SUGARCANE FOR ETHANOL — SHOULD FIELD MANAGEMENT PRACTICES BE MODIFIED?

PART 2 — OTHER AGRONOMIC EFFECTS

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Abstract

In continued studies to evaluate optimum management practices for ethanol production, reviews were undertaken of trials in which treatments had a significant effect on cane quality. Recoverable yields of sucrose and total fermentable sugars were compared in relation to the effects of nitrogen, chemical ripeners, deterioration after burning, and topping height. It was shown that certain practices which were ideal for sugar production required modification to optimise productivity of total fermentable solids.

Introduction

The effects of management practices on the production of ethanol from sugarcane have been outlined by Humbert[5], who found benefits from supplementary fertiliser applications, optimum soil moisture conditions, and the use of chemical ripeners. On the other hand Thompson[8] considered that no great improvement of sugarcane yields could be expected from altered management practices, although he recognised the need for more research on the subject. Subsequent to the evaluation of optimum varieties and harvest seasons for ethanol production in the Zimbabwe lowveld (Cackett and Rampf[4]), an additional range of experiments was selected for review because of quality responses to applied treatments. They included studies on nitrogen effects, chemical ripeners, deterioration after burning, and topping heights, and the object was to determine whether the effects of treatments on recoverable sugar were similar or different to the effects on quality as defined by the percentage of total fermentable solids.

The criteria of quality, and the abbreviations used, are the same as those described by Cackett and Rampf[4] in Part 1 of this series of two papers.

Nitrogen Effects

Results from a large number of fertiliser trials conducted in the lowveld have shown that ERC% cane is depressed by increasing levels of nitrogen early in the season, but that in late-season crops only the control value is depressed and subsequent increases in nitrogen have no significant effect on ERC% cane. This is clearly shown in Figure 1, where mean responses are presented for five early- and five late-season trials, representing 25 and 26 ratoon crops respectively.

Yield responses are shown in Figure 2 for the same early- and late- season trials. From these graphs it can be seen that :

(a) cane yield responses in early- and late-season were virtually indentical.

(b) in the late-season trials the ERC yield responses followed the same pattern as the cane yield response, values being slightly higher because of low ERC% cane in the control plots.

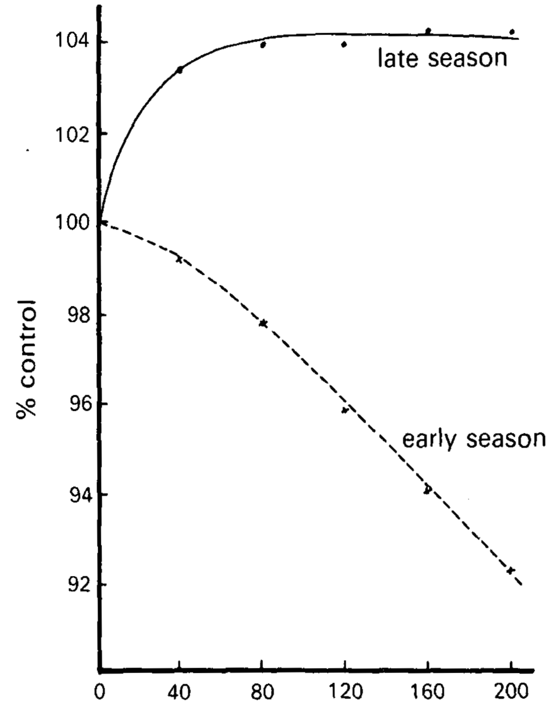

FIGURE 1. Relationship between ERC% cane and nitrogen level in early- and late-season crops.

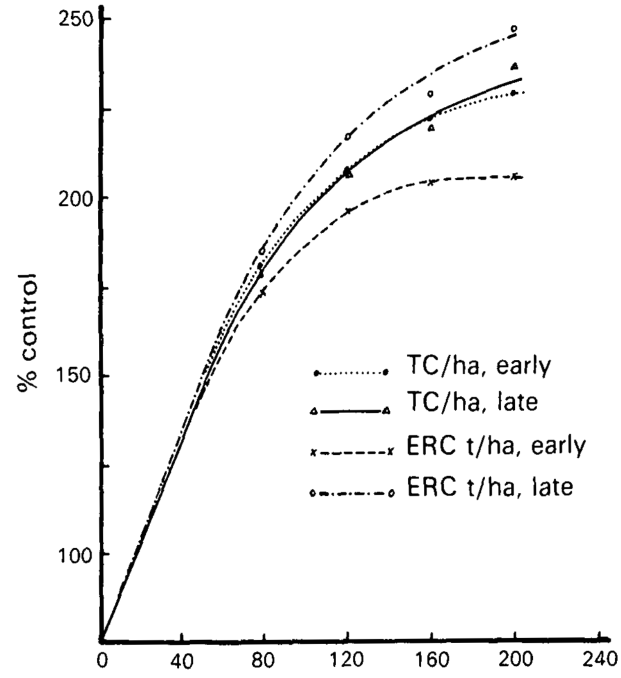

FIGURE 2. Yield responses to nitrogen.

