STUDIES IN THE ANATOMY OF SUGARCANE STALK*

Part II. Milling Characteristics of Varieties

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I. INTRODUCTION

IN sugarcane, all the matter insoluble in water is known as fibre, the quantity of which is distinctly a varietal character affected, to some extent, by the age and conditions of growth. That the efficiency of milling was determined by this quantity was well known long time back, and as a general rule, it was stated that the higher the fibre content of a cane was, the greater was the difficulty in milling it.

It was only recently that the effect of the quality of fibre was noted. Dymond (1942) found that although Co 290 contained less of fibre than Co 281, the former was markedly inferior to the latter, because the fibre of Co 290 retained 24–25% more of juice per unit weight of fibre than that of Co 281. Puertas (1943) also noted that juice was more easily expressible from the fibre of some varieties than from that of others. Lower extraction necessitates addition of greater amount of water of imbibition, to evaporate which larger quantity of fuel is required, with the result that the cost of production is increased, unless the variety yields sufficient bagasse for the purpose. Besides, the quality of fibre affects the economy of factory working also directly in that the bagasse of some varieties is good as fuel, because it burns well and is sufficient for the purpose. Camden Smith as reported by Hedlay (1936) found that bagasse of varieties like Co 301, P.O.J. 2714 and P.O.J. 2725 did not burn well. Dymond (*loc. cit.*) noted that the bagasse of Co 290 was poorer than that of Co 281, so far as its steam raising quality was concerned.

It thus becomes essential to determine both quantity and quality of fibre so that these characteristics receive due consideration in the score-card for ultimate selection of seedlings. As would appear from what has been stated above, the problem concerns largely with the study of structural variations in different varieties and in order, therefore, to understand how far

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the anatomical makeup of a cane stalk would be an index of its milling propensities, varieties dominant at one time or other in the province, *viz.*, Co 210, Co 213, Co 299, Co 313 were selected for this study. Co 419 and Rheora, the latter being one of the main varieties before the introduction of Coimbatore canes, were also included because considerable difficulty in obtaining maximum extraction from them was generally reported from different factories. The bagasse of these varieties was also found to contain uneconomical quantities of sugar. These six varieties together covered fairly wide range of milling characteristics.

The present contribution deals only with the quantity of fibre in relation to major anatomical features. Besides, an attempt has been made to set out the problem in its various details with a view to focus pointed attention of workers in the line.

II. Material and Methods

Transverse sections taken from middle internodes of normal healthy looking stalks of each variety were stained in 1% solution of safranin in 50% alcohol and mounted in Canada balsam after the usual process of dehydration. In the preliminary stage the following characters were taken into consideration.

1. Vascular Bundles—Average number and size in (*a*) peripheral and (*b*) central regions.

2. Thickness of cell walls in (*a*) Parenchymatous matrix at 0·6 mm. and 1·2 mm. from epidermis and in centre and (*b*) Sclerenchymatous vascular sheaths in peripheral and central regions.

The number and size of vascular bundles were noted in 48 unit areas (the field of microscope being taken as a unit) in each region. In order that the unit areas were comparable to one another in different varieties, care was taken to keep the edge of a microscope-field always touching the epidermis. The size of vascular bundles was measured in terms of radial and tangential axes, the product of which gave a highly reliable idea of its area in cross-section, as reported elsewhere (Khanna and Sharma, 1947). The thickness of cell walls was measured for two adjacent walls in both the tissues, averages being taken from 16 readings for each tissue at each depth.

III. Results of Investigations

The six varieties selected for the study could be placed (Table I) in three distinct groups, *viz.*, (i) the high-fibre group having Co 299 as an example (ii) the medium-fibre group to which Co 210, Co 213 belonged and (iii) the low-fibre group which included Co 313, Co 419 and Rheora.

TABLE I

Showing average fibre % cane of the six sugarcane varieties in different months

Months	Varieties						Mean
	Co 210	Co 213	Co 299	Co 313	Co 419	Rheora	
November ..	14·84	13·95	16·24	12·96	11·60	11·00	13·43
December ..	15·33	14·40	16·66	13·38	11·99	11·38	13·86
January ..	15·78	14·82	17·40	13·90	12·53	11·89	14·38
February ..	16·57	15·58	18·04	14·60	13·13	12·49	15·07
March ..	17·50	16·19	18·71	15·40	13·83	13·10	15·79
April ..	18·34	16·98	19·70	16·06	14·47	13·93	16·58
Average ..	16·39	15·32	17·79	14·38	12·92	12·30	14·85

S.E. per plot (month) = ±0·6571 or 4·42% of the mean.

