ESTIMATING SUCROSE CONTENT IN THE TOP PART OF CANE STALKS TO IDENTIFY OPTIMUM TOPPING HEIGHT

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Abstract

It has been shown that accurate and controlled topping of sugarcane stalks can substantially increase the yield of recoverable sugar produced per hectare. Control of the height of topping may also benefit growers who do not have a direct interest in sucrose recovery since the cost of loading and transporting low quality top material may reduce the profitability of the crop. A means by which the sucrose content of the top 50 cm of stalk can be estimated is described. Samples of 50 stalks were taken from variety trials on the north and south coast of Natal during 1985 and 1986 to establish how variety, crop age, season, numbers of green leaves, and length of the elongating internodes influenced the sucrose and estimated recoverable sugar (ers) contents at the top of cane stalks. More than 85 % of the variation in sucrose content was due to these variables which were used in regression equations to predict the sucrose content and ers at various distances from the apical meristem. The equations were used to show how, if the height of topping was adjusted, the cash value of the crop and cash return after subtracting loading and haulage costs could be affected.

Introduction

The quality of cane sent to the Noodsberg mill during 1979/80 improved considerably after the height of topping was adjusted according to cane maturity and cutters were trained to top consistently (Mann[5]). Correct topping height was ascertained by using data obtained by Wood[8] who showed that the yield of recoverable sugar may be increased by removing as many as 7 internodes when young cane is cut in April. Variety, age and season influenced the vertical distribution of recoverable sugar in stalks and therefore the optimum topping height. Growers who do not benefit directly from mill profits may be interested only in the maximum sucrose yields which can be obtained by topping at the apical meristem. However, the costs of handling low quality stalk material that is often included when the topping height is too high may reduce the profitability of the crop, particularly if the price per ton of cane is low and the distance to the mill is great.

Sucrose storage in the developing cane stalk has been studied in detail by van Dillewijn[6] and has been extensively reviewed by Glaziou and Gayler.[2] Sugars accumulate in the internodes from when they are formed until long after the internode is fully extended. Distribution patterns of sugars and fibre were reported by Fernandes and Benda[1] who confirmed the observations that the quality decreases rapidly near the top of the stalk. They concluded that sugars are concentrated initially at the nodes and later midway between the nodes, where they quickly reach the highest concentration found in the internode. Stalk elongation rate and sucrose storage rate were negatively correlated when cane was grown at different controlled temperatures by Hatch and Glaziou.[3] A negative correlation may therefore be expected between the length of the elongating internodes and sucrose content. The increased sucrose accumulation during water stress has been ascribed to the weakening demand for assimilates in the elongating portion of the stalk (Wardlaw and Passioura[7]). Water stress also increases the rate of leaf senescence and reduces leaf extension rate (Inman-Bamber and de Jager[4]) and the number of green leaves may therefore correlate negatively with sucrose content.

It was thus considered that the number of green leaves and some measure of the current rate of stalk elongation could indicate the sucrose content at the top of the stalk and could be used by growers to control the height of topping.

Methods

Samples containing 50 stalks of 8 varieties were taken from released variety trials during 1985 and 1986 (Table 1). During 1985, the number of green leaves and the distance from the apical meristem to each of the top 18 nodes of 10 out of the 50 stalks in each sample were measured. All 50 stalks were topped at the 5th node, which is the node at the base of the 5th leaf sheath, counting the sheath associated with the youngest leaf that is at least half unfurled as sheath number one. The stalks were then fed into a disintegrator, 1 to 4 internodes at a time, a record being kept of the number of internodes disintegrated on each stalk of each occasion. From this record it was then possible to calculate the length of stalk disintegrated on each occasion. By weighing the stalks before each section was disintegrated, the mass of stalk disintegrated could also be determined. After at least 70 cm of stalk had been treated in this way, the remainder of the stalk was disintegrated as a whole. During 1986, stalks were also topped at the base of the 5th leaf sheath, but the distances from the meristem of only the first 5 nodes were recorded. Stalks were cut into sections 5 or 7 cm long for the first 20 to 28 cm from the 5th node downwards, and then into sections 10 cm long up to 70 or 78 cm from the 5th node. Green leaves were counted and dry matter, brix and sucrose content (pol % determined in a saccharimeter) of each portion were determined.

