cane and sugar yields. The advantages of SDI in principle have been well documented (Hutmacher *et al*., 1993; Haynes, 1985; Butler, 2002). Earlier work on drip irrigation at the Zimbabwe Sugar Association Experiment Station (ZSAES) was abandoned, mainly because of clogging of emitters due to poor water quality.

The need to retest drip irrigation in Zimbabwe arose when new drip systems introduced improved technology to emitters, filtration and water treatment systems. Some sugarcane farmers in Zimbabwe had started using SDI without adequate knowledge of layouts and varieties suitable for this type of irrigation. Blatchford (1996) reported an increase in cane yield from an average of 92 to 116 tons cane/ha after converting from furrow irrigation to

SDI. Blatchford had problems with germination when using furrow irrigation, and it had been necessary to re-establish a large area of land before he had changed over to using SDI. Fourie (1997) increased his cane yield from an average of 80 to 130 t cane/ha when he converted from overhead to SDI.

Placing a drip tape below each cane line is a common method of using SDI in sugarcane. In Swaziland the tramline or pineapple layout was used with SDI in commercial sugarcane (Ndlovu, 2000). This paper reports on the results of an experiment that compared cane and ERC yields of 10 sugarcane varieties planted in standard and tramline layouts and usingSDI. The longevity of varieties ZN1L, ZN6, CP72-1312, ZN7, NCo376, ZN5, N14, CP84-1318, ZN8 and ZN3L when using SDI was also assessed.

Materials and methods

Experimentation

A variety trial was planted at ZSAES on a fairly uniform sandy clay loam soil with 28% clay, 9% silt, 66% sand, pH 6.67 ($CaCl_2$) and conductivity of 250 ms/cm. The trial was laid out in a randomised complete block design with five replications. The net plot size was five cane rows, each 8 m long. Varieties ZN1L, ZN6, CP72-1312, ZN7, NCo376, ZN5, N14, CP84-1318, ZN8 and ZN3L were planted in standard and tramline SDI layouts. In the standard layout, cane rows were spaced 1.5 m apart and a drip line (tape) was placed at 0.23 m below ground level under each cane row. In the tramline layout, the drip tape was placed 0.10 m deep and between two cane rows that were 0.42 m apart. The drip tapes were laid out at 1.8 m apart.

Planting

Planting was done by hand on 26 June 1997. Cane was planted in double rows using three-eyed setts that had been dipped in a fungicide for five minutes, to control smut. In the standard layout, sugarcane was planted about 0.10 m above the tape. In the tramline layout, two cane lines shared a drip tape that was placed 0.10 m deep.

Irrigation scheduling

A T-Tape Typhoon 25 drip tape was used. The emitters were spaced 0.4 m apart, and delivered 1.6 L of water per emitter per hour. The drip system had two sand filters and one separate disc filter tank. Prior to covering the cane setts, 10 mm water was applied to ensure that moisture reached the setts, and to check that the emitters were not blocked. After planting, water was applied in 3-hour pulses until the soil profile reached field capacity. Thereafter irrigation water was applied every third day, based on established crop factors derived from a comparison of Class A pan evaporation and the sugarcane canopy and growth stages. The contribution of water from rainfall was calculated by dividing the rainfall amount by the crop factor. Drying off was done using the 3 x TAM formula.

Fertigation

The amounts of potash and phosphate fertilisers applied were based on soil sample analysis prior to planting. Fertigation was done using a Dosatron. Muriate of potash at 60 kg K_2O/ha and ammonium nitrate (AN) at 120 kg N/ha were applied to the plant cane. The N fertiliser was increased to 180 kg N/ha in the ratoon crops, applied as AN at 30 kg N/ha at each fertigation event. Single super phosphate was applied to the soil surface by hand at 60 kg P_2O_5/ha, 14 days after harvesting. Trifluralin was applied twice, at six weeks after cutting and before drying off, to reduce root intrusion. The Trifluralin resulted in yellowing of the older cane leaves, and was initially confused with natural senescence and Yellow Leaf Syndrome.

Weed control
The pressure of weeds was very low, and where weeds appeared they were eradicated using hoes or were pulled out by hand.

