

# THE RESULTS OF FROST SIMULATION STUDIES ON SUGARCANE IN THE RHODESIAN LOWVELD

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## Abstract

Trials were conducted in the Rhodesian lowveld to study the effects of simulating both mild and severe frost damage on sugarcane of different ages, by cutting off varying amounts of terminal buds and stalks, in mid-winter. Results are presented on the effects of varying degrees of damage on cane yields, cane quality, and sugar yields. Yield and quality changes which occurred between the time that damage was imposed and normal harvest at 12 months of age are discussed in relation to their influence on the decision whether to cut back the cane after injury or to leave it standing until maturity at 12 months. Yield considerations provide an important guide to any such decision, but the final choice must include a more detailed evaluation of quality factors in relation to the value to the producer of the harvested product.

## Introduction

Frosts are not a regular feature of the climate in the south-eastern lowveld of Rhodesia, and they are not considered a serious hazard to sugarcane production in the area. The low altitude (approx. 400 m a.s.l.) is an effective safeguard against frost in all but the most extreme circumstances, and although minimum temperatures tend to run low in winter, severe frosts are of rare occurrence.

Light ground frosts are not uncommon in low-lying sheltered areas, but they rarely cause measurable injury to sugarcane. Severe frosts, on the other hand, generally occur in spells of a few consecutive nights in association with cold dry south-westerly winds, and although most winters remain free of such conditions, they have been recorded periodically between mid-June and early-August and have been responsible for extensive damage to sugarcane in susceptible areas.

The extent of frost damage to sugarcane increases as the temperature drops, and as the period of exposure to freezing temperatures lengthens (Roth<sup>5</sup>, Irvine<sup>3</sup>). Moderate freezing conditions for several hours can result in greater frost injury than lower temperatures for shorter duration (Humbert<sup>1</sup>), and it has been shown that cane held at  $-1^{\circ}$  for 36 hours may be completely frozen, whereas at  $-3^{\circ}\text{C}$  for 4 hours only terminal buds may be damaged (Irvine<sup>3</sup>).

Generally a light frost in which the temperature does not fall below  $-2^{\circ}\text{C}$  and which lasts for an hour or less, will only cause superficial damage to the canopy and spindle leaves (Roth<sup>5</sup>). Lower temperatures down to  $-5.5^{\circ}\text{C}$  will freeze the terminal buds and young internodes, while temperatures below  $-6^{\circ}\text{C}$  can freeze entire stems (Irvine<sup>2</sup>).

The terminal growing point is more susceptible to frost than other parts of the plant, and best frost resistance is found in the lower internodes, nodes, and buds (Roth<sup>5</sup>), probably because the higher brix in the cane juice lowers the freezing point (Humbert<sup>1</sup>). Thus young cane is more susceptible than other cane approaching maturity, and high sucrose early-maturing varieties suffer less damage.

The degrees of frost injury to sugarcane in Rhodesia can be classified more in accordance with South African conditions (Wilson<sup>6</sup>), where damage is relatively mild with most

injury to canopy and terminal buds, than with conditions in the U.S. (Humbert<sup>1</sup>), where damage is generally severe and where more emphasis is placed on degrees of stalk injury. Thus frost damage can be separated into the following categories :

- (a) Extremely mild damage causing cold chlorosis, i.e. patterns of yellowing across the leaves which result from short spells with temperatures just below freezing point.
- (b) Scorching and death of the upper exposed parts of leaves, with the innermost and covered parts of the spindle leaves remaining green and uninjured.
- (c) Death of the upper exposed leaves and the spindle leaves, without affecting the terminal growing point. This is frequently accompanied by part or all of the meristem becoming discoloured and appearing permanently damaged, but careful sectioning through the meristem after 7-10 days will show signs of regrowth and the formation of a new spindle (Ranger<sup>4</sup>).
- (d) Where some or all of the terminal buds are killed in addition to (b) and (c), resulting in side-shooting from upper node buds.
- (e) Where the effects of extreme temperatures can kill varying numbers of lateral buds progressing downwards to ground level. Such damage is normally followed by an increase in microbial activity which can cause further deterioration of the stalk extending below the lowest level of frost damage.

Categories (a), (b), and (c) do not result in any permanent injury to the cane but merely cause a set-back in growth, the extent of which depends on the age of the cane and the prevailing growing conditions. Category (d) causes a cessation of terminal growth and the production of side-shoots, but it is not normally followed by progressive downward rotting and deterioration of the stalk, which is often a feature of category (e).

Severe frosts in the Rhodesian lowveld in June 1968, and in August of 1972 and 1974, caused extensive damage to cane of all ages and stressed the need for information on how to treat the crop after injury. The uneven pattern of damage which is typical in the field makes it impossible to compare different degrees of injury under natural conditions. Trials were initiated, therefore, in which degrees of damage were simulated by cutting off varying proportions of terminal buds and stalks on different ages of sugarcane. The limitations of this technique, in that it is not followed by stalk deterioration after injury as can happen after frost damage, were fully recognised.

## Methods

Two trials were conducted in 1975 to study the effects of simulating mild and severe frost damage respectively, on sugarcane of different ages, by cutting off varying amounts of terminal buds and stalks. These trials were repeated in 1977 when additional data were recorded to enable quality changes to be studied from the time damage was imposed until

harvest at 12 months of age. In all cases the effects of simulated frost damage were measured in the plant crop only.

**A. Terminal damage to sugarcane of different ages.** These trials were intended to simulate the effects of light frost, in which damage is generally confined to desiccation of the top leaves and death of terminal buds, but with no effect on lateral buds and terminal internodes. Frost damage was simulated artificially by cutting off varying proportions of terminal buds to provide six treatments as follows :

1. Control — no damage.
2. All leaves removed above the terminal bud.
3. The terminal bud and all leaves above it removed from 25% of cane stalks.
4. As for treatment 3, but removed from 50% of cane stalks.
5. As for treatment 3, but removed from 75% of cane stalks.
6. As for treatment 3, but removed from 100% of cane stalks.

To ensure removal of the terminal bud in treatments 3 to 6, the requisite number of cane stalks were topped at a point approximately 5 leaves below the top visible dewlap.

