

THE INFLUENCE OF DROUGHT ON CANE QUALITY AND YIELD, AND ITS EFFECT ON THE CURRENT CANE PAYMENT SYSTEM IN ZIMBABWE

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Abstract

Rain in the 1995-96 season was delayed and only started in mid-January. Irrigation on Mkwazine Estate was severely restricted and yields were reduced to between 44 and 101 tons cane per hectare (normally about 120 t/ha). An opportunity was taken to study the influence of drought on the variability in yield and quality and its effect on the cane payment system. The Zimbabwe sugar industry cane payment system is based on estimated recoverable crystal (ERC). Standard errors (SEs) in ERC % cane expected with the present accepted sampling rate of one in 50 tons were determined for small, medium and large producers. Cane samples were taken for direct analysis of cane (DAC) from selected fields and from bundles delivered to the factory in early, mid and late season. The data obtained validated the cane payment system and sampling frequency in midseason when the cane was reasonably uniform. Here the SEs of the ERC % cane were within the expected limits, despite the atypical season. Cane uniformity and the SEs for ERC % cane were worst in early and late season and greater than anticipated. The influence of production per week on calculated SEs of mean ERC % cane is discussed. In 'abnormal' years SEs may be improved by increasing the sample rate and weight.

Keywords: cane yield, cane quality, drought, ERC % cane, cane payment, Zimbabwe

Introduction

In Zimbabwe, sugarcane farmers are paid according to the tonnage of sugar produced, which is expressed as estimated recoverable crystal (ERC). The tonnage of ERC produced is obtained by multiplying the weight of cane stalks delivered to the mill by the ERC % cane value obtained from direct analysis of cane (DAC) as recommended (Anon, 1985). ERC % cane is a cane quality parameter calculated from the formula

$$\text{ERC \% cane} = a.\text{pol} - b.\text{non-pol} - c.\text{fibre}$$

where all variables are expressed as % cane, and where the constants a, b and c are derived from mill performance data to represent pol losses in filtercake, molasses and bagasse respectively. In the mill laboratories where the DAC is done for cane payment, the constants in the formula are changed annually in accordance with variability in mill performance. However,

¹Agreement between Sugarcane Growers and Millers of Zimbabwe (ERC Committee, 1992)

to ensure continuity and uniformity of presentation of research data, the following standard ERC % cane formula, with fixed a, b and c constants, is used at the Zimbabwe Sugar Association Experiment Station:

$$\begin{aligned} \text{ERC \% cane} &= 0,980 \text{ pol \% cane} \\ &- 0,417 \text{ non-pol \% cane} - 0,035 \text{ fibre \% cane.} \end{aligned}$$

Samples of stalks are taken for DAC when cane is delivered to the mill. 'Grab' sampling is used at Hippo Valley Estates mill, and 'swing' sampling is used at Triangle mill. The grab sampler is a hydraulically operated unit which grabs several stalks from selected cane bundles. Two grabs comprise one sample. The swing sampler is designed to obtain a sample from the full width and depth of the cane while it is in a state of free fall from one conveyor to the next (Anon, 1985). Two 'cuts' comprise one sample. The weight of cane delivered to the mill is measured accurately at weighbridges using calibrated scales certified by the government assize department to a tolerance of 20 kilograms. Variability arises when relating the ERC % cane value obtained in the DAC laboratory to the true ERC % cane of the entire consignment. Producing a representative cane sample that can give a true ERC % cane value from DAC analysis is not possible. Each sample has an associated standard error (SE) or reliability. As the sampling rate and sample weight increase, the ERC estimate should come closer to the true ERC % cane value. Sampling and analyses cost money and a decision has to be made on what an acceptable and cost-effective sampling rate should be. In the Zimbabwe sugar industry, the target rate is one sample for every 50 tons of cane ('unpublished data').

Rains in the 1995-96 season were late and only started in mid-January. Irrigation was severely restricted on Mkwazine Estate for all fields harvested in 1995. Most of these fields received only one or two irrigations after cutting and were severely stressed until the rains broke. It was obvious that cane growth would be adversely affected and cane yields greatly reduced by the drought. The opportunity was taken to test the reliability of the cane payment system while drought increased variability within each field.

