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# EFFECT OF AGE AND SEASON ON COMPONENTS OF YIELD OF SUGARCANE IN SOUTH AFRICA

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## Abstract

In normal circumstances, the planning of the harvest schedule on any sugarcane farm depends mainly on perceptions of the growth patterns in each field. The economic importance of harvest age was emphasized in an earlier publication, and in this paper the complexity of the pattern of sucrose accumulation is considered. Variety NCo376 was planted in randomised plots on a Swartland soil form on the North Coast of Natal. Each plot was allocated one of eight ratooning dates from 1 June 1989 to 1 August 1990 at two-month intervals. Plots were sampled at 8, 10, 12, 14 and 16 months after these dates so that yields and yield components could be determined. Soil water content of each plot was determined weekly with a neutron probe. Increments of cane and sucrose yield were influenced more by seasonal weather patterns than by crop age. Antecedant LAI accounted for 56 % of the variance in subsequent sucrose yield increment. An additional 12 % of the variance was associated with sucrose yield at the time of the first sampling of each interval. Season accounted for 84 % of the variance in sucrose content and crop age accounted for an additional 10 % of the variance. The highest sucrose yields (19.9 tons/ha) were obtained at 16 months of age in crops that were ratooned in February and April 1990. All other crops experienced periods of low soil water content between 8 and 14 months and suffered the loss of stalks as a result.

## Introduction

In South Africa sugarcane may be harvested as young as 10 months and as old as 24 months. The maximum age at harvest is usually subject to rules adopted by local pest and disease committees who can restrict harvest age in order to reduce the susceptibility of sugarcane to the borer *Eldana saccharina*. The decisions about harvest age are often governed by growers' perceptions about how the crop will respond if growth is allowed to continue. These perceptions may vary depending on whether cane yield, sucrose yield or sucrose content are being considered. The results from early growth analysis work in Natal led to the conclusion that stalk elongation, dry matter production and sucrose accumulation slowed down as the crop got older (*Gosnell, unpublished data). The reason given was that leaf production and hence leaf area index (LAI) declined with age. It was also assumed that respiration losses increased with age. These results were difficult to interpret because the effects of age and season were confounded. Rostron (1972) conducted an experiment that was designed to separate these effects. The trial was irrigated so measurements made in the second year of the experiment could be compared with those made in the first year with some confidence. Rostron concluded that growth declined after 10 months of age except in crops that started in January and February. These crops produced the highest yields in the experiment. There is a need to compare the results obtained in irrigated conditions with the dynamics of crop development in rainfed conditions in order to help growers with decisions about harvest schedules. Growth analysis work is expensive and the results may have limited application unless the growth processes are quantified in sufficient detail to allow for extrapolation beyond the climatic and soil conditions of the trial. This work was undertaken to augment the results of the irrigated experiment of Rostron (1972) and to provide detail on growth processes for improving the process level model (CANEGRO) being developed at the Experiment Station (Inman-Bamber, 1991).

## Methods

Establishment procedures for the experiment were described by (Inman-Bamber, 1994). In October 1988, 16 plots (25 m × 10 rows, 1.2 m apart) were planted to NCo376 on a sandy clay soil of the Swartland form at the La Mercy Experiment Farm on the Natal north coast (29°34'N, 30°8'E, 72 m altitude). Fertilizer was applied in the furrow and later as a top dressing to provide 90 kg N, 48 kg P and 150 kg K $ha^{-1}$. Ratooning dates (Table 1) were allocated randomly to eight plots in each of two blocks. The eight ratoon date treatments will be referred to at T1 to T8. Fertilizer, amounting to 140 kg N, 30 kg P and 140 kg K $ha^{-1}$, was applied along the row when tillering began in ratoon crops.

Destructive sampling was carried out exactly 8, 10, 12, 14 and 16 months after ratooning (Table 1). On each occasion,