Water measurement
Water was measured using a KENT flow meter, and the amounts applied are given in Table 1. Water distribution was evaluated by the ZSAES Mobile Irrigation Performance Unit (MIPU), which measured drip emitter output after harvesting the first ratoon (1R) crop. Assessment showed that 90% of emitters were working properly and that the system was operating satisfactorily. Where emitter blockages were suspected, that section of the lateral was dug out and unblocked by tapping the pipe while under pressure. The blocked emitters were then replaced. The checking and unblocking of emitters was done annually, soon after cutting. The laterals were flushed twice during irrigation and the sand filters were flushed automatically for three minutes every 30 minutes.

Data collected
Cane was cut by hand and a Martin Decker scale was used to weigh the cane harvested from each plot. Cane yield was extrapolated from the weight of five cane rows. Moisture % cane, fibre % cane, juice purity and ERC % cane were determined at the ZSAES laboratory. Stalk numbers, lengths and diameters were measured. Results from all varieties were compared with the standard variety NCo376.

Data analysis
Data from the trials was analysed using MSTAT version 4.0 (EM 1987 Michigan State University) computer software. Regression analysis was performed to compare the ERC yield declines in the 10 sugarcane varieties.

Financial analysis
ERC yield was used to assess financial benefit, comparing NCo376 with the other varieties in the trial.

Results and discussion

The amount of water applied and the rainfall received from plant crop to fifth ratoon is shown in Table 1. Similar amounts of irrigation water were applied to both layouts.

Table 1. Irrigation and rainfall water received from plant crop to fifth ratoon.

Crop	Irrigation water (mm)		Rainfall	
	Standard	Tramline	mm	Year
Plant	1000.0	1005.1	425.2	1998
1R	683.8	686.6	958.4	1999
2R	486.3	486.9	~	2000
3R	534.2	561.3	584.8	2001
4R	708.8	731.6	162.9	2002
5R	720.5	762.0	635.6	2003

Moisture % cane
Data comparing the moisture % cane of 10 varieties irrigated using SDI showed that, in general, CP72-1312 had the lowest and ZN1L the highest moisture content in both layouts.

Fibre % cane and juice purity
CP72-1312 and ZN3L had more fibre than NCo376 in the standard layout. CP72-1312 had more fibre in the tramline layout than in the standard layout. Differences in juice purity were small and non-significant in both layouts.

ERC % cane
ERC % cane of the new varieties was compared with that of NCo376 and N14. All varieties were either sweeter or continued to produce higher ERC % cane than NCo376 in the six crop cycles. Except for N14, all varieties planted in the tramline layout produced significantly higher ERC % cane than NCo376. ZN6 produced the highest ERC % cane in the standard layout (Figure 1). Variety ZN3L performed outstandingly well in both layouts.

Seven of the 10 varieties produced higher ERC % cane in the standard than the tramline layout. ZN5, NCo376 and ZN3L produced higher ERC % cane when planted in the tramline layout than in the standard layout. ERC % cane in both layouts showed a steady decline from the second (2R) to the fourth (4R) ratoon crops (Figure 2). The general trend was for the varieties to produce higher ERC % cane in the standard than in the tramline layout. The sharp increase in ERC % cane in the fifth ratoon (5R) was difficult to explain. Increases in ERC % cane are usually associated with poor cane growth, but in this instance the cane grew well, as shown by the cane yield produced.

Cane yield
The varieties receiving SDI produced high cane yields. N14 produced the heaviest cane yield when it was planted in the tramline layout. NCo376, ZN1L, ZN5 and ZN3L produced slightly heavier cane yields when planted in the standard layout (Figure 3). In the standard layout, CP72-1312 and ZN5 produced significantly lower cane yields than NCo376.