The three phases of the investigation were:

- to examine the uniformity of cane in commercial fields after a drought by analysing yields, and estimating ERC % cane and other stalk parameters and their associated SEs at various sampling rates

- to establish the reliability expected from the present one in 50 tons cane sampling system used for cane payment, by calculating from statistics the expected SEs in ERC % cane for small (10 ha), medium (100 ha) and large (10 000 ha) scale cane producers for one week, one month, one season and 10 seasons
- to evaluate the effect of drought on the cane payment system by comparing the actual SEs obtained in the field for the one in 50 tons target sampling rate with the expected SE from statistics for the same sampling rate.

Method

Estimation of cane uniformity using ERC% cane and other millable stalk parameters

Fields, water, varieties and age of cane

Details of fields, water applied, varieties and ages of cane sampled are given in Table 1.

At each sampling, 100 samples comprised of four millable stalks each, were taken from the field. These 'field' samples were from standing cane after burning but before cutting and were evenly distributed over the area sampled. The cane was burnt in the afternoon; sampling and cutting were done the following morning. The harvested cane was despatched to the mill in bundles and crushed within 36 hours of cutting. One sample of four stalks was taken from each bundle immediately before crushing. These samples were termed 'mill' samples.

Early season sampling

An area of 5,46 hectares was sampled in early season. The cane harvested from the area comprised 46 bundles and the cane yield was 43,87 tons per hectare.

Mid-season sampling

The area sampled in mid-season was 1,10 hectares. Cane yield was 100,85 tons per hectare, and 22 bundles of cane were obtained.

²TR Loudon, 1987 Cane Sampling Enquiry. South African Sugar Association Central Board.

Late season sampling

The 2,35 hectares sampled had a cane yield of 84,80 tons per hectare and produced 39 bundles of cane.

Statistical analyses

Means were calculated for ERC % cane, purity, fibre % cane and for cane lengths, diameters and weights. Equation 1 was used to obtain SEs for ERC % cane, fibre % cane and purity:

$$\text{Standard error} = \left(\frac{\sum(x - \bar{x})^2}{(n - 1)} \right)^{0.5} \quad (1)$$

Data from the 100 samples were statistically analysed. Adjacent sample numbers were then paired and averaged to give 50 samples of eight stalks each. These were further successively paired, averaged and statistically analysed in the same fashion to give samples consisting of 16 and 80 stalks, with the sample numbers falling to 25 and 5 respectively.

Present cane sampling and payment system

SEs expected from statistics for periods of up to 10 seasons

SEs of ERC % cane expected with the present cane sampling system were calculated using a table of standard deviations (²unpublished data) (Table 2) and the statistical Equation 2.

Standard error of the combined test average consignment tests

$$= \frac{\text{standard deviation of a single consignment test}}{\text{square root of 'n'}} \quad (2)$$

where n = the number of consignments.

SEs of ERC % cane expected from statistics for hypothetical yield

The hypothetical yield was assumed to be 115,2 tons cane per hectare and consignments consisted of multiples of eight bundles of six tons each, delivered each week over a milling season of 24 weeks. The SE calculations were made for small, medium and large scale producers. The hypothetical cane yield was chosen to give a yield which:

Table 1
Field and crop data for samples of sugarcane taken in early, mid and late season at Mkwazine Estate, Zimbabwe, and water received by the crop.

Season	Date	Section	Field	Variety	Crop	Age (months)	Water (mm)		
							Rainfall	Irrigation	Total
Early	3 June	7	83C	N14	2R	12,7	666	249	915
Mid	19 August	5	74I	N14	P	15,2	678	700	1 378
Late	29 October	5	73E	NC0376	1R	11,9	679	679	1 292

- was close to the industrial average of 120 tons per hectare per annum
- gave round figures for tons cane cut, cane bundles, samples taken and harvest weeks.

Actual ERC % cane SEs of the hypothetical consignments

Actual SEs were obtained thus:

- the tonnage of cane (A) for each area sampled was calculated
- the number of cane samples (B) that would have been taken on this tonnage at the normal sampling rate of one in 50 tons was determined
- the total number of cane stalks that would have been sampled (C) was obtained by multiplying B by four
- the SE (D) corresponding to field samples containing C stalks in the correct part of the season was determined by calculations similar to those used to produce data in Table 1.