Results and Discussion

Since sucrose % (S) tended to increase logarithmically to a maximum value with distance from the meristem, a transformation of the form ln(A–S) seemed to be appropriate. The asymptote (A) is the sucrose content at infinite distance from the apex. An asymptote of at least one unit more than the maximum S was required to avoid negative values in the transformed data. The highest sucrose content was almost 19 % and an asymptote of 20 % was thus acceptable.

Green leaf number (LFNO), length of the stalk above the 5th node (TOPD), crop age (AGE) and month of harvest (MN) were included as independent variables together with distance (DIST) in multilinear models that were fitted to the transformed data by least squares analysis. The length from the 5th node to the mid-point of each stalk section was measured. The leaves that were counted included the youngest leaf that was more than half unfurled and the oldest or most necrotic leaf with more than 20 cm of green lamina.

Table 1

Details of trials sampled

Site	Crop age (mths)	Varieties	Soil form	Sampling date
Dalton	23,9	N12, N14, NCo 293, NCo 376	Hutton	1985 31 Jul
Mtubatuba	11,7	N12, N13, NCo 376	Oakleaf	15 Aug
Paddock	14,6	N12, N13, NCo 376	Longlands	28 Aug
Paddock	14,6	N17, N18	Longlands	28 Aug
Mtubatuba	12,6	N12, N13, N17, N18	Oakleaf	10 Sep
Paddock	16,4	N12, N13, NCo 376	Longlands	25 Sep
Paddock	17,1	N12, N13, NCo 376	Longlands	17 Oct
Sezela	12,1	N12, N13, N14, NCo 376	Glenrosa	8 Nov
Sezela	12,9	N12, N13, N14, NCo 376	Glenrosa	2 Dec
Mtunzini	12,9	N12, N13, N17, N18	Shortlands	9 Dec
Monzi	9,0	N12, N14, NCo 376	Dundee	1986 7 May
Sezela	16,7	N12, N14, N16, NCo 376	Cartref	14 May
Mtunzini	11,6	N12, N14, N16, NCo 376	Shortlands	4 Jun
Monzi	10,0	N12, N14, NCo 376	Dundee	6 Jun
Monzi	11,7	N12, N14, NCo 376	Dundee	7 Jul
Sezela	12,3	N14, NCo 376	Kroonstad	8 Aug
Mtunzini	14,1	N12, N14, N16, NCo 376	Shortlands	14 Aug
Sezela	19,2	N12, N13, N14, N16, NCo 376	Cartref	28 Aug
Paddock	16,4	N12, N14, N16, NCo 376	Longlands	16 Oct
Mtubatuba	13,3	N12, N13, NCo 376, N17, N18	Oakleaf	21 Oct
Paddock	13,9	N12, NCo 376	Longlands	24 Oct
Sezela	11,2	N12, N13, N14, N16, NCo 376	Glenrosa	8 Nov
Mtubatuba	14,3	N12, N13, N14, N16, NCo 376	Oakleaf	19 Nov
Paddock	15,0	N12, NCo 376	Longlands	27 Nov

The influence of LFNO, TOPD, AGE, and MN on sucrose was expected to decrease with distance from the meristem. The products of DIST and LFNO (DXLF), DIST and TOPD (DXTOP), DIST and AGE (DXAGE), and DIST and MN (DXMN) were therefore considered to be independent variables in the models. The square terms of LFNO, AGE and MN were necessary components of the model since the influence of these factors was expected to vary as they increased in value. Data obtained from only the top 60 cm of stalk were considered in the analysis. The combinations of these variables that best fitted the transformed sucrose data of all samples of each variety were as follows:

$\ln(20-S) =$

for N12: $A + BxDIST + CxDIST^2 + DxLFNO + ExAGE + FxMN + GxMN^2$

for N13: $A + BxDIST + CxDIST^2 + DxLFNO + ExAGE + FxMN + GxMN^2, + HxTOPD$

for N14: $A + BxAGE + CxMN + DxMN^2 + ExDXMN$

for N16: $A + BxDIST + CxDIST^2 + DxAGE + ExMN + FxMN^2$

for 376: $A + BxLFNO + CxLFNO^2 + DxAGE + ExMN + FxMN^2 + GxDXMN$

These equations were also fitted to the estimated recoverable sugar contents (ers) of the cut sections of stalk less than 60 cm from the apical meristem. Ers was calculated as a function of sucrose content (S), total soluble solids of the cane juice (brix) and the fibre content of the cane sample [$ers = S - 0{,}485 \times (brix - S) - 0{,}057 \times fibre$]. The value of the intercept (A) and the partial regression coefficients (B to H) for both sucrose and ers contents are given in the appendix.