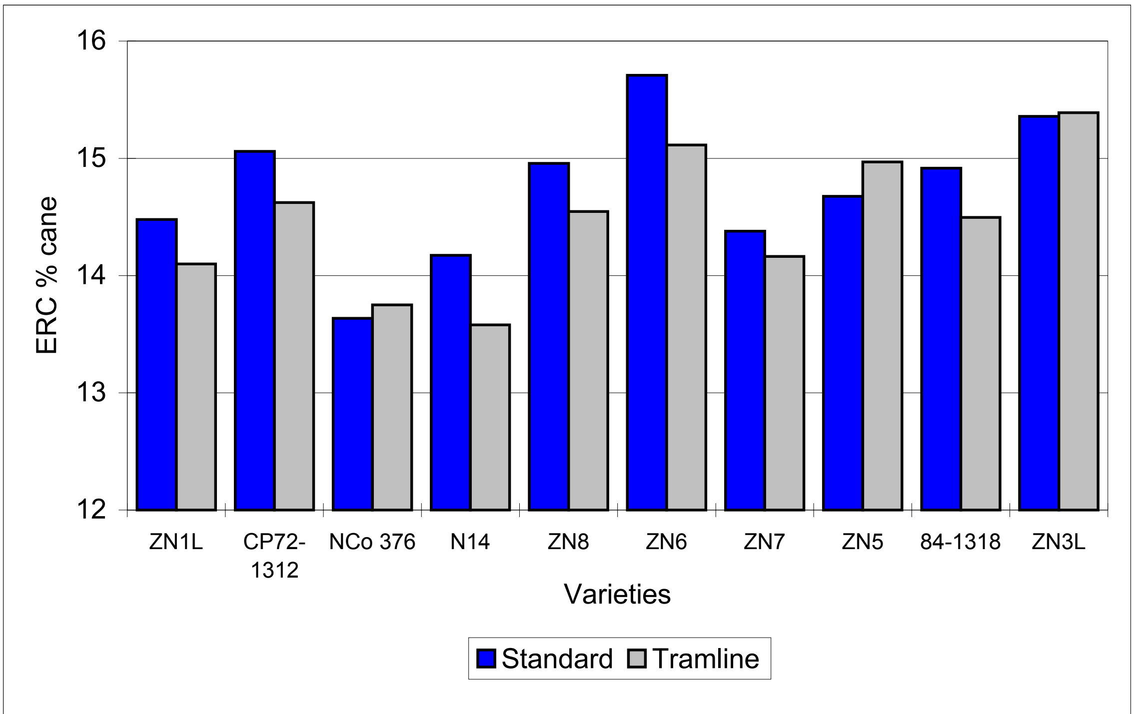

Figure 1. ERC % cane of 10 sugarcane varieties planted in standard and tramline layouts and irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station, 1997 to 2003. Mean data from plant crop to fifth ratoon.

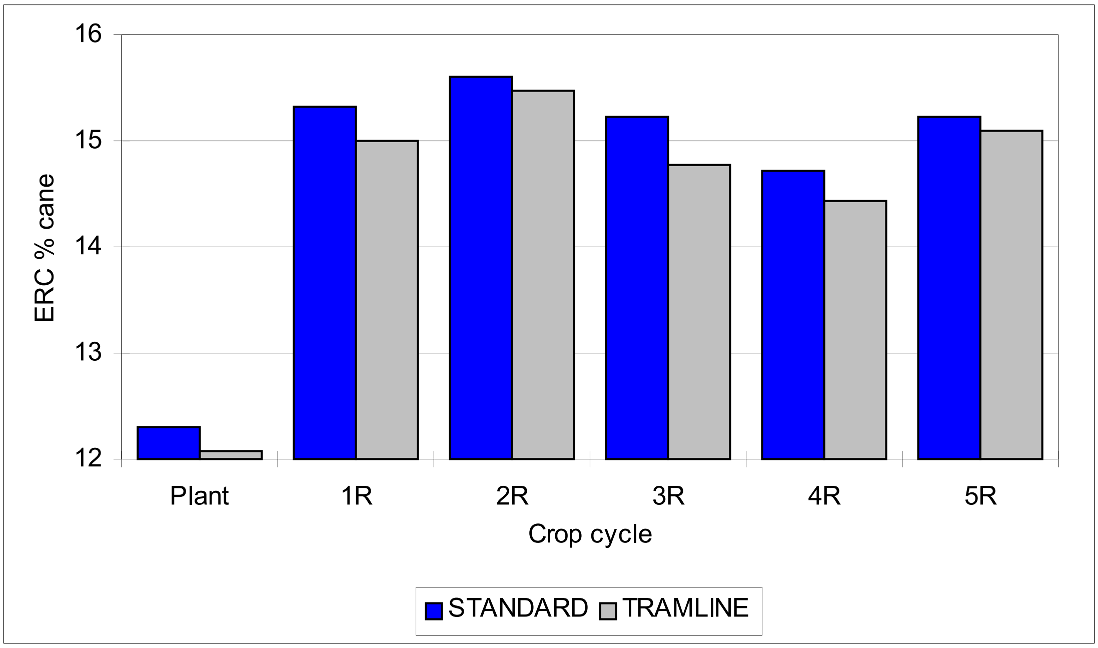

Figure 2. ERC % cane comparing six crop cycles (plant to fifth ratoon) of 10 sugarcane varieties grown at the Zimbabwe Sugar Association Experiment Station in standard and tramline layouts and irrigated by subsurface drip, 1997 to 2003. Mean data of six crop cycles.

