

A STUDY OF THE APPLICATION OF THE HAND REFRACTOMETER TO MATURITY TESTING OF SUGAR CANE IN NATAL

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Sugar cane is well known to exhibit in common with other living things, a marked degree of variability. Most of us are all too familiar however, with the complaint of the grower who finds a difference in test between two consignments cut from the same field, and it may therefore be of interest

to show once again variations in sucrose content which can exist. An example of variation between two sticks of similar appearance and a bull-shoot growing in the same stool of Co.281, 19 months old plant cane, are shown in the following figures obtained in December, 1936.

No. of dead leaf internodes	Length of dead-leaf cane.	Extracted Juice.			Approx. Suc. % cane at 74 Java Ratio.
		Refract. Solids.	Pol.	Purity.	
14	63 inches	19.4	18.56	95.7	13.73
14	65 "	17.6	15.77	89.6	11.67
Bull-shoot 8	24 "	13.2	9.98	75.6	7.39

An example of the variation exhibited by cane of the same age growing in two blocks within 100 feet of each other is afforded by the following fig-

ures obtained in a variety trial harvested during September, 1936.

Variety	Extracted Juice.			Sucrose % cane.
	Brix.	Pol.	Purity.	
P.O.J. 2725	24.1	22.71	94.2	18.18
P.O.J. 2725	20.0	18.24	91.2	15.65 (this plot contained an ant-heap).

It is obvious, therefore, that large variations in the sucrose content of cane growing in a field do exist, and it is of course possible that differences of even greater magnitude than those shown above may be found at times.

The sampling of cane for sucrose-testing purposes is thus necessarily a matter of great difficulty. In order to get a sample at all representative of a quantity of cane, a large number of sticks must be included in the sample. At the factories

the crusher juice from individual consignments is sampled from as much of the cane as it is possible to obtain, usually upwards of 75 per cent, and this method will therefore probably always remain the most satisfactory way of sampling cane.

However, it is often useful to have some indication of the sucrose content of the cane before harvesting, and to this end it is the usual practice to cut a small bundle of cane from the field and send

this "hand sample" into the factory where it is tested by crushing in a laboratory mill. This method is cumbersome and entails so much labour that the sample is usually very small, too small often to be adequately representative of the field. Sometimes also the sample is carried long distances and when conveyed by rail often arrives at the factories some days after cutting. Such delay affects the sucrose content as well as the sender's patience, and still more time must elapse before the grower finally gets the result of the test. Furthermore, for some reason not fully understood the test by the laboratory mill usually indicates a sucrose content for the field higher than that realised when the final test is made. These difficulties, particularly the inadequacy of the samples, have caused some of us to despair of ever obtaining tests on which any sort of reliance can be placed.

There can be no doubt, however, about the desirability of pre-harvest testing of cane in spite of the difficulties this presents. This is demonstrated by the number of hand samples tested at the factories each season. Cases have occurred early in the season where growers have harvested cane because its age and well grown appearance apparently indicated maturity, only to find on milling that the tests were below the rejection point on the Fahey scale. Most growers, therefore, are naturally anxious to know if the cane they intend harvesting is sufficiently mature or if it would be advisable to postpone harvesting until a higher sucrose content is attained. In general the grower must supply a certain quota of cane weekly so that it is not always possible for him to harvest cane at its peak of maturity, and his chief concern in this connection is to harvest those fields which at the time are most mature. Certain considerations will set a limit to the harvesting of the ripest fields, as for example the arrangement of transport will bring about difficulties.

Pre-harvest testing nevertheless would allow the cutting of the cane to be guided more scientifically than is the case at present, and if a method could be devised which would be sufficiently reliable and convenient to carry out regularly the gain to the industry would be enormous. This is of itself sufficiently important to warrant a close investigation of the possibilities of obtaining a method of performing such tests.

Reports in the literature have stressed again and again the advantages of the hand refractometer in the testing of growing cane. This instrument can show only the total solids in solution in the juice but such a close correlation has been found to exist between the total solids and sucrose content of sound, undamaged, cane that the hand refractometer has proved to be of great value in testing cane for sucrose. Thus we find its extensive use

for such purpose in many countries such as Hawaii (1), Java (2), Mauritius (3), British Guiana (4), Jamaica (5), and Barbados (6). The reports from such countries do not always describe the actual details of its use, and those which do give details (1, 2, 6), differ in technique.

All these reports are unanimous in their conclusions that when properly applied the instrument has great advantages over the hand sample testing method in both convenience and reliability, and the tendency is for the hand refractometer to supersede the older method (7). The convenience of the refractometer method lies in the fact that growing cane can be sampled in the field and there is no need to cut the canes and transport them to the factory. The reliability of the method is inherent in the possibility of sampling a greater number of canes than could normally be done with the older method.

As a consequence no doubt of the favourable reports from other countries some hand refractometers are already in possession of growers in this country, but it is very doubtful if the use of the instrument is fully understood by those people. For instance, at least one case has occurred of a grower who obtained a reading of about 20 with the refractometer and was upset when the cane testing service returned a sucrose test in the neighbourhood of 14 per cent. Similarly, the writer has been asked if the instrument could be used to check cane-testing at the factories. The answer is, of course, entirely in the negative. The device if properly used can only give an indication of the sucrose content of cane, and the scale reading (solids in solution) must not be confused with sucrose content. It is particularly idle to cherish the thought that if a few drops of juice be squeezed from a stick of cane on to the instrument the reading of the scale will be equal to the sucrose content of the whole field of cane, and thus provide a check on the cane-testing staffs.

Such erroneous ideas tend either to discount the value of the instrument or to create suspicion, and it is essential that growers be informed of the correct use of this valuable device.