(c) in the case of the early-season trials, the effect of nitrogen in causing a decrease in ERC% cane was reflected by a more quadratic ERC yield response curve. This indicated that early-season crops can attain peak yields with less nitrogen than late-season crops.

In order to determine the effect of nitrogen levels on TF% cane and TF yields, two early and two late-season trials with fairly typical cane yield responses were selected, and TF values were estimated from brix data (Cackett and Rampf[4]). The effect of nitrogen levels on TF% cane is shown in Figure 3.

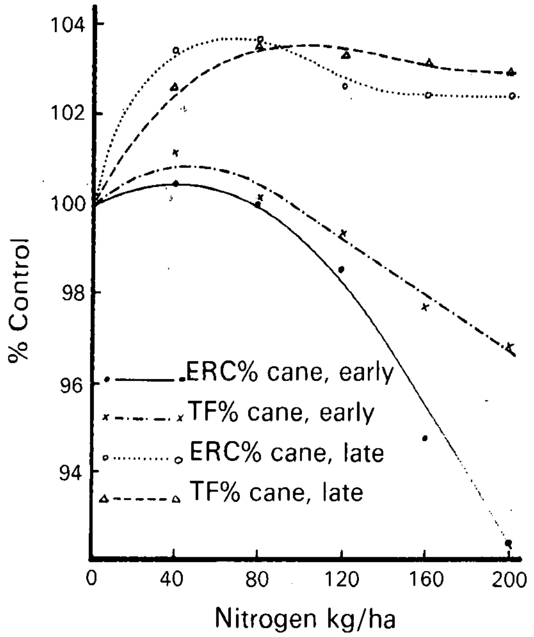

FIGURE 3. Quality responses to nitrogen in early- and late-season cane.

In the late-season trials the TF% cane response was basically the same as the ERC% cane response, with values not significantly affected by level of nitrogen. However, in the early-season trials, the reduction in TF% cane caused by increasing nitrogen levels was considerably less pronounced than for ERC% cane, thus indicating that the yield response patterns were likely to differ.

The effects of nitrogen on yields are shown in Figure 4. Because responses up to 80 kg of nitrogen per ha were all very similar, this point was used as a base in order to show up the responses more clearly. In the early-season trials the cane yield and ERC yield responses followed a typical pattern, but the TF yield responses fell between the two because TF% cane was less severely depressed by increasing levels of nitrogen. In the late-season trials the response trends were the same for all three yield factors, as was expected.

These results indicate that, whereas for optimum sugar yields nitrogen levels should be reduced for crops harvested during the early part of the season, for TF yields, high nitrogen levels can be used throughout the year.

Ripener Effects

Several trials have been conducted in the lowveld to study the effects of chemical ripeners on ERC% cane, with treatments including different sugarcane varieties, varying application rates of different ripeners, different times of application in relation to harvest date, and application at different times of year to study seasonal responses. Results of these trials have been reported (Anon[1, 2]), but no consideration was given to the effects of treatment on total fermentable sugars.

Estimates of TF% cane were derived from brix values for comparison with ERC% cane responses in a trial comparing three ripeners each at two application rates applied to three varieties twelve weeks before harvest in mid-May. Treatments were sampled for quality analysis at the time of spraying, six weeks later, and again at harvest twelve weeks after application. Data for NCo 376 at the lowest rate for each ripener are shown in Table 1, meaned for the plant and first ratoon crops.

These data have been plotted in Figure 5, where it can be seen that although the ripeners had a marked effect on TF% cane, responses were less pronounced than in the case of ERC% cane. Similar responses were recorded in other chemical ripener trials, with the TF% cane response being less than the ERC% cane response in all cases.