**Table 1**

**Crop age (months) for eight dates of ratooning and five sampling occasions**

| Treatments | Ratoon date | Sampling date | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1990 | | | | | | 1991 | | | | | |
| | | 1 Feb | 3 Apr | 4 Jun | 1 Aug | 1 Oct | 4 Dec | 4 Feb | 3 Apr | 5 Jun | 30 Jul | 1 Oct | 2 Dec |
| T1 | 1 Jun 1989 | 8 | 10 | 12 | 14 | 16 | | | | | | | |
| T2 | 1 Aug 1989 | | 8 | 10 | 12 | 14 | 16 | | | | | | |
| T3 | 1 Oct 1989 | | | 8 | 10 | 12 | 14 | 16 | | | | | |
| T4 | 1 Dec 1989 | | | | 8 | 10 | 12 | 14 | 16 | | | | |
| T5 | 1 Feb 1990 | | | | | 8 | 10 | 12 | 14 | 16 | | | |
| T6 | 1 Apr 1990 | | | | | | 8 | 10 | 12 | 14 | 16 | | |
| T7 | 1 Jun 1990 | | | | | | | 8 | 10 | 12 | 14 | 16 | |
| T8 | 1 Aug 1990 | | | | | | | | 8 | 10 | 12 | 14 | 16 |

* 'The growth of sugarcane', PhD thesis, University of Natal (1967).

six samples were taken from pre-planned grid positions in alternate rows in each plot. A given number of living stalks were cut at ground level at each sampling position and removed together with the associated dead leaf and stalk material. The number of stalks in a sample was constant within a treatment and sampling occasion but was otherwise varied from 15 to 30 in order to maintain a row length of 0.5 to 1.0 m for each sample. Stalks like those in the sample were counted between pegs 8 m apart in three of the undisturbed rows in each plot. Stalk means for leaf number, leaf area, sucrose content, fresh stalk mass and sucrose mass were established. The 8-m counts were used to obtain LAI, cane and sucrose yield. The data presented are means of 12 samples. A 50-mm OD aluminium tube was inserted at the centre of each plot to a depth of 1.5 m and a neutron probe (CPN, Pacheco, CA, USA) was read at 0.15 m intervals to a depth of 1.35 m once a week. The water content of the 0 to 100 mm layer was obtained gravimetrically for each plot from a composite sample made with a 20-mm core sampler. Calibration of the probe was described by Inman-Bamber (1994).

## Results and discussion

*Leaves*

Green leaf number per stalk may be used as an indicator of the water status of the crop (Inman-Bamber and de Jager, 1986) and it is clear that this attribute was closely related to seasonal fluctuations in profile available water (PAW). Differences between treatments in April 1990 and February 1991 were due to differences in stages of development rather than degrees of water stress (Figure 1). Mean green leaf number per stalk of NCo376 in treatments 1 to 4 decreased to about six during a dry period in August 1990. This degree of stress was again observed in treatment 8 in September 1991. Age effects were less evident in LAI than in green leaf number (Figure 2). The crop ratooned in February 1990 (T5) developed the highest LAI (>5.0) and the lowest LAI (<1.5) was recorded in the T8 crop. It is interesting that the rapid increase in the number of green leaves per stalk in the T8 crop after 14 months was not accompanied by an increase in LAI.

*Cane yield*

The increment in cane yield over the two month interval between sampling dates was influenced largely by seasonal