The foregoing considerations together with the desirability of obtaining a quick method of testing seedlings prompted the work which is represented in this paper. This work was carried out during 1936 and was spread over most of the season. While it is considered very unlikely that results will differ year by year, it must be borne in mind that both the results and conclusions to be drawn from them may be dependant on seasonal variation.

The hand refractometer employed in making the tests is that manufactured by Zeiss, and it has a scale with a range of 0° to 30° graduated to 0.2°,

while the nearest 0.1° can be estimated. There are smaller and cheaper instruments made by other manufacturers which give a very clear reading, and although graduated only in whole degrees are quite suitable for the work, as the accuracy of sampling is hardly likely to be within the accuracy with which the scale may be read. A juice extracting punch designed in Java (8) was used in many of the tests while a modification of this, desirable for field sampling and used for this purpose will be described later. In making each test a drop of juice was placed on the plate of the refractometer and the reading taken. This was done as rapidly as possible to minimise evaporation effects and the punch and refractometer were then thoroughly washed and dried ready for the next reading. The zero point

was constantly checked by taking the reading given by distilled water and either adjusting the scale to read zero, or a correction was made by deducting the reading given by the water from that obtained on juice.

The first tests were devoted to a general exploration of the cane stalk. To this end it was necessary to examine first of all the variations in an individual internode. The punch extractor was pushed through the rind into the cane and readings taken at various points as illustrated in Fig. 1.

The following are some typical results obtained on sound healthy internodes:—

Internode from a stick of P.O.J. 2878.

Position of Reading	Side of Internode (Fig. 1).			
	Bud side	Opposite side	Front	Back
1	18.6	19.2	19.2	19.2
2	20.8	20.4	20.4	20.4
3	20.4	20.2	20.4	20.2
4	20.6	20.4	20.4	20.4
5	18.6	18.6	19.0	19.0

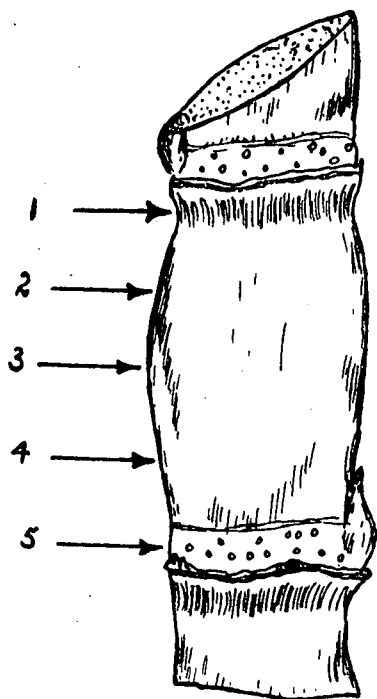


Figure 1.

Internode from a stick of Uba.

Position of Reading	Side of Internode (Fig. 1).		
	Bud side	Opposite side	Back
1	14.8	14.2	14.8
2	16.0	15.6	16.0
3	15.8	15.8	15.8
4	16.0	16.0	15.8
5	14.2	14.2	13.0

Large differences were not apparent within a healthy internode provided positions as at 1 and 5 were avoided. Internodes which had suffered any appreciable damage such as that caused by borers or severe splitting showed large variations and points near to the damaged parts showed a much lower reading than those obtained further away. This is illustrated in the example shewn (Fig.2).

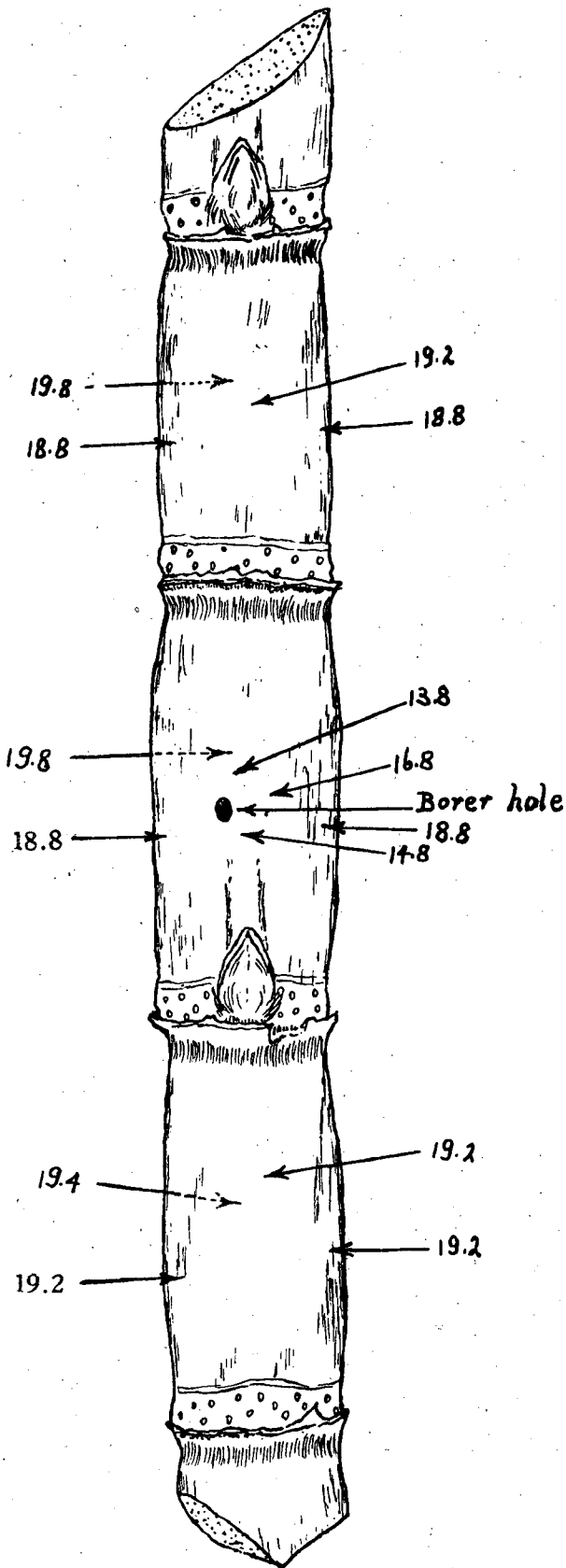
Such differences apparent in damaged internodes are of major interest and worthy of careful note. It was once asserted to the writer that the side of an internode exposed to the sun would show a higher reading than would the shaded side. A stick of Co.290 was taken to illustrate this, and to the consternation of the writer who had never before found such variation, the reading on the exposed