These responses are better represented in terms of yield because ripeners have the effect of causing small yield reduc-

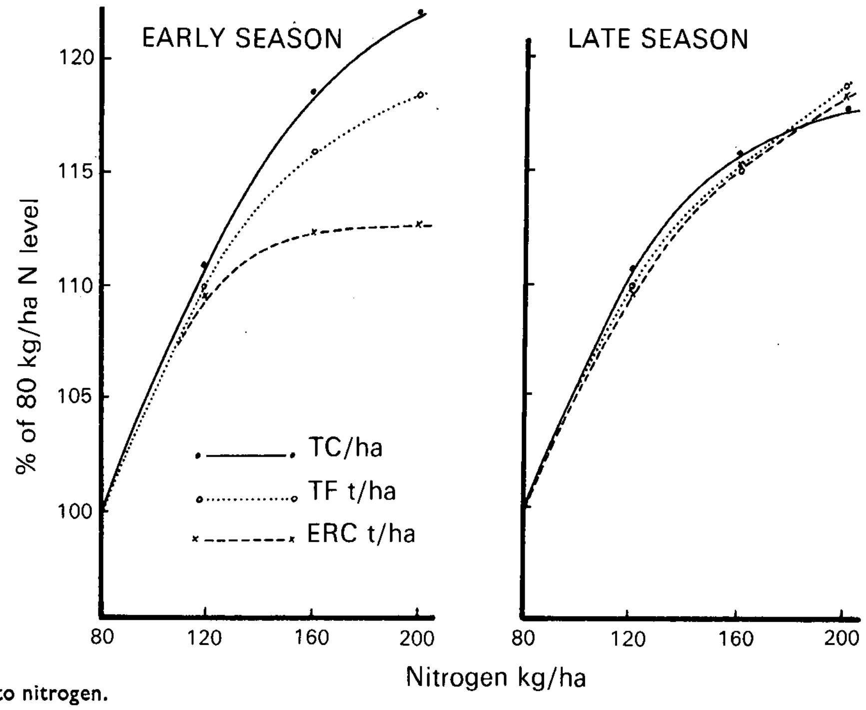

FIGURE 4. Yield responses to nitrogen.

TABLE 1
Quality responses to chemical ripeners

Weeks after spraying	ERC% cane			Brix% cane			TF% cane		
	0	6	12	0	6	12	0	6	12
Control	7,33	9,73	10,78	11,84	13,50	14,25	10,87	12,49	13,23
Polaris at 4 kg/ha a.i.	7,33	10,61	12,47	11,84	14,70	16,00	10,87	13,67	14,94
Embark at 0,75 kg/ha a.i.	7,33	10,62	12,21	11,84	14,50	15,65	10,87	13,47	14,60
Ethrel at 0,75 kg/ha a.i.	7,33	10,31	12,03	11,84	14,30	15,15	10,87	13,28	14,11

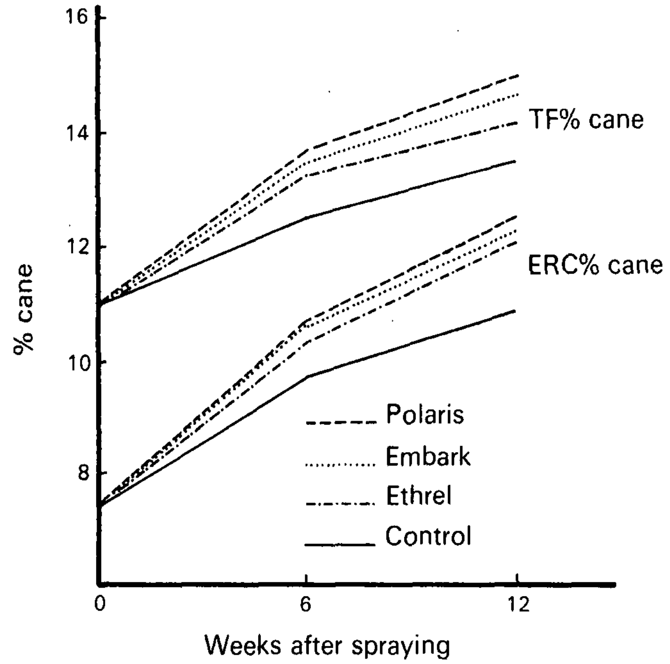

FIGURE 5. Effect of ripeners on ERC% and TF% cane.

tions. Table 2 shows results for NCo 376 from three trials all harvested in April/May.

The ERC yield response was consistently greater than the TF yield response in all trials, with mean increases of 13,4% and 5,5% respectively. Whereas ripeners have the effect of increasing pol% cane, they lower RS% cane because of the check on cane growth. Thus the percentage increase of total fermentables (pol + 0,95 RS) is less than the percentage increase of sucrose.