**A1. 1975.** The trial was laid out in randomised blocks with four replications, with plantings of variety NCo 376 made in December, October, and August of 1974 to provide cane of 6, 8, and 10 months of age respectively when the treatments were imposed, which was during the first week of June, 1975. All treatments were harvested at 12 months of age from planting, at which stage all side-shoots were removed and discarded before plots were weighed and subsampled for quality analyses.

**A2. 1977.** This trial was similar in most respects, but was planted three times in 1976 to provide cane of three ages when treatments were imposed in June, 1977. Larger plots were provided to enable sampling for yield and quality at monthly intervals between the time of damage until harvest at 12 months of age from planting, a procedure which was not followed in the 1975 trial.

**B. Stalk damage on sugarcane of different ages.** These trials were designed to simulate the effects of severe frost, in which damage extends to the stalks below the terminal bud and can affect varying amounts of stalk depending on the severity of the frost and the degree of rotting and fermentation which results. Frost damage was simulated artificially by cutting off varying quantities of stalk to provide four treatments as follows :

1. Control — no damage.
2. Top 25% of all stalks cut off and discarded.
3. Top 50% of all stalks cut off and discarded.
4. Top 75% of all stalks cut off and discarded.

**B1. 1975.** The trial was laid out in randomised blocks with five replications and conducted concurrently with, and in the same way, as Trial A1 to provide cane of 6, 8 and 10 months of age when treatments were imposed in June, 1975. At the time of harvest all side-shoots and bull-shoots were removed and discarded before plots were weighed and subsampled for quality analyses.

**B2. 1977.** This was a repeat of Trial 2, planted at three times in 1976 to provide cane of three ages when treatments were imposed in June, 1977. Sampling for yield and quality was conducted at monthly intervals from the time of stalk damage until harvest at 12 months of age.

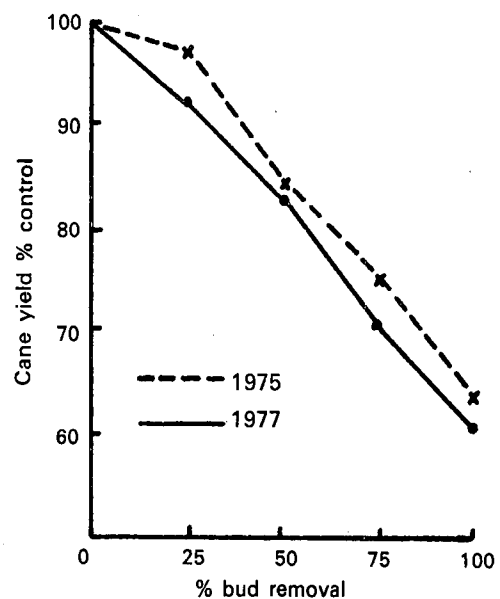
**Results**

**1. Terminal damage to sugarcane of different ages.**

(a) **Cane yields.** No significant differences were recorded in cane yields at 12 months of age when treatments were imposed on either 8-month or 10-month old cane, both in 1975 and in 1977. However, imposing damage on 6-month old stalks caused yields to decline linearly with increase in the proportion of terminal bud removal. This effect was recorded in both years, but leaf removal caused a significant yield drop in 1975 only. Cane yield responses are shown in Table 1 and the effects of terminal bud removal are represented in Figure 1 as percentages of the control yields.

**TABLE 1**  
Cane yields (t/ha) after damage at 6 months of age

Treatments	Cane yields t/ha		
	1975	1977	Means
Control — no damage . . . . .	127,7	128,2	128,0
All upper leaves removed . . . . .	106,9	122,5	114,7
25% terminal buds removed . . . . .	123,9	117,8	120,8
50% terminal buds removed . . . . .	105,9	106,2	106,0
75% terminal buds removed . . . . .	95,3	90,6	93,0
100% terminal buds removed . . . . .	80,9	77,5	79,2
L.S.D. P = 0,05 . . . . .	10,5	18,9	—
P = 0,01 . . . . .	14,5	26,2	—
Trial mean . . . . .	106,8	107,1	107,0
S.E. mean ± . . . . .	3,5	6,3	—
C.V.% . . . . .	6,5	11,7	—



**FIGURE 1** Cane yield (% control) after damage at 6 months.

(b) **Quality effects.** Monthly sampling of all treatments after terminal damage was imposed on the 1977 trial was conducted for the purpose of recording changes in reducing sugars and ers%\* cane during the period from time of damage until harvest at 12 months of age.

When damage was imposed at 6 months there were no significant differences between any of the treatments throughout the sampling period in terms of either reducing sugars or ers% cane. There was no indication of terminal damage causing an increase in reducing sugars or a decrease in ers%

\* ers = estimated recoverable sugar.