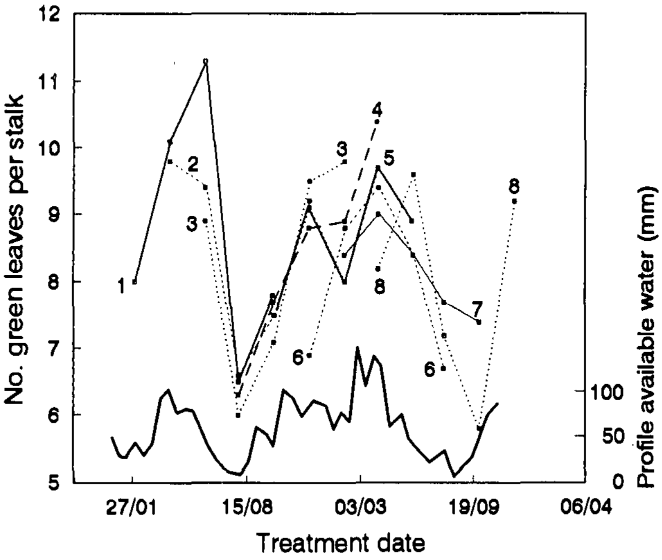


**FIGURE 1** Number of green leaves per stalk of crops in eight ratoon date treatments.

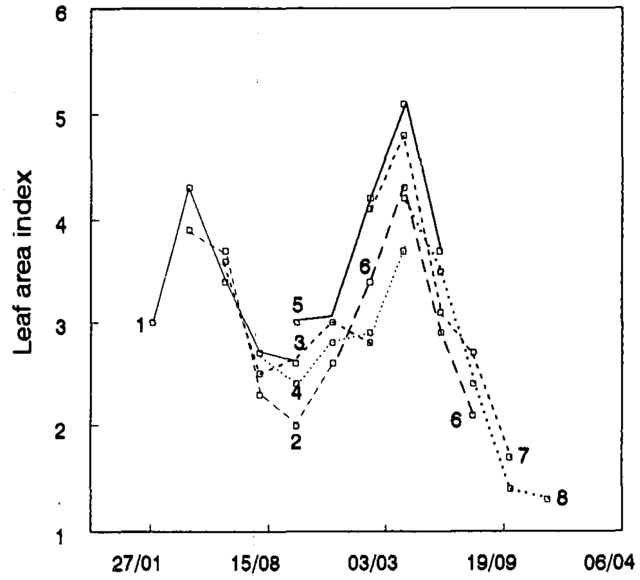


**FIGURE 2** Leaf area index (LAI) of crops in eight ratoon date treatments.

weather patterns but increments in yield between 14 and 16 months were considerably lower than those of younger crops (Figure 3). The two youngest crops produced as much as 58 and 60 t/ha in two months during the 1990/91 summer. This represents a growth rate of 1 ton per hectare per day which is close to the growth rate measured in irrigated NCo376 on the north coast (Inman-Bamber and de Jager, 1988). Increments were zero or negative during the two dry periods and the oldest crop was particularly prone to this yield decrement.

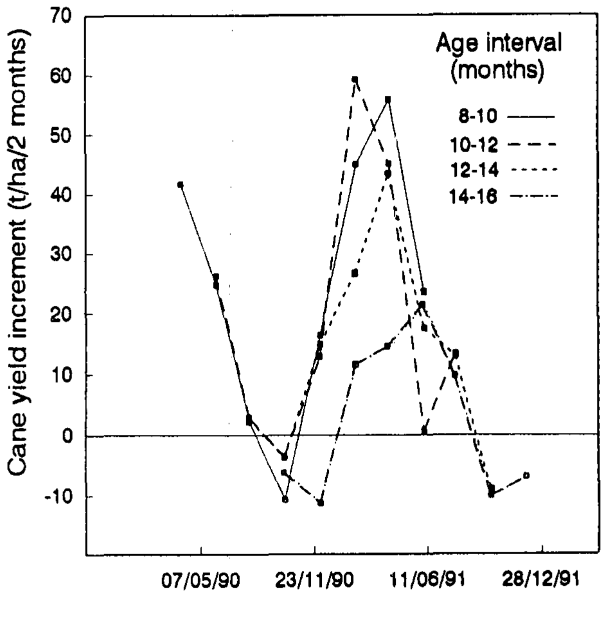


**FIGURE 3** Cane yield increment between ages 8, 10, 12, 14 and 16 months.

*Sucrose yield*

Seasonal influence on sucrose content was also strong compared to the influence of age (Figure 4). Sucrose content of the treatments 1 to 4 (20 values) were described by the following regression function:

$$-4.4 + 2.41X_1 - 0.12X_1^2 + 0.42X_2 \pm 0.72\%$$

where $X_1$ = time (months) after 1 January 1990 and $X_2$ = crop age in months.