Deterioration Effects

Quality deterioration in cane begins from the moment of harvest, following which loss of sucrose is caused by the enzyme invertase converting sucrose to inverts and thus lowering the purity of the juice. The rate of sucrose inversion varies with temperature, moisture and variety, and it is generally accelerated by burning, freezing and mechanical damage (Meade and Chen[7]).

Trials have been conducted in the lowveld to study loss of sucrose in stacked cane after burning, and results showed that losses varied with harvest season in accordance with temperature changes (Anon[2]). This is shown in Figure 6, where the drop in ERC% cane has been plotted against days after burning for three harvest dates, viz. June (winter), September (spring), and December (summer). The data represent means of four varieties at each harvest date, and the means of two ratoon crops, all adjusted for moisture losses.

RS% cane was not measured in this experiment, and brix data were thus used to provide estimates of TF% cane. A comparison of the effects of burning on ERC% cane and ERF% cane is given in Table 3, and the ERF data have been expressed as percentages of Day 1 values and plotted in the lower section of Figure 6.

As expected, results show that losses of recoverable fermentables were relatively small when compared with ERC losses, indicating that the drop in sucrose was mainly associated with inversion to reducing sugars.

The fact that there was a drop in ERF% cane with age after burning showed that there were other losses involved. Irvine[6] found that the soluble polysaccharide content of burned cane increased significantly seven days after burning,

TABLE 2
Effects of ripeners on ERC and TF yields

Trial Ref.	Ripener	kg/ha a.i.	Applied (weeks before harvest)	Yield t/ha			
					Control	Ripener	% increase
7310/5	Polaris	4	8	ERC	14,47	16,26	12,4
(P-2R)				TF	20,36	22,15	8,8
7310/6	Polaris	4	8	ERC	15,91	18,52	16,4
(P-2R)				TF	23,63	25,04	6,0
7310/6	Polaris	4	12	ERC	15,91	18,75	17,9
(P-2R)				TF	23,63	24,85	5,2
7310/7	Polaris	4	12	ERC	16,88	18,82	11,5
(P-1R)				TF	20,81	22,53	8,3
7310/7	Embark	0,75	12	ERC	16,21	17,70	9,2
(P-1R)				TF	20,75	20,99	1,2
7310/7	Ethrel	0,75	12	ERC	16,21	18,27	12,7
(P-1R)				TF	20,75	21,46	3,4
Means	—	—	—	ERC	15,93	18,05	13,4
				TF	21,66	22,84	5,5

TABLE 3
Effect of burning on ERC and ERF% cane

Days after burning	June		September		December	
	ERC % cane	ERF % cane	ERC % cane	ERF % cane	ERC % cane	ERF % cane
1	12,81	14,80	13,54	15,29	12,25	13,74
2	12,80	14,70	13,72	15,33	11,97	13,36
3	12,87	14,51	13,49	15,48	11,62	13,64
4	12,72	14,60	13,53	15,39	11,22	13,51
7	12,41	14,50	12,81	14,90	10,21	13,73
10	12,41	14,56	12,51	15,22	8,83	13,03
14	11,80	14,50	11,01	14,74	7,54	12,45

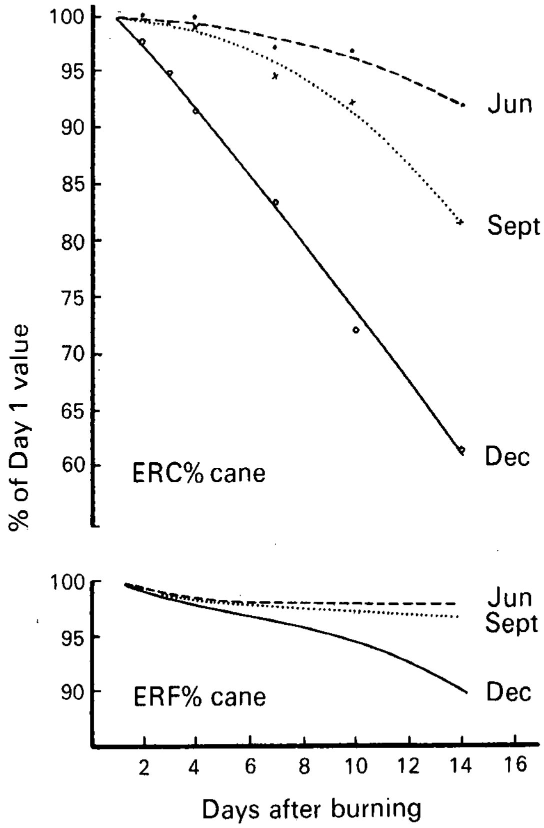

FIGURE 6. Quality losses after burning.

whereas delayed milling of unburned cane produced no measurable increase in soluble polysaccharide content after fourteen days. Bruijn[3] also recorded increases in soluble polysaccharides associated with deterioration after burning, and he showed that fermentation of inverts in the stalk accounted for only very small quantities of ethanol (up to 1% by volume of juice).

