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# Anatomical features of stem in relation to quality and yield factors in *Saccharum* clones

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**Abstract.** The results from a study of the relationships between external productive features of millable canes and quality characters as well as anatomical differences of stem in relation to both yield components and quality factors in 16 clones of *Saccharum* involving rinded and rindless samples are discussed in this paper. The wide variations recorded for the various characters studied brought out the diversity in the genotypes besides indicating the relative importance of certain attributes in production and quality breeding, where cane weight and sucrose content play a leading role. The study revealed the major contribution of rind to fibre content and the value of appropriate levels of fibre as also the need for examining the different physical characteristics of the fibre which are conducive to both high levels of sucrose storage potential and better milling quality. From anatomical studies, varietal differences were recorded, but neither the smallest nor the largest cell volume was associated with extreme levels of fibre, brix or sucrose content.

**Keywords.** *Saccharum*; anatomical features; quality and yield factors; fibre; rind in sugarcane.

## 1. Introduction

Sugarcane is an important commercial crop in which the millable cane forms the crucial raw material for sugar production. The mature stem constituting the millable cane acts as the primary sink for sucrose in the plant and hence it needs to be studied critically in all its aspects to understand the inherent factors influencing sugar accumulation and storage. The past breeding efforts aimed at improving the millable cane production and its juice quality had no doubt met with great success in increasing the sugar production per unit area. But no comprehensive studies appear to have been made to correlate the basic structural features of stem with external productive features of the cane as well as fibre, brix and sucrose qualities especially on samples of whole canes and canes wherein rind had been removed. The present study was designed to examine the important anatomical characters particularly those of storage tissues in relation to their influence on productive attributes of cane as well as the quality characteristics in a wide range of genotypes and obtain information of value for future sugarcane breeding work.

## 2. Materials and methods

Sixteen varieties representing two from each of the species *Saccharum barberi* Jesw and *S. officinarum* L., three IA clones (derivatives of foreign clones × *S. spontaneum* L.) and nine commercial stocks were utilised for the studies. Mature millable canes from 12-month old plant crop were harvested from the varietal maintenance plot planted in January 1977 for recording the observations. Cane length, length and number of internodes, girth at middle internode of cane and weight of canes were recorded on six stalks for each variety and the mean worked out.

Five canes with rind intact and five canes in which the rind portion was completely removed (without rind) for each variety were used for recording the per cent extraction. The crushed juice so obtained for the 32 samples was analysed for brix and sucrose (Pol) following standard methods (Van der Plank 1936). The fibre content was estimated for a similar set of 32 cane samples by direct determination on cane (Spencer and Meade 1963).

For all the varieties, samples from mature middle internodes representing whole canes and cane excluding rind portion were preserved in FAA (90 : 5 : 5). From the preserved material, thin anatomical sections were taken and examined under the microscope. The total number of vascular bundles per microscopic field (7x × 8x) was recorded based on 25 random readings using several sections from samples involving rind as well as storage tissues only. The length and width of cells of storage tissue were measured under a Meopta binocular microscope in 25 cells for each variety using ocular micrometer under high power and the values expressed as $\mu 10^2$. The cell volume was calculated by multiplying the length by the width squared (Oworu *et al* 1977) and expressed as $cm^3\ 10^{-6}$. The cell wall thickness was measured under oil immersion on 25 cells at random using the ocular micrometer and expressed in microns.

Statistical analyses of the means of varieties for each character to work out the SE, *t* test on extraction per cent, brix and sucrose for pairs of samples from rinded and rind removed samples as well as simple correlation coefficients (*r* values) on 23 pairs of characters were carried out.

## 3. Results

The details of varieties used and the data gathered on quantitative attributes of millable canes are presented in table 1. Examination of the data revealed that, in general the latest commercial varieties which are improvements over earlier varieties such as CoC 67–1, Q 63, Co 7201 and Co 62175 tended to have desirable combinations for the major attributes of millable cane showing higher values than the earlier commercial varieties and the rest based on general mean + SE. The IA clones had taller canes combined with longer and fewer internodes, but their girth and cane weight were comparatively poor. The relative contribution of girth in Co 419 and Co 527, girth and number of internodes in Co 62175, cane length and at least two other factors in Co 7201 and Q 63 and all the factors in CoC 67–1 to increase in individual cane weight were indicated.