side was considerably higher than that on the other side. Moreover each reading taken on the internode was different, the variations covering a range of about 4°. A closer study of this stick showed borer damage in an internode lower down and the inside of the stick was red and rotten in appearance. The variations were merely due to the varying amounts of rotten tissue penetrated by the punch. Examination of a number of other canes proved conclusively that no appreciable variation was ascribable to exposure of part of the cane to the sun.

When an internode is cut through laterally it is sometimes found that the innermost portion gives a lower reading than does the portion nearest the rind. This is not always the case as the following figures illustrate (Fig. 3).

The reason for such variation is not understood, and as the reading obtained on juice extracted by thrusting the punch through the rind into the internode appears to give a sufficiently accurate average value, this phenomenon has not as yet been further studied.

It was found also that the mill juice gave a lower refractive solids test than did the average of tests on each internode, and a good example of this is seen in the following tests on portions of cane selected because of the uniformity of the internode tests.



Portion of a stick of Co.290.

No. of Internode from Ground level	Refractometer Test on Internode
21	21.2
22	21.8
23	22.0
24	22.2
25	21.6
26	22.2
27	22.6
28	22.4
29	22.8
30	22.4
31	22.4
32	22.0
33	21.8

Arithmetical Average 22.1

Figure 2.

Refractive Solids on Juice extracted by Mill 20.0.

Portion of a Stick of Co.281.

No. of Internode from Ground level	Refractometer Test on Internode
6	20.0
7	20.0
8	19.8
9	19.6
10	19.0
11	19.2
12	18.6*
13	19.4
14	19.8

Arithmetical Average 19.6

Refractive solids on Juice extracted by mill 19.0.
* Not included in portion crushed.

Reports from Hawaii (9) and Java (10) indicate the possibility of diurnal variation in refractive solids of cane, the reading obtained in the early part of the morning being shown lower than that obtained later in the day. This appears to be the case under conditions of rapid evaporation from irrigated cane but was not always found to exist in Hawaii. A few tests carried out here during the course of the year did not show this effect, possibly because the conditions were not suitable, but in any case the variation found overseas is usually fairly small and not likely to affect maturity testing to any appreciable extent.

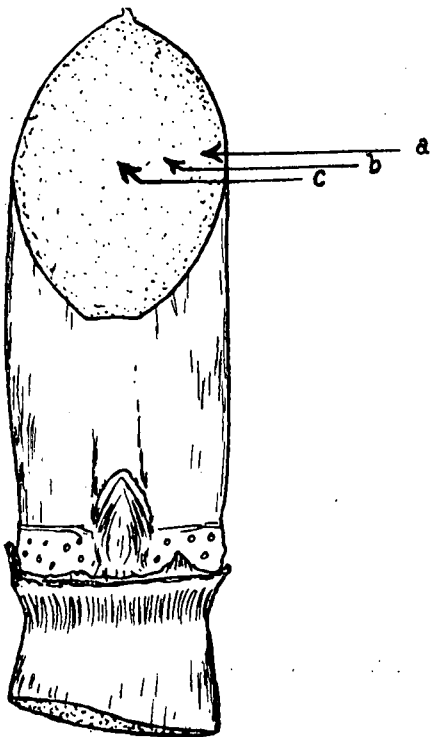


Figure 3.