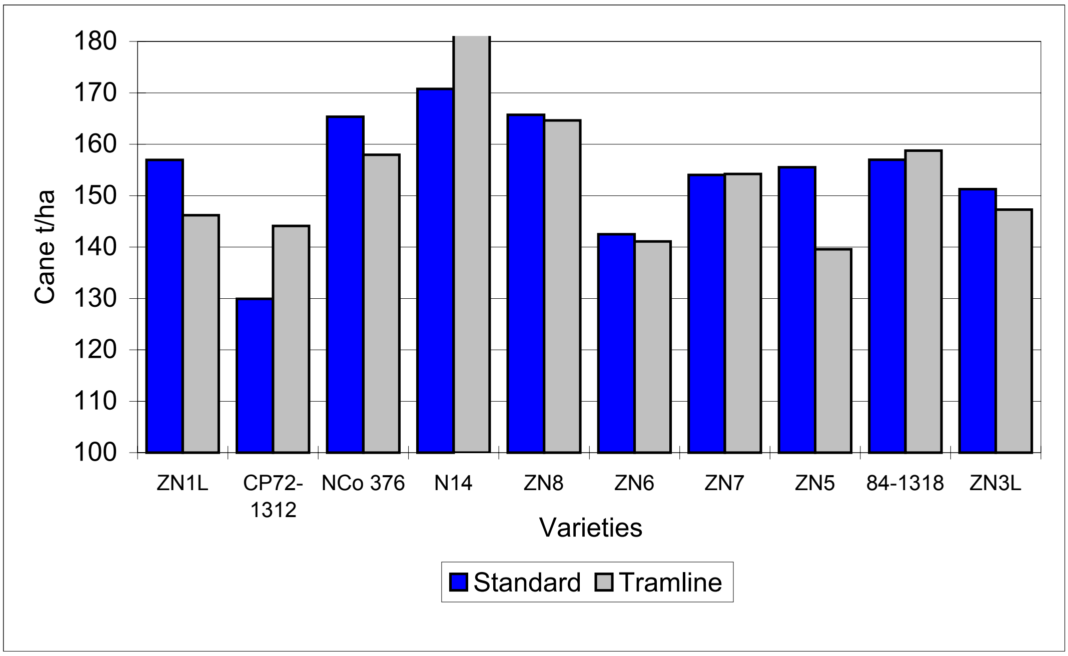

Figure 3. Cane yield (t/ha) of 10 sugarcane varieties planted in standard and tramline layouts and irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station, 1997 to 2003. Mean data from six crop cycles.

In the plant crop (P), the differences between the cane yields of N14 and NCo376 were small. The yield of NCo376 declined sharply in the 2R crop, and remained lower than that of N14 until the 5R crop. Data in Figure 4 show the mean cane yields from P to 5R.

In the standard layout, cane yield declined by 3.3% from P to 1R and by 14.9% from 1R to 2R, as well as 3R (Figure 4). There was a steady decline thereafter. In the tramline layout, yield decline was steady from P to 5R (Figure 4).

