# SOME PHYSICAL PROPERTIES OF SUGAR CANE

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## INTRODUCTION

The introduction of the new variety canes (canes other than Uba) during the past few years has given rise to two questions which call for a reply. We have been much concerned with the problem as to what constitutes a hard or soft cane, and as to what calorific value is to be expected from the bagasse of these canes. During the past few months a good deal of work has been done at the Experiment Station on these points, and the results are set forth in what follows.

It is a matter of common experience that some canes are harder than others and that certain parts of the stick of cane are harder than other parts of the same stick. Thus the rind and nodes are harder than the pith of the internodes and Uba cane is in general considered harder than, for example, the P.O.J. canes. But such comparisons are merely relative and it is said that when P.O.J. 2878 was first introduced into the Javanese sugar factories it was considered a hard cane, whereas in South Africa it is looked upon as one of the "soft canes." When, however, it was desired to translate this hardness or softness into measurement, the problem of how to state the measurements was by no means obvious.

When an engineer, for example, desires to know the physical characteristics of the metals he is about to use, he finds the hardness recorded in Brinell numbers, the yield point in tons per square inch, brittleness in Izod impact numbers, the compression in pounds per square inch and so on, and machines are designed for obtaining these values.

In making tests like these, the experimenter is able to prepare his metal and cut it into standard shapes. For example, in the universally adopted tensile test, a specimen, cut somewhat like a dumb-bell as in Fig. 1, is pulled in the direction of its axis, and the load per unit area needed to break it is determined. Such a test could not be applied to sugar cane, because if such a standard piece could be cut from all canes which it was desired to study it is obvious that the rind would always be cut away and the results would only apply to the centre parts of the stick. Moreover, it is more probable that the ends of the dumb-bell would be pulled off the test piece rather than breakage occurring, where it is desired, namely on the narrow portion of the rod.

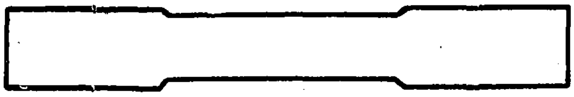

Fig. 1

Furthermore, owing to the irregularity in shapes and sizes of canes in general, it would be impossible to refer results to a standard dimension such as pounds per *square inch.* The square inch would at times include the rind around the stick and at other times only the pith.

It is clear, therefore, that the usual engineering devices cannot be applied to sugar canes and some other methods must therefore be evolved. The object in conducting this investigation was not with the hope of being able to correlate the results with the horsepower used by the mill's crusher for example, but rather to see (i) how the canes vary under different growth conditions (irrigation, etc.) and ((ii) how the varieties vary amongst themselves.

A search in the literature revealed that the problem of skin hardness had been worked by quite a number of investigators who had worked on plums, tomatoes, mealies, pears, and on sugar cane, but there was nothing to be found which would suggest a means of studying the stick itself.

At this point Mr. Reim, of the Howard College, came to the rescue with an instrument he had used for measuring the hardness of coke, and Mr. Macbeth, of Natal Estates, taking the principles of Mr. Reim's machine, modified it to suit the demands of the projected work. This instrument was used to test the stick of cane itself, and that found in the literature to examine the rind.

Having solved these difficulties the rest of the programme would present nothing as perplexing and the work could now proceed.

## THE HARDNESS OF SUGAR CANE.

**Rind Hardness.**—The instrument used for measuring the hardness of the rind of the canes is described by Venkatraman,[1] and a photograph of the instrument used to obtain the results recorded herein is shown in Fig. 2.

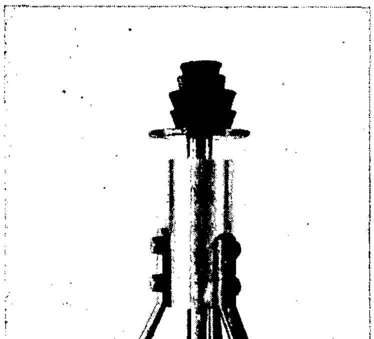

Fig. 2

Venkatraman set out to produce a sugar cane which would be resistant to the rats, jackals, porcupines and wild pigs which damage the canes grown by the villagers in the Indian cane growing areas. He succeeded admirably in combining a tough rind with a good sucrose content in Co.281 as will be seen below, but he modestly says that all the various animals which damage the cane have not been prevented from their destructive work. A cane has not been bred which will resist the attacks of elephants for example!

The instrument as will be seen from the figure is of simple construction. A plunger passes through a guide block and on the top is a platform for carrying weights. The plunger and table are of steel. At the bottom of the plunger is a brass piece which screws into the plunger rod by means of a coarse thread. In the brass nipple a piercing needle is placed by drilling a suitable hole, plugging the hole with a match and then driving into the wood a gramophone needle, the point of which had been cut off and ground quite flat. This was found to be a more simple arrangement than that described by Venkatraman and it allowed of the easy renewal of a broken piercer. The diameter of the needle was 0.9 m.m. (Venkatraman used a bit 0.7 m.m.) and it projected below the nipple 4 m.m. This is quite long enough to penetrate the skin of any cane.

The cane upon which the measurements are to be made rests in a brass carrier which is big enough to take any size of cane and when smaller pieces are being experimented with they can be packed with bits of lead to prevent them from rolling and thus breaking the piercing needle

When conducting the measurements a short piece of cane is placed on the carrier, consisting of two or three internodes in length, as shown in the figure. The piercer touches the rind and weights are added slowly until the point penetrates the rind which it does suddenly, leaving no doubt as to the accuracy of the measurement. Having taken one measurement, three more are taken at 90 deg. from each other. In most cases the results are in close agreement, but should a measurement differ greatly from its predecessor or successor the test is repeated twice, as near the questioned measurement as possible without putting the piercer on the fibres already broken by the needle. It very seldom happened that the first measurement had to be rejected.

The readings were taken for every node on every stick examined and some 15,823 measurements of rind hardness have been made.

The hardness figures were then added up and divided by the number of nodes, thus giving what was taken as the average of the stick. The canes examined were divided into irrigated and non-irrigated classes and the summary of the results is as follows:—

TABLE I.