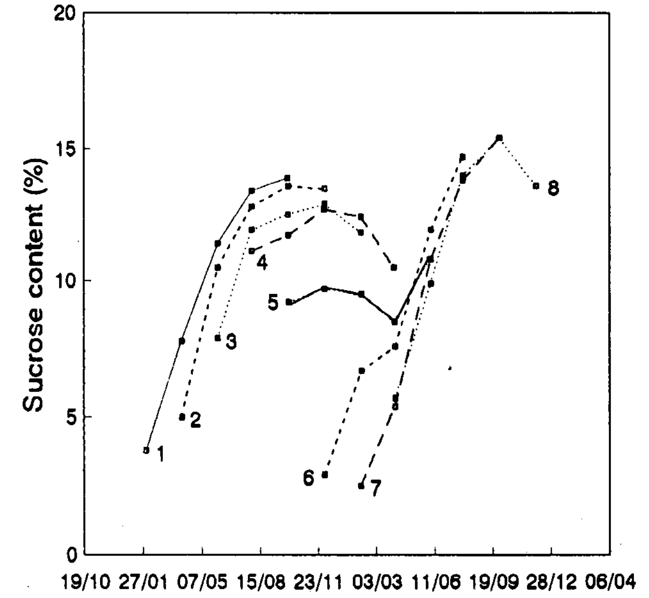


**FIGURE 4** Sucrose content of crops in eight ratoon date treatments.

Time (season) accounted for 84 % of the variance in sucrose content and crop age accounted for an additional 10 % of the variance. In August 1990, sucrose content was 13 % in the 14 month crop and only 2 % lower in the eight month crop. Sucrose content of the crops in treatments 6,7 and 8 was also governed more by season than by age but the sucrose content of the crop ratooned in February 1990 (T5) was remarkably constant and distinct from that of all other treatments. It is interesting that the substantial increases in sucrose content of young crops during the 1990/91 summer period occurred when cane yield increments were large. Only the oldest crops showed a reduction in sucrose content during this time.

*Sucrose yield*

Sucrose yield increment between 8 and 10 months exceeded increments between 10 and 12 and 12 and 14 months during April to October 1990 but there were no meaningful differences between these age intervals thereafter (Figure 5). The effect of season on sucrose yield increment was overriding. Apart from the large increments in sucrose yield between 14 and 16 months during June to October 1991, increments after 14 months were close to zero or were negative. The conditions under which the older plants of T5 and T6 crops were able to accumulate large amounts of sucrose after 14 months need to be examined carefully. From the data in Figure 6 it is clear that sucrose accumulation was reduced substantially when profile available water (PAW) approached zero. Graded responses to an increase in PAW after the first stress period, were evident in crops of treatments 2, 3 and 4. Sucrose yield of the T2 crop declined further after rain replenished PAW. During the 4-month period following the recovery in PAW, the T3 crop accumulated 2.5 t sucrose/ha and the T4 crop accumulated 5.1 t/ha. Recovery after water stress therefore diminished with crop age.

Ratoon dates for T6 and T7 were 12 months later than for T1 and T2 respectively (Table 1) and PAW reached zero in July of both years of the experiment. The reponses of T6 and T7 crops to water deficit were similar to their counterparts of T1 and T2 indicating that the observed growth patterns may be repeated to some extent each year at this site.

Canopy development of the T5 crops was retarded during the first stress period (data not shown) but this crop experienced favourable soil water conditions thereafter. The development of the T6 crop coincided with the most favourable conditions of the experiment and this crop produced the highest yield of sucrose (19.9 t/ha). In a rainshelter experiment it was noted that many physiological and developmental processes of sugarcane recovered fully after periods of water stress even more severe than those occurring in the La Mercy experiment. However measurements in the rainshelter experiment were made when the crop was younger than 10 months. An explanation for the inability of older crops to recover from water stress is required.

LAI accounted for 56 % of the variance in subsequent sucrose yield increment (Figure 7). An additional 12 % of the variance was associated with sucrose yield at the time of the first sampling of each interval. Thus low rates of canopy photosynthesis coupled with high rates of respiration may largely account for the observed sucrose accumulation rates.