Month of harvest influenced the sucrose contents of NCo 376, N12, N14 and N16 in the normal curvilinear manner even after the effects ascribed to distance from the apex, crop age and green leaf number were removed. Stalk quality was best in September and poorest in May. The influence of month of harvest declined with distance from the apex in varieties NCo 376, N13 and N14. Sucrose contents increased with crop age in all varieties. The number of green leaves accounted for a significant amount of residual variation in the sucrose contents of NCo 376, N12 and N13. In NCo 376 the influence of the number of leaves was greater when several (10) rather than a few (5) green leaves were present. The distance of the 5th node (TOPD) was significantly associated with residual variation in N13 only. The number of green leaves and the length of the elongating internodes did not significantly account for the distribution of sucrose in the top of the stalks, regardless of age or season as was expected. However, these factors were both negatively correlated with sucrose content as was expected. The extent to which these models fitted the data for NCo 376, N12 and N14 is shown in Figure 1. The models tended to overestimate the sucrose contents when values were low but the estimates were reasonably accurate at the higher sucrose levels.

The influence of the number of green leaves, crop age, month of harvest on the distribution of S and ers in stalks of NCo 376 and N12, is reflected in the estimates of S and ers produced from the above equations (Table 2). The lowest ers values measured in the samples collected in this survey as well as in those analysed by Wood[8] were greater than −4 % and this was the lowest value allowed in the estimates of ers in Table 2.

How much top is to be left in the field can only be decided once the crop has been established and maintained, and the corresponding costs assessed. It also depends on what further costs are involved in transporting the cane to the mill and on the cash value of the crop. Topping height will have a greater influence on the cash return if cane payment is based on fibre and juice purity in addition to sucrose since purity decreases rapidly towards the top of the stalk. Ers, which is a function of all three components, may establish how topping height could influence returns if payment were based on a similar function.

Some hypothetical cases, using NCo 376 as an example, illustrate the extent to which changes in topping height may affect the profitability of the harvesting and haulage operation. The following assumptions were made:

(a) Cost of cutting and topping = R1,50 t^{-1} topped at apex, thus cutters are not penalised for low topping