Information gathered on the quality characters of whole canes as well as from rindless samples is presented in table 2. The *t* test on pairs of samples in respect of extraction per cent, brix and sucrose indicated absence of significant differences

**Table 1.** Particulars of varieties used and quantitative description of their mature canes.

| Varieties | Species/Parentage | Mature cane (Mean of six canes) | | | | |
|---|---|---|---|---|---|---|
| | | Length (cm) | No. of inter-nodes | Inter-node length (cm) | Girth (cm) | Weight (kg) |
| Agoul | *S. barberi* Jesw | 155·3 | 18·3 | 8·47 | 2·43 | 0·52 |
| Pathri | *S. barberi* Jesw | 153·3 | 16·3 | 9·39 | 2·40 | 0·60 |
| Manjri Red | *S. officinarum* L. | 155·3 | 17·7 | 8·79 | 2·03 | 0·72 |
| 57 NG 77 | *S. officinarum* (hybrid) | 150·0 | 20·7 | 7·26 | 1·87 | 0·28 |
| IA 3333 | PR 1016 × *S. spontaneum* L. (SES 13) | 196·3 | 14·3 | 13·70 | 1·37 | 0·20 |
| IA 3336 | do. | 181·0 | 15·0 | 12·07 | 1·57 | 0·24 |
| IA 3402 | PR 1028 × *S. spontaneum* L. (SES 87B) | 223·3 | 15·3 | 14·57 | 1·57 | 0·36 |
| Co 285 | *S. officinarum* × *S. spontaneum* L. | 148·7 | 14·0 | 10·62 | 1·77 | 0·28 |
| Co 419 | POJ 2878 × Co 290 | 158·7 | 18·7 | 8·50 | 2·73 | 1·16 |
| Co 527 | Co 349 × Co 342 | 147·7 | 19·3 | 7·64 | 2·67 | 0·68 |
| Co 62175 | Co 951 × Co 419 | 179·7 | 25·7 | 7·00 | 2·93 | 1·44 |
| Co 7201 | Co 740 × Co 658 | 233·0 | 19·3 | 12·05 | 2·40 | 1·32 |
| Co 7327 | Co 775 (Polycross material) | 153·7 | 16·0 | 9·60 | 2·13 | 0·52 |
| CoC 67-1 | Q 63 × Co 775 | 238·7 | 23·0 | 10·85 | 2·97 | 1·24 |
| B 37172 | POJ 2878 × B 2934 | 156·3 | 22·3 | 6·80 | 2·10 | 0·68 |
| Q 63 | Trojan × CP 29-116 | 186·0 | 22·0 | 8·33 | 2·77 | 0·80 |
| | Mean | 176·1 | 18·6 | 9·73 | 2·23 | 0·69 |
| | SE | 7·89 | 1·11 | 0·62 | 0·15 | 0·11 |

for these traits estimated from rinded and rindless samples. In four varieties, rindless samples recorded higher values than the rinded. In Q 63, the rinded sample gave much higher extraction than rindless sample and in IA 3336 and Co 62175, both the samples gave identical results. The *t* test on fibre content was not done as there was no relevance and in all the varieties, the fibre content was almost double or even more in the rinded samples. The three IA clones and 57 NG 77 recorded fibre levels above the general mean + SE in both types of samples. Agoul and Co 7327 had very high fibre content in rinded canes, while B 37172 had a higher percentage in the rindless sample also.