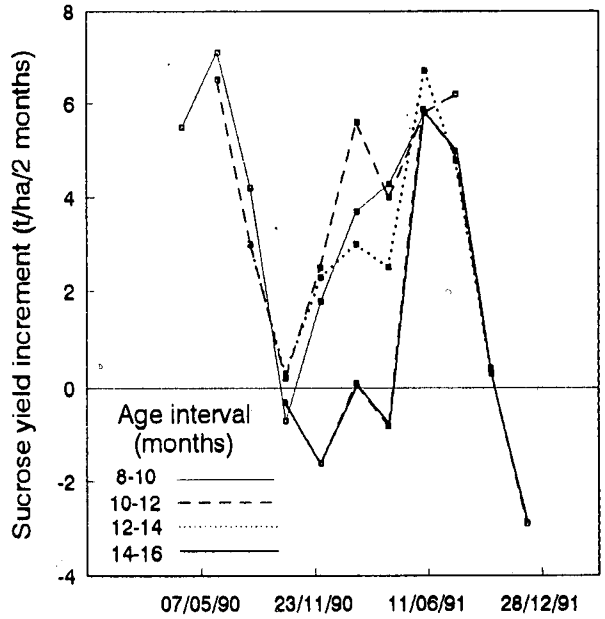


**FIGURE 5** Sucrose yield increment between ages 8, 10, 12, 14 and 16 months.

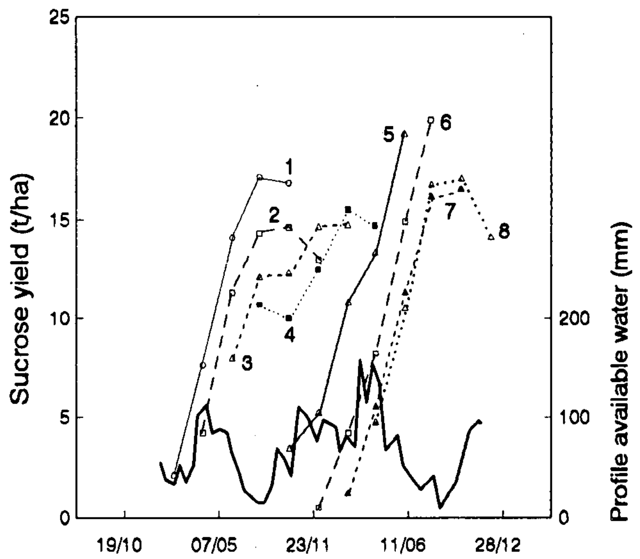


**FIGURE 6** Sucrose yield of crops in eight ratoon date treatments and profile available water (PAW) in T1, T4 and T8 plots.

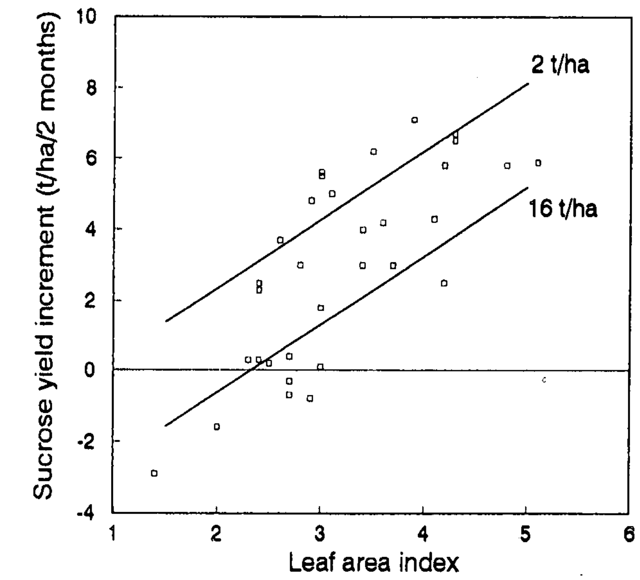


**FIGURE 7** Sucrose yield increment between ages 8, 10, 12, 14 and 16 months in relation to LAI at the younger age. Yield increments (Y) predicted from the regression equation $Y = -1{,}07 + 1{,}93X_1 - 0{,}212X_2 \pm 1{,}6$ t/ha/2 months ($r^2 = 0{,}68$, $n = 32$), where $X_1$ = LAI and $X_2$ = antecedent sucrose yield.

Another difference between crops of treatments 5 and 6 and crops of the other treatments was the stalk population at 14 and 16 months (Figure 8). Stalk density in T5 and T6 crops was greater than 15/m$^2$ and changed little between 14 and 16 months but in other crops densities were less than 15/m$^2$ and/or density decreased considerably between 14 and 16 months. The decline in cane yield of the T8 crop after 12 months was probably due to the loss of stalks during and after the dry period. It is interesting that the recovery in PAW after 14 months in the T8 crop did not result in renewed cane or sucrose accumulation even though green leaf number increased considerably (Figure 1).

Flowers emerged in the T8 crop at 10 months and at 16 months 35 % of the stalks had flowered (Figure 9). This may have contributed to the lack of yield increase after 12 months. Flowering in T6 and T7 crops was also profuse but these crops were harvested in August and October before flowering effected yields detrimentally (Nuss, 1989).