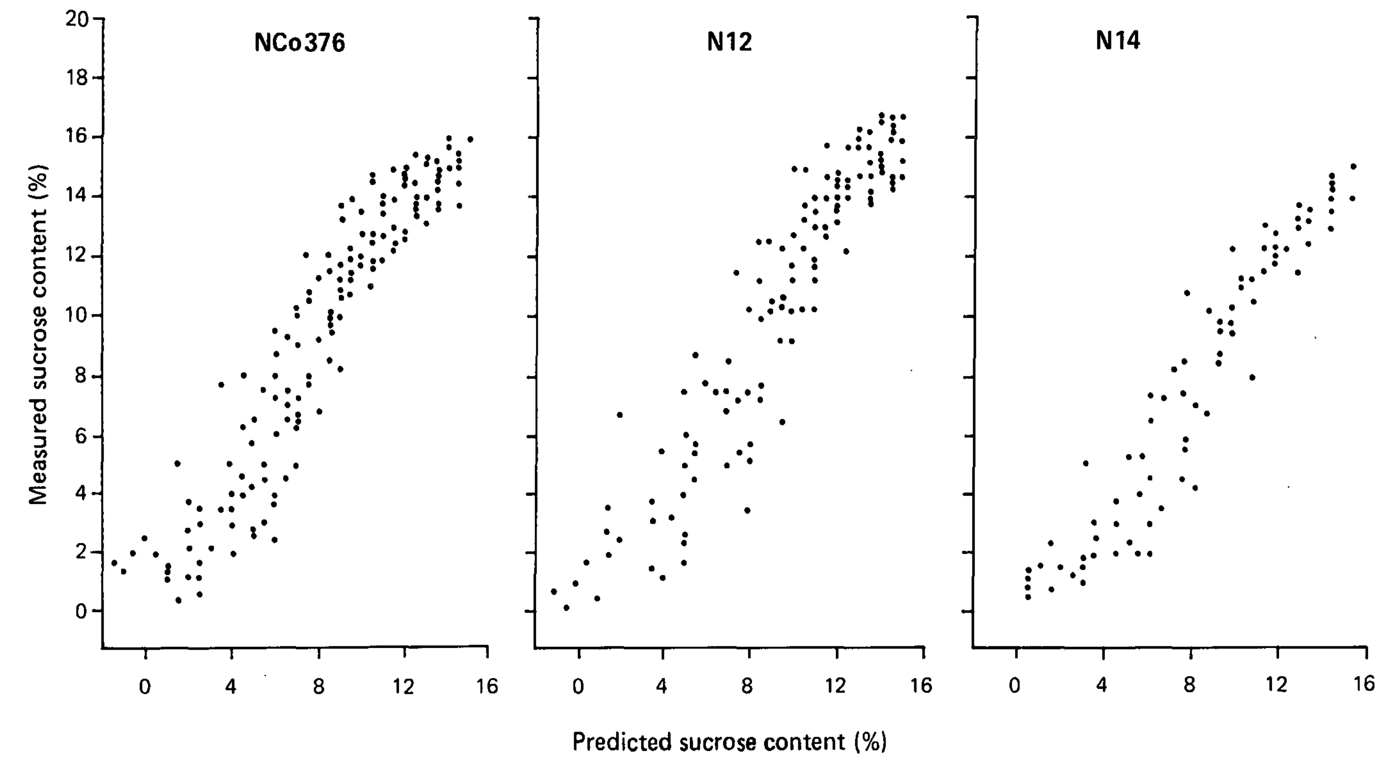

FIGURE 1 Sucrose contents estimated from regression models and measured values.

Table 2

Sucrose content (S) and estimated recoverable sugar (ers) of cane stalks of NCo 376 and N12 at increasing distances from the apical meristem for crops differing in age (mths), cut in different months (MN), and with differing numbers of green leaves (LF)

Age (mths)	MN	LF	Sucrose content (pol %)										Ers %									
			Distance from apex (cm)																			
			5	10	15	20	25	30	35	40	45	50	5	10	15	20	25	30	35	40	45	50
NCo 376																						
15	Nov	6	5	7	8	10	11	12	13	14	15	15	2	5	6	8	9	11	12	13	13	14
15	Nov	7	5	7	9	10	11	12	13	14	15	15	3	5	7	9	10	11	12	13	14	14
15	Nov	9	4	6	7	9	10	11	13	13	14	15	2	4	6	8	9	10	11	12	13	14
15	Nov	10	1	4	6	7	9	10	11	12	13	14	−1	1	4	6	7	9	10	11	12	13
15	May	7	0	1	3	4	4	5	6	7	8	8	−3	−1	0	1	2	3	4	5	6	7
15	Jun	7	4	5	6	7	8	8	9	10	11	11	1	2	4	5	6	7	8	8	9	10
15	Sep	7	7	8	9	10	11	12	13	14	14	15	5	6	8	9	10	11	12	12	13	14
15	Nov	7	5	7	9	10	11	12	13	14	15	15	3	5	7	9	10	11	12	13	14	14
15	Dec	7	4	6	8	9	11	12	13	14	15	15	1	4	6	8	9	11	12	13	13	14
12	Nov	7	4	6	8	9	11	12	13	14	14	15	2	4	6	8	9	10	11	12	13	13
15	Nov	7	5	7	9	10	11	12	13	14	15	15	3	5	7	9	10	11	12	13	14	14
18	Nov	7	6	8	10	11	12	13	14	15	15	16	4	6	8	9	11	12	12	13	14	14
N12																						
15	Nov	6	5	8	10	12	13	14	15	15	16	16	3	6	9	11	12	13	14	14	14	15
15	Nov	7	3	6	9	11	12	13	14	15	15	15	0	4	7	9	11	12	13	13	14	14
15	Nov	9	0	1	5	7	9	11	12	13	13	14	−4	−2	2	5	8	9	10	11	12	13
15	Nov	10	0	0	2	5	7	9	10	11	12	13	−4	−4	−1	3	6	8	9	10	11	12
15	May	7	0	0	0	2	5	7	8	10	11	11	−4	−4	−4	−1	2	5	7	8	9	10
15	Jun	7	0	0	3	6	8	10	11	12	13	13	−4	−4	0	3	6	8	9	10	11	12
15	Sep	7	2	6	9	11	12	13	14	15	15	15	−1	4	7	9	10	12	13	13	14	14
15	Nov	7	3	6	9	11	12	13	14	15	15	15	0	4	7	9	11	12	13	13	14	14
15	Dec	7	2	5	8	10	12	13	14	14	15	14	−1	3	6	8	10	11	12	13	14	14
12	Nov	7	0	4	7	9	11	12	13	14	14	15	−4	1	5	7	9	11	12	12	13	13
15	Nov	7	3	6	9	11	12	13	14	15	15	15	0	4	7	9	11	12	13	13	14	14
18	Nov	7	5	8	10	12	13	14	15	15	16	16	3	6	9	11	12	13	14	14	15	15