RIND HARDNESS.

| Name of Cane. | Weight in pounds needed to penetrate the rind of the cane. | |
|---|---|---|
| | Irrigated. | Not irrigated. |
| Uba .. .. .. .. .. .. .. | 8.0 .. | 10.9 |
| Co. 281 .. .. .. .. .. .. | — .. | 10.5 |
| P.O.J. 2878 .. .. .. .. .. | 7.8 .. | 10.3 |
| P.O.J. 2725 .. .. .. .. .. | 8.9 .. | 9.9 |
| Co. 290 .. .. .. .. .. .. | 8.5 .. | 9.2 |
| Co. 301 .. .. .. .. .. .. | — .. | 8.3 |
| P.O.J. 2714 .. .. .. .. .. | 7.9 .. | — |

It will be noticed that all the irrigated canes are softer than the non-irrigated canes, a result which would be expected. It is astounding, however, what weight is required to puncture the rind of some of the sticks near the base, 16lbs. being quite a common figure in Uba and Co.281.

Canes have been examined which were grown on hill sides and flat lands, under irrigation and not under irrigation, plant canes and ratoon canes, but the only factor which seems to affect the rinds in a measureable manner is irrigation. as reported in Table 1.

There were. however, some peculiarities noticed, thus in many sticks in every variety it was found that two sides at 180 deg. to each other were softer than the sides at right angles to these two points. Usually the buds were on these soft sides. An example is given in Table 2, which records the figures for a Uba stick grown at Doornkop, 2,000 feet above sea level.

TABLE II.

| Node Number | Bud. | | Between the Buds. | |
|---|---|---|---|---|
| Base .. .. | 9 lbs. | 9 lbs. | 12 lbs. | 11 lbs. |
| 2 .. .. .. | 9 ,, | 9 ,, | 12 ,, | 12 ,, |
| 3 .. .. .. | 9 ,, | 8½ ,, | 13 ,, | 12 ,, |
| 4 .. .. .. | 9 ,, | 11 ,, | 13 ,, | 11 ,, |
| 5 .. .. .. | 8 ,, | 8 ,, | 10 ,, | 9½ ,, |
| 6 .. .. .. | 9 ,, | 8 ,, | 9 ,, | 9 ,, |
| 7 .. .. .. | 7½ ,, | 8 ,, | 10 ,, | 9 ,, |
| 8 .. .. .. | 9 ,, | 8 ,, | 9½ ,, | 10 ,, |
| 9 .. .. .. | 7 ,, | 7 ,, | 10 ,, | 9 ,, |
| 10 .. .. .. | 6 ,, | 5½ ,, | 9 ,, | 8 ,, |
| 11 .. .. .. | 6½ ,, | 7 ,, | 10 ,, | 9½ ,, |
| 12 .. .. .. | 6 ,, | 7½ ,, | 11 ,, | 10 ,, |
| 13 .. .. .. | 7 ,, | 7 ,, | 10 ,, | 11 ,, |
| 14 .. .. .. | 7 ,, | 7 ,, | 11 ,, | 11 ,, |
| 15 .. .. .. | 6 ,, | 6 ,, | 10½ ,, | 11 ,, |
| 16 .. .. .. | 6 ,, | 6 ,, | 10 ,, | 10 ,, |
| 17 .. .. .. | 6 ,, | 7 ,, | 10½ ,, | 10 ,, |
| 18 .. .. .. | 7 ,, | 6 ,, | 11 ,, | 11 ,, |
| 19 .. .. .. | 8 ,, | 7 ,, | 13 ,, | 12½ ,, |
| 20 .. .. .. | 7 ,, | 10 ,, | 16 ,, | 17 ,, |
| 21 .. .. .. | 9 ,, | 7 ,, | 14 ,, | 15 ,, |
| 22 .. .. .. | 7 ,, | 9 ,, | 13 ,, | 13 ,, |
| 23 .. .. .. | 7 ,, | 7 ,, | 9 ,, | 9 ,, |
| 24 .. .. .. | 7½ ,, | 7 ,, | 9 ,, | 9 ,, |
| 25 .. .. .. | 7 ,, | 7 ,, | 9 ,, | 9 ,, |

| Node Number | Bud. | | Between the Buds. | |
|---|---|---|---|---|
| 26 .. .. .. | 7 ,, | 6½ ,, | 8½ ,, | 8½ ,, |
| 27 .. .. .. | 6½ ,, | 7 ,, | 9½ ,, | 9 ,, |
| 28 .. .. .. | 6½ ,, | 7½ ,, | 8½ ,, | 8 ,, |
| 29 .. .. .. | 7½ ,, | 7½ ,, | 8½ ,, | 9 ,, |
| 30 .. .. .. | 7½ ,, | 7 ,, | 9 ,, | 10 ,, |
| 31 .. .. .. | 7 ,, | 7 ,, | 8 ,, | 9½ ,, |
| 32 .. .. .. | 6 ,, | 6 ,, | 8½ ,, | 9 ,, |
| Top of stick .. | 6¼ ,, | 7¼ ,, | 8 ,, | 9¼ ,, |
| Total weight .. | 240¼lbs. | 244¾lbs. | 343 lbs. | 336 lbs. |
| Avge. per node | 7.27 lbs. | 7.41 lbs. | 10.39 lbs. | 10.18 lbs. |

It will be seen that the average weight required to pierce the bud sides of the stick is practically the same on both sides; i.e. 7 lbs., and that between the buds is 10 lbs. per node.

It will be noted also that there is very little difference between the weights required to puncture the rind at the base of the stick and at the top.

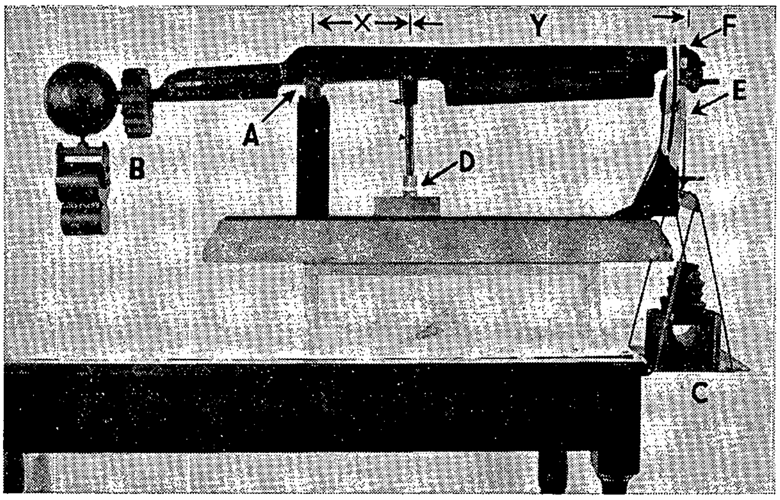

Fig. 3

Some varieties, however, decrease in hardness towards the top of the stick and usually all the sticks from the same field behaved in the same way; i.e. they either all were as hard at the base as at the top or else there was a gradual decrease in hardness, the difference being about 3 or 4 lbs. between the top and the bottom of the cane.