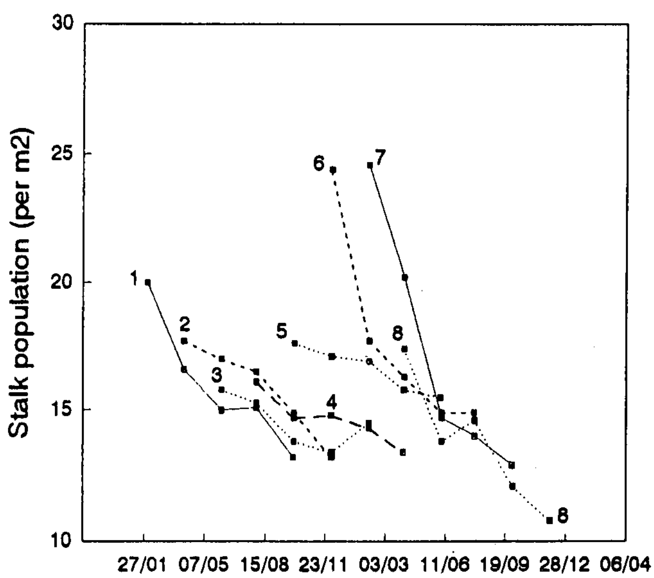


**FIGURE 8** Stalk population of crops in eight ratoon date treatments.

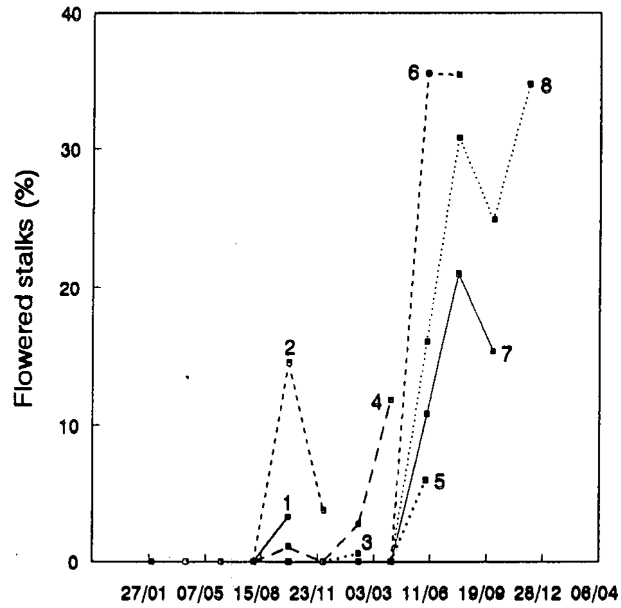


**FIGURE 9** % flowered stalks of crops in eight ratoon date treatments.

Maximum sucrose yield increments in the irrigated experiment conducted by Rostron (1972) (Figure 10) were only slightly greater than the increments measured in the rainfed crop at La Mercy. Maximum growth rates were measured in early winter in both experiments. The effect of crop age on sucrose yield increment was more pronounced in the irrigated experiment possibly because yields and therefore respiration rates, were greater at equivalent ages. Sucrose yield at the start of a 2-month growth interval accounted for 45 % of the variance in sucrose yield increment. Rostron (1972) noted that increments in cane yield were small after lodging occurred and this together with high respiration rates could account for the decrease in sucrose accumulation in high yielding crops. However the high sucrose yields produced by some crops in the irrigated experiment and in the La Mercy experiment supported the relatively low maintenance respiration coefficient used in the CANEGRO model.

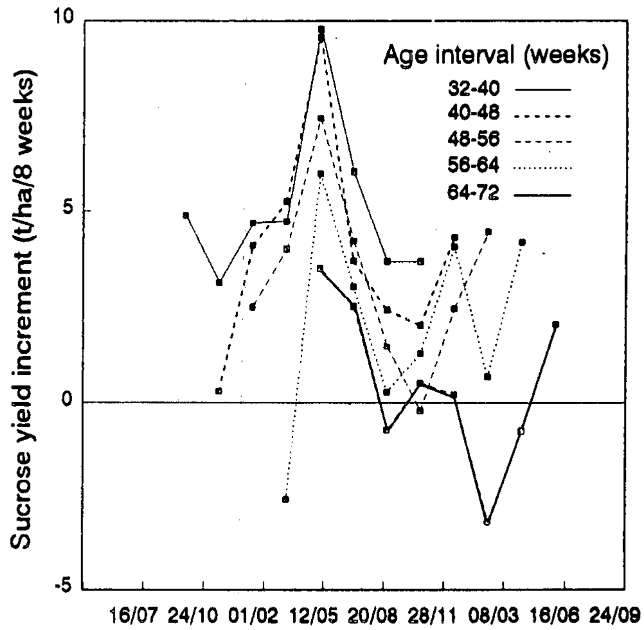


**FIGURE 10** Sucrose yield increment over eight weeks between ages 32 and 72 weeks in an experiment on irrigated NCo376 at Pongola conducted by Rostron (1972).