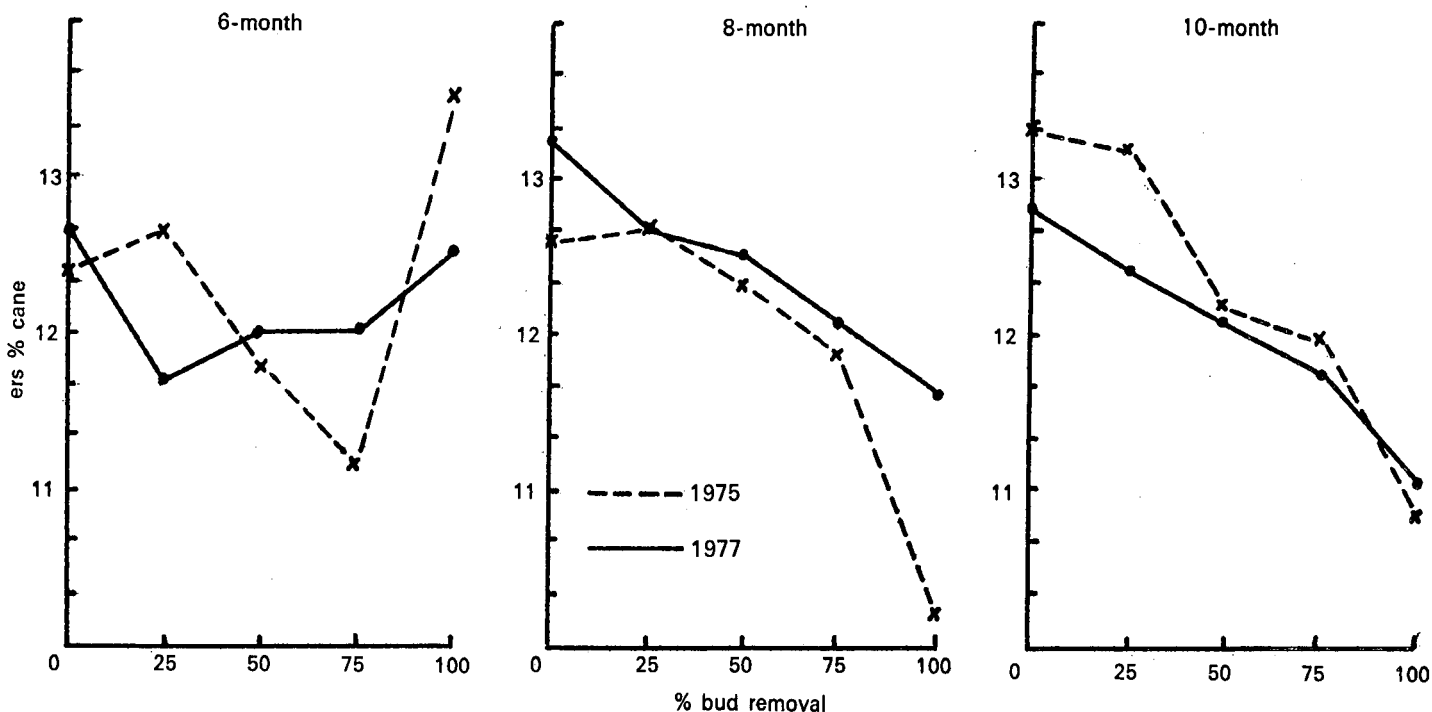


FIGURE 2 Effects of terminal bud removal on ers% cane.

cane as a result of side-shooting, and sugar accumulation in the stalk proceeded normally from 6 to 12 months of age regardless of the degree of terminal damage imposed.

The effects of terminal bud removal on ers% cane at harvest are shown in Figure 2 for both years and all three age groups. In 1975 there was evidence of a decline in ers% cane after 50% and 100% terminal bud removal on 6-month old cane, and a sharp increase in ers% cane when all terminal buds were removed. Differences in ers% cane when treatments were imposed on 6-month old cane were not significant in 1977, although a rise after 100% bud removal was again evident.

Damage imposed on 8-month old cane in 1977 caused a general decline in ers% cane which was linearly related to the proportion of buds removed. In 1975 the drop in ers% cane was only significant when more than 50% bud removal was effected, and there was a pronounced drop when all terminal buds were removed.

The effect on ers% cane when damage was imposed on 10-month old stalks was similar in both years, with values declining significantly with increase in the degree of terminal bud damage.

Removal of the upper leaves without any terminal bud damage had no significant effect on ers% cane in any of the age groups.

TABLE 2

Effects on ers% cane of terminal damage on 8-month old cane sampled monthly until harvest

Treatments	Age in months				
	8	9	10	11	12
Control — no damage . . .	8,48	9,97	10,89	11,78	13,25
All upper leaves removed . . .	8,15	9,26	10,58	11,94	13,10
25% terminal buds removed . . .	8,84	10,87	11,34	11,90	12,68
50% terminal buds removed . . .	8,13	9,55	10,51	12,01	12,56
75% terminal buds removed . . .	8,48	9,31	10,04	11,82	12,14
100% terminal buds removed . . .	8,80	9,54	10,11	11,00	11,64
L.S.D. P = 0,05 . . . . .	N.S.	N.S.	N.S.	N.S.	0,84
P = 0,01 . . . . .	N.S.	N.S.	N.S.	N.S.	1,17
Trial mean . . . . .	8,48	9,75	10,58	11,74	12,56
S.E. mean ± . . . . .	0,36	0,40	0,40	0,31	0,28
C.V. % . . . . .	8,41	8,13	7,53	5,33	4,46

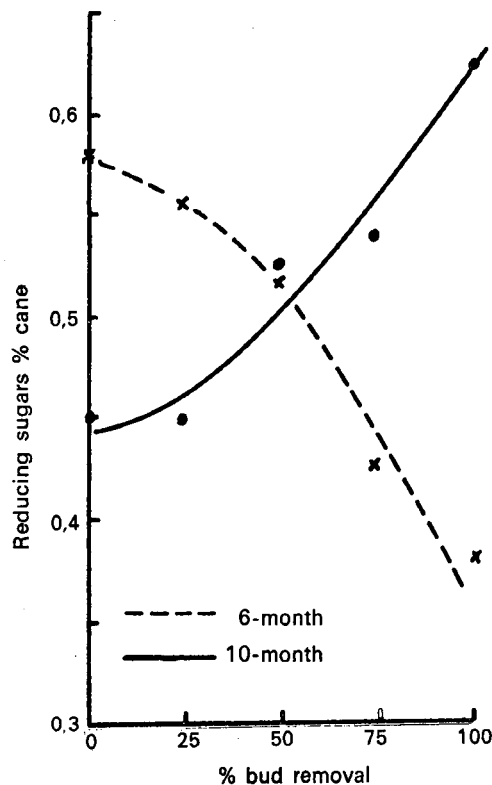


FIGURE 3 Effects of terminal bud removal on reducing sugars % cane

Monthly sampling after damage was done to 8 and 10-month old cane showed that differences in ers% cane between treatments only became evident and attained significance at the time of harvest. This may be seen in Table 2, which shows ers% cane values for all treatments at monthly intervals from damage at 8 months of age until harvest at 12 months.

(c) *Reducing sugars.* At the time of harvest differences in reducing sugars between treatments were relatively small, but marked response trends were evident in the 6-month and 10-month groups as shown in Figure 3.

Increasing amounts of terminal bud damage on 6-month old cane caused a steady decline in the reducing sugar content of the stalks, whereas in 10-month old cane this trend was reversed. Differences between treatments after damage was imposed at 8 months were not significant.