The diameter of the needle used for piercing the rind must be kept the same, if comparable results are to be obtained. That of course, is to be expected and for all the results recorded in this paper, the one needle sufficed. To see what the difference would be, however, the same stick was examined using two different needles, the diameters of which were 0.9 m.m. and 1.3 m.m. The average of the stick with the former was 9.0 lbs. per node and using the latter, 14.3 lbs.

### Pith and Node Hardness.

The instrument used to determine the hardness of the pith and node is shown in Fig. 3. It consists of a balanced beam on square knife edges A, and was sensitive enough to turn at less than 1 gram. At one end of the beam are balancing weights B, and at the other, a pan C, is shown carrying the weights necessary to punch a depression in the piece of cane D, shown below the punch at the middle of the beam. Just above the pan, on its own support and not attached to the moving beam, is a bright piece of metal E, into which fits a movable slide F. This slide is painted black at the top and at the bottom, but the middle section, ¾in. long, is left unpainted. This unpainted piece is clearly visible in the figure. The punch has a parabolic end and swings freely from its point of suspension on the beam.

The method of making the measurements is as follows. A piece of cane is cut about one quarter inch below the node (the node shows up well in the figure as a bright band at the base of D) and about an inch and a quarter above the node as shown in Fig. 4. The piece of cane thus obtained is then placed on the block as shown and the punch brought down so that it is above and touching the centre of the cane. The sliding indicator F, is now adjusted so that a pointer, on the end of the beam, points at the line forming the top of the bright

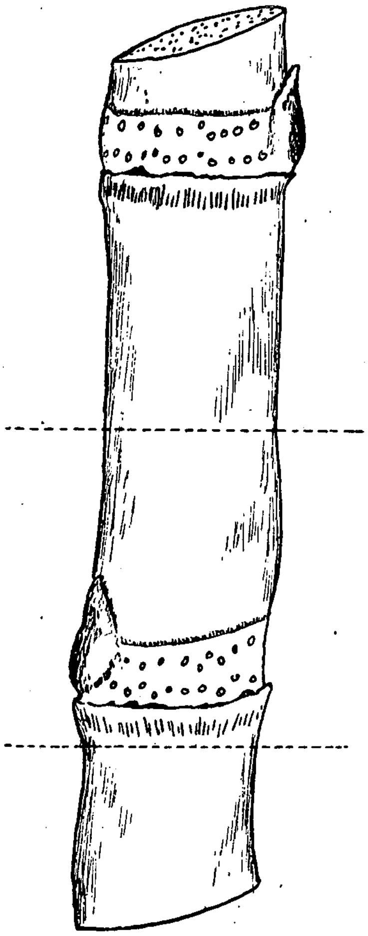

Fig. 4

section. Weights are then applied in sufficient quantity to bring the pointer to the bottom of the bright section. In doing this, the end of the beam will have travelled ¾in. and since the ratio of the distance from the fulcrum to the punch, X, and to the end of the beam, X plus Y, is as 1 to 4, it follows that the punch penetrated $\frac{3}{16}$ in. into the cane. The weights actually put on the pan have therefore to be multiplied by four to get the true value of the force applied to sink the punch $\frac{3}{16}$in. into the cane. This, then, is the basis of the measurements made, i.e., what weight is required to press a hole $\frac{3}{16}$in. into the pith of the cane? The measurements were made on both sides of the cane, turning the sample upside down after making the first measurements, and will be referred to as the pith and node figures.

The results obtained from these measurements, 22,982 in all, are summarised in Table 3.

An examination of the Table will show that the canes used for this investigation were as typical as possible in regards to soil, height grown above sea level, and position in the sugar belt. Irrigated and non-irrigated canes have been included from wherever possible.

TABLE III.