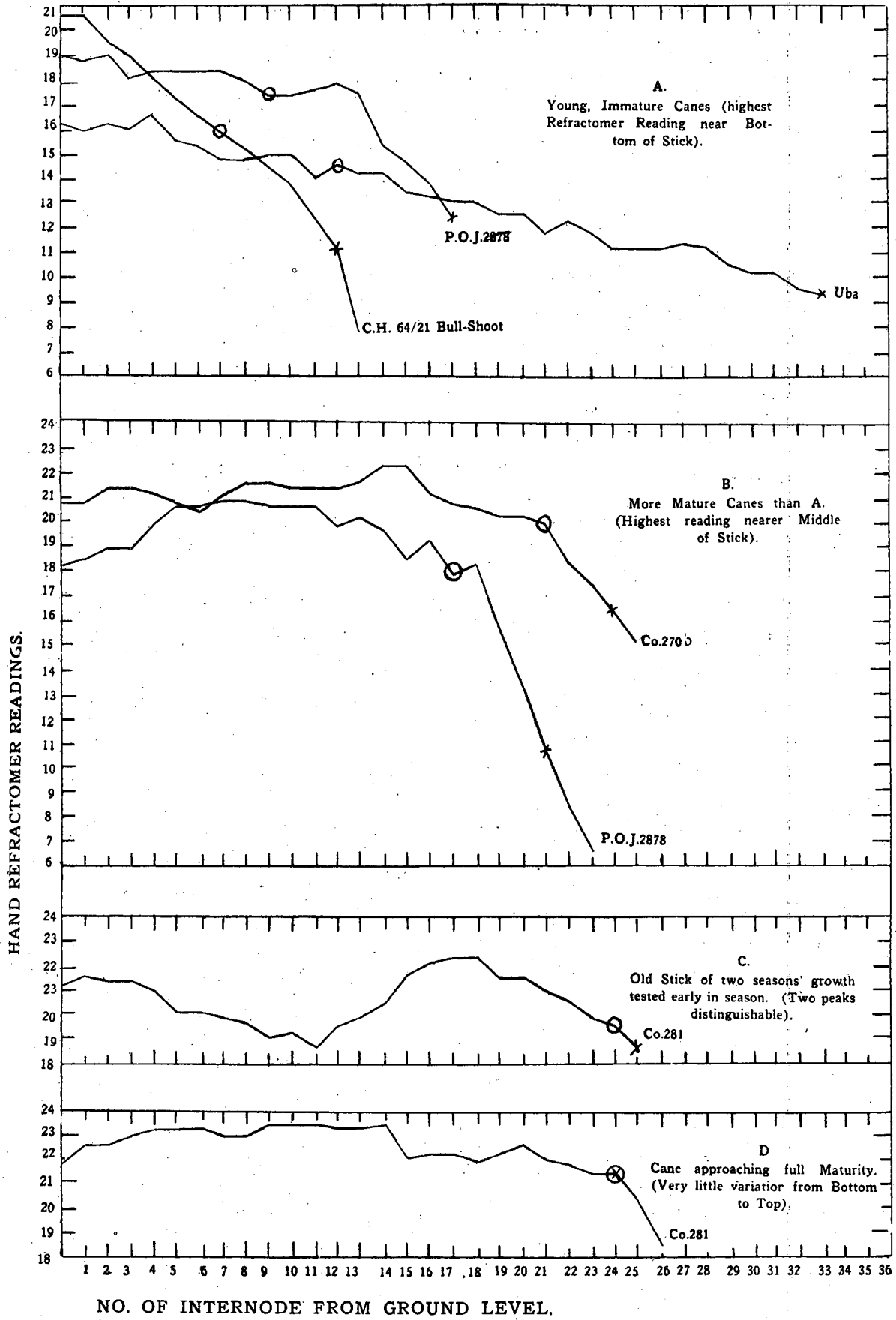
Examination of over 100 sticks of cane was carried out throughout the year in order to test the variation between internodes in each stick. After extracting a drop of juice from each internode and taking the reading with the hand refractometer the sticks were crushed in a clean, dry, laboratory mill and the extracted juice tested for refractive solids and polarization.

In general it was found that provided the cane is healthy no large differences exist between adjacent internodes except in the top portion, near to and including the green leaf section. Further it was found that the internode of the dead leaf section which gave the highest refractometer reading varied considerably in position from the ground level, as did also the internode which approximated most closely in test to the juice extracted by the mill.

There appears to be various types of distribution of the internode giving the highest test. Thus immature canes of any order of growth, together with bull-shoots and young cane, show the highest test at or near the ground level, older and more mature canes show a peak reading somewhere near the middle of the dead-leaf section, while old, fairly mature, canes which have had two seasons growth, exhibit two peaks.

Canes which were approaching full maturity, as shewn by the high test of the juice extracted from them, exhibited very little variation from ground level to top dead leaf-sheath internode. Typical canes shewing the variation between internode tests are illustrated by the diagrams in Fig. 4.

Position inside Internode. (Fig 3).	Variety from which Internode was obtained				
	Uba	Uba	P.O.J. 2725	Co.281	Co.281
a	21.8	20.6	20.6	19.2	18.5
b	21.7	20.6	20.4	20.0	19.3
c	21.4	20.0	19.6	20.0	19.4
Punch-test though Rind	21.8	20.2	19.8	19.6	19.4



x Internode bearing Top Dead Leaf-Sheath.
 c Internode approximating most closely to Mill Juice in Refractive Solids.

Figure 4.

As the data obtained from the internode by internode testing accumulated, attempts were made to find some simple way of testing any cane which would give under our conditions, as closely as possible, a test approximately equal to the refractive solids of the juice extracted by the mill. After several tests it became apparent that the mill juice compared very closely in refractive solids with the average of the readings obtained from three particular internodes.

These internodes are:—

- (a) The third from the ground level.
- (b) One at or near the middle of the stick.
- (c) The internode bearing the top dead leaf-sheath.

The accuracy with which internodes (a) and (b) are selected is not of very great importance as the variation between adjacent internodes in these portions of the stalk is not great. Care must be taken in the selection of the top dead-leaf sheath internode, however, as in the top portion of the cane variations are greater. The selection of these internodes presents no difficulty, and the great point in the favour of this method is the fact that the punch test thus obtained compared equally well with that of the mill juice from all healthy canes of whatever variety, age or condition of growth.

Details of the closeness of the comparison between the two tests are as follows:—

No. of Comparisons	Correlation Co-efficient	Refractive Solids.	
		Internode Combination Mean	Mill Juice Mean
111	+0.9329	18.42	18.13

The difference between any two comparisons was usually small, the maximum difference at any time being $\pm 1.8^\circ$. In only 19 cases did the difference lie between $\pm 1.0^\circ$ and $\pm 1.8^\circ$, while in 54 cases it was $\pm 0.5^\circ$ or less.

It can be seen that the correlation between the internode combination or punch test and the mill juice refractive solids, apparently holds for all

varieties but there seems to be a definite tendency for the mill juice test figure to be higher in the lower ranges and lower in the higher ranges of refractive solids. This is no doubt due to some extent to the top portion of the cane ripening up and showing a higher refractive solids test as it increases in sucrose content. On the total of 111 such comparisons made, the following averages and differences are obtained:—

Refractive Solids.