S.E. (V) = ±0·06707.

S·E. (P×V) = ±0·1643.

C.D. at 5% = 0·1858.

C.D. at 1% = 0·2442.

At 5% Co 299, Co 210, Co 213, Co. 313, Co 419, Rheora

At 1% Co 299, Co 210, Co 213, Co 313, Co 419, Rheora.

Conclusion : The varietal differences are highly significant.

(*a*) *Vascular bundles.*—The detailed examination of slides in respect of the two characters studied brought out (Table II) that the differences among the varieties of the first and second groups and Co 313 of the low-fibre group (Plate II, Figs. 1–4) were not significant so far as the number of vascular bundles per unit area in peripheral region was concerned, while Co 419 and Rheora although falling in the same group occupied the two extremes (Plate II, Figs. 5 and 6) and were significantly different from all the four varieties, *viz.*, Co 210, Co 213, Co 299 and Co 313. As regards the size, Co 419 and Rheora had respectively the largest and smallest vascular bundles. The differences in the size were significant at 5% level in all varieties except Co 299 and Co 213. When the two characters of vascular bundles were considered together as reflected by the total area occupied by them in unit area of parenchymatous ground tissue, Co 419 and Co 210 had approximately the same area while Rheora was nearer Co 213 and Co 299 than Co 419. Co 313 occupied an intermediate position.

In the central region also, Co 419 and Rheora occupied the two extremes in respect of both the characters discussed above, and were significantly different when they headed the list in a particular character. Rheora and Co 419 had respectively the largest and the smallest number of vascular