Apparently higher level of brix was observed in rindless samples of varieties especially 57 NG 77, Co 527 and Q 63, while the contrary was true in most other varieties. Five varieties had apparently higher levels of sucrose in rinded samples,

**Table 2.** Quality characters in varieties estimated on whole canes and after removal of rind.

| Varieties | Extraction per cent | | Fibre per cent | | Brix per cent | | Sucrose per cent | |
|---|---|---|---|---|---|---|---|---|
| | with rind | rind removed | with rind | rind removed | with rind | rind removed | with rind | rind removed |
| Agoul | 32·3 | 41·7 | 25·32 | 7·74 | 19·12 | 19·32 | 16·98 | 16·96 |
| Pathri | 46·7 | 41·7 | 16·37 | 7·85 | 19·92 | 18·82 | 17·61 | 16·96 |
| Manjri Red | 50·0 | 45·7 | 13·21 | 5·41 | 18·62 | 16·91 | 15·97 | 13·66 |
| 57 NG 77 | 28·5 | 37·5 | 24·54 | 12·88 | 15·91 | 19·32 | 12·25 | 15·74 |
| IA 3333 | 40·0 | 30·0 | 20·79 | 10·85 | 17·41 | 17·11 | 14·12 | 14·36 |
| IA 3336 | 33·3 | 33·3 | 21·87 | 10·60 | 19·22 | 19·81 | 15·69 | 16·94 |
| IA 3402 | 44·4 | 37·5 | 21·40 | 10·62 | 12·60 | 11·70 | 10·17 | 8·60 |
| Co 285 | 35·7 | 40·0 | 18·68 | 8·08 | 17·31 | 17·71 | 14·67 | 15·09 |
| Co 419 | 51·7 | 48·0 | 11·44 | 6·92 | 17·92 | 18·92 | 15·38 | 16·46 |
| Co 527 | 47·1 | 43·8 | 17·94 | 7·24 | 16·81 | 18·52 | 14·70 | 16·25 |
| Co 62175 | 50·0 | 50·0 | 11·12 | 5·49 | 17·92 | 18·12 | 16·32 | 15·98 |
| Co 7201 | 45·4 | 40·9 | 15·84 | 9·03 | 18·02 | 17·51 | 16·04 | 14·92 |
| Co 7327 | 46·2 | 38·5 | 20·21 | 7·68 | 19·72 | 20·32 | 17·18 | 18·16 |
| CoC 67-1 | 48·2 | 42·8 | 16·39 | 6·81 | 21·22 | 21·92 | 19·21 | 19·79 |
| B 37172 | 35·3 | 41·9 | 13·82 | 10·79 | 18·42 | 17·92 | 16·49 | 15·79 |
| Q 63 | 62·5 | 40·0 | 15·00 | 7·68 | 18·62 | 21·92 | 15·97 | 20·15 |
| Mean | 43·6 | 40·9 | 17·75 | 8·48 | 18·05 | 18·49 | 15·55 | 15·99 |
| SE | 2·20 | 1·33 | 1·12 | 0·56 | 1·25 | 0·65 | 0·59 | 0·71 |
| *t* test | Not significant | | —— | | Not significant | | Not significant | |

while in 11 varieties the values were higher in the rindless samples, though the differences as judged by *t* test were not significant. Q 63 which showed much higher extraction per cent than other varieties in rinded sample recorded high increase in brix and sucrose in the rindless sample. CoC 67–1 had values above the general mean + SE for all the quality traits excepting fibre content.

In table 3, the data on anatomical features are presented. In general, all the varieties recorded greater concentration of vascular bundles in the rind region than storage tissues though the proportion varied widely with the varieties (figure 1). The varieties Pathri, IA clones and Co 62175 had very high number of vascular bundles in the whole cane section, while in the two *S. officinarum* varieties and Co 419, the number of vascular bundles was much higher in storage tissues compared to other varieties. Pathri had the lowest number of vascular bundles in the storage tissues whereas Co 7201 and Agoul had the lowest number in whole cane sections.