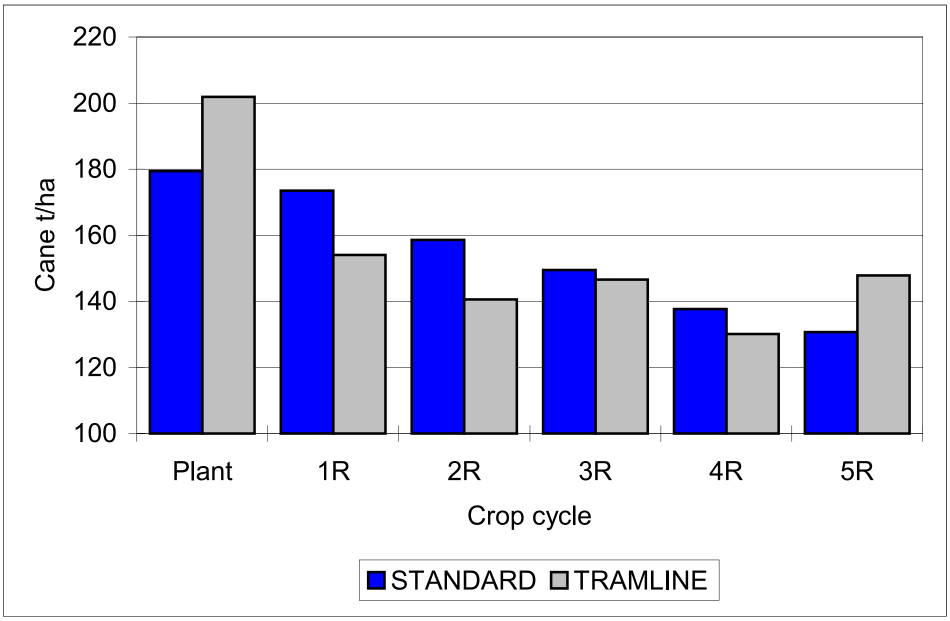

Figure 4. Mean cane yield (t/ha) comparing six crop cycles (plant to fifth ratoon) of 10 varieties grown in standard and tramline layouts, irrigated by subsurface drip at Zimbabwe Sugar Association Experiment Station, 1997 to 2003.

ERC yield

The 10 sugarcane varieties differed in ERC yield in both layouts. ZN8 and N14 produced the heaviest ERC yield in both the standard and tramline layouts (Figure 5). ERC yield of CP72-1312 was higher in the standard than in the tramline layout. There was higher ERC yield in the P and 5R crops in the tramline than the standard layout.

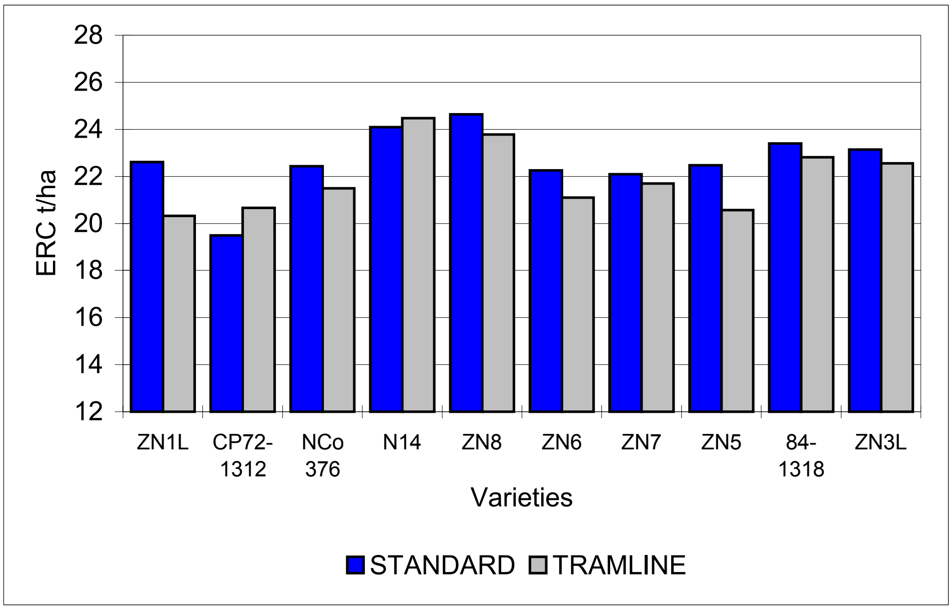

Figure 5. ERC yield (t/ha) of 10 sugarcane varieties planted in standard and tramline layouts and irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station, 1997 to 2003. Mean data from plant crop to fifth ratoon.

Stalk population

The P, 1R and 4R crops had significantly more millable stalks in the tramline than the standard layout (Figure 6a). Differences were insignificant in the 2R and 5R crops. There were more gaps in the tramline than the standard layout from 2R to 5R.