(d) *Sugar yields.* The effects of treatments on sugar yields are shown in Table 3 for both years and all three age groups, and Figure 4 shows the effects of terminal bud removal as percentages of control yields.

When terminal bud removal was imposed on 6-month old cane, the drop in ters/ha followed the trend recorded for

cane yield (Figure 1), with minor variations caused by the rather erratic ers% cane responses (Figure 2). The response from cane damaged after 8 months, when cane yields were unaffected by treatments, was strongly influenced by ers% cane responses, with the 1977 data reflecting a higher degree of variability than the 1975 results, but with both showing a trend for ters/ha to decrease with increasing terminal bud damage. In the case of 10-month old cane, responses in the two years were similar, but the decline in ters/ha was less pronounced than on the crops which were damaged at an earlier stage of development.

Removal of the upper leaves without damage to terminal buds caused a marked drop in ters/ha when imposed on 6-month old cane in both years, but the response to this treatment from 8 and 10-month old cane was erratic and yields were not significantly different from the controls in either year.

## 2. Stalk damage to sugarcane of different ages.

(a) *Cane yields.* Increasing amounts of stalk damage on 6-month old cane caused large reductions in yield when the crop was harvested at 12 months. Yield losses were very similar when stalk damage was imposed at 8 and 10 months of age, but in both cases losses were considerably less than those recorded on 6-month old cane. The effects of stalk damage treatments on cane yields are shown in Figure 5, where yield data have been represented as percentages of controls.

Results showed that losses were greater in 1977 than in 1975, and that the responses from 8 and 10-month old cane were almost identical within years.

Monthly sampling after treatments were imposed in 1977 showed that stalk damage had the effect of arresting the development of millable cane from the time that damage was effected regardless of age. Growth after stalk damage was restricted to marginal gains in stalk mass, but was confined mainly to the development of side-shoots and tillers which were still immature at the time of harvest. An example of this effect is shown in Table 4, where results from alternate monthly samples are presented following stalk damage at 6 months of age.

TABLE 3  
Effects of terminal damage on ters/ha

Treatments	6-month		8-month		10-month	
	1975	1977	1975	1977	1975	1977
Control—no damage	15,87	16,25	15,65	18,18	17,54	17,96
Upper leaf removal .	13,93	14,66	15,36	16,48	17,15	14,58
25% bud removal .	15,69	13,84	16,01	14,75	17,12	15,83
50% bud removal .	12,51	12,75	15,69	16,63	16,31	16,05
75% bud removal .	10,60	10,94	14,44	14,17	15,44	15,04
100% bud removal .	11,00	9,82	12,19	14,87	14,18	15,29
L.S.D. P = 0,05 .	1,81	1,99	1,93	2,52	1,68	N.S.
P = 0,01 .	2,51	2,75	2,67	N.S.	2,32	N.S.
Trial mean . . . .	13,27	13,04	14,89	15,85	16,29	15,79
S.E. mean ± . . . .	0,60	0,66	0,64	0,83	0,56	1,14
C.V. % . . . . .	9,06	10,12	8,60	10,54	6,83	14,42

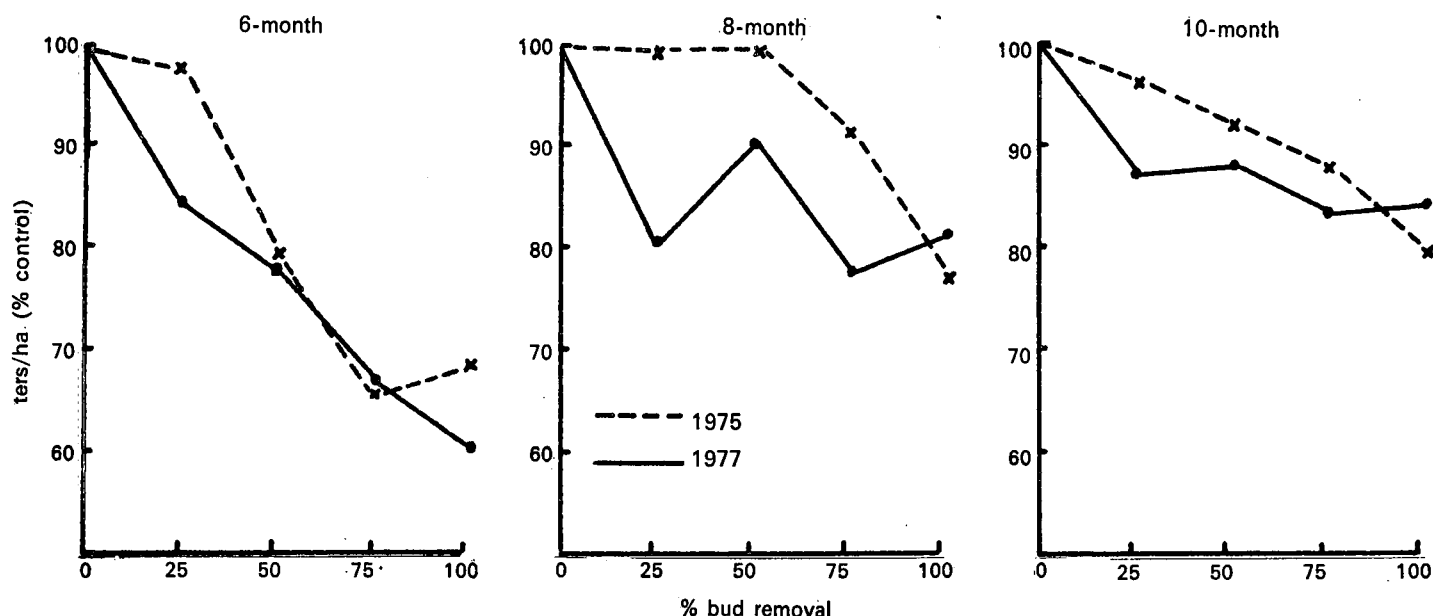


FIGURE 4 Effects of terminal bud damage on ters/ha.