| Cane. | Age in months | Plant or Ratoon. | Source. | Weight in pounds to make $\frac{3}{16}$-inch hole. | | Rind hardness Lbs. | Not irrigated. | Irrigated. |
|---|---|---|---|---|---|---|---|---|
| | | | | Pith. | Node. | | | |
| **Uba** .. .. | 12 | Plant .. .. | Saccharine Estates | 88.4 | 122.8 | 9.3 | — | I. |
| | 14 | Second ratoon | Umfolozi .. .. | 71.6 | 122.2 | 6.7 | — | I. |
| | 22 | Plant .. .. | Maidstone .. .. | 89.6 | 132.8 | 9.5 | N.I. | — |
| | 22 | Plant .. .. | Experiment Station | 105.2 | 132.8 | 10.1 | N.I. | — |
| | 22 | Plant .. .. | Doornkop .. .. | 80.4 | 122.4 | 8.0 | N.I. | — |
| | 12 | Bull shoot*.. | .. | 64.0 | 100.0 | 7.1 | N.I. | — |
| | 12 | Bull shoot*.. | .. | 62.0 | 102.0 | 7.0 | N.I. | — |
| **Co. 281** .. | 11 | Plant .. .. | Umhlali .. .. | 85.6 | 131.2 | 10.5 | N.I. | — |
| | 15 | Plant .. .. | Waldene .. .. | 87.0 | 130.0 | 10.5 | N.I. | — |
| **Co. 290** .. | 12 | Plant .. .. | Saccharine Estates | 82.0 | 116.0 | 8.2 | — | I. |
| | 14 | First ratoon . | Umfolozi .. .. | 63.2 | 105.6 | 8.9 | — | I. |
| | 12 | First ratoon . | Umhloti .. .. | 83.6 | 111.8 | 8.2 | — | Flats |
| | 22 | Plant .. .. | Maidstone .. .. | 73.6 | 109.2 | 9.1 | N.I. | — |
| | 24 | Plant .. .. | Sinembe .. .. | 82.0 | 121.2 | 9.1 | N.I. | — |
| | 11 | Plant .. .. | Hillbrow .. .. | 78.4 | 114.4 | 9.5 | N.I. | — |
| | 22 | Plant .. .. | Chakas Kraal .. | 74.0 | 112.8 | 10.8 | N.I. | — |
| **Co. 301** .. | 22 | Plant .. .. | Experiment Station | 88.0 | 124.8 | 8.5 | N.I. | — |
| | 11 | Plant .. .. | Experiment Station | 91.6 | 122.8 | 8.2 | N.I. | — |
| **P.O.J. 2725** | 12 | First ratoon . | Umfolozi .. .. | 53.6 | 76.0 | 7.6 | — | I. |
| | 12 | First ratoon . | Saccharine Estates | 85.6 | 116.4 | 7.2 | — | I. |
| | 22 | Plant .. .. | Umbogintwini .. | 80.0 | 98.4 | 9.4 | N.I. | — |
| | 22 | Plant .. .. | Chakas Kraal .. | 85.2 | 108.4 | 10.8 | N.I. | — |
| | 22 | Plant .. .. | Maidstone .. .. | 69.6 | 110.4 | 8.5 | N.I. | — |
| | 22 | Plant .. .. | Chakas Kraal .. | 80.0 | 108.4 | 11.1 | N.I. | — |
| **P.O.J. 2878** | 23 | Plant .. .. | Saccharine Estates | 81.5 | 104.4 | 8.8 | — | I. |
| | 14 | First ratoon . | Umfolozi .. .. | 60.8 | 91.6 | 7.1 | — | I. |
| | 12 | First ratoon . | Saccharine Estates | 71.2 | 108.8 | 7.7 | — | I. |
| | 24 | Plant .. .. | Chakas Kraal .. | 80.0 | 109.6 | 10.3 | N.I. | — |
| | 14 | Fourth ratoon | Experiment Station | 68.4 | 93.6 | 7.6 | — | I. |
| | 22 | Plant .. .. | Chakas Kraal .. | 82.0 | 110.1 | 9.8 | N.I. | — |
| | 12 | Bull shoot*.. | Saccharine Estates | 58.0 | 86.4 | 6.7 | — | I. |

* The term "Bull shoot" is a South African expression for a cane produced by late tillering in the second year of the growth of the crop.

The first obvious deduction is that *the pith of the cane is softer than the node,* that, of course, was quite expected. The reason for this is not so well known, and Figs. 5 and 6 have been included to make the point clear. These represent thin sections of cane cut so as to show the anatomy of the nodes. In Fig. 5, the fibres which extend all down the cane are clearly seen as white lines. Running across the cane, are a series of white lines, these are the transverse fibres and their intersection with the longitudinal fibres, felting together as it were, makes the node dense and strong. In this particular cane, the nodes were seven inches apart, but in Fig. 6, the nodes are very near together and are more dense than those in Fig. 5. Such a cane, owing to its dense nodes and to the great number of them is very strong and hard. The rind is better shown in Fig.5. than in Fig. 6.

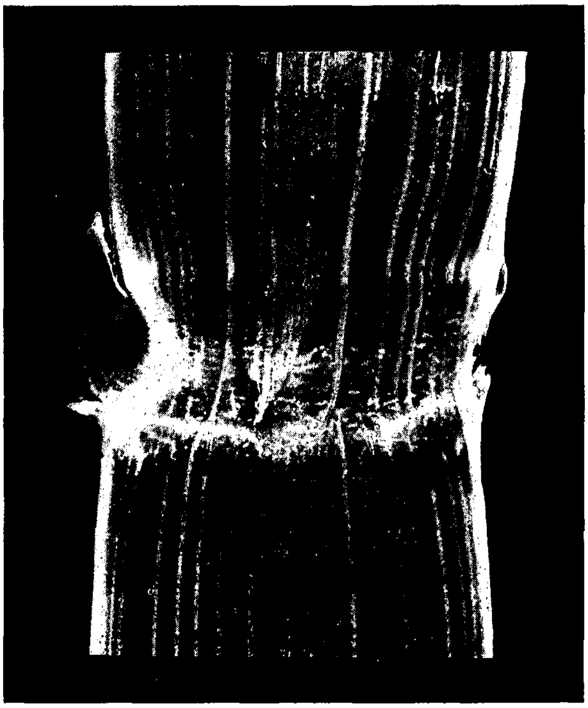

Fig. 5

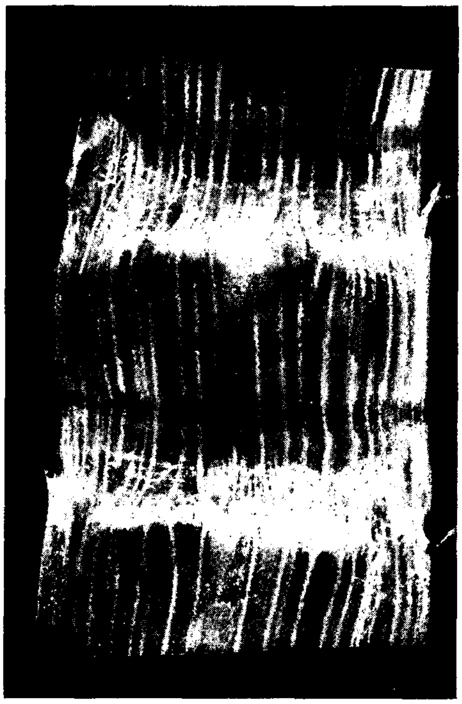

Fig. 6

The next point which the Table shows is that *the pith and node figures for any variety of cane do not differ greatly amongst themselves when the cane is irrigated or when it is not.* Thus, for Uba it is shown that the pith figure of 88.4 lbs. together with the node figure of 122.8 lbs., does not differ greatly from the pith of Doornkop's cane, 80.4 lbs. and node 122.4 lbs. The first sample was irrigated cane and the latter grew without irrigation, at 2,000 feet above sea level. Examining the Table will show that the statement is true for each variety.

It will also be noted that *age does not make much difference to the hardness of the stick.* For example, Co. 290 grown at Hillbrow, when 11 months old, had a pith hardness of 78.4 lbs. and node of 114.4 lbs., and Co. 290, 22 months, from Mr. J. E. Martin's Estate, had a pith hardness of 74.0 lbs. and the node hardness of 112.8 lbs. The same is true of the Co. 301, grown at the Experiment Station.