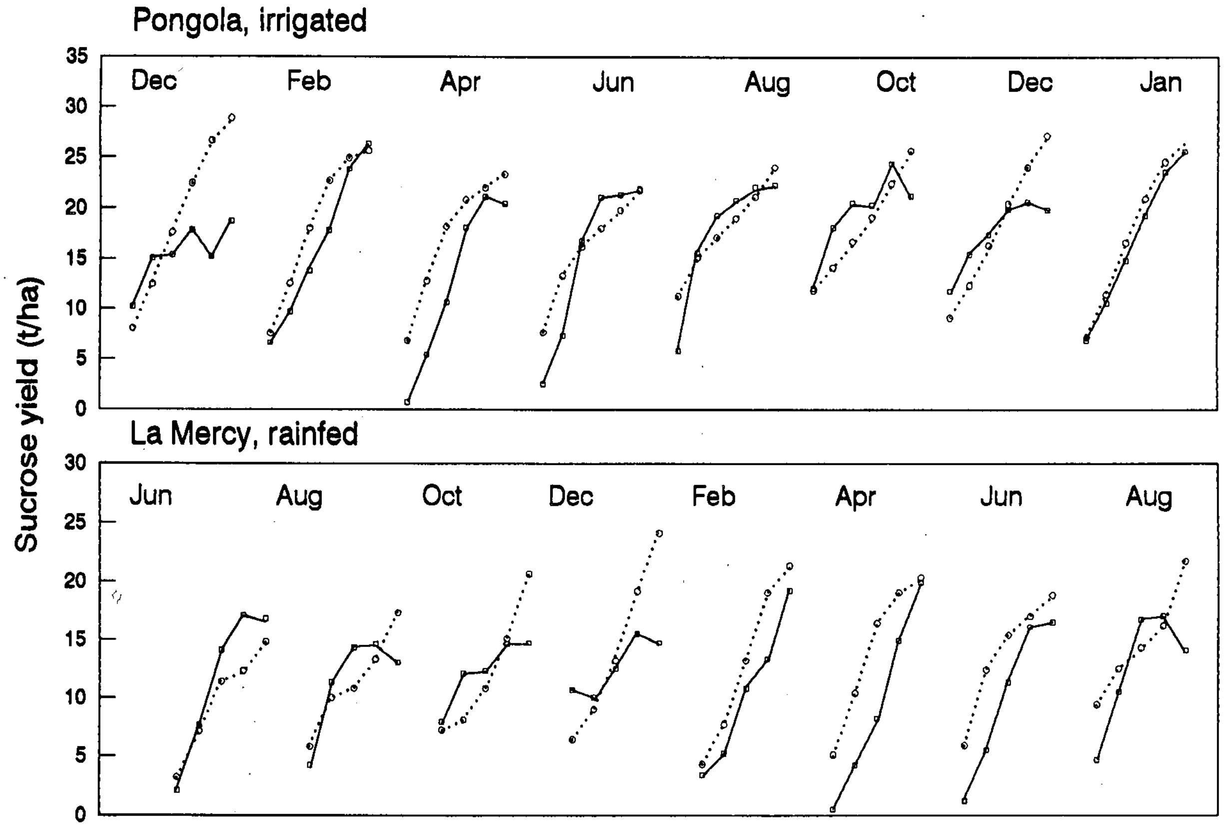


**FIGURE 11** Measured (——) and simulated (· · ·) sucrose yield of crops starting at eight week intervals at Pongola and two month intervals at La Mercy. The month of ratooning is given. Data from Pongola were reworked from Rostron (1972).

The large discrepancies between simulated and measured yields in the later stages of some of the crops (Figure 11) is probably due to inadequate modelling of LAI and of stalk senescence in crops that have been severely stressed or that have lodged or flowered.

## Conclusions

Seasonal weather patters had an overriding effect on green leaf number per stalk, LAI, sucrose content and sucrose accumulation rate. Sucrose accumulation rate was influenced considerably be antecedent LAI and to a smaller extent by antecedent sucrose yield. The poor performance of crops after 14 months was ascribed to both these factors and to a loss of large stalks during dry periods. The data indicated that a considerable amount of sucrose can be accumulated after 14 months if LAI remains high.

## Acknowledgements

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