The length and width of cells in parenchymatous storage tissue were higher than the general mean + SE in five and four varieties respectively. Similarly, the cell volume was greater in Co 419, Co 285, Pathri, M Red, Co 527 and Co 7201 among which Pathri recorded higher brix and sucrose than general mean + SE. Comparatively, smallest cell size was found in Agoul, 57 NG 77, IA 3336, Co 62175

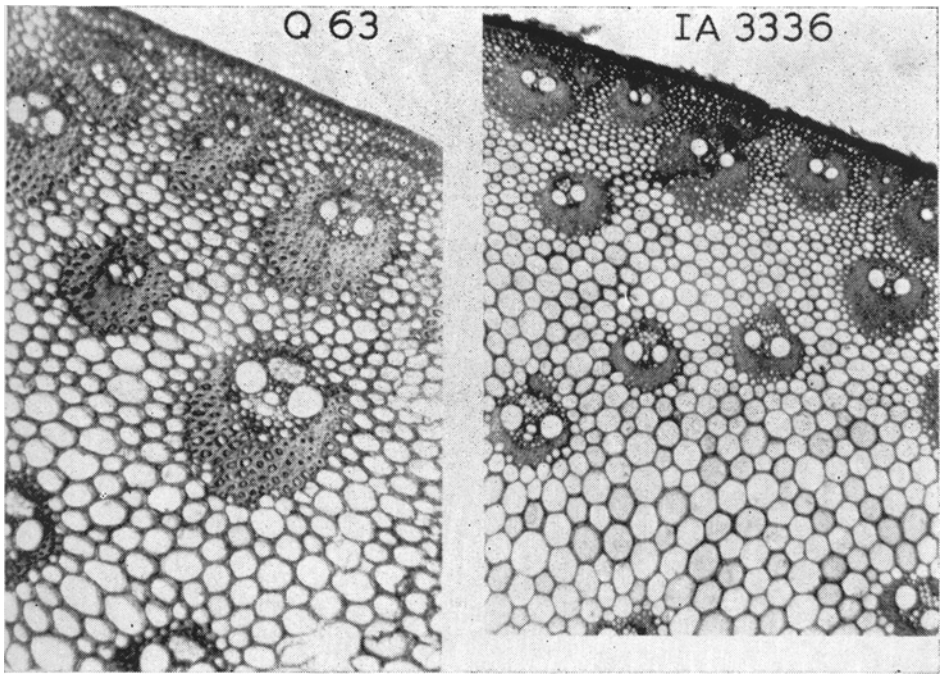


**Figure 1.** Anatomical features of stem (internodal region) (× 2,250).

**Table 3.** Anatomical features of stem in different sugarcane varieties with rind and rind removed.

| Varieties | No. of vascular bundles (per unit area) | | | | Parenchymatous cell | | | |
|---|---|---|---|---|---|---|---|---|
| | with rind | | rind removed | | Length ($\mu$ $10^2$) | Width ($\mu$ $10^2$) | Volume $cm^3$ $10^{-6}$ | Wall thickness ($\mu$) |
| | mean | range | mean | range | | | | |
| Agoul | 8·0 | 7–9 | 4·7 | 3–7 | 1·34 | 1·13 | 1·71 | 1·71 |
| Pathri | 14·0 | 13–15 | 2·9 | 2–5 | 1·82 | 1·49 | 4·04 | 1·71 |
| Manjri Red | 12·0 | 11–15 | 5·8 | 3–11 | 1·58 | 1·52 | 3·65 | 1·73 |
| 57 NG 77 | 12·0 | 7–14 | 5·8 | 4–8 | 1·57 | 1·28 | 2·01 | 2·33 |
| IA 3333 | 13·2 | 10–15 | 4·4 | 2–8 | 1·48 | 1·30 | 3·04 | 1·36 |
| IA 3336 | 13·6 | 10–15 | 3·6 | 2–5 | 1·29 | 1·03 | 1·53 | 1·86 |
| IA 3402 | 13·1 | 11–16 | 3·5 | 2–5 | 1·67 | 1·33 | 2·93 | 1·12 |
| Co 285 | 11·6 | 9–15 | 3·9 | 3–5 | 1·80 | 1·53 | 4·21 | 1·73 |
| Co 419 | 10·2 | 8–12 | 7·4 | 5–9 | 1·90 | 1·56 | 4·62 | 1·84 |
| Co 527 | 10·3 | 6–13 | 3·9 | 2–6 | 1·73 | 1·42 | 3·49 | 1·02 |
| Co 62175 | 15·6 | 14–17 | 3·4 | 2–5 | 1·55 | 1·20 | 2·23 | 1·52 |
| Co 7201 | 7·5 | 6–9 | 4·7 | 3–6 | 1·78 | 1·38 | 1·39 | 1·69 |
| Co 7327 | 11·0 | 8–13 | 4·7 | 3–6 | 1·56 | 1·33 | 2·76 | 1·82 |
| CoC 67-1 | 10·1 | 8–14 | 4·3 | 2–6 | 1·68 | 1·34 | 3·02 | 1·24 |
| B 37172 | 11·0 | 9–13 | 4·2 | 3–5 | 1·49 | 1·24 | 2·13 | 1·85 |
| Q 63 | 11·9 | 9–15 | 4·8 | 3–6 | 1·59 | 1·38 | 3·03 | 2·72 |
| Mean | 11·9 | .. | 4·5 | .. | 1·61 | 1·33 | 2·99 | 1·77 |
| SE | 9·53 | .. | 0·32 | .. | 0·10 | 0·10 | 0·27 | 0·37 |