SE (D) was assumed to be an accurate estimate of the standard deviation of ERC % cane for the one in 50 tons sampling rate.

Table 2
Standard deviation of sucrose % cane for various sampling rates.

No. bundles in sample	Standard deviation of single consignment test, expressed in test units of sucrose % cane				
	No. bundles in consignment				
	8	6	4	3	1
8	0,44	–	–	–	–
7	0,48	–	–	–	–
6	0,53	0,51	–	–	–
5	0,59	0,58	–	–	–
4	0,67	0,66	0,63	–	–
3	0,78	0,77	0,75	0,73	–
2	0,97	0,96	0,95	0,93	–
1	1,39	1,39	1,38	1,36	1,26

Actual SEs for the hypothetical yield

In a reasoning similar to the one used to derive Table 2, it was assumed that A was the consignment for each part of the season; the actual SEs (E) for early, mid and late season for small, medium and large scale producers for cane tonnages equivalent to the hypothetical yield of 115,2 tons per hectare, delivered in similar consignments, were calculated using Equation 2.

The effects of drought

Drought effects were evaluated by comparing the actual SEs of the hypothetical yield with the SEs expected from statistics.

Calculations

Calculations done to obtain derived data presented in this paper are detailed in Appendixes 1 to 4.

Results and Discussion

Cane uniformity

Mid-season cane had thicker and longer stalks and appeared to be more uniform than that sampled in early and late season. The cane yield was related to the combined rainfall and irrigation water levels. Table 1 shows that early season cane received the least irrigation. Although rainfall on the three fields was similar, early season cane benefited only marginally from the rain as it did not have a long growing period before harvest. Mid and late season cane benefited more since it was already better developed when the rains came, having received higher irrigation rates in the early stages, and since it had a longer growing period under better moisture conditions. Table 3 shows that in all parts of the season the SEs for ERC % cane, fibre % cane and purity decreased as the sample weight increased, indicating that the accuracy of the estimate of the true ERC % cane value increased as the sample size increased.

This was as expected. However, for a given sample number the mid-season cane gave smaller SEs than did early and late season cane. This showed that the cane was most uniform in the mid-

Table 3
Effect of sample size on reliability of direct analysis of cane.

No. stalks per sample	No. of samples	Sample weight (kg)			Standard errors								
					ERC % cane			Fibre % cane			Purity (%)		
		Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
4	100	2,32	5,08	3,54	1,19	0,64	1,08	1,17	0,90	1,59	2,79	1,29	3,98
8	50	4,64	10,16	7,08	1,02	0,51	0,82	0,94	0,70	1,35	2,16	1,02	3,06
16	25	9,28	20,32	14,16	0,91	0,42	0,73	0,71	0,46	1,26	1,79	0,80	2,77
80	5	46,40	101,60	28,32	0,64	0,07	0,26	0,35	0,20	1,13	1,10	0,41	0,44

season where the highest cane yield was obtained and less uniform in the early and late season. Trends in stalk weights, lengths and diameters were similar.

Table 4 gives means of ERC % cane, fibre % cane, purity and stalk weights, lengths and diameters for samples taken in the field and from bundles in the mill.

There were no significant differences in ERC % cane, fibre % cane and purity between field and mill data in the early season. This showed that conclusions drawn from data of cane samples taken in the field should apply to DAC sampling done in the factory before milling. However, there were significant differences ($P = 0,05$ and $0,001$) in ERC % cane between field and mill samples in the mid and late season respectively. These significant differences appear to have been partly due to cane deterioration as the mid and late season samplings were done in early and midsummer when the weather was hot, and the early season sampling was done in cold weather in mid-winter. Since growers aim to deliver cane to the mill before significant deterioration has taken place, the conclusions drawn from field data will be applicable to cane which has not deteriorated significantly between burning and milling for the mid and late season.

Present sampling and cane payment system

SEs expected from statistics for periods up to 10 seasons

The expected SEs for each of these producers for weekly, monthly, one season and 10 seasons are given in Table 5. The SEs show that the accuracy of the ERC % cane estimate from DAC analysis:

- increased as the amount of cane delivered increased

- increased for each producer as the season progressed and more cane was delivered
- for any period was better for the larger producer as more cane would be delivered per unit of time
- for small and large producers became closer as the amount of cane increased and as the season progressed.