*No significant difference is observable when the cane is plant or first ratoon.* This is seen, for example, in the first three lines of the Co. 290 figures.

*A situation may have far more effect on the hardness than any other factor.* All the canes from Umfolozi are softer than any of those from any other situation, even than canes from Natal Estates, which were also irrigated. I am not sure that this is a general fact because I cannot trace it anywhere else.

*Bull shoots are definitely very soft, even without irrigation.* One obtained from Natal Estates is shown in Table 3, but the complete data which was summarised in this Table is given as Table 4. This was a fine stick of cane, weighing 13 lbs., having long internodes, as can be seen in the Table. One of the points of interest which the Table brings out is the small variation in the hardness of the pith up the stick, the node has a tendency to harden towards the top, while the rind hardness is greatest in the middle. This is quite a common observation, though not a general rule. The last three or four nodes and pith in a stick are frequently several pounds harder than those further from the top. This is probably due to the concentration of the vascular bundles in the top parts of the stick. As the stick grows and new tops form, the ground tissue, which is softer material, pushes the vascular bundles in the former tops further apart, and hence the whole internode becomes softer.

## TABLE IV.

**Bull Shoot of P.O.J. 2878, twelve months' old. Saccharine Estate, irrigated land.**

| Pounds weight to penetrate $\frac{3}{16}$ inch. | | Diameter of Stick in inches. | | Length of Internode in inches. | RIND HARDNESS—Pounds weight. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pith. | Node. | Internode. | Node. | | | | | | Average. |
| 60 Base of stick | 68 | $2\frac{5}{16}$ | $2\frac{7}{16}$ | 4 | 6 | 8 | 7 | 6 | 6.7 |
| 52 | 88 | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $6\frac{1}{2}$ | 6 | 7 | 7 | $6\frac{1}{2}$ | 6.6 |
| 52 | 76 | $2\frac{1}{8}$ | $2\frac{1}{8}$ | 8 | 7 | $7\frac{3}{4}$ | $6\frac{3}{4}$ | 6 | 6.0 |
| 52 | 80 | $2\frac{1}{16}$ | $2\frac{1}{16}$ | 9 | $6\frac{1}{4}$ | 7 | $7\frac{1}{2}$ | 5 | 6.4 |
| 52 | 80 | $1\frac{15}{16}$ | $1\frac{15}{16}$ | $9\frac{3}{4}$ | $7\frac{1}{2}$ | $7\frac{3}{4}$ | $9\frac{1}{2}$ | 8 | 8.2 |
| 48 | 88 | $1\frac{7}{8}$ | $1\frac{13}{16}$ | $10\frac{1}{4}$ | 9 | 7 | $9\frac{1}{2}$ | 8 | 8.4 |
| 60 | 76 | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $10\frac{3}{4}$ | $9\frac{1}{2}$ | 6 | $7\frac{1}{2}$ | 7 | 7.0 |
| 56 | 100 | $1\frac{11}{16}$ | $1\frac{5}{8}$ | $10\frac{3}{4}$ | $7\frac{1}{2}$ | 7 | $6\frac{1}{2}$ | $5\frac{3}{4}$ | 6.7 |
| 68 | 100 | $1\frac{9}{16}$ | $1\frac{9}{16}$ | $8\frac{1}{4}$ | $5\frac{1}{2}$ | 5 | 7 | 6 | 5.9 |
| 80 | 96 | $1\frac{7}{16}$ | $1\frac{1}{2}$ | $5\frac{3}{4}$ | $5\frac{1}{2}$ | 6 | 5 | 6 | 5.6 |
| 60 Top | 96 | $1\frac{7}{16}$ | $1\frac{7}{16}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | 6 | $6\frac{1}{2}$ | 6 | 6.2 |
| Average 58.0 | 86.4 | | | | | | | | 6.7 |

The most outstanding fact in the whole of Table 3 is the fact that *the rind is always softer in irrigated cane than that in non-irrigated cane.*

The engineer whose business it is to crush Uba cane for sucrose extraction, on considering all these points, may enquire what then is a hard or soft cane? It has been stated that the measurements do not show any great variation in pith or node hardness whether a cane is irrigated or not, but the Table does show that the rind and nodes are much harder in some varieties than in others. The pith does not vary so greatly. The nodes of Uba are the hardest recorded; 132 lbs. for non-irrigated and 122 lbs. for irrigated. The next hardest nodes are those of Co. 281, which is given as 131 lbs. and 130 lbs. The rind of both these canes is hard. They head the list in Table 1.

Uba cane very frequently has very short internodes, which means that it has many nodes which are closed together like those in Fig. 6. Moreover, Uba cane is a much thinner cane than the others released from quarantine, which means that the ratio of hard rind to pith is greater in Uba cane than in the larger varieties. For these two reasons, it seems to the writer, that Uba cane is the hard cane we all know. Next in order comes Co. 281.

There is another peculiarity of Uba which may cause it to be a little harder than other canes, and which can be shown in the following way. If the rind is stripped off an internode and one takes hold of a fibre bundle with a tweezers and pulls it carefully out of the stick, it will be found that it is difficult to pull the bundle out and that when it finally comes away from the stick, the bundle has a lot of pieces of cane sticking to it. If, however, one tries the same operation on 2725, for example, it will be found that the bundle parts easily from the stick and comes away cleanly. There will be no cane sticking to the fibre. That is to say there is some cementing material in Uba which holds the fibres firmly and to some small extent will assist in resisting the crushing.

Table 5 is a copy of the figures resulting from the examination of a single stick of Uba. In addition to those recorded, the data given in Table 2 was taken also. This gives some idea of the number of measurements made on each stick. The weight lifted on to the pan for the node and pith hardness was in this case one quarter of 3796 plus 5316 lbs. or 2278 lbs. and as the weights had to be taken off the pan also, this figure must be double. Hence, to get the data for the stick, two tons had to be lifted, to which must be added the half-a-ton necessary to find the rind hardness. At the end of a day, when eight sticks had been examined, the workers were fairly tired of the job. In the whole work reported, 38,805 measurements have been made.