and B 37172. No consistent relationship was observed between cell size and sucrose content. CoC 67-1 and Q 63 with cell volume of 3·02 to 3·03 $cm^3$ $10^{-6}$ recorded the highest sucrose content in storage tissues but in IA 3402 with nearly an equal cell volume, the sucrose content was the lowest with 8·60 per cent. The cell wall thickness of 57 NG 77 and Q 63 was far higher than the mean + SE while Co 527 and IA 3402 had the lowest value. There was no precise relationship between this character and sucrose content or cell volume.

The correlation ($r$) values worked out for 23 pairs of characters are presented in table 4. Highly significant negative correlation was obtained in respect of extraction per cent of both rinded and rindless samples with fibre per cent on similar samples. Negative and significant correlation was also recorded for fibre per cent rindless samples with sucrose per cent whole cane. The anatomical characters showed positive correlations with many physical characteristics of cane and sucrose, but they were very low. Cell length and cell width of juice cells were highly positively correlated. The remaining pairs of characters showed negative correlation with very low $r$ values. The number of vascular bundles showed low and negative correlations with fibre content and sucrose on rinded sample and a similar result was recorded in the case of cell volume with sucrose in storage tissues. The

**Table 4.** Correlation of characters involving economic attributes and anatomical features in stem of sugarcane.

| Character pairs | | Correlation *r* value |
|---|---|---|
| X | Y | |
| Fibre per cent (Wc) | Extraction per cent (Wc) | −0·6856** |
| ,, | Extraction per cent (cmr) | −0·7077** |
| ,, | Sucrose per cent (Wc) | −0·4508 |
| ,, | Sucrose per cent (cmr) | +0·0076 |
| ,, | No of vascular bundles (cmr) | −0·2442 |
| Fibre per cent (cmr) | Extraction per cent (Wc) | −0·6590** |
| ,, | Extraction per cent (cmr) | −0·7574** |
| ,, | Sucrose per cent (Wc) | −0·5733* |
| ,, | Sucrose per cent (cmr) | −0·3114 |
| ,, | No. of vascular bundles (cmr) | −0·1600 |
| Extraction per cent (Wc) | Sucrose per cent (Wc) | +0·2553 |
| No. of vascular bundles (cmr) | Sucrose per cent (Wc) | −0·2128 |
| ,, | Sucrose per cent (cmr) | −0·0206 |
| ,, | Cell volume (Parenchyma cell) | +0·1767 |
| Cell length (Parenchyma cell) | Cell width (Parenchyma cell) | +0·8221** |
| ,, | Cane girth | +0·3616 |
| ,, | Cane length | +0·0587 |
| ,, | Internode length | +0·0031 |
| Cane girth | Parenchyma cell width | +0·1686 |
| ,, | Parenchyma cell volume | +0·1866 |
| Cell volume (Parenchyma cell) | Cane weight | +0·2177 |
| ,, | Sucrose per cent (Wc) | +0·0199 |
| ,, | Sucrose per cent (cmr) | −0·0946 |

* Significant at 5% level; ** Significant at 1% level; Wc = Whole cane basis; cmr = Cane minus rind basis.

extraction per cent and sucrose on whole cane basis had positive correlation, but it was of a low order.