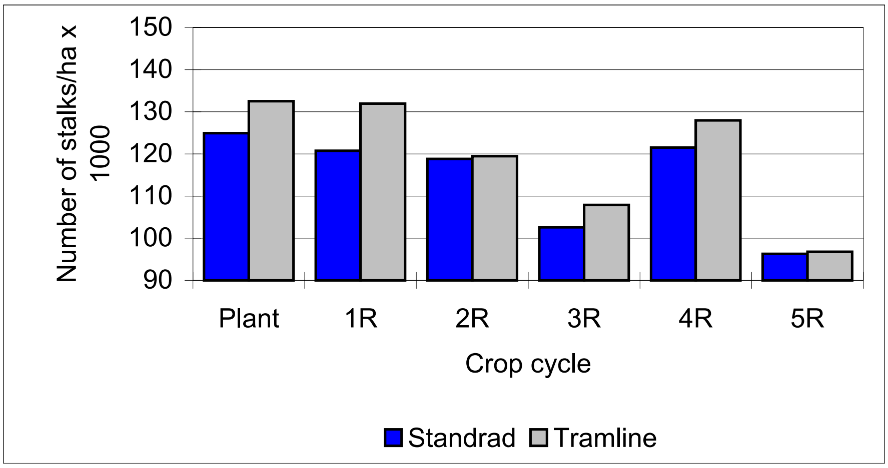

Figure 6a. Number of stalks/ha of 10 sugarcane varieties planted in standard and tramline layouts and irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station, 1997 to 2003. Mean data from plant crop to fifth ratoon.

When annual millable stalks were averaged over the six crop cycles, ZN1L, NCo376 and ZN3L produced more millable stalks than the rest of the varieties (Figure 6b). The number of millable stalks of CP72-1312, N14, ZN7 and CP84-1318 increased only from P to 1R. The number of millable stalks of ZN7 increased annually until 2R, when high stool mortalities occurred. In 5R, the number of millable stalks of all varieties except NCo376, N14 and ZN8 decreased sharply. CP84-1318, ZN1L and CP72-1312 had very low millable stalk numbers in 5R, indicating poor variety longevity.

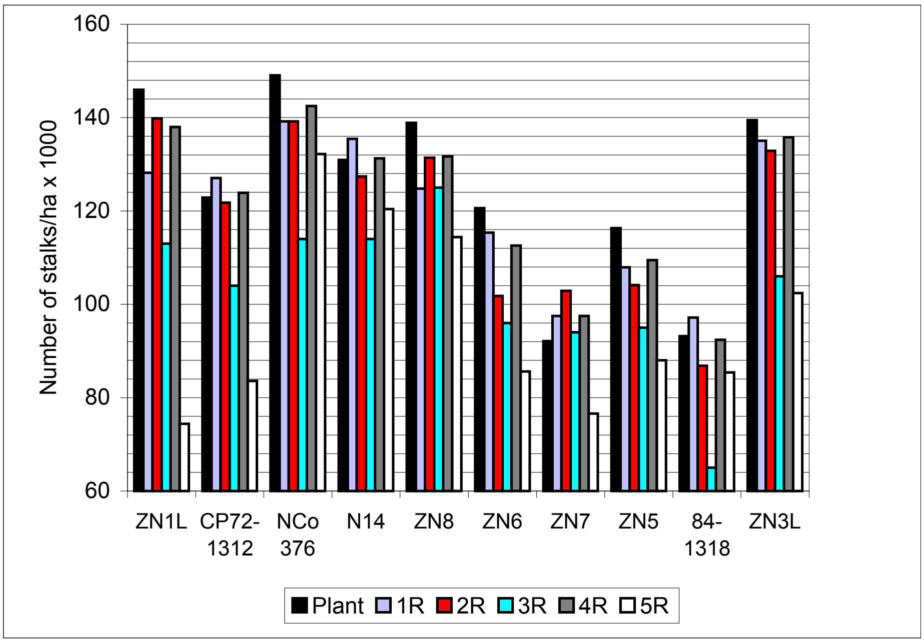

Figure 6b. Number of stalks/ha of 10 sugarcane varieties planted in standard and tramline layouts and irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station, 1997 to 2003. Mean data from plant crop to fifth ratoon.

The general reduction in the number of millable stalks over the ratoons was expected, as stalk numbers per unit area confirmed variety population characteristics. However, some stools were pulled out when blunt cane cutting knives were used and when trash was racked, and this contributed to the loss of stalks.

Stalk length

NCo376 produced the longest stalks in the standard and ZN7 in the tramline layout. ZN5 produced significantly shorter stalks than all the other varieties. Stalks were shorter in the tramline than the standard layout.

Stalk diameter

Differences in stalk diameters were significant, and all varieties produced thicker stalks than NCo376 in both layouts. ZN5 produced the thickest stalks in both layouts.

Lodging and flowering

Lodging was similar in both layouts. However, the heaviest lodging was in variety ZN8 in the tramline layout. Flowering was seasonal and varietal differences agreed with established characteristics.

Variety selection for SDI

Regression analysis was performed to compare ERC yield decline between the 10 varieties, and r^2 values ranged between 0.0002 and 0.7 (Figure 7).