TABLE 4

Effects on cane yields (t/ha) following stalk damage at 6 months of age

Treatments	Age in months			
	6	8	10	12
Control — no damage . . . . .	67,9	94,1	119,9	115,4
25% stalk damage . . . . .	58,5	65,5	65,3	67,7
50% stalk damage . . . . .	37,4	38,5	40,2	42,6
75% stalk damage . . . . .	26,0	26,1	25,0	20,3
L.S.D. P = 0,05 . . . . .	13,3	20,4	21,2	13,1
P = 0,01 . . . . .	18,6	28,6	29,6	18,2
Trial mean . . . . .	47,4	56,0	62,6	61,5
S.E. mean ± . . . . .	4,3	6,6	6,9	4,3

(b) *Quality effects.* The effects of treatments on ers% cane at harvest are shown in Figure 6.

When damage was imposed on 6-month old cane difference in ers% cane between treatments were not significant in 1975, whereas in 1977 there was a trend for values to drop when more than 25% of stalks were cut off, and ers% cane at 75% damage was significantly lower than all other treatments.

In the case of 8-month old cane, the drop in ers% cane was proportional to the level of damage imposed, due to the effects of side-shooting and increasing percentages of reducing sugars, and similar results were obtained in both years. When damage was done to 10-month old cane a similar decline in ers% cane was recorded in 1977, but in 1975 cutting stalks

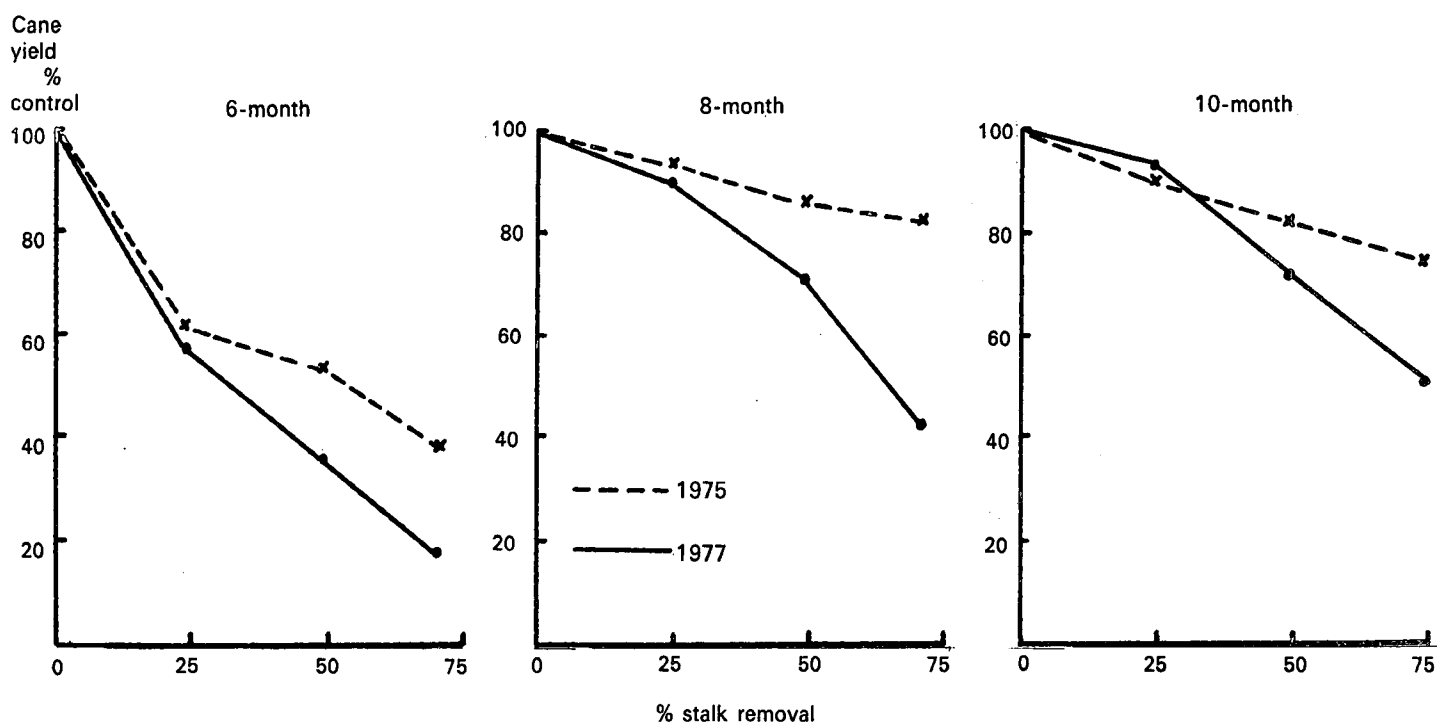


FIGURE 5 Effects of stalk damage on cane yields.