Range of punch test refractive solids.	Average Third Bottom, Middle, Top, punch test.	Average test Mill Juice.	Difference.
11.0 - 16.9	15.28	15.56	-0.28
17.0 - 18.9	18.03	18.00	+0.03
19.0 - 19.9	19.51	18.98	+0.53
20.0 - 22.5	20.87	19.95	+0.92

Such a tendency was shown by all varieties tested thus:—

Refractive Solids.

Variety.	Range of punch test Refractive Solids.	Average Third Bottom, Middle, Top punch test.	Average test, Mill Juice.	Difference.
Co.281	11.0 - 16.9	14.52	14.75	-0.23
	17.0 - 18.9	18.40	18.32	+0.08
	19.0 - 19.9	19.60	18.85	+0.75
	20.0 - 22.5	21.05	20.21	+0.84
Co.301	15.0 - 17.9	16.90	17.14	-0.24
	18.0 - 19.9	19.42	18.89	+0.53
	20.0 - 22.5	20.47	19.36	+1.11
Uba	11.0 - 16.9	14.53	14.77	-0.24
	17.0 - 18.9	18.40	18.50	-0.10
	19.0 - 19.9	19.42	18.95	+0.47
All other varieties (chiefly P.O.J. canes).	11.0 - 16.9	15.88	16.16	-0.28
	17.0 - 18.9	17.83	17.65	+0.18
	19.0 - 19.9	19.54	19.10	+0.44
	20.0 - 22.5	21.32	20.65	+0.67

This tendency of the punch test to give a lower reading in the lower ranges and a higher reading in the higher ranges is probably a point in its favour, as it accentuates the difference between mature and immature canes, while as the purity of the juice is usually higher at the higher densities the tendency noted probably helps to increase the strength of the correlation between the punch test and the polarization of the juice.

As we are interested chiefly in the prediction of sucrose percentage by means of the hand refractometer, the details shown below are still more interesting. The correlation coefficient between the refractive solids and the polarization of the mill juice, and, what is more important, the correlation coefficient between the refractive solids given by the punch test on the third bottom, middle, top

dead leaf-sheath internodes, and the corresponding polarisation of the mill juice were both very highly significant.

They are as follows:—

Total number of tests	74
Mean mill Refractive Solids	18.40
Mean Internode combination Refractive Solids	18.32
Mean polarization of Mill Juice	16.58
Correlation coefficient, Mill Refractive Solids and Polarization	+0.9671
Correlation coefficient, Internode Combination Refractive Solids and Polarization	+0.9022

On dividing the figures showing the comparison between the punch test and polarization into groups, the following averages appear:—

Range of Refractive Solids by Punch test.	Average Refractive Solids by Punch test.	Average Polarization Mill Juice.	Approximate sucrose % cane at 74.0 Java Ratio.	(Approx. Sucrose % Cane) ÷ (Punch test Refractive Solids).
11.0 - 16.9	15.26	13.03	9.64	0.63
17.0 - 18.9	18.07	16.82	12.11	0.69
19.0 - 19.9	19.53	17.76	13.14	0.67
20.0 - 22.4	20.67	18.67	13.83	0.67
Average of all tests.	18.40	16.58	12.27	0.67

By using the above average of 0.67, calculated as shown above, we can arrive at the following approximate values for sucrose content of cane. These figures are merely tentative and are given as a guide to those growers already in possession of the hand refractometer.

Refractometer reading on juice extracted from 3rd. Bottom, Middle and Top dead leaf-sheath internodes.	Corresponding approximate sucrose per cent cane.
11.0	7.4
12.0	8.0
13.0	8.7
14.0	9.4
15.0	10.0
16.0	10.7
17.0	11.4
18.0	12.1
19.0	12.7
20.0	13.4
21.0	14.1
22.0	14.7
23.0	15.4

The next step then was to apply the instrument to field conditions. In this connection it was obvious that a number of sticks would have to be sampled, and the quickest way of doing this is to accumulate the juice from the canes and thus make a single test with the refractometer for the whole area. This can conveniently be accomplished with a special punch fitted with a container into which the drops of juice run, and from which the final composited sample is drawn. Illustrations of such a punch appear in the literature (1) and from the ideas thus suggested a similar instrument was improvised. This home-made instrument has disadvantages, some are inherent in its improvisation out of a bottle held to the punch with a rubber cork, wire and a piece of old motor car tube, but the chief draw-back is that such an improvised article would not be available to growers, who are unlikely to construct their own. Enquiries have now been instituted with a view to obtaining the punch used in Hawaii and if possible to make this available for purchase in Natal.

An experiment was carried out to test the variation between samples composited in the above manner. This was performed on about 2 acres of Co.281, 13 months old plant cane, in a fertilizer trial.

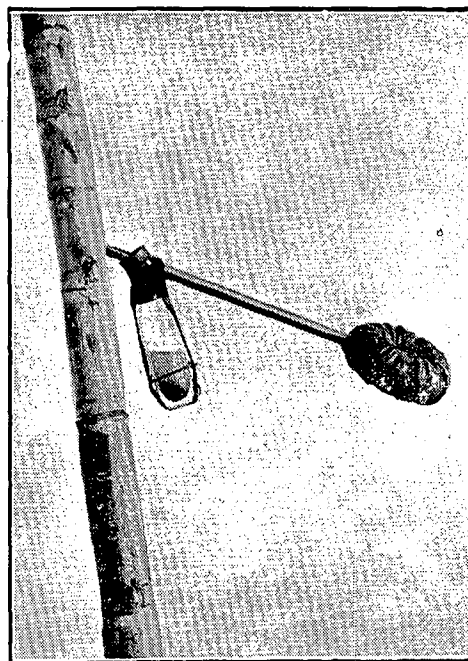


Fig. 5.