While chemical changes must account for some of the sucrose loss during cane deterioration, it is likely that the bulk of this loss is due to decomposition resulting from bacterial action, and direct loss of juice from broken and cracking stalks.

Topping Effects

Studies were conducted in 1980 to compare ERC and ERF yields at different topping heights, with the object of determining whether higher topping was justified in cane harvested for production of total fermentables.

Three separate trials were conducted on un-flowered twelve-month old cane harvested in May, September, and December respectively, and one additional trial was done on flowered cane harvested in October.

Each trial included eleven treatments with six replications, with each "plot" comprising thirty stalks randomly selected from a commercial field. All stalks were burnt but untopped. Stalks were individually measured and weighed before being partitioned for quality analysis in accordance with the following treatments :

To : All stalks topped at the natural breaking point (NBP); tops individually measured to obtain an average length; then all thirty bulked, weighed, and analysed.

T1 : One internode removed per stalk, i.e. the internode immediately below the NBP; individual lengths recorded; all thirty bulked, weighed, and analysed.

T2 - T9 : As for T1, progressing in single internode steps to the 9th internode below the NBP.

T10 : Remaining portions of stalk individually measured and internodes counted; total weight recorded; analysis conducted on three separate sub-samples after shredding.

From the data collected it was possible to calculate changes in plant mass and height at different topping positions (Table 4), and also changes in the different quality parameters. The effects of varying amounts of top removal on yields of ERC and ERF are shown in Tables 5 and 6.

Figures 7, 8 and 9 show the effects of different topping heights on ERC and ERF yields in un-flowered cane harvested in May, September and December respectively. In the early-season crop (May) it was apparent that ERC yields only started dropping after removal of 1 — 2 internodes below the NBP, but that highest ERF yields were obtained with whole-stalk harvest and a loss in yield was evident even at the highest topping position. In September, ERC yield declined after topping at the NBP, but highest ERF yields were again obtained with whole stalk harvest. In the late-season crop ERC yields were improved with topping, and losses were only recorded when topped lower than the third internode below the NBP. The decline in ERF yields was less marked than at earlier harvests, with only a very small proportion lost by topping at the NBP.

In terms of total plant mass, results indicated that in the early and late-season crops about 15% of whole stalk mass could be discarded as tops without affecting ERC yields, but that in September higher topping was desirable with only about 7% discarded. For optimum ERF yields, however, untopped cane would be preferable throughout the year, but particularly early in the season when the tops have a high reducing sugar content.

TABLE 4
Mass and height of 30 stalks at different topping positions

Treatment	Mass % whole stalk				Height % whole stalk			
	Un-flowered			Flowered	Un-flowered			Flowered
	May	September	December	October	May	September	December	October
WS (whole stalk)	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
WS — To ..	90,94	93,08	91,88	96,80	86,10	90,19	85,89	86,71
WS — (To-1) ..	88,64	91,46	89,97	95,62	82,94	88,17	83,34	83,82
WS — (To-2) ..	85,66	89,67	88,04	94,22	79,39	86,06	81,04	81,36
WS — (To-3) ..	82,32	87,53	86,12	92,53	75,59	83,33	78,92	78,80
WS — (To-4) ..	78,73	84,85	84,17	90,58	71,64	80,11	76,98	76,03
WS — (To-5) ..	74,99	81,65	81,83	88,39	67,56	76,05	74,67	72,94
WS — (To-6) ..	71,09	77,97	79,02	85,90	63,43	71,37	72,10	69,46
WS — (To-7) ..	67,15	73,78	76,01	82,95	59,38	66,17	69,53	65,49
WS — (To-8) ..	63,26	69,08	72,95	79,43	55,48	60,69	67,02	61,18
WS — (To-9) ..	59,31	63,93	69,73	75,20	51,54	55,01	64,23	56,56
Means ..	78,37	82,98	83,61	89,24	72,10	77,92	86,70	75,67