SEs expected from statistics for the hypothetical yield

Harvesting scenarios for small, medium and large scale producers for a hypothetical cane yield of 115,2 tons per hectare are presented in Table 6. SEs expected from statistics are also given.

The following assumptions were made in the table:

- cane yield was 115,2 tons per hectare
- 25% of the crop was harvested in early season, 50% in mid-season and 25% in late season
- each bundle of cane weighed six tons
- one consignment of cane consisted of eight bundles and weighed 48 tons
- a sampling rate of one in 50 tons approximated to one in eight bundles.

The SEs were lowest in mid-season when the majority of the cane was delivered. The larger the producer, the lower was the SE and therefore the more accurate was the ERC % cane estimate.

Actual SEs of the hypothetical consignments

Actual SEs of the hypothetical consignments are given in Table 7. Mid-season cane had the lowest SE per consignment.

Table 4
Data means for samples from the field and from bundles before milling.

DAC analysis											
Season	No. samples		ERC % cane			Fibre % cane			Purity (%)		
	Field	Mill	Field	Mill	Significance	Field	Mill	Significance	Field	Mill	Significance
Early	100	46	9,89	9,98	NS	13,84	13,56	NS	84,95	84,16	NS
Mid	100	44	12,06	12,35	*	14,62	14,93	NS	88,94	90,38	***
Late	100	78	12,33	13,03	***	15,17	14,48	**	83,17	85,10	***

Stalk parameters											
Season	No. samples		Stalk weight (kg)			Stalk length (m)			Stalk diameter (cm)		
	Field	Mill	Field	Mill	Significance	Field	Mill	Significance	Field	Mill	Significance
Early	100	46	0,59	0,52	*	1,33	1,27	NS	2,48	2,21	***
Mid	100	44	1,27	1,23	NS	2,48	2,61	*	2,49	2,34	***
Late	100	78	0,89	0,84	NS	2,03	2,05	NS	2,46	2,53	*

Table 5
Expected standard error of average ERC % cane.

Type of producer	Weekly	Monthly	Seasonally	10 seasons
Small (10 ha)	1,3900	0,6950	0,2837	0,0897
Medium (100 ha)	0,4396	0,2198	0,0897	0,0284
Large (10 000 ha)	0,0440	0,0220	0,0090	0,0028

Actual SEs of the hypothetical yield

Actual SEs calculated for the hypothetical yield and the SEs expected are given in Table 8.

The effect of drought

Cane harvested in mid-season gave SEs which fell within the expected range of SEs, while early and late harvested cane had SEs outside the expected tolerances. These results have shown that the ERC % of mid-season cane was accurately predicted by the current payment system whereas those of early and late season cane were not. For the small scale producer, the late season SE was only 0,0398 units outside the range showing that the cane was more uniform than in early season when the SE was out by 0,2265 units. Trends were similar for medium

and large scale producers, with the latter being out by a non-significant 0,0013 units in late season. Results showed that, as expected, accurate estimation of ERC % cane was closely associated with cane uniformity.

The unavailability of irrigation water and late rains are factors that do not normally occur simultaneously in the region. When irrigation water is assured, as is usually the case, cane uniformity improves, provided the producer adopts good cane husbandry practices. Although the present cane payment system has thus been validated for 'normal' years, in 'abnormal' years lack of uniformity has been shown to reduce the accuracy of the estimation of ERC % cane. Flowering would also be expected to have some impact, especially in late season.

Effect of sample weight on accuracy of ERC % cane estimate

In abnormal years the number of stalks per sample may be increased to ensure that the expected SEs are achieved. Actual SEs were calculated for each sample size given in Table 3 for small, medium and large producers for early and late season. Sample sizes required for SEs to fall within tolerances were obtained from graphs of sample size against actual SEs and are given in Table 9.

Table 6
Cane deliveries and SEs of ERC % cane expected from statistics over 24 weeks with the present payment system and a cane yield of 115,2 tons per hectare.