Home-made Test Punch used for Field Work.

Eighteen samples were taken, each consisting of the juice drawn from the three internodes of the equivalent of 20 canes taken at random over the whole block. By the equivalent of a cane is meant the sampling of the third internode from one stick, the middle internode from another stick and the top dead leaf-sheath internode from a third stick, all growing near each other. Only obviously immature sticks were avoided and each sample included juice from 60 sticks.

The tests were as follows:—

21.2	21.2	21.4
21.0	21.0	21.1
21.2	21.4	21.2
21.6	21.2	21.4
21.4	21.4	21.2
21.4	21.4	21.2

Average 21.27

Standard deviation 0.1602.

For $P = 0.01$, expected variation ± 0.46 .

To sum up these figures there is very little variation between samples and the probability of one such test varying from the average by more than ± 0.46 is but 1 in 100 chances.

Incidentally the hand samples drawn from this field in the course of harvesting a few days later

and tested according to the ordinary routine, gave the following for Brix of juice:—

22.0	22.0	21.9
21.7	22.1	21.6
20.6	21.7	21.9
21.4	21.9	21.8
21.0	21.8	21.7
21.4	21.2	21.7
22.2	22.1	21.8
21.9	21.0	21.4
21.2	21.4	21.6
21.1	21.7	21.9
21.5	21.7	21.2
21.1	21.3	21.8
21.0	21.4	21.2
21.0	21.5	22.1

Average 21.56

Standard Deviation 0.3802.

For $P = 0.01$, expected variation ± 1.04 .

The result of this experiment indicated the possibility of obtaining a reasonably close estimate of the sucrose content of cane growing under such conditions. The conditions however, were such that the cane appeared of somewhat uniform growth, and therefore possibly test, and the question then arose as to what would the variation have been had the cane not been so uniform in test?

As opportunity of testing out the sampling technique under very severe conditions was given by the great variation as between 147 stools of some P.O.J.2878 x Uba Marot seedlings, each one of which is a distinct "variety."

Individual apparently mature sticks drawn from these seedlings tested as follows:—

Seedling Number.	Ref. solids on punch test.	Mill Juice.			Approximate sucrose per cent cane.
		Ref. solids	Pol.	Purity.	
120	20.7	20.8	19.41	93.3	14.6
113	19.9	19.6	18.56	94.7	13.9
21	17.4	18.4	17.26	95.7	12.9
142	16.5	16.6	14.92	89.9	11.2
65	16.5	16.4	14.22	86.7	10.7
58	15.9	15.4	12.13	78.8	9.1

Thus the population contained canes which showed a gradual variation from nearly 15% to 9% in sucrose, or 20.7 to 15.9 in refractive solids, and such conditions are no doubt far more severe than would be offered by a field of cane grown commercially.

Tests were first made on the equivalent of 10 sticks, as this number was considered a minimum having regard to the limits of the sampling device. Except for the number of canes, the method was the same as that used for the Co.281 field tests given above. Twelve such tests were made as follows:—

18.2	18.0	18.4
18.2	17.9	18.2
18.0	19.0	18.4
16.6	18.0	17.9

Mean 18.07.

Standard Deviation 0.5533.

For $P = 0.01$, expected variation ± 1.72 .

The result of a single test will therefore be within ± 1.72 in refractive solids at odds 99 to 1.

Six tests were then made on the equivalent of 15 canes as follows:—

18.4	18.0
18.2	19.0
18.2	18.1

Mean 18.32.

Standard Deviation 0.3602.

For $P = 0.01$, expected variation ± 1.45 .

i.e. A variation from this mean greater than ± 1.45 need not be expected in more than 1 chance in 100.

The difference between these averages is not significant, and furthermore there is not much advantage in sampling more than 10 "composited" canes.

Factory tests were not obtainable for comparative purposes in the above two field tests, but the writer hopes to carry out a number of field tests with the hand refractometer during the course of the next season, to correlate these with actual factory tests and thus provide a measure of the experimental error involved.

Conclusion.

The work summarised in this paper carried out during 1936, indicates that the hand refractometer promises to be very useful in the testing of growing cane for sucrose content. The instrument properly used, will furnish an estimate of the sucrose of a limited area of cane provided the sample of juice is obtained in such way as to make it representative of the average of that cane. A close approximation to the juice of the cane is most conveniently obtained by the aid of a special punch extractor, which enables the extracted juice to be accumulated from many canes, thus necessitating but one reading of the refractometer for each sample.

A suitable combination of internodes in which to insert the punch in the collection of the juice sample consists of:—

- (a) The third internode from ground level.
- (b) An internode in the middle of the stick,
and
- (c) The internode bearing the top dead leaf-sheath.

It is not necessary to confine the sampling of these internodes to one stick at a time as the sample may be made more representative by drawing the samples from one of these internodes in each of three sticks growing near each other. Care must be taken to ensure that the correct rotation of sampling of each of these three internodes is adhered to, so that approximately equal proportions of juice from each of these types of internode is included in the sample. Only damaged, decayed and obviously immature canes should be avoided in obtaining the sample, which to be of value, must include juice from many canes and be collected at random from all parts of the field.

Readings of the refractometer so obtained must not be confused with the sucrose content of the cane and a table of tentative sucrose per cent cane values is given for interpreting the readings of the instrument scale.

The error involved in such a method of testing cane will depend chiefly upon the accuracy with which the sampling is performed. As the sampling is unlikely to be as accurately representative as that

obtainable when whole consignments of cane are milled, the hand refractometer method cannot be used as a check on the tests arrived at by the factory cane testing staffs. It may however be applied to pre-harvest maturity testing, in which case it is far more convenient and probably more accurate than our present hand sample testing method.