TABLE 5
ERC yields in relation to topping heights

Treatment	kg/30 stalks				% whole stalk value			
	Un-flowered			Flowered	Un-flowered			Flowered
	May	September	December	October	May	September	December	October
WS (whole stalk)	4,87	4,18	3,72	5,95	100,00	100,00	100,00	100,00
WS — To ..	4,89	4,17	3,75	5,94	100,41	99,76	100,81	99,83
WS — (To-1) ..	4,88	4,15	3,75	5,92	100,21	99,28	100,81	99,50
WS — (To-2) ..	4,85	4,12	3,74	5,86	99,59	98,56	100,54	98,49
WS — (To-3) ..	4,79	4,06	3,72	5,79	98,36	97,13	100,00	97,31
WS — (To-4) ..	4,68	3,96	3,67	5,68	96,10	94,74	98,66	95,46
WS — (To-5) ..	4,54	3,83	3,60	5,56	93,22	91,63	96,77	93,45
WS — (To-6) ..	4,37	3,67	3,49	5,43	89,73	87,80	93,82	91,26
WS — (To-7) ..	4,17	3,48	3,36	5,26	85,63	83,25	90,32	88,40
WS — (To-8) ..	3,97	3,26	3,23	5,05	81,52	77,99	86,83	84,87
WS — (To-9) ..	3,74	3,01	3,09	4,79	76,80	72,01	83,06	80,50
LSD P = 0,05	0,04	0,04	0,03	0,04	0,82	0,96	0,81	0,67
P = 0,01	0,05	0,05	0,04	0,06	1,03	1,20	1,08	1,01
Mean ..	4,52	3,81	3,56	5,57	92,87	91,10	95,60	93,55
SE mean ± ..	0,01	0,01	0,01	0,02	0,21	0,24	0,27	0,34
CV %	0,73	0,90	0,70	0,67	0,73	0,90	0,70	0,67

TABLE 6
ERF yields in relation to topping height

Treatment	kg/30 stalks				% of whole stalk value			
	Un-flowered			Flowered	Un-flowered			Flowered
	May	September	December	October	May	September	December	October
WS (whole stalk)	5,55	4,49	4,07	6,24	100,00	100,00	100,00	100,00
WS — To ..	5,44	4,43	4,03	6,21	98,02	98,66	99,02	99,52
WS — (To-1) ..	5,39	4,40	4,01	6,17	97,12	98,00	98,53	98,88
WS — (To-2) ..	5,31	4,36	3,98	6,11	95,68	97,10	97,79	97,92
WS — (To-3) ..	5,19	4,28	3,94	6,02	93,51	95,32	96,81	96,47
WS — (To-4) ..	5,04	4,17	3,88	5,91	90,81	92,87	95,33	94,71
WS — (To-5) ..	4,86	4,04	3,80	5,77	87,57	89,98	93,37	92,47
WS — (To-6) ..	4,64	3,86	3,68	5,63	83,66	85,97	90,42	90,22
WS — (To-7) ..	4,42	3,66	3,54	5,45	79,64	81,51	86,98	87,37
WS — (To-8) ..	4,19	3,42	3,40	5,22	75,50	76,16	83,54	83,65
WS — (To-9) ..	3,93	3,16	3,25	4,95	70,81	70,38	79,85	79,33
LSD P = 0,05	0,05	0,04	0,02	0,04	0,90	0,89	0,49	0,64
P = 0,01	0,06	0,06	0,03	0,06	1,08	1,34	0,74	0,96
Mean ..	4,91	4,02	3,78	5,79	88,39	89,63	92,88	92,78
SE mean ± ..	0,02	0,01	0,01	0,02	0,36	0,22	0,25	0,32
CV %	0,84	0,90	0,46	0,67	0,84	0,90	0,46	0,67