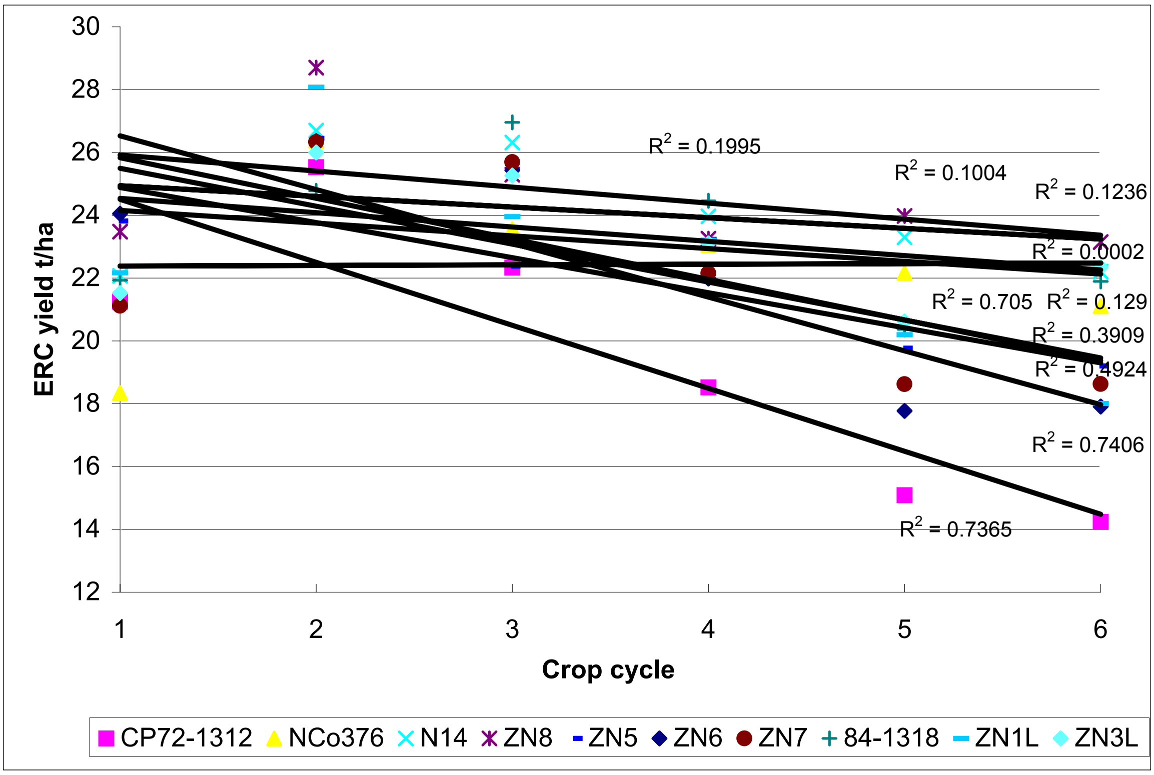

Figure 7. ERC yield decline of 10 sugarcane varieties, shown using regression lines and r^2 values. Varieties were planted in standard and tramline layouts and irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station. Numbers 1-6 represent crop cycles from plant crop to fifth ratoon.

There were four groups in the standard layout:

- NCo376 (r^2=0.0002) (alone) produced lower ERC yields than N14 and ZN8, but was the most stable over the six year crop cycle.
- N14 (r^2=0.199) and ZN8 (r^2=0.10) produced the greatest ERC yield and had similar good stability, as shown by a steady ERC yield decline.
- ZN5 (r^2=0.70), ZN7 (r^2=0.39) and ZN1L (r^2=0.49) produced a similar trend. ZN1L had the most rapid decline.
- CP72-1312 (r^2=0.73) and ZN6 (r^2=0.74) had the most rapid ERC yield decline from P to 5R.

In the tramline layout, varieties responded differently but maintained a similar variety grouping. ERC yields of N14 (r^2=0.16) and ZN8 (r^2=0.02) were considered most stable, with a gentle slope. NCo376 was the most stable variety and its ERC yield did not decline in the tramline layout.

In the tramline layout, N14, ZN8 and NCo376 were very stable, and N14 produced the best ERC yield (Figure 8). The gentleness of the trend slopes indicated good longevity of ZN8 and N14 under SDI, and these two varieties also produced the best ERC yields in both layouts. N14 was selected for planting in the standard layout and ZN8 for the tramline.