TABLE II

Showing anatomical characters of six varieties of sugarcane

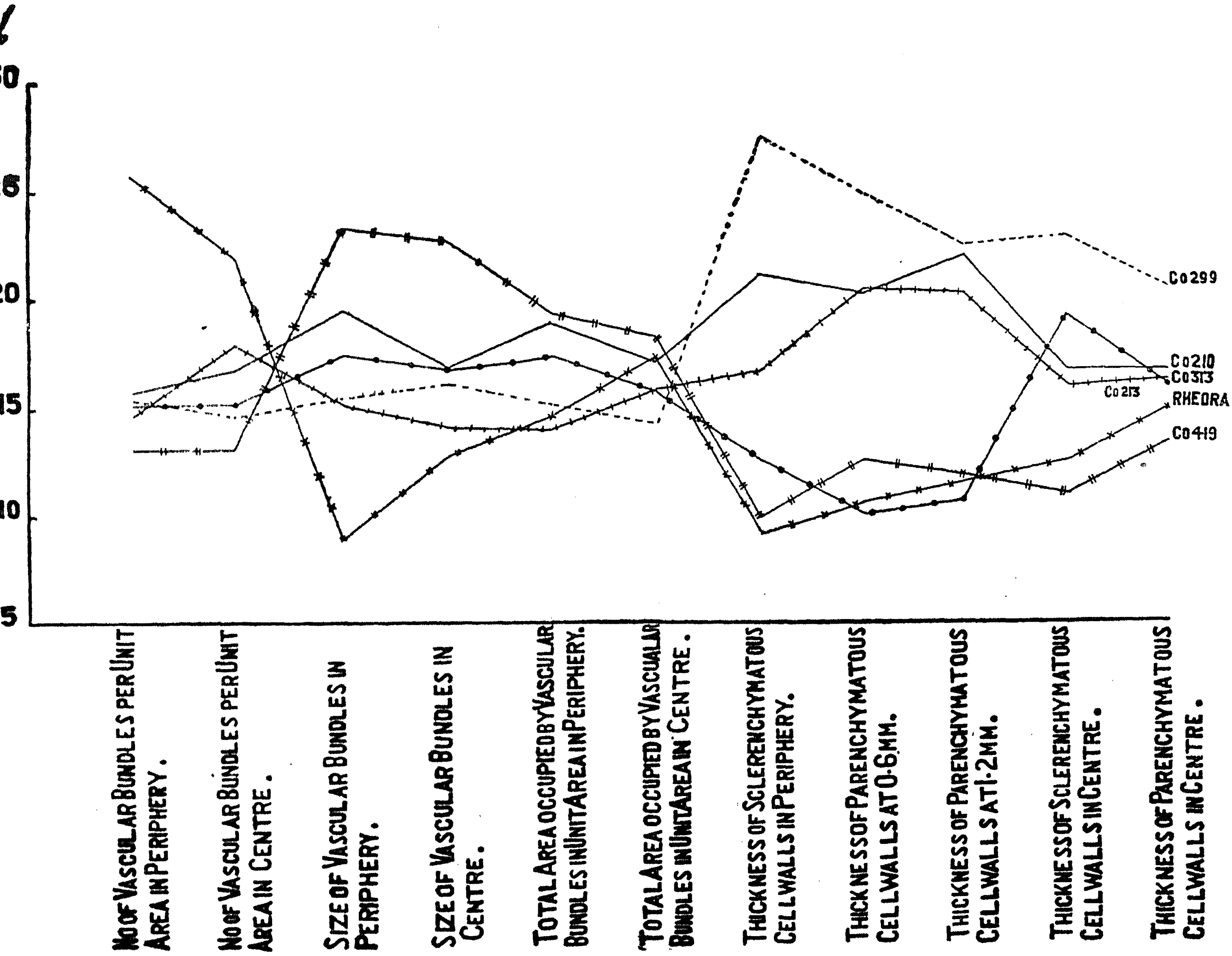
Characters	Co 210	Co 213	Co 299	Co 313	Co 419	Rheora	General mean	C.D. at 5%
A. *Vascular bundles*								
I. *In peripheral region*:								
(*a*) No. per unit area								
Actual ..	9·17	8·64	9·00	8·96	7·71	14·98	9·74	0·58
% of total ..	15·7	14·8	15·4	15·3	13·2	15·6	..	..
(*b*) Size—								
Actual ..	404·4	316·4	324·8	367·8	485·0	188·5	347·8	32·7
% of total ..	19·4	15·2	15·6	17·6	23·3	9·1	..	..
(*c*) Total area occupied by vascular bundles in unit area								
Actual ..	3708	2734	2932	3295	3739	2824	..	..
% of total ..	19·3	14·2	15·2	17·1	19·5	14·7	..	..
II. *In Central region*:								
(*a*) No. per unit area								
Actual ..	3·44	3·73	3·02	3·14	2·75	4·48	3·43	0·32
% of total ..	16·7	18·1	14·7	15·3	13·4	21·8	..	..
(*b*) Size—								
Actual ..	359·6	306·0	346·3	362·6	486·5	281·4	356·5	34·4
% of total ..	16·8	14·3	16·2	16·9	22·7	13·1	..	..
(*c*) Total area occupied by vascular bundles in unit area								
Actual ..	1237	1141	1046	1139	1328	1261	..	..
% of total ..	17·3	16·0	14·6	15·9	18·6	17·6	..	..
B. *Thickness of cell walls*								
I. *Parenchyma*:								
(*a*) At 0·6 m.m.—								
Actual ..	23·12	23·31	28·31	11·56	14·62	12·12	18·84	3·25
% of total ..	20·4	20·6	25·1	10·2	12·9	10·7	..	..
(*b*) At 1·2 m.m.—								
Actual ..	23·69	21·81	24·25	11·56	12·81	12·50	17·77	2·19
% of total ..	22·2	20·5	22·8	10·8	12·0	11·7	..	..
(*c*) In centre—								
Actual ..	13·94	13·56	17·19	13·44	11·31	12·62	13·68	1·64
% of total ..	17·0	16·5	20·9	16·4	13·8	15·4	..	..
II. *Sclerenchyma*:								
(*a*) In peripheral region:								
Actual ..	54·0	39·31	64·56	29·94	23·62	21·75	38·94	4·77
% of total ..	21·2	16·9	27·7	12·8	10·1	9·3	..	..
(*b*) In centre—								
Actual ..	18·37	17·50	25·25	21·19	12·25	13·81	18·06	3·11
% of total ..	17·0	16·2	23·3	19·6	11·3	12·7	..	

Note.—1. The field of the microscope measuring 1·7 mm. in diameter was taken as unit area of parenchymatous matrix in which the number of vascular bundles were counted.

2. All measurements were expressed in divisions of eye-piece micrometer each of which was equal to $14 \cdot 4^2$ sq. μ and 0·21 μ respectively for the size of vascular bundles and the thickness of cell walls.

bundles per unit area, but their position was reversed when the size was considered. Of the remaining four varieties, Co 210, Co 299 and Co 313 formed a compact group while Co 213 served as a link between them on one hand and Rheora on the other, so far as the size was concerned, while in respect of the number per unit area, there was no clear grouping amongst the six varieties studied. On the basis of total vascular area also, there were no well-demarcated groups except that Co 299 and Co 419 were distinctly set apart at the two ends. The varieties of the two groups having medium and low fibre were, therefore, found scattered so far as the characters of vascular bundles were concerned.