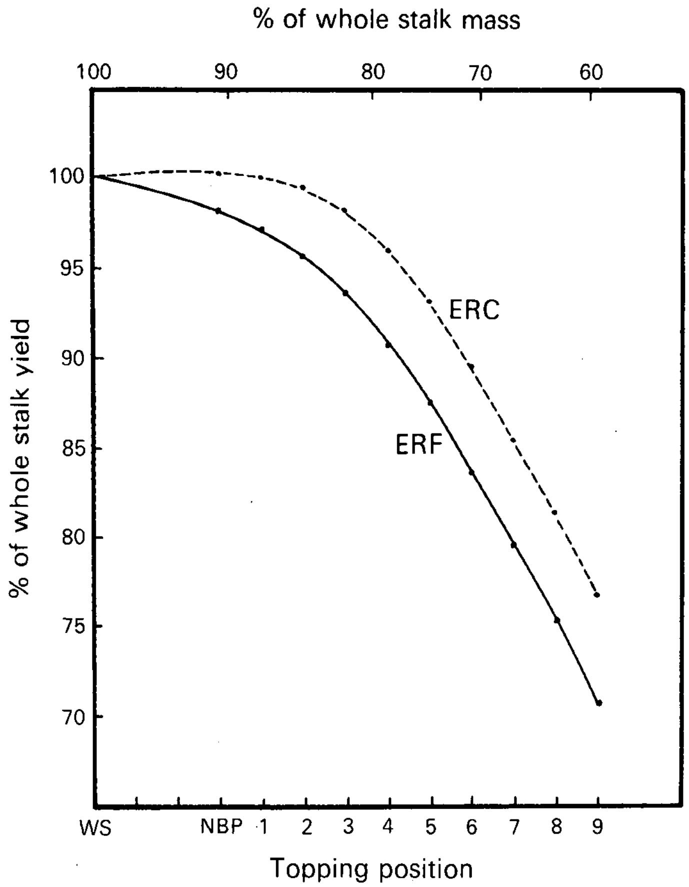

FIGURE 7. May harvest: effect of topping height on ERC and ERF yields.

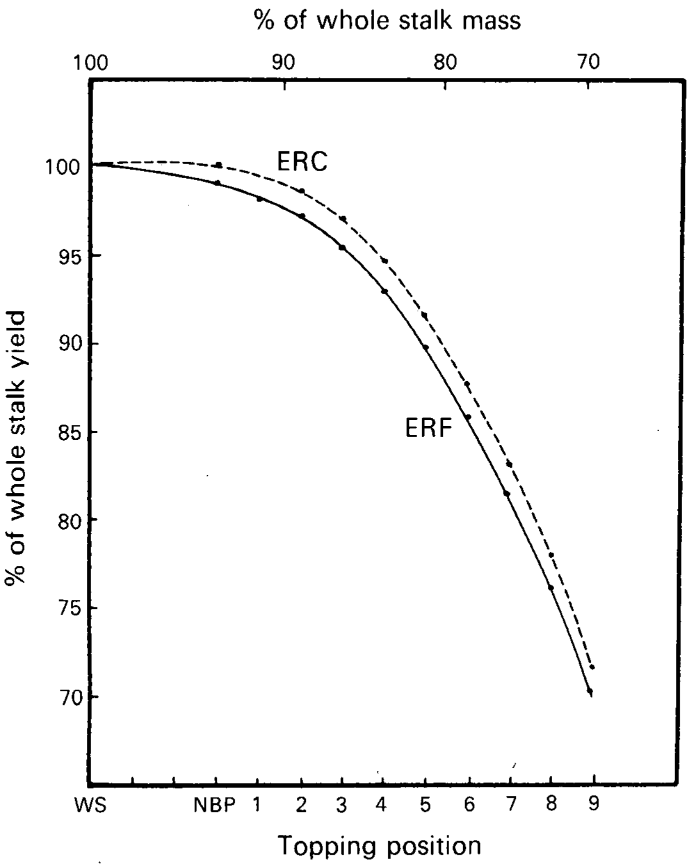

FIGURE 8. September harvest: effect of topping height on ERC and ERF yields.

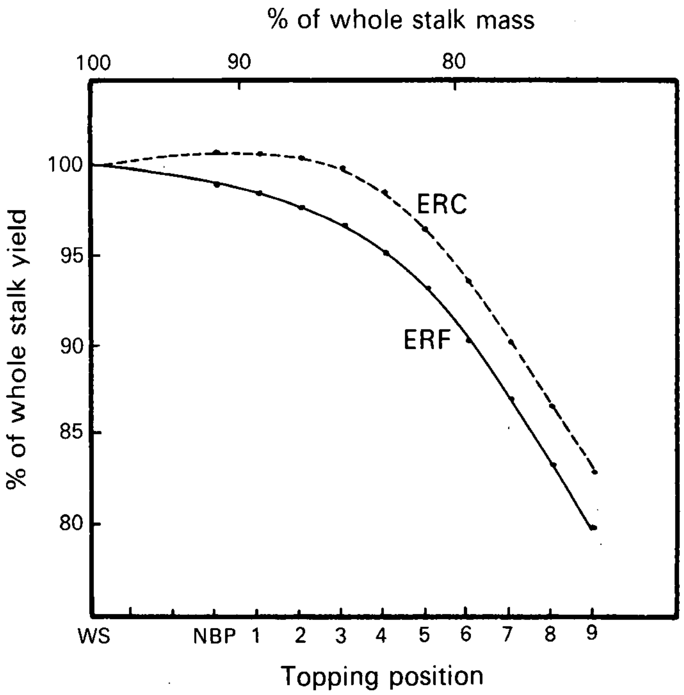

FIGURE 9. December harvest: effect of topping height on ERC and ERF yields.