My thanks are due to Mr. B. E. Beater, B.A., for kindly drawing Figures 1, 2 and 3.

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South African Sugar Association,
Experiment Station,
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The PRESIDENT: Thank you, very much Mr. Christianson. The paper is open for discussion.

Mr. WATSON: In the punch that you refer to made in Hawaii, what is the method of extracting the juice from the receptacle? Do you have to take the instrument to bits?

Mr. CHRISTIANSON: I have not been able, as yet, to get hold of an adequate description of the Hawaiian punch. But in this instrument which we made ourselves, you would not find it necessary to take the thing to pieces. You just merely turn the thing upside down and drain it. As far as mixing the juice is concerned, as you are going through a field of cane, you are agitating the bottle the whole time, and as a matter of fact you could not find any difference between the several readings from the same quantity of juice.

Mr. FELTHAM: I wish to congratulate Mr. Christianson on his paper. I might say, from my own point of view, if all he has got here is likely to happen, it is like a dream come true. We have had other investigators who have tackled this sampling of cane, and we have found a great variation of cane in the same stool. Although it was proved last year that hand sampling of cane was possible, some of the variations between hand sampling and mill results were very surprising. Mr. Christianson states here: "for some reason not fully understood the test by the mill laboratory usually indicates a sucrose content for the field higher than that realised when the final test is made." I think that is largely due to the sample. The hand samples that we get from the field are usually nice and clean. When they come to the mill, they are all dirty and full of trash, so I think that explains the difference to some extent. I am afraid that the numbers of tests that will have to be made when using a refractometer in the field is going to make it a pretty unhealthy job for the planter, particularly in the case of damaged cane. Now in our laboratory work, when it comes to damaged cane, there is not as much difficulty; the difficulty arises in convincing the planter that he has got old and damaged cane. As we all know, damaged cane can have a brix of 22, and a purity of 50. More emphasis should be placed on the point of damaged cane, otherwise we are going to fall out of the frying pan into the fire, as far as the planters are concerned.

Mr. MOBERLY: I have been very much interested in Mr. Christianson's paper. I am very glad to see that he has put a warning note on the last page: "As the sampling is unlikely to be as accurately representative as that obtainable when whole consignments of cane are milled, the hand refractometer method cannot be used as a check on the tests arrived at by the factory testing staffs." I hope that that point will be well borne in mind. That is one fear that I have already had in my mind, namely this hand refractometer getting into

the hands of people who might not understand it. Planters well know that there are many planters who might get hold of these instruments and try to use them in a way which nobody would claim for them, and Mr. Christianson himself does not claim that they can be used as a check on sucrose testing.

There is one point which I wanted to criticise, at the bottom of page 8, the table in the last column "Approximate Sucrose % Cane, divided by the Punch Test refractive solids." It is noticed that they are more or less similar, and the reading of 0.67 is suggested as a ratio for interpreting the refractometer readings in terms of sucrose. Now if you examine these figures in the last column, you will find that in effect they are Java ratios multiplied by purity. That is what they work out at. If you work it out, you will find that in the first case 0.63 corresponds with a juice purity of 85; 0.69 corresponds with a juice purity of 93.2, and the 0.67 corresponds with a juice purity of 90.5. So that before you can use any ratio to convert the refractometer readings into sucrose, you must have some idea of what the purity of the cane is likely to be. For instance, if the refractometer reading was 20, a 6.3 reading would give you a sucrose of 12.6, whereas 6.7 would give a better sucrose of 13.4, which is quite a considerable difference, and bigger differences would occur. What I think would be a better way of making that conversion, would be to use, not a uniform 67, but one which corresponded more closely with the range of the refractometer reading, because the lower densities normally correspond with lower purities, and the higher densities with higher purities. It is not a clear, straight line connection, but still there is roughly that connection. So if you want to get an approximate idea of the sucrose, you should see in what range your readings fall, have a ratio which corresponds to that, lower for the lower ranges, higher for the higher ranges; then multiply that by the refractometer readings, and that would give you an approximation of your sucrose—an approximation only, but one which might be very useful for deciding whether a field is ready to cut, but not one which would enable you to go round to the laboratory afterwards and tell the chemist that he doesn't know his business.

Mr. COIGNET: I would like to draw attention to the difficulty of judging the maturity of the cane by the refractive solids, because in leafy cane there is a tendency for the colloidal water to ooze first, and the sample obtained from it may be more or less due to the amount of colloid water contained in the sap, which may perhaps lead astray the planter in judging of the maturity of the cane, because there will be more tendency for the raw sap to ooze out before the sucrose is liberated.

Mr. Palairat: Though there are very interesting points in this matter with regard to the value of these tests to the chemist, I should like to raise

the question of its value to the planter. We all know very well that our canes mature at very varying sucrose contents, due to climatic conditions, soil conditions, and many other such things. Therefore one is inclined to feel that the actual sucrose is not likely to be entirely an indication of maturity. Looking at Figure 4, and Mr. Christianson's comments on that, it seems that a better indication of maturity might be obtained by comparing the bottom reading with one of the two higher ones and the middle one with the top, because you might likely get a case where one field is showing a high reading, but is not yet mature, another field is showing a lower reading and is mature, and in that case it is clear that the latter field would be the one to cut first. I would like Mr. Christianson to give us some idea as to what combination of the three readings or comparison of the readings is likely to give the most valuable information in that respect, and if he will just give a general idea as to the value of these tests generally to the planter, from the pure point of view of which field to cut.