(*b*) *Thickness of cell-walls.*—These varieties, however, segregated into three groups, more or less compact in the case of the low-fibred ones (Fig. 1)



TEXT-FIG. 1. Anatomical Characters of Sugarcane Varieties.

when the thickness of cell walls was taken into consideration. Co 299 representing the high-fibre group was a class by itself, being quite distinct in that it had very high lignification all over the entire cross-section (Plate II,

Fig. 1). Co 210 and Co 213 together formed a group as they were not significantly different from each other except in the thickness of cell walls in vascular sheaths in the peripheral region. Taking the total lignification of both the tissues—the parenchyma and sclerenchyma into consideration, Co 210 came next to Co 299 and Co 213 after it (Table II).

In the low-fibred group, Co 419 and Rheora were not significantly different from each other and showed on the whole, the poorest lignification of the tissues. Co 313 was found to be erratic in its behaviour. Whereas the variety was poorest in the lignification of the parenchymatous matrix of the rind, it was proportionately high so far as the tissues of the core were concerned. The sclerenchyma in centre was as highly lignified as that of Co 210 and significantly more than that of Co 213. In respect of the parenchymatous ground tissue it was significantly higher than that in Co 419. The variety might, therefore, be treated as a link between the medium-fibre group consisting of Co 210 and Co 213 on one hand and Co 419 and Rheora group on the other, but much closer to the latter.

The varieties, therefore, could be arranged in ascending order of lignification of tissues on the whole as follows: (Rheora–Co 419)–Co 313–(Co 213–Co 210) Co 299 which agreed closely with the sequence of varieties when arranged on the basis of their fibre contents.

IV. Enunciation of the Problem

The utility of sugarcane in the factory is determined by the ease, with which it yields its juice and the facility with which the latter in its turn, gives up the required product, namely sugar. The two-distinct phases of processing the raw material into the finished article, are respectively called extraction and condensation. The present paper naturally confines itself to the former only.

Extraction of juice is a very complex process depending upon a variety of factors which may be grouped together as (i) mechanical pertaining to (*a*) the opening between rollers, (*b*) their peripheral speed and roughness of their surfaces, (*c*) the hydraulic pressure on them and (*d*) the curvature of the trash turner, and (ii) botanical dealing with sugarcane. Of the latter group which may be further subdivided into (*a*) morphological and (*b*) anatomical—the quality and quantity of fibre in cane are the most important ones to be taken into consideration.

A stalk of sugarcane from a miller's point of view may be considered as a composite recepticle made of innumerable small containers—the cells—more or less cylindrical in shape, each of which must be ruptured to yield its contents, either by mechanical pressure or by heat. The peripheral layers of cells of the stalk constitute a jacket—the rind—which gives the necessary protection to the inner cells and requisite strength to the whole structure. The hard covering may be deemed to have protruded inwards so as to form partitions—the nodes—to give further strength to the stalk. It is, therefore, essential to know how much and what type of material has been used to form the walls of the containers, the cells, the strengthening jacket, the rind, and the transverse partitions—the nodes.

This together with certain contents of the cells which are insoluble in water, constitutes fibre in sugarcane of which in its Lousiana variety the main components according to Brownie and Blouin as cited by Deerr (1921) were:

	In rind %	In core %
Cellulose ..	51·0	49·0
Pentosans ..	26·9	32·0
Legnin ..	17·2	15·0

Within varietal limits the quantity of fibre is known to vary according to the age and environment. But regarding quality nothing definite can be stated at present although on theoretical considerations it is not likely to vary to any appreciable extent. Similarly whether the exact composition of fibre in a mature stalk is susceptible to the influences of environment is not known. The behaviour of cane stalk in various operations during the process of extraction and the utility of the resultant bagasse as fuel in relation to its morphological and anatomical characters, need much systematic work in this country before operating peculiarities of a cane variety can be forecast in its infancy. Below are given some of the difficulties often met with, depending upon how far the machinery is easily adjustable to suit the new requirements, when a change-over from one variety to another takes place.