### TABLE V.

*Cane.*—Uba.
*Age.*—22 months. Plant.
*Source.*—Field F2, Experiment Station.

| | Pounds weight to penetrate $\frac{3}{16}$ inch. | | Diameter of stick in inches. | | Length of Internode. in inches. |
|---|---|---|---|---|---|
| | Pith. | Node. | Inter-node. | Node. | |
| | 80 | 140 | 1 | 1 | $4\frac{1}{2}$ |
| | 80 | 132 | 1 | 1 | 4 |
| | 84 | 132 | 1 | 1 | 3 |
| | 88 | 128 | 1 | $\frac{15}{16}$ | 3 |
| | 104 | 140 | $\frac{15}{16}$ | $\frac{7}{8}$ | $2\frac{3}{4}$ |
| | 104 | 140 | $\frac{15}{16}$ | $\frac{7}{8}$ | 2 |
| | 100 | 160 | $\frac{7}{8}$ | $\frac{7}{8}$ | 1 |
| | 112 | 152 | $\frac{15}{16}$ | $\frac{7}{8}$ | 1 |
| | 104 | 144 | $\frac{15}{16}$ | $\frac{7}{8}$ | $1\frac{1}{2}$ |
| | 108 | 128 | $\frac{15}{16}$ | $\frac{15}{16}$ | $1\frac{1}{2}$ |
| | 108 | 156 | $\frac{15}{16}$ | $\frac{15}{16}$ | $1\frac{1}{4}$ |
| | 100 | 136 | $\frac{15}{16}$ | 1 | $1\frac{1}{4}$ |
| | 112 | 120 | $\frac{7}{8}$ | 1 | 1 |
| | 112 | 140 | $\frac{7}{8}$ | 1 | $\frac{3}{4}$ |
| | 92 | 120 | $\frac{15}{16}$ | $\frac{15}{16}$ | $\frac{3}{4}$ |
| | 100 | 116 | $\frac{7}{8}$ | $\frac{15}{16}$ | $\frac{3}{4}$ |
| | 80 | 128 | 1 | $\frac{15}{16}$ | $1\frac{1}{2}$ |
| | 100 | 120 | 1 | $\frac{15}{16}$ | $1\frac{3}{4}$ |
| | 100 | 140 | $\frac{7}{8}$ | $\frac{7}{8}$ | 1 |
| | 96 | 124 | $\frac{15}{16}$ | $\frac{15}{16}$ | 1 |
| | 88 | 140 | $\frac{15}{16}$ | $\frac{15}{16}$ | $1\frac{1}{4}$ |
| | 92 | 136 | 1 | 1 | $1\frac{1}{4}$ |
| | 96 | 124 | 1 | 1 | $1\frac{1}{2}$ |
| | 76 | 140 | 1 | 1 | 2 |
| | 80 | 136 | 1 | 1 | 2 |
| | 84 | 120 | $1\frac{1}{16}$ | $1\frac{1}{16}$ | $2\frac{1}{4}$ |
| | 92 | 140 | $1\frac{1}{16}$ | $1\frac{1}{16}$ | $2\frac{1}{4}$ |
| | 92 | 136 | $1\frac{1}{16}$ | $1\frac{1}{16}$ | 2 |
| | 88 | 120 | $1\frac{1}{16}$ | $1\frac{1}{16}$ | $2\frac{1}{2}$ |
| | 92 | 132 | 1 | 1 | $2\frac{1}{4}$ |
| | 88 | 140 | 1 | 1 | $2\frac{1}{4}$ |
| | 80 | 120 | 1 | 1 | $2\frac{1}{2}$ |
| | 92 | 124 | 1 | 1 | $2\frac{1}{2}$ |
| | 88 | 136 | 1 | 1 | $2\frac{1}{4}$ |
| | 100 | 136 | $\frac{15}{16}$ | $\frac{15}{16}$ | $2\frac{1}{4}$ |
| | 92 | 128 | $\frac{15}{16}$ | $\frac{15}{16}$ | $2\frac{1}{4}$ |
| | 100 | 120 | $\frac{15}{16}$ | $\frac{15}{16}$ | $2\frac{1}{4}$ |
| | 100 | 120 | $\frac{7}{8}$ | $\frac{15}{16}$ | $1\frac{3}{4}$ |
| | 100 | 140 | $\frac{7}{8}$ | $\frac{15}{16}$ | $1\frac{1}{4}$ |
| | 112 | 132 | $\frac{7}{8}$ | $\frac{15}{16}$ | $\frac{3}{4}$ |
| Total weight | 3,796lbs. | 5,316lbs. | | | |
| Average .. | 94.9 | 132.9 | | | |

## THE CALORIFIC VALUES OF BAGASSES.

There has been much argument about the Calorfic value of the bagasse from new variety canes and a fall in B.T.U. has been blamed for steam-raising troubles in the boiler house. With the object of clarifying this controversy the author now gives, for the first time in South Africa, the calorific value of a series of canes grown on South African soil. These results should remove from different bagasses, once and for all, the blame for bad steam. The results are set forth in the following Table:—

### TABLE VI.

CALORIFIC VALUES OF BAGASSES.

| Name of variety. | Age in months. | Calorific values in B.T.U. A | B | Avge. | Ash free. |
|---|---|---|---|---|---|
| P.O.J. 2725 .. | 22 | 8377 | 8347 | 8362 | 8470 |
| P.O.J. 2725 .. | 22 | 8271 | 8231 | 8251 | 8378 |
| P.O.J. 2725 .. | 11 | 8126 | 8117 | 8122 | 8294 |
| P.O.J. 2878 .. | 24 | 8294 | 8259 | 8277 | 8401 |
| Co. 290 .. .. | 22 | 8272 | 8266 | 8269 | 8379 |
| Co. 290 .. .. | 11 | 8135 | 8108 | 8122 | 8239 |
| Co. 281 .. .. | 23 | 8290 | 8315 | 8305 | 8391 |
| Co. 281 .. .. | 12 | 8174 | 8177 | 8176 | 8314 |
| Uba, Doornkop | 22 | 8327 | 8346 | 8336 | 8463 |
| ,, Cornubia | 24 | 8265 | 8273 | 8269 | 8452 |
| ,, La Lucia | 24 | 8224 | 8179 | 8202 | 8384 |
| ,, Burnside | 23 | 8358 | 8372 | 8365 | 8474 |
| ,, Felixton | 22 | 8247 | 8221 | 8234 | 8487 |
| Arithmetical average of all varieties.. .. .. | | | | | 8394 |

In the first column is the name of the variety tested, and all the important released varieties are included. They have been selected from different places, different soils and young and mature canes have been examined. Columns A and B give the actual values obtained in duplicate experiments and the average of these is shown in the next column. Finally, the ash-free value is shown.