## 4. Discussion

The cane varieties utilised in this investigation represented a fairly wide range of variability in respect of the physical cane attributes, quality and anatomical characteristics. The present study has brought out that the weight of cane is highly influenced by a combination of attributes such as length, girth and internode length. The relative importance of girth to cane weight and cane weight on juice content has been indicated in this study also in conformity with the statements recorded by Rao and Krishnamurthy (1968) and Rao *et al* (1967).

The importance of fibre characteristics in sugarcane improvement was emphasised by Buzacott (1956), Sockhill (1958) and Rao *et al* (1973). The three quality attributes namely extraction per cent, brix and sucrose estimated from rinded and rindless samples did not reveal significant differences. The rind in sugarcane is perhaps a necessary evil both from the point of the plant's survival and human utility considerations especially in milling of canes. The rind is needed for providing a grip in the mills. Otherwise, the rindless material would become a total powder and get mixed with the juice as impurities. The generally higher extraction per cent obtained from the rinded cane samples and the high percentage of fibre in such samples also indicate the important role of the fibre in milling property as stated earlier by Sockhill (1958) and Stevenson *et al* (1970). At the same time, inference from the varieties with slightly higher fibre from rindless sample as in Q 63 also emphasises the need for examining the physical characteristics of the fibre as discussed by Rita *et al* (1978a, b) for varietal differences to be taken care of in selection. The higher fibre in rinded cane is quite in conformity with the earlier and generally recognised findings. The brix and sucrose contents were apparently higher in rindless samples compared to rinded ones, but without any statistical significance for the *t* test. The varieties CoC 67-1 as well as Q 63 not only combined several physical attributes of cane enhancing the individual cane weight, but also recorded higher performance in quality attributes over others, besides having a lower level of fibre content.

Though Artschwager (1925) made comprehensive studies on the anatomy of sugarcane plant, so far no references seem to be available linking sugar storage potential in tissues with anatomical differences. However, Oworu *et al* (1977) in sugarcane and Milford (1973) in sugar beet made some studies on sucrose uptake in relation to cell size and fibre content in storage tissues through in vitro physiological cum biochemical studies. Oworu *et al* (1977) even suggested the association between smaller cell size, higher cell wall thickness as well as larger number of vascular bundles and higher rate of sucrose uptake and recommended that breeders may exploit this to find out whether such a relation existed with reference to actual sucrose synthesis and storage in sugarcane stem by examining a number of varieties. In the present study, the proportion of vascular bundles in the rind to the storage tissues and also the number within either of them varied somewhat with the variety. The relationship between cell length, width or volume of cell with quality characters and sucrose storage capacity of the tissues was very complex. A certain cell volume was found to be optimum in certain varieties and associated with high level of sucrose accumulation, but the same was not true in certain other varieties with the same cell volume. It was also observed that neither the biggest nor the smallest cell size was actually associated with the highest level of sucrose content. Probably, there may be a certain optimal size and the interaction of several other factors, perhaps those involving physiological, biochemical and environmental factors, would operate in addition to these anatomical features. The correlation between number of vascular bundles and fibre content was low and negative. The anatomical characters showed positive correlation with many physical characteristics of cane and sucrose but they were of a very low order. Previous studies on similar character correlations are rather stray and therefore comparison with past findings becomes difficult.

The competition between fibre and sucrose for the products of photosynthesis may lead to a high level in one to be associated with low level in the other. In the present study, no precise correspondence could be established between the vascular bundles or other factors arising from differences between rinded and rindless samples and sucrose production/storage potential. However, the study has enabled understanding the existence of wide varietal differences as also small to varying amounts of differences arising from rinded and rindless samples in respect of anatomical factors and quality characters.

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