Preparation of cane.—During the preparatory stage the cane stalk is cut up into very small pieces before passing through the rollers. Montgomery (1935) reported the experience of Alexander Smith who found that a closer setting of knives was necessary for short stalked variety D 1135 than that required for Yellow Calendonia. At Chanpatia and Motihari knives had to be adjusted nearer together while preparing Co 395 and B.O. 3. As a result of this preparation, certain varieties, for instance, B.O. 3 were reduced to a finely divided pulp, while in others like B.O. 9 the texture of the blanket was coarse. The effects of this differential disintegration would be discussed in their appropriate places.

Feeding.—The rate of feeding the rollers is mainly determined by the grip that the roller is able to maintain on the blanket of the prepared cane. If the cane is very finely divided, the rollers are unable to take a feed with the result that chocking takes place because the rollers slip over the blanket without pushing it forward. This feeding difficulty is due to low fibre content of the cane as was found to be the case with Co 419 or to its very fine division in the preparatory process, *e.g.*, in B.O. 3. Both the causes weaken the cohesion of the resultant blanket. In B.O. 9, no feeding difficulty was experienced because of the coarse texture of the blanket which provided a good grip. In addition to its effect on dry crushing, the degree of fineness of preparation determines the quantity of water of imbibition that can be safely used. The finer the disintegration, the less the quantity of water that can be left in to leach out remaining juice from the pulp because the quantity of water being the same, a finely textured blanket provides a much poorer grip to the rollers than a coarse-textured one.

Extraction (proper) is the operation when the prepared cane pulp is pressed in between the rollers to separate the liquid and solid components of the blanket. That other factors namely the opening between the rollers, their peripheral speed and hydraulic pressure on them, being the same, the volume of fibre in the blanket determines the extraction, is well known; so also its effect on the movement of bagasse on the trash turner. The quality of fibre comes into the picture in certain varieties in which, for instance, Co 513 the fibre tends to fur the rollers resulting in the lifting of scraper plates of the back and top rollers. Also, in the absence of adequate cohesion in blanket, cush-cush falls in juice thus overloading the juice strainers. Finally with the same pressure bagasse of certain varieties retains greater quantity of moisture than that of others.

Addition of water of imbibition.—The economic quantity of water of imbibition is determined by (i) the juice holding capacity of the fibre, (ii) the texture of the blanket and (iii) the availability of fuel in the shape of bagasse of which the first two factors are mainly a function of the quality of fibre while the last named that of both its quality and quantity. Provided the blanket is cohesive enough to flow, varieties rich in fibre of good thermal value, admit of greater quantity of water of imbibition resulting in more thorough leaching of bagasse and therefore higher milling efficiency which in the ultimate analysis may be defined as

$$\frac{100 \times \text{sugar extracted}}{\text{total sugar per cent. in cane.}}$$

Bagasse as Fuel.—Bagasse in order to be useful as fuel in the boiler room should not be so fine as to be wafted away through the chimney nor should it be so coarse as to contain flakes which would retard combustion. It should contain adequate quantity of moisture which according to Alexander Smith as reported by Hedlay (1936) was found to be 40%. These desirable qualities of bagasse together with the thermal value and resultant absence of clinkers in furnace are directly the attributes of the quality of fibre. That quantity would determine whether bagasse is sufficient or not, is too obvious to be mentioned.

V. Discussion of Data

From the observations recorded earlier it would appear that the number of vascular bundles per unit area and their size were not factors of sufficient importance to explain the differential behaviour of the six varieties when they were milled. The total area under them per unit area in the two regions in different varieties also was in no way helpful in understanding their divergent milling properties. As these varieties segregated into three groups, when the lignification of cell-walls of two tissues namely parenchyma and sclerenchyma in different regions was taken into consideration, thickness of cell walls could, therefore, be taken as a sufficiently good index of fibre in cane. Buzacott (1940) and Rao (1941) also found a positive correlationship between the fibre content and rind hardness which in the ultimate analysis was found to be the function of the lignification of cells forming the vascular sheaths and of parenchymatous matrix as also of the area under vascular bundles (Khanna and Panje, 1939).

Turning to the milling characteristics of these varieties, Co 210 and Co 213 were found to posses the same operating peculiarities which appeared to be quite natural in view of their fibre content. The change-over from one variety to the other did not involve any adjustment of mill settings because both the canes were very similar to each other in their anatomical characters.

With the introduction of Co 299, the mill settings had to be adjusted to suit the greater volume of fibre in cane. Once a satisfactory adjustment was arrived at, no further trouble was experienced and the resultant bagasse was more than sufficient. All these features to a large extent could be foreseen from the much greater lignification of tissues in this variety than in Co 210 and Co 213.