Producer	Small			Medium			Large		
	10			100			10 000		
Area (ha)	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Season	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
% cut	25	50	25	25	50	25	25	50	25
Tons cane cut	288	576	288	2 880	5 760	2 880	288 000	576 000	288 000
Total bundles	48	96	48	480	960	480	48 000	96 000	48 000
Total samples taken (1 in 8 bundles)	8	16	8	80	160	80	8 000	16 000	8 000
Harvest time	1 - 6	7 - 18	19 - 24	1 - 6	7 - 18	19 - 24	1 - 6	7 - 18	19 - 24
Consignments	6	12	6	60	120	60	6 000	12 000	6 000
Expected SE	0,5675	0,4013	0,5675	0,1794	0,1269	0,1794	0,0179	0,0127	0,0179
Bundles/consignment	8			8			8		
Consignments/week	1			10			1 000		
Consignments/month	4			40			4 000		
Consignments/season	24			240			24 000		

Table 7
Actual SEs of hypothetical consignments in sampled areas.

Season	Cane yield (t/ha)	Area (ha)	A Consignment (t)	B Samples required	C Number of stalks	Weight of stalks (kg)	D SE of A (field samples with C stalks)
Early	43,87	5,46	239,89	5	20	11,70	0,87
Mid	100,85	1,10	110,66	2	8	4,64	0,51
Late	84,80	2,35	199,29	4	16	9,28	0,73

Table 8
Effect of drought on expected ERC % cane SEs when 25% cane is harvested in early and late season, and 50% in mid season.

Season	Producer	Actual SE from samples taken	Expected SE (ex Loudon)	Difference
Early	Small	0,7940	0,5675	+0,2265
	Medium	0,2511	0,1794	+0,0717
	Large	0,0251	0,0179	+0,0072
Mid	Small	0,2235	0,4013	-0,1778
	Medium	0,0707	0,1269	-0,0562
	Large	0,0071	0,0127	-0,0056
Late	Small	0,6073	0,5675	+0,0399
	Medium	0,1920	0,1794	+0,0126
	Large	0,0192	0,0179	+0,0013

Table 9
Sample size for SEs to fall within tolerances.

Producer	No. stalks required per sample size	
	Early season	Late season
Small	80	19
Medium	58	16
Large	89	16

Larger sample sizes of up to 89 stalks were required in early season, and lower sizes of up to 19 stalks in late season because cane growth was more variable in early season. Sample sizes required will vary depending on cane uniformity in a particular abnormal season. However, it will be difficult to ensure that proper sampling, adequate mixing and representative sub-sampling are done when dealing with large sample sizes.

Conclusions

This investigation, done in one of the lowest rainfall seasons in the region and when irrigation water was severely restricted, demonstrated that it is not possible to obtain an ERC % cane value that coincides precisely with the true ERC % cane value that would be obtained if all stalks from a specific cane field

were treated as one sample and analysed. The ERC % cane value obtained in the DAC laboratory will always have a standard error associated with it and, in this study, the SE was lowest in mid-season.

The results have shown that the more uniform the cane, the greater the accuracy of the DAC analysis. Although moisture stress during drought is usually unavoidable, cane producers should endeavour to practice good cane husbandry during these times to improve cane uniformity and, thus, estimates of ERC % cane. Cane producers should also appreciate that, although individual analytical values may be within the range of the SE, the ERC % cane estimate becomes more accurate as the season progresses and as the years pass. At any one time, the larger the number of samples and the larger the amount of cane delivered, the more accurate the estimate.

The overall difference between small, medium and large scale producers will lessen over successive seasons, and this should be taken into consideration by the small grower. The mid-season data have validated the cane payment system by showing that, in normal seasons when cane fields are expected to have cane with more uniform growth, the present sampling rate of one in 50 tons will give ERC % cane values within the tolerances for cane payment purposes in Zimbabwe. Sampling weights and rates may be increased in abnormal seasons to ensure that SEs of ERC % cane fall within expected ranges.