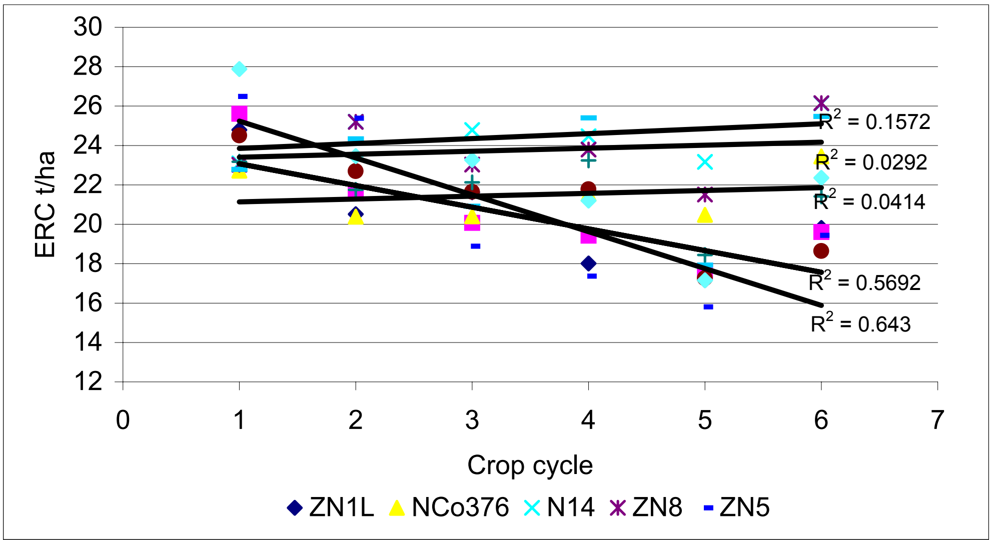

Figure 8. ERC yield decline of varieties ZN1L, NCo376, N14, CP72-1312, ZN3L, ZN5, ZN6, ZN7, ZN8 and CP84-1318, shown using regression lines and r^2 values. These varieties were represented by ZN1L, NCo376, N14 and ZN5 for good, medium and poor stability over six crop cycles. The varieties were planted in the tramline layout and irrigated by subsurface drip at the Zimbabwe Sugar Association Experiment Station, 1997 to 2003.

The most promising new variety under SDI was ZN8, which produced good ERC yields in both layouts.

Analysis of benefit-to-cost

Considering sugar and gross revenue, it would be prudent to grow ZN8 in the standard layout and N14 in the tramline layout. N14 appeared to be the best overall variety in terms of cane and ERC yields. The CP varieties did better when they were planted in the standard layout. There was only a slight benefit from growing the ZN varieties in the standard layout (Table 2).

It would be more beneficial to use the tramline than the standard layout, because the tramline layout required 5556 m of drip tape, compared with 6667 m for the standard layout. However, the tramline layout required 68% more seed than the standard layout. Taking into account the cost of tape and the difficulty in removing the tape at plough-out, the tramline layout was best. More than 75% of the tape removed from the standard layout was not re-usable. After an irrigation to wet the soil surface, the tape from the tramline layout was pulled up and rolled, using two men per hectare per day. Care was nevertheless required to avoid kinking the tape during removal.

Table 2. Financial benefit comparing mean ERC yield from plant to fifth ratoon crops of varieties ZN1L, ZN3L, ZN5, ZN6, ZN7, ZN8, CP72-1312 and CP84-1813 compared with N14 and NCo376 irrigated by subsurface drip and planted in the standard and tramline drip layouts at Zimbabwe Sugar Association Experiment Station, 1997 to 2003.

Item	Standard	Tramline
NCo376	100%	100%
All new varieties	100%	101%
New ZN varieties	102%	101%
Latest (ZN8 alone)	110%	106%
CP varieties	110%	96%
N14	107%	114%

Conclusions

There were declines in cane and ERC yields from the second to the fifth ratoon crop in both the standard and tramline layouts. ZN8 produced the best ERC yield in the standard layout and N14 in the tramline. Therefore, it was more beneficial to grow N14 in the tramline and ZN8 in the standard layout. This was also confirmed by the regression analysis. Results showed that measuring ERC yield could be a useful tool in assessing the stability of sugarcane varieties grown under subsurface drip irrigation.

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