In the case of Co 313 for which a large number of mill tests have been made during past nine years (1939–40 to 1947–48), only in a few cases a certain amount of difficulty, largely due to low fibre content, was met with. Its bagasse was reported to be insufficient in six cases: it was light but burnt well. Addition of comparatively large quantity of water of imbibition required for economic recovery, sometimes resulted in slipping or choking of rollers. The position of this variety in respect of the lignification of tissues explained all these peculiarities except the fineness of bagasse and necessity of large quantity of water of imbibition which were the attributes of the quality of fibre.

Milling of Co 419 was found to bristle with difficulties at every stage. It gave trouble throughout in almost all the milling tests. The cane broke under the impact of knives and was inclined to choke splitters; also the feed was very irregular due to insufficient cohesion of the blanket which therefore, often choked the rollers. Some factories reported uneconomically high polarity of bagasse while others found it simply impossible to crush it alone with the then settings which in almost all cases were adjusted for medium-fibred canes like Co 210 and Co 213.

It would not be out of place to discuss exactly why a low-fibred variety could not be milled efficiently with mechinery set for medium-fibre canes. As the blanket of prepared canes approaches the top and back rollers, it is broken up into its solid and liquid components, namely fibre and juice the former of which together with a small quantity of the latter is thrown out while the greater part of the latter retained. The mass thus ejected consists of a solid residue, the fibre and a fluid residue the juice, and is equal to the "escribed" volume which is obtained by multiplying the width of the opening between the rollers, by their length and the surface speed (Deerr, 1921). Now "escribed" volume remaining constant, the quantity of juice allowed to pass through the rollers will be greater if the quantity of the solid residue is reduced. Again in order to obtain maximum extraction, it is essential that compressed bagasse between the coacting rollers forms a juice-tight seal so that the extracted juice is not reabsorbed by the bagasse which has passed the maximum pressure between the rollers. Consequently reduction in the amount of fibre in the emergent material would allow more of juice to be reabsorbed and this together with inadequate expulsion of juice would explain higher polarity of the bagasse.

Moreover, as stated before the amount of fibre determines the pressure on trash tuner and thereby the speed of the blanket. Mill setting remaining the same, a decrease in solid residue will therefore, reduce the pressure on the trash turner and a blanket of finely prepared bagasse will not be cohesive enough to maintain a regular feed for the top and back rollers.

In view of what has been stated above, low fibre content explained all the difficulties experienced while milling Co 419. Rheora in which total lignification was estimated to be more or less equal to that of Co 419 had exactly the same operating peculiarities. According to Sinclair (1941) it was reduced to such a fine state in the final bagasse that much of it was blown away through furnace without proper combustion; also the polarity of final bagasse was higher than in Coimbatore varieties.

SUMMARY

1. The present contribution deals with milling characteristics of six sugarcane varieties in relation to their anatomical make-up.

2. A short review of literature is given. Whereas the influence of fibre content on efficient milling was known long time back, that of the nature of fibre has been realised only recently. The problem in its various details is enunciated.

3. Six varieties, *viz.*, Co 299 with high fibre, Co 210 and Co 213 having medium fibre and Co 313, Co 419 and Rheora with low fibre were studied for the following characters.

A. The number of vascular bundles per unit area and their average size in a unit area in (i) the peripheral and (ii) central regions.

B. The thickness of cell-walls of (i) parenchymatous tissue at depths of 0·6 mm. and 1.2 mm. from the epidermis and in central region and (ii) of sclerenchymatous tissue in the periphery and centre.

4. The number of vascular bundles per unit area and their size, and total area under them as such, did not seem to explain the differential behaviour of these varieties when milled.

5. Co 299 was found to have the greatest amount of lignification of cell-walls over the entire cross-section; as also the fibre. Co 210 and Co 213 came next to it from both points of view. Co 313 was intermediate between the medium-fibred group and Co 419 and Rheora which showed poorest lignification and lowest fibre.

6. The magnitude of lignification in both the tissues in different regions was found to be a reliable index of fibre in cane.

7. The operating peculiarities of the six varieties were explained on the basis of fibre content of the cane and therefore on the magnitude of lignification of both the tissues. Co 210 and Co 213 could be milled efficiently with the same settings. Co 299 required regulation of speed because of higher fibre content. In the case of Co 313, some trouble was experienced because of rather low fibre percentage. Milling of Co 419 and Rheora was found to bristle with difficulties. Their bagasse was not sufficient; there were frequent choking at splitters or rollers; and the polarity of the

bagasse was uneconomically high, all of which could be explained by poor lignification of tissues.