(b) Cost of loading, infield transport and transloading = R4,50 t^{-1}

(c) Haulage cost = R0,23 t^{-1} km^{-1}

(d) Stalk population of NCo 376 = 130 000 ha^{-1}

(e) Stalk height = 150 cm

(f) Haulage distance = 10 or 50 km

(g) Month of harvest = November

(h) Ers is 1,5 % lower than S and the mean S = 12,5 %, payment for ers is therefore 10 % more than for S.

The measured mass per unit length of NCo 376 stalks was as follows:

distance from apex (cm):	5	10	15	20	25	30	35	40	45	50–200
stalk g cm^{-1}:	4,1	4,2	4,3	4,5	4,6	4,7	4,8	4,8	4,9	5,0

The maximum values for cash return (crop value, transport and loading costs) are underlined in the following example so that optimum topping height may be noted:

Top height from apex (cm)	S and ers at top height (%)		S and ers at mill (%)		Cane yield (t ha^{-1})	Crop value (V) (R ha^{-1}) S and ers.		V – all transport costs (R ha^{-1}), S and ers 10 km		50 km	
Case 1: the price of A pool sucrose is R280 t^{-1}, the crop is 12 months old and has 6 leaves											
0	1,8	−1,8	15,1	13,3	94	3894	3859	3201	3076	2332	2208
10	6,0	3,3	15,9	14,3	88	3923	3859	3184	3120	2376	2311
20	9,2	7,1	16,7	15,0	81	3793	3765	3099	3070	2350	2322
30	11,6	9,9	17,2	15,6	75	3610	3603	2960	2952	2271	2263
40	13,5	12,0	17,7	16,1	68	3386	3389	2779	2782	2150	2153
50	15,0	13,6	18,1	16,5	62	3130	3137	2567	2575	1998	2005
Case 2: the price of A pool sucrose is R280 t^{-1}, the crop is 12 months old and has 10 leaves											
0	0,0	−4,0	14,0	12,3	94	3702	3575	2919	2791	2050	1923
10	2,5	−0,2	14,9	13,4	88	3676	3619	2937	2880	2129	2071
20	6,5	4,5	15,8	14,3	81	3604	3588	2909	2893	2161	2141
30	9,6	8,0	16,5	15,1	75	3466	3473	2815	2822	2127	2133
40	11,9	10,6	17,1	15,6	68	3276	3293	2670	2687	2041	2058
50	13,8	12,5	17,6	16,1	62	3047	3067	2484	2505	1915	1936
Case 3: the price of B pool sucrose is R140 t^{-1}, the crop is 12 months old and has 10 leaves											
0	0,0	−4,0	14,0	12,3	94	1851	1787	1068	1004	199	136
10	2,5	−0,2	14,9	13,4	88	1838	1809	1099	1070	291	262
20	6,5	4,5	15,8	14,3	81	1802	1794	1107	1099	359	351
30	9,6	8,0	16,5	15,1	75	1733	1736	1082	1080	394	397
40	11,9	10,6	17,1	15,6	68	1638	1647	1032	1040	403	411
50	13,8	12,5	17,6	16,1	62	1523	1534	961	971	392	402

In Case 1 the cane is mature and the greatest return is obtained by topping at the apical meristem if the distance to the mill is 10 km and payment is for sucrose. The top 10 cm of stalk should be removed if either the haulage distance is increased by 40 km or payment is for ers. If payment is for ers and the distance is 50 km, the topping should be done at 20 cm below the apex. The effect of topping height on cash return is more marked when B pool prices are considered as in Case 3.