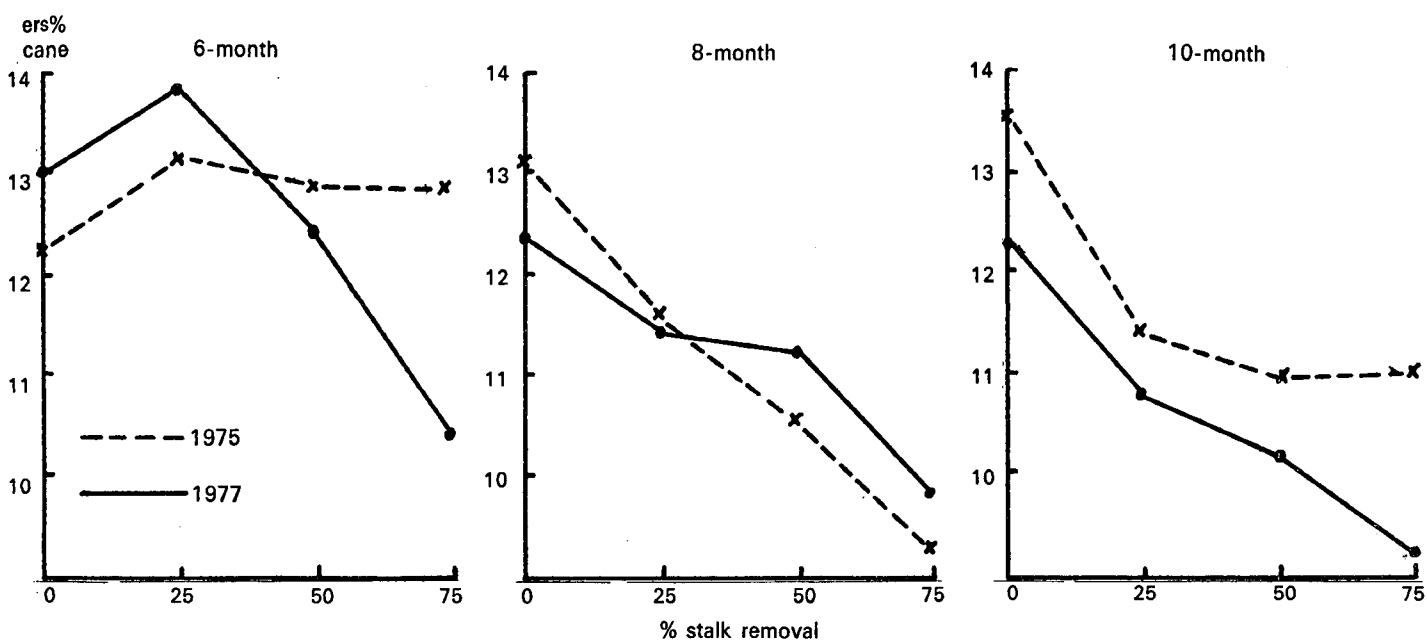


FIGURE 6 Effects of stalk damage on ers% cane at harvest.

back caused a drop of about 2,5% ers but there was no significant difference between the three degrees of damage.

Monthly sampling after stalk damage was imposed on the 1977 crop showed that there was a marked increase in ers% cane from the top to the bottom stalk internodes, so that an increase in the degree of damage was accompanied by an increase in ers% cane in the residual stalk. This was evident at 6, 8, and 10 months of age and is clearly shown in Figure 7, where changes in ers% cane are shown for all three age groups from the time of damage until harvest at 12 months of age.

Damage at 6 months of age caused a temporary depression in ers% cane, but values started rising again by 9 months of age and had matched the control value by 11 months. When damaged at 8 months, ers% cane values dropped sharply and then steadied before rising again after 10 months. Damage at 10 months slowed down the rise in ers% cane after 25% stalk damage, and caused increasing reductions in ers% cane after 50% and 75% damage.

(c) *Reducing sugars.* These were measured in the 1977 trial only, and results showed that harvest values were related to stalk damage treatments in reverse trends to those recorded for ers% cane. The effects of treatments on reducing sugars at harvest are shown in Figure 8.

Analyses for reducing sugars in the monthly samples taken after damage was imposed on the 1977 crop reflected a high degree of variability, but showed that responses followed

trends which were essentially opposite in pattern to those recorded for ers% cane and presented in Figure 7. At 6 months treatments clearly defined the large differences in reducing sugars from the top to the bottom stalk internodes, but values changed after stalk removal and were similar in all treatments from 10 months of age until harvest. The effect of stalk damage on 8 and 10-month old cane was to arrest the normal reduction in reducing sugars shown by the control.

(d) *Sugar yields.* The effects of treatments on sugar yields (ters/ha) are shown in Table 5 for both years and all three age groups, and Figure 9 shows the effects of stalk damage expressed as percentages of control yields.

TABLE 5  
Effects of stalk damage on ters/ha

Treatments	6-month		8-month		10-month	
	1975	1977	1975	1977	1975	1977
Control—no damage	14,81	15,00	16,32	16,00	19,37	16,28
25% stalk damage	9,68	9,35	12,63	13,45	15,01	13,37
50% stalk damage	8,64	5,43	10,49	10,38	12,70	9,69
75% stalk damage	6,52	2,13	8,83	5,31	11,78	6,12
L.S.D. P = 0,05	1,83	1,66	1,57	3,30	2,61	1,19
P = 0,01	2,56	2,31	2,20	4,60	3,66	1,66
Trial mean	9,91	7,98	12,07	11,28	14,72	11,36
S.E. mean ±	0,59	0,54	0,51	1,12	0,85	0,39
C.V. %	13,40	15,18	9,44	12,22	12,88	7,66