ACKNOWLEDGEMENTS

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REFERENCES

1. Buzacott, J. H. .. "The Relationship between Hardness of Sugarcane and Varietal Resistance to Beetle Borer (*Rhabdocnemis obscure* Boisd)," *Tech. Commun. Bur. Sug. Expt. Sta.*, Queensland, 1940, **8**, 127–52.

2. Deerr, Noel .. *Cane Sugar*, Norman Rodger, London, 1921.

3. Dymond, G. C. .. "Varietal milling results in Natal," *Proc. 16th Cong. S. African Sugar Tech. Assoc.*, 1942, 37–42.

4. Hedlay, E. P. .. "Some physical properties of sugarcane," *Proc. 10th Cong. S. African Sugar Tech. Assoc.*, 1934, 39–47.

5. Khanna, K. L., and Panje, R. R. "Studies in the Rind Hardness of Sugarcane. I. Anatomy of the Stalk and Rind Hardness," *Ind. Jour. Agric. Sci.*, 1939, **9**, 1–14.

6. ——— and Sharma, S. L. "Studies in the anatomy of sugarcane stalk.—Milling characteristics of varieties," *Proc. Ind. Sci. Cong.*, 1940, 46–47.

7. ——————— .. "Studies in the anatomy of sugarcane stalk. I. Chewing canes," *Proc. Ind. Acad. Sci.*, 1947, **24**, 13–31.

8. Montogomery, J. W. .. "Milling and boiling characteristics of new varieties," *Proc. 15th Hawai Sug. Tech. Associ.*, 1936, 189–97.

9. Puertas, R. P. .. "A study of cane fibre, its composition and its effects on milling efficiency," *Proc. 17th Meeting Associ. Sugar Tech.*, Cuba, 1943, 95–110.

10. Thuljaram Rao, J. .. "Rind hardness as a possible factor in resistance of Sugarcane Varieties to the stem borer," *Curr. Sci.*, 1941, **10**, 365–66.

EXPLANATION OF PLATE II

T.S. of peripheral region of stems of six sugarcane varieties.—Fig. 1, Co 299; Fig. 2, Co 210; Fig. 3, Co 213; Fig. 4, Co 313; Fig. 5, Co 419; and Fig. 6, Rheora. Figs. 1 and 2 show high lignification of cell walls, more so in the former where the lumen of cell in vascular sheaths is hardly visible; the vascular bundles are well defined. Fig. 3, cell walls are not so thick as in the first two: vascular bundles imperceptibly merge into ground tissue. Fig. 4, lignification is not so great as in the first three. The lumen of cells is distinctly present; vascular bundles in all the four are more or less equal in size. Figs. 5 and 6, similar to Fig. 4. Vascular bundles are largest but smallest in number in Fig. 5, and the reverse in Fig. 6 ($\times 80$).