Mr. CHRISTIANSON: In reply to Mr. Palaret, there is, of course, no doubt quite a lot to be said for different methods of maturity testing, and as a matter of fact the method used in Hawaii is to take two readings, a reading from the top of the cane and one from the middle. It struck me, in doing this work, that maturity is also seasonal. For instance, if you look back to 1934, it is very difficult to claim that any cane reached maturity. It doesn't matter how long you leave that cane you would not get an improvement. As the planter's chief concern is to cut the ripest cane on his farm at a particular time, I thought it would be better to adhere to this method which has been laid down in this paper.

In reply to Mr. Coignet, he makes the statement that perhaps colloidal water comes out first. It certainly does not look like it from the results. Crushing the portion of cane which gave similar internode tests, that is to say page 4, top of page 5, the mill result was actually much lower than the punch test. Mr. Coignet must not forget that these figures are not argued out; they are the result of experiments. The high co-efficient shows a close relation between the punch tests and the actual content of the canes.

Mr. Moberly mentioned purity, and considered that this table would have been better calculated out, taking into consideration the lower purities one usually finds in the lower ranges of refractive solids. However, Mr. Moberly does not appear to have noticed one point in particular, and that is that these punch tests gave too high a reading in the high ranges and too low a reading in the low ranges, and tends to offset that. Furthermore these figures are calculated from actual results.

Mr. WATSON: Before you close this paper, Mr. President, perhaps it is a little help on the general

subject to refer to the routine adopted on one plantation in Hawaii for making use of this technique and the conversion of the hand refractometer figures. A certain amount of routine is necessary for the planter to make efficient use of the technique. Mr. Palaret has made the point that different canes mature at different standards. Mr. Christianson raises the point that seasonal maturity varies very much. The routine I refer to is something like this. Each field that is going to be harvested is sampled at fortnightly intervals, from perhaps a month before the opening of the harvest season, and the converted figures are plotted on a graph, and when that graph starts to flatten out, there is no further improvement in apparent sucrose, that field is counted as ready to harvest, whether or not that field is showing as high sucrose as is expected for the variety of cane or not. I think that type of routine covers Mr. Palaret's difficulty either in hand refractometer sampling or in cane sampling—bundle sampling.

Mr. DODDS: I believe that the hand refractometer will prove a very useful instrument here, as it has done in other countries. I must say that progress in this development here has been rather slow, possibly because, when the instrument was first received, the chemist who first investigated it at the Experiment Station gave an unfavourable report. It is now evident that that report was perhaps a little premature. Certainly the instrument has its limitations, as we have seen, and needs to be used with considerable discrimination. But I am sure that it is going to be of real use to us. It is of special use at the Experiment Station in seedling tests, where we have large numbers of seedlings to deal with, and wish to get an approximate idea of the quality of the juice without sacrificing too much of the stool of the cane, of which, perhaps, we have only one solitary stool of cane of great potential value. For this kind of work the hand refractometer is really a Godsend. It is also of use, as we have seen in determining pre-maturity tests of cane, and not so much, as Mr. Moberly has reminded us, for the taking of mill samples. There are two types of hand refractometer on sale, perhaps more. There is one that is offered by a firm of optical suppliers, in Johannesburg. It is a rather expensive instrument—about £15. There is a much smaller one which is made in London, and, as far as we know, is perfectly reliable, which is obtainable at a cost of about £5 or £6. I believe there are specimens of both instruments here for your examination. From the Experiment Station, we shall be very pleased to give any information that may be desired about these instruments.

I would like, finally, to express my appreciation of the careful and laborious work that Mr. Christianson has put into this important matter.

Mr. BOOTH: I would like to ask Mr. Christianson as to whether, in view of all his work done,

he would recommend that the average planter go to the expenditure of ten to fifteen pounds, and whether it would be a source of danger?

Mr. RAULT: I wish to associate myself with what Mr. Dodds has said and some of the other speakers in thanking Mr. Christianson for this paper, and for the amount of work he has done in showing us, after all, the limitations of that kind of work. I think we should congratulate him on doing something, and showing us practically what we can get. I don't think he has ever pretended to say that such a method replaces entirely the mill test, and nobody is really going to make use of this test to challenge the work done in the laboratory. That is not the idea at all. But it is a practical method of helping the planter and whoever is in the field. We ourselves, at our mill, where we have to do so many tests for our own fields, will welcome such an instrument being given to our field managers. It is a way of keeping them very interested in the maturity of the cane without always having to run to the chemical laboratory, and once they have such an instrument in their hands, and certain methods given them showing how to use it, it will be all for the good of the determination of sucrose in the cane.

I would also like to suggest to Mr. Christianson, in the next work he is going to do, to investigate

the problem which is always being discussed—it is the effect of rainy weather on the cane. You all know the sudden drop that we get in sucrose, and there are many explanations given to it, and more often than not we cut cane and test it away from the fields, whilst with this method we can leave the cane in the field. Some light could be thrown on the amount of water in the cane.

There is another point on which I would like Mr. Christianson to tell us something. He has mentioned that sometimes they do not want to sacrifice valuable cane. How far does this punching affect the cane? Would that affect your cane at all by repeated testing of the cane for experimental purposes?

Mr. CHRISTIANSON: Replying to Mr. Rault, when he asked about the amount of damage done with this punch, one, of course, gets the cane going red, and apparently some sort of disease then sets in, but it must be purely local. Of course, in taking subsequent tests, one has to avoid any such damaged portion.

The PRESIDENT: I am sure we are all very much interested in Mr. Christianson's paper and indebted to him for it. I trust Mr. Christianson will carry on the good work. I would ask you to join me in a hearty vote of thanks to Mr. Christianson for his excellent paper. (Applause).