The calorific value as the mean of all varieties turns out to be 8394 B.T.U. which compares very well with the figures given by Prinsen Geerligs ("Cane Sugar and its Manufacture"). i.e. Coates, 8325 B.T.U.; Louisana, 8368 B.T.U. and Cuba, 8435 B.T.U.

It is therefore clear that once again it is shown that this basic value does not alter very greatly in any part of the world. The International Sugar Journal[2] reported the value for two varieties which support this point. The varieties tested were P.O.J. 2878, showing 8330 B.T.U. and H. 109, having 8310 B.T.U. Both tests were done by the Waimanalo Sugar Company, but it is not stated whether they are ash-free or not. If they are not ash-free values, the figures would be somewhat higher than reported.

It should not be forgotten, however, that the figures in the Table are the highest values obtainable and include the latent heat of condensation of the water formed by the combustion. This heat passes away in the flue gases and is therefore not available, consequently Prinsen Geerligs makes allowance for it in his formula, which as is well known takes the form

$$\frac{8550+7119S+6750G-972W}{100}$$

It is the opinion of the writer that 8550 is too high and that it would be better to substitute the average figure now found, namely 8394.

There has been some discussion as to the value attached to bagasse as fuel and the following suggestion is made, showing how the value may be obtained. When using coal in the factories, its calorific value may be taken as 13,000 B.T.U., which at 82% efficiency gives the B.T.U. extracted by the furnace, as 10,660. When burning bagasse, an efficiency of 64% can be obtained, and taking 8394 B.T.U. as the calorific value of the dry material 5372 B.T.U. are extracted or 2636 B.T.U. from a bagasse containing 50% moisture. It is clear, therefore, that the ratio of heat used is as 10,660 is to 2630 or very nearly 4 to 1. Hence, coal at any factory is worth four times as much as bagasse.

Before concluding this paper, the author wishes to record his sincere thanks to all those who assisted in the work involved. To Mr. F. B. Macbeth and Mr. Brickhill, of Natal Estates, thanks are due for making the machines used in the hardness tests. To Mr. Reim, of Howard College, for lending the first hardness machine, and for his interest and advice in the preliminary discussions.

### References.

[1] The Sugar Tech. Association (India), 1928, 15.
[2] International Sugar Journal, 1934, 126.

Experiment Station,
South African Sugar Association,
Mount Edgecombe, Natal,
February, 1936.

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Mr. G. C. WILSON: I congratulate you on your very excellent and interesting paper and the very lucid manner in which you have presented that paper. I am sure, gentlemen, it has raised quite a number of points which should be of great interest to all Technologists and Dr. Hedley will be very pleased to hear your comments and answer any questions which you may put to him.

Mr. ELYSÉ: It is certainly most gratifying to attend our Annual Congress and to have the usual original paper read by Dr. Hedley. As you know, daily when the mill is crushing, the Chemist has to hand in the laboratory report. Well, like the Doctor who has his best bedside manner, the Chemist usually arranges his face with the purport of his Report. If a Chemist has to tell the Manager and the Chief Engineer that his mill extraction has dropped he fully expects to be asked for a reason. Well, with years of experience we have fondly imagined we have developed a practised eye to give many reasons but I think in Dr. Hedley's paper, without a doubt he has burst many a bubble. I used to imagine that a Bull Shoot was a very hard stick of cane, not the pith itself, but the rind, and Dr. Hedley definitely states here it is a soft cane.

We will have to find some other explanation now to give the Chief Engineer why the Mill Ertraction has dropped and I would like to congratulate Dr. Hedley on his most original paper. It is certainly most gratifying to attend the Annual Congress and have data which is not found in authorities' books.

Mr. CAMDEN SMITH: Mr. Chairman, I also wish to congratulate Dr. Hedley on his original contribution to the knowledge of the Physical Properties of Cane with which we deal, and might I also ask him to take courage and proceed with these experiments. To my mind the most important measurement in investigating the Physical Properties of fibre of cane is the measurement of the tensile strength of the fibre. Especially that of the rind. As the last speaker has just mentioned it is quite noticeable when crushing these new variety canes that the bagasse coming from the last mill is not so finely divided. There are large flat flakes of rind which form a very prominent feature of the bagasse. The experience we have had in the last year in burning the bagasse of these new variety canes has brought forward a deal of trouble and difficulty from the Boiler House. It is too early to state any cause for the complaint but it is quite probably due to the presence of these large flakes of rind in the bagasse. New variety canes have those characteristics—they are not so easily burnt. According to Dr. Hedley's measurements, the calorific value differs very little. In fact his tables show that the new variety canes are slightly softer of the rind than the Uba but the question arises what are the tensile strengths of the fibres of the new variety canes. It would be a very great gain to our knowledge if he would proceed with this and give us some information on the tensile strength of the fibre for after all the brittleness of the cane does not count for very much. One which refuses to be broken up is the great difficulty. It not only affects the extraction but a cane having a high tensile strength in its fibres will very definitely give a bagasse which is difficult to burn and which will lead to trouble in the Boiler House.

Mr. HAYES: I should like to associate myself with the previous speakers in congratulating the author on a very interesting paper. It is, of course, clear that the object of the paper has been to try and place the canes in their order of hardness and not to associate the figures obtained with any definite milling value. It is interesting, therefore, to see that the skin hardness places the canes in one series and the pith and node hardness places them in another order.

It would be interesting to have the area and construction of the punch used on the pith and to know the type of calorimeter used for the calorific value determinations.