Acknowledgements

The author would like to thank Mkwasine Estate for allowing cane samples to be taken on the estate, and Hippo Valley Estate and Triangle Ltd for help in collecting mill cane samples and other data. Thanks are also due to Mr M Murdoch, Head: Biometry Department, Mr JH Meyer, Head: Chemistry and Soils Department, SA Sugar Association Experiment Station and Mr MA Brokensha, General Manager: Cane Testing Services, South African Sugar Association, for their help and guidance in the statistical analyses of data. Dr RA Wood, Consultant, SA Sugar Association Experiment Station and Dr M St J Clowes, Director: Zimbabwe Sugar Association Experiment Station, are thanked for their constructive criticism and discussion.

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APPENDIX 1
Calculations of expected SE data in Table 5.

Producer and period	A Consignments	B = square root of A	C = SE of single consignment (from Table 2)	D = C/B = expected SE
SMALL				
Weekly	1	1,00	1,39	1,3900
Monthly	4	2,00	1,39	0,6950
Seasonally	24	4,90	1,39	0,2837
10 seasons	240	15,49	1,39	0,0897
MEDIUM				
Weekly	10	3,16	1,39	0,4396
Monthly	40	6,32	1,39	0,2198
Seasonally	240	15,49	1,39	0,0897
10 seasons	2 400	48,99	1,39	0,0284
LARGE				
Weekly	1 000	31,62	1,39	0,0440
Monthly	4 000	63,25	1,39	0,0220
Seasonally	24 000	154,92	1,39	0,0090
10 seasons	240 000	489,90	1,39	0,0028

APPENDIX 2
Calculations of expected SE data in Table 6.

Producer and period	A Consignments	B = square root of A	C = SE of single consignment (from Table 2)	D = C/B = expected SE
SMALL				
Early	6	2,45	1,39	0,5675
Mid	12	3,46	1,39	0,4013
Late	6	2,45	1,39	0,5675
MEDIUM				
Early	60	7,75	1,39	0,1794
Mid	120	10,95	1,39	0,1269
Late	60	7,75	1,39	0,1794
LARGE				
Early	6 000	77,46	1,39	0,0179
Mid	12 000	109,54	1,39	0,0127
Late	6 000	77,46	1,39	0,0179

APPENDIX 3
Calculation of actual SEs for Table 8.

Producer and season	A Consignment (t)	B Cane (t)	C = B/A = consignments	D = square root of C	E = stalks for 1 in 50	F = SE of one consignment	G = SE of C consignments
SMALL							
Early	239,89	288	1,2006	1,0957	20	0,87	0,7940
Mid	110,66	576	5,2051	2,2815	8	0,51	0,2235
Late	199,29	288	1,4451	1,2021	16	0,73	0,6073
MEDIUM							
Early	239,89	2 880	12,0055	3,4649	20	0,87	0,2511
Mid	110,66	5 760	52,0513	7,2147	8	0,51	0,0707
Late	199,29	2 880	14,4513	3,8015	16	0,73	0,1920
LARGE							
Early	239,89	288 000	1200,55	34,6490	20	0,87	0,0251
Mid	110,66	576 000	72,1466	72,1466	8	0,51	0,0071
Late	199,29	288 000	38,0149	30,0149	16	0,73	0,0192

APPENDIX 4
Determination of sample size required during drought for the small scale producer.

A No. samples	B Stalks/sample	C Weight of sample	D SE of sample rate	E Consignments	F Square root of E	G = D/F Actual seasonal SE
EARLY						
100	4	2,32	1,19	1,2006	1,0957	1,0860
50	8	4,64	1,02	1,2006	1,0957	0,9309
25	16	9,28	0,91	1,2006	1,0957	0,8305
5	80	46,40	0,64	1,2006	1,0957	0,5841
Target	80					0,5675
MID						
100	4	5,08	0,64	5,2051	2,2815	0,2805
50	8	10,16	0,51	5,2051	2,2815	0,2235
25	16	20,32	0,42	5,2051	2,2815	0,1841
5	80	101,60	0,07	5,2051	2,2815	0,0307
Target	4					0,4013
LATE						
100	4	3,54	1,08	1,4451	1,2021	0,8984
50	8	7,08	0,82	1,4451	1,2021	0,6821
25	16	14,16	0,73	1,4451	1,2021	0,6073
5	80	28,32	0,26	1,4451	1,2021	0,2163
Target	19					0,5675

Actual SEs (D) were plotted against stalk numbers (B). The number of stalks corresponding to the target SE were read from the graph.