In the case of flowered cane harvested in October, results showed that topping at the NBP would be satisfactory for both sugar and ethanol production, with less than 0,5% loss in yield in each case.

Discussion

Nitrogen fertiliser practices seem unlikely to require extensive modification on cane grown for ethanol production, although higher levels of nitrogen early in the season would be of benefit. It is possible that TF yields could be improved with a more balanced supply of nitrogen, with late top-dressing aimed at sustaining active growth through to harvest. Trials are in progress which will give valuable information in this regard, and others are being planned to study the effects on quality of using luxury fertility and moisture regimes to maximise cane yields.

Chemicals are now extensively used on a commercial scale to accelerate the ripening process in sugarcane, their main effect being to store that proportion of sucrose which would normally have been inverted to sustain growth in immature cane. Ripening is not necessary in the growing of sugarcane for ethanol, because reducing sugars are equally as important as sucrose in the fermentation processes. Chemical ripeners nevertheless cause an increase in TF yields, although to a lesser extent than ERC yields, but the relatively small increase may be difficult to justify in economic terms.

Quality deterioration after harvest is a serious problem in cane grown for sugar production because it results in a direct loss of sugar from inversion. While every effort is normally made to get cane to the mill as soon as possible after harvest, unavoidable delays frequently arise because of mill stops, excessive rain, etc., and they can lead to considerable yield losses, particularly during hot weather and in cane which has been chopper harvested. The fact that deterioration losses are much less in cane harvested for total fermentables is a bonus for ethanol producers, but it does not serve to alter management practices in any way.

Optimum topping height must be evaluated, not only in agronomic terms based on cane quality criteria, but also in

TABLE 7
ERC and ERF content of tops

Component	May		September		December		October (flowered)	
	ERC % cane	ERF % cane	ERC % cane	ERF % cane	ERC % cane	ERF % cane	ERC % cane	ERF % cane
To*	– 0,53	2,94	0,53	2,86	– 1,10	1,64	0,63	2,55
T1	0,89	4,81	3,30	5,59	0,13	4,34	6,44	8,29
T2	2,67	6,55	5,78	7,61	1,38	4,98	9,23	10,92
T3	4,94	8,50	8,90	10,29	4,16	7,12	11,92	13,51
T4	7,11	10,40	11,19	12,35	7,60	9,88	13,41	14,82
etc.								

* To = top above NBP; T1 = 1st internode below NBP; T2 = 2nd internode below NBP; etc.
.... economic optimum topping position.

economic terms related to the cost of transporting and milling material with low ERC or ERF content.

As an incentive for producers to send only high quality cane for milling, a cane payment formula is used which relates the price per ton of cane to $E - 0{,}35\bar{E}$, where E is the ERC or ERF% cane of the consignment; $\bar{E}$ is the industrial average value, and 0,35 represents the millers' share of the cane. In the 1980 season at the Triangle Mill, the average percentages of ERC and ERF were 11,48 and 13,31 respectively. When multiplied by 0,35, these figures showed that any cane sent for milling which was less than 4,02% ERC or 4,66% ERF would have represented a direct loss of income to the grower. For practical purposes these figures may be rounded off to 4% and 5% respectively, and they provide a means of assessing the optimum topping height in economic terms when related to the ERC and ERF contents of the tops (Table 7).

Results showed that it was not economic to mill untopped cane for ethanol production because the gain in ERF yield was small in relation to the throughput of fibre. During early and mid-season there was a benefit in topping higher for ERF yield than for ERC yield, but optimum topping heights were the same late in the season and in flowered cane.

Conclusion

High yields of recoverable fermentables for ethanol production can be achieved using the field management practices recommended for optimum sugar yields, but productivity can be improved with minor changes in agronomic practice. However, a high standard of field management, coupled with adequate consideration of economic influences, would be necessary for the potential gains to be of measurable benefit.

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