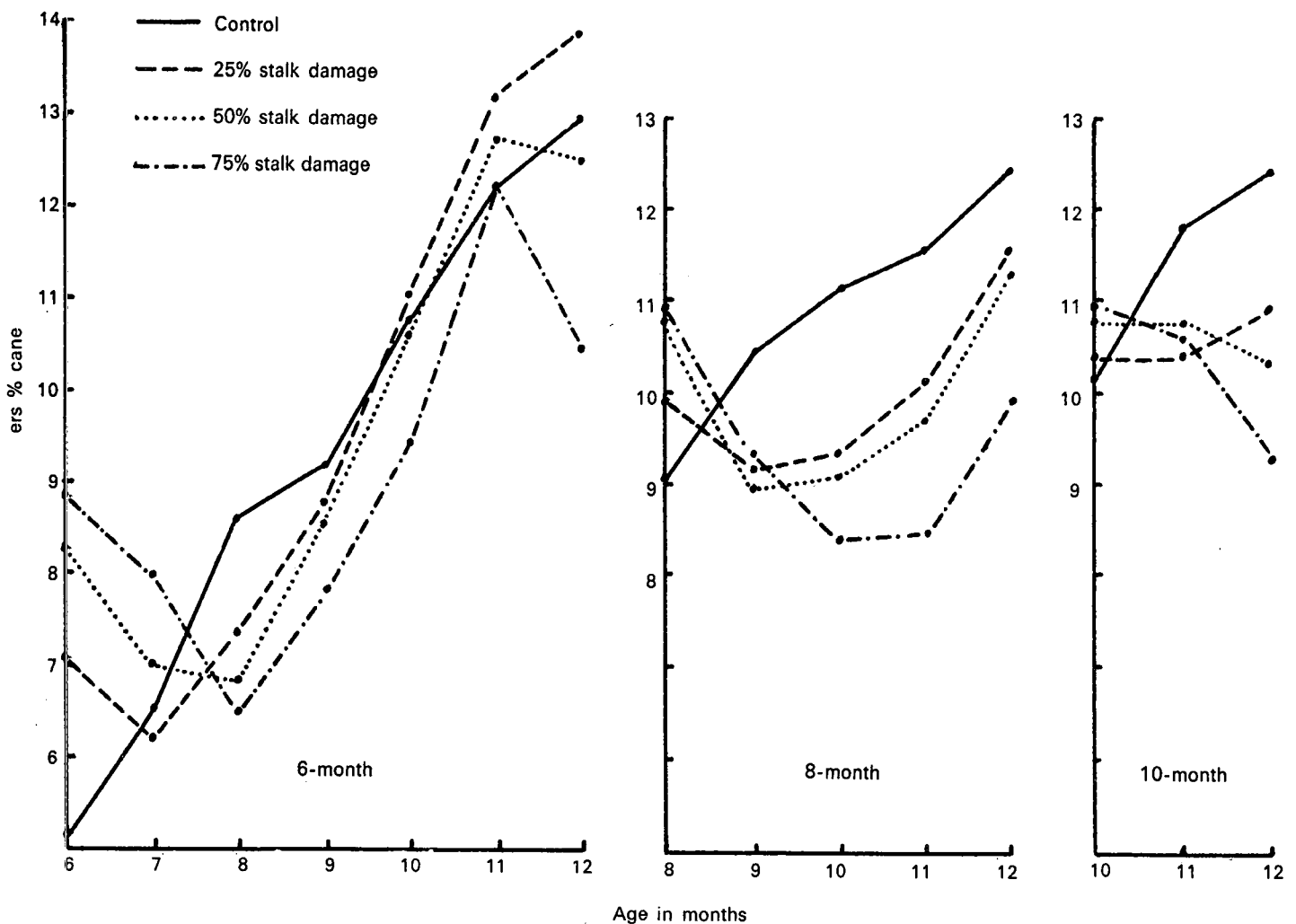


FIGURE 7 Changes in ers% cane after stalk damage at different ages.

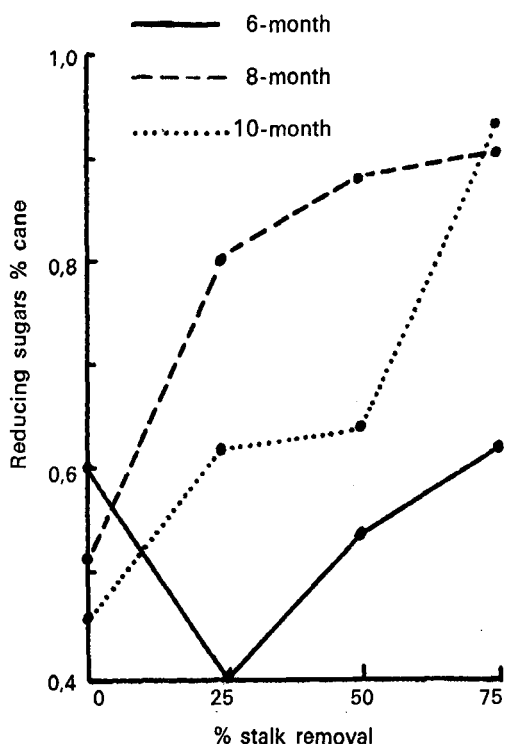


FIGURE 8 Effects of stalk damage on reducing sugars at harvest.

Losses in ters/ha caused by increasing amounts of stalk damage were greatest when treatments were imposed on cane at 6 months of age, and were similar when cane was damaged at 8 or 10 months of age.

**Discussion**

When the terminal growing point has been killed, cane does not normally deteriorate further provided the weather remains cold and dry (Roth<sup>3</sup>), which is normally the case during the lowveld winter months. It is considered therefore, that the removal of upper leaves and terminal buds provided a useful means of simulating conditions of mild frost in the field, and that treatment responses were reasonably indicative of what would happen under natural conditions.

In cane damaged at 8 or 10 months of age there was no indication of a reduction in cane yield even with 100% removal of terminal buds, but side-shooting caused an ultimate reduction in sucrose which led to reduced sugar yields when harvested at 12 months of age. These losses increased from about 10% after 25% terminal bud removal to about 20% when all terminal buds were removed (Figure 4). Monthly sampling after terminal bud removal showed that it did not have the effect of causing an immediate reduction in ers% cane after damage was imposed, but that it merely slowed down the rate of sugar accumulation. Results showed, therefore, that there was no justification for premature harvest as suggested by Wilson<sup>6</sup>, and that injured cane of 8 months of age or more could be left in the field for normal harvest at 12 months with relatively small losses in ters/ha, and with satisfactory quality provided topping was done at the point of development of side-shoots.

When bud removal was effected at 6 months of age, the loss in cane yield was in direct proportion to the degree of damage (Figure 1), but there was no significant effect on the quality of residual stalk. With 75-100% terminal bud damage ters/ha was reduced to 60-70% of control yields, and a decision as to whether to cut back the cane to ground level or leave it standing then depends on yield estimation on the basis of ters/ha/month. The linear yield decline when the crop is left standing and harvested at 12 months is shown in Figure 10.

A benefit from cutting back in July is that a higher ratoon yield can be expected than from a late-season December crop, but 6 months of growth is sacrificed. The ratoon yield (after 18 months) would fall within the range indicated by the shaded area in Figure 10, showing that there would be a yield advantage in cutting back a crop with 50% terminal bud damage or more, but that it would be more economical to leave the crop standing if damage was less than 50%.

Cutting off varying amounts of stalks did not provide a true simulation of severe frost effects as the damage was not followed by stalk deterioration and rotting. The extent of stalk deterioration after frost is a function of prevailing weather conditions, and in cold dry weather the cane does not normally deteriorate far below the lowermost level of damage.