The best return is obtained by topping 20 cm below the apex if the haulage distance is 10 km, and by topping 40 cm below the apex if the haulage distance is 50 km. In this case, the payment system has no effect on the optimum topping height. The costs used in this exercise may not be generally applicable and growers could repeat the calculations using relevant costs. Nevertheless, it is apparent that height of topping can have a considerable effect on the sucrose content of cane consignments and may significantly affect the economics of moving cane to the mill after it has been cut and topped.

Conclusions

The number of green leaves, together with the crop age and month of harvest, provide a useful estimate for the sucrose content of sections of stalk within 50 cm of the apical meristem. The use of these estimates is encouraged because of the effect that topping height has on the profitability of harvesting B pool cane and/or hauling cane to the mill over long distances.

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APPENDIX I

Intercept (A) and partial regression coefficient (B to H) of variables contributing significantly and meaningfully to models describing sucrose content and estimated recoverable sugar (ers) content in stalks of sugarcane

Variety	Independent variable	Symbol	Sucrose content		Ers content	
			Coefficient	Standard error	Coefficient	Standard error
NCo 376	INTERCEP	A	6,2861060	0,38340400	7,1810060	0,44818100
	LFNO	B	−0,3846190	0,07650100	−0,5214080	0,08942600
	LFNO²	C	0,0274990	0,00470466	0,0359140	0,00549953
	AGE	D	−0,0226020	0,00674869	−0,0293750	0,00788890
	MN	E	−0,4378000	0,05967500	−0,4892430	0,06975700
	MN²	F	0,0249600	0,00343766	0,0379850	0,00401846
	DxMN	G	−0,0023528	0,00009500	−0,0027270	0,00011106
N12	INTERCEP	A	5,3218980	0,43152100	5,8254850	0,52246600
	DIST	B	−0,0502490	0,00562106	−0,0571620	0,00680572
	DIST²	C	0,0003780	0,00008186	0,0004131	0,00009911
	LFNO	D	0,1574720	0,01899300	0,1755720	0,02299600
	AGE	E	−0,0523440	0,00890512	−0,0630240	0,01078200
	MN	F	−0,5026380	0,07991700	−0,5769990	0,09675900
	MN²	G	0,0245540	0,00459380	0,0281240	0,00556196
N13	INTERCEP	A	2,1807490	0,26376300	2,2484670	0,20226600
	DIST	B	−0,0267310	0,01130500	−0,0221280	0,01404900
	DIST²	C	0,0004730	0,00008410	0,0005048	0,00010451
	LFNO	D	0,1094270	0,01669200	0,1139570	0,02074300
	TOPD	G	0,0047934	0,00093758	0,0052833	0,00121651
	DxAGE	E	−0,0004997	0,00040462	−0,0007848	0,00050282
	DxMN	F	−0,0023228	0,00046926	−0,0030831	0,00058315
N14	INTERCEP	A	6,15769030	0,20599600	6,4842850	0,22595900
	AGE	B	−0,0297190	0,00517363	−0,0332060	0,00567502
	MN	C	−0,7219990	0,05428300	−0,7807620	0,04954300
	MN²	D	0,0436330	0,00318239	0,0470270	0,00349080
	DxMN	E	−0,0021179	0,00008837	−0,0023670	0,00010901
N16	INTERCEP	A	8,8378020	0,37583100	9,7722330	0,43494400
	DIST	B	−0,0414470	0,00612777	−0,0461270	0,00709160
	DIST²	C	0,0003209	0,00009022	0,0003393	0,00010441
	AGE	D	−0,0254240	0,00832432	−0,0374060	0,00963364
	MN	E	−1,2848040	0,09926700	−1,4358360	0,11488000
	MN²	F	0,0728910	0,00622344	0,0805620	0,00720232