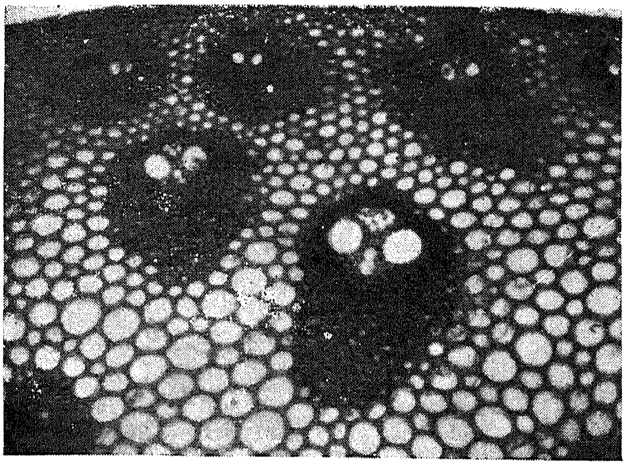

FIG. 1

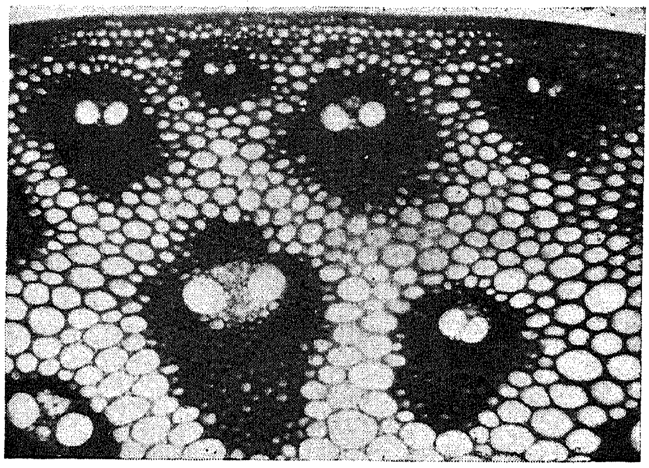

FIG. 2

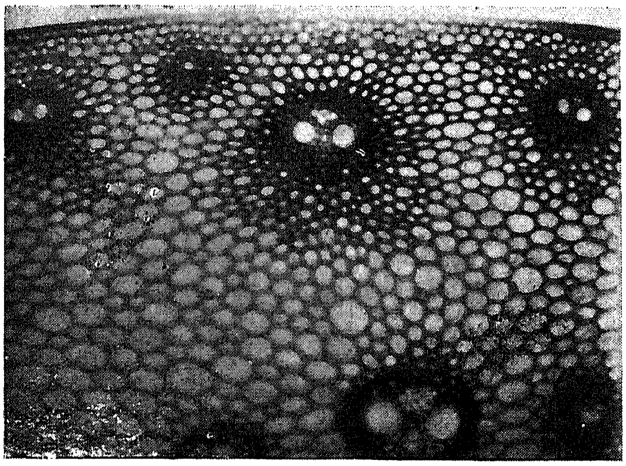

FIG. 3

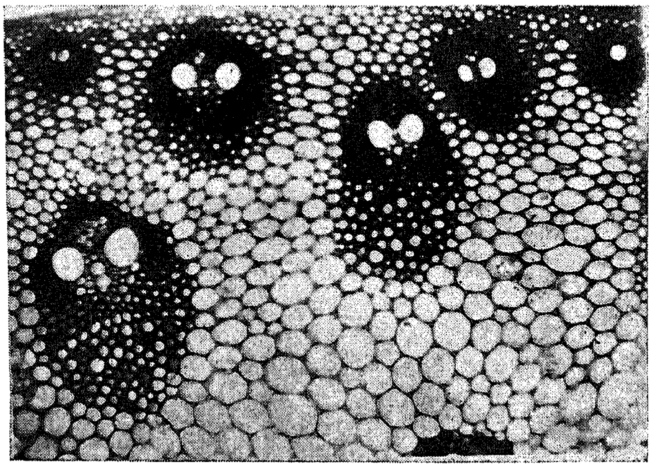

FIG. 4

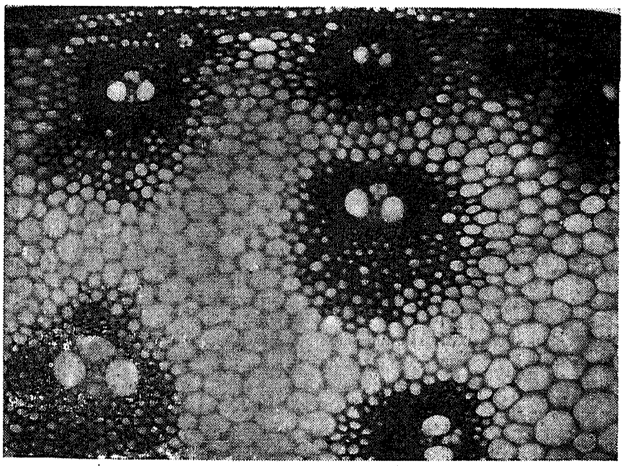

FIG. 5

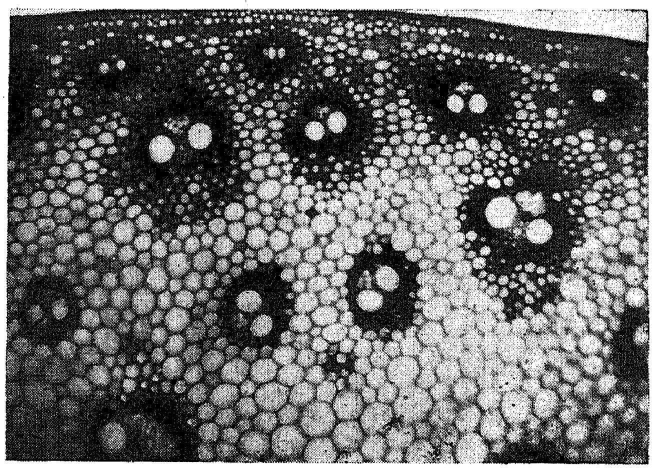

FIG. 6