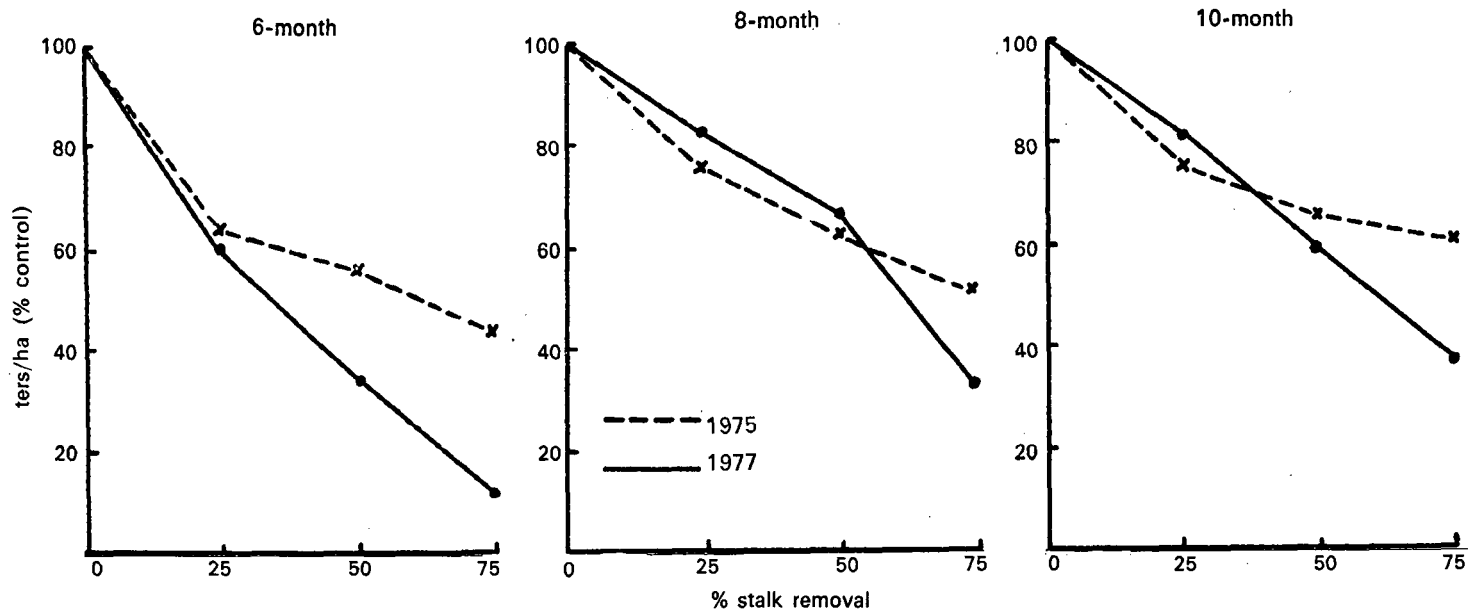


FIGURE 9 Effects of stalk damage on ters/ha at harvest.

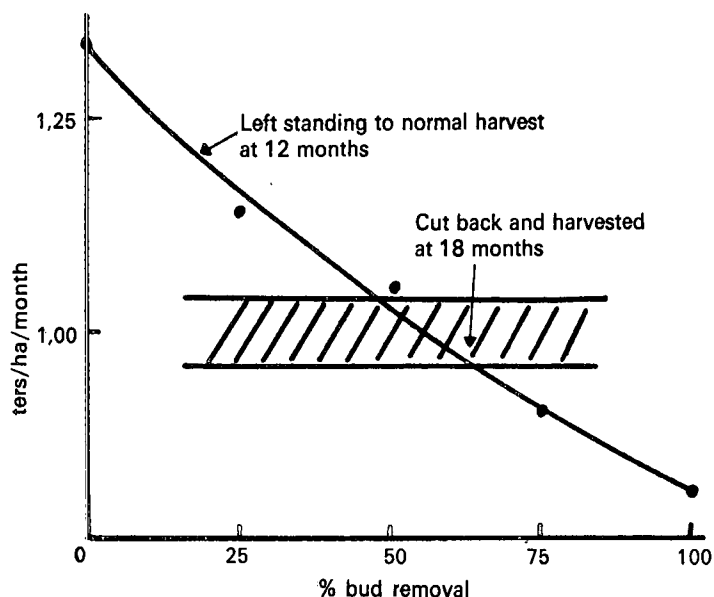


FIGURE 10 Effect of cut back on ters/ha/month after bud damage at 6 months.

Normally side-shooting starts at the lowest level of rotting, so that the defined treatments in these trials can be taken to represent this limit rather than the actual level of frost damage.

The results of these trials showed that cane yields were linearly reduced by increasing degrees of damage in all three age groups (Figure 5), and that ers% cane was lowered and reducing sugars increased immediately after damage was imposed. The net result of these effects was a pronounced reduction in sugar yields, the effect being most marked on 6-month old cane and less pronounced on 8 and 10-month old cane (Figure 9).

Results clearly showed that 6-month old cane, even with 25% stalk damage should be cut back and discarded as soon as possible after injury and allowed to ratoon. In the case of 8 and 10-month old cane, Table 6 shows the effects on ters/ha/month of either cutting back within a month of injury or leaving the cane standing until normal harvest at 12 months.

With the figures in the B columns based on estimates of ratoon yields, these data show that with 25% stalk damage there could be marginal benefits in leaving the cane standing after injury at either 8 or 10 months of age. With greater

TABLE 6  
Effect of cut-back on ters/ha/month

	Cut-back		Left standing	
	A	B	A	B
<b>8-month old cane</b>				
Control — no damage . . .	1,27	1,31	1,33	1,33
25% stalk damage . . .	1,03	1,20	1,12	1,23
50% stalk damage . . .	0,87	1,14	0,87	1,10
75% stalk damage . . .	0,46	0,96	0,44	0,89
<b>10-month old cane</b>				
Control — no damage . . .	1,39	1,37	1,36	1,36
25% stalk damage . . .	1,00	1,18	1,11	1,24
50% stalk damage . . .	0,93	1,15	0,81	1,08
75% stalk damage . . .	0,62	1,00	0,51	0,93

A: ters/ha/month at time of harvest

B: ters/ha/month meant to include subsequent ratoon

degrees of damage, higher mean monthly sugar yields are likely to be achieved if the cane is cut back, but in all cases differences were relatively small.

However, the decision on whether or not to cut back frost damaged cane cannot be based on yield estimates alone, as the ers% cane at harvest will have a considerable influence on the value of the sugar recovered from immature cane. Thus when small yield differences exist and cut-back appears to be only marginally beneficial, more detailed economic considerations could sway the decision in favour of leaving the cane standing in order to provide the quality, and thus the price, of the harvested product.

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