Mr. W. A. CAMPBELL: As an old Miller, I am very much impressed with the figures given by Dr. Hedley, purely from a practical point of view. As you know, when Umfolozi had their floods the Umfolozi cane was sent to Mount Edgecombe and it was the easiest milling cane we ever struck. Now he gives in his report the penetrability of the Umfolozi cane as being probably the softest cane. We know irrigated cane comes through the mill just like butter. There is an Estate just adjoining ours and the cane is perfectly clean and yet that cane is the very devil to crush. Why, I cannot tell you, but I am going to ask Dr. Hedley during the coming season to examine it and we will send him samples. The horse power goes up tremendously when this cane is being crushed yet to look at the cane you would say it is the finest milling cane you can get. If you are running at 110 tons per hour, you drop to 103 to 104 with this particular cane. I consider the information given here as most valuable and borne out by practical results at Mount Edgecombe. There is one thing Mr. Camden Smith was speaking about, the question of sweet canes in the furnaces and I do say that you mill Engineers have got a very serious problem in front of you this coming season and next season in particular. The old type of furnace will give a lot of trouble. I am speaking from practical experience and the changing of the green bagasse furnace to the dry bagasse furnace and I am pretty sure quite a number of the old type furnaces will have to be altered. Mr. Camden Smith has told you something about that cane. I must thank Dr. Hedley for a very fine paper indeed.

Mr. PATRICK MURRAY: I should like to thank Dr. Hedley for his original paper. The hardness of cane depends on the quantity of fibre in the cane. The nodes and internodes have more or less fibre in them and the density of these nodes and internodes gives the density of the cane. I would like Dr. Hedley to have taken the amount of fibre in the nodes and inter-nodes and also the specific gravity of the canes because in wood the specific gravity is definitely associated with hardness. If you had given the specific gravity of these canes you would have given more definite results. With regard to the calorific value, I am glad you propose using 8,400 B.T.U. in future and I agree with the idea.

Mr. DUCHENNE: With reference to what Mr. Murray has just said, we have made some tests at Umfolozi on different canes both hard and soft and we have certainly found those canes which are very hard have a higher specific gravity than the soft.

Mr. PORTEOUS: Mr. President, I should like to add my thanks to Dr. Hedley for a very able paper. To me he has touched on the threshold of a very interesting subject indeed. Quite a number of important points have been taken up by others but nevertheless I should like to refer to Mr. Camden Smith's suggestion that a tensile test should have been taken. I think that is imperative. Moreover I should like to see Dr. Hedley take an impact test which would give us quite a lot of information about the hardness of canes. I should like to know why Dr. Hedley has rejected the impact and tensile test as I gather from his paper he did do. It is interesting also to peruse Dr. Hedley's test on the calorific values. In my experience I have found difficulty in getting such figures and am glad to have them now. It seems to me, as Mr. Campbell has just said, that the mills are going to have a considerable amount of difficulty this year in the mill. It is quite clear we are going to be short of fibre and that after all is the substance from which we are going to get calorific value and it is going to be absolutely necessary before you get good steam conditions in the factory. It is quite clear, of course, as Dr. Hedley has demonstrated, that the calorific value of the fibre remains the same whether it is soft or hard cane. I am glad to see this is confirmed. I would like to associate myself with Mr. Hayes. Some Calorimeters differ quite an amount and if Dr. Hedley indicated what type of Calorimeter he used it would be of assistance.

Mr. HESLOP: I should like to congratulate Dr. Hedley on his paper, these figures are very interesting indeed. I wonder, however, whether they can be taken as standards for the varieties tested. If they can it would be very interesting to repeat them in a few years' time and see whether the canes have changed their indicator figures. I feel that after these canes have become acclimatised that they will become similar to Uba, that they will revert to the characteristics which are characteristic of Uba—i.e., hardness, difficult to handle in the mill and factory.

Perhaps such an examination as I suggest in a few years' time would reveal another set of figures.

Mr. BIJOUX: The calorific value does not appear to change and the composition of the bagasse does not seem to make any difference.

Dr. McMARTIN: In reply to Mr. Heslop's question I may say that concerning the alteration of these new varieties of cane so that they will become similar to Uba, the idea seems very prevalent at the present moment that because they are introduced from other countries, the changed conditions will cause them to assume features which characterise the one variety which has been grown here in the past. It is true, as Dr. Hedley has shown in the case of rind hardness, that local environmental conditions affecting the growth of the plant can impose upon it characters which differ from those of the same variety in a different environment, but these differences are not permanent. Each variety of cane has its own hereditary constitution which is maintained by propagating the variety by cuttings; were the cane propagated by seed, the resulting population from one plant would be a heterogeneous collection of hard and soft, high socrose and low sucrose, good growing and bad growing cane. By propagating as we do, the original characters of the cane are maintained, and no proof has ever yet been given that characters acquired through environment are transmitted to succeeding generations. Were this the case, it would be impossible to maintain as varieties stocks of many of our plants which are propagated by vegetative means instead of by seed, and we should not have our varieties of roses, dahlias, potatoes, carnations, and many other plants. Why then, should we expect any different behaviour in sugar cane, and above all why expect then to become like a cane which itself is an introduced variety, and is not indigenous to Natal?

Mr. HAYES: Mr. Chairman. I should like to mention that Dr. Hedley gave the calorific value of coal of 13,00 . Is not that figure rather high?

Dr. HEDLEY: The 13,000 B.T.U. was taken as the value at Natal Estates and was given as the Power Station figure, moreover it is quite an average figure for Natal coals. I made quite certain of the point before using it. Now there have been so many points raised that it means another paper to answer them. I am very grateful to you all in that you have taken so much interest in what I looked upon as one of the most tedious pieces of work I have ever been connected with.

No! I did not reject the impact test, I could not get the instruments!

We have had so much work to do this year that we have not had the time to do half the suggestions put forward to-day, some of which occurred to us, but I may be able to give you a more interesting paper of definite value next year and this paper although it lays down certain measurements even if the figures are not absolutely accurate, shows certain canes are hard and certain canes are soft and certain parts of the cane are hard and certain parts are soft, in a metrical fashion.

The Calorimeter was a standard Mahler bomb and is used for the determinations of the B.Th.U. values of Natal coals in Mr. W. E. Martin's office.

The punch used had a semi-elliptical end, the minor axis was ⅝in. and the major axis 1½in. so that on the ⅝in. bar from which the punch was cut had a symmetical elliptical point obtained in this way.

Mr. WILSON: As I mentioned previously, we have listened to a very valuable and original paper. I hope that Dr. Hedley will carry on his investigations still further in connection with the tensile strength and the compressability. I am sure Dr. Hedley the interesting discussion we have had is a compliment to your paper and I would ask you gentlemen to join with me in a heart vote of thanks to the author.