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STUDIES IN SUGARCANE

IV. Variations in the Concentration of Juice in Sugarcane.

BY

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In the course of studies on the biochemistry of sugarcane with particular reference to its maturity and arrowing, the authors felt a need for an exact knowledge of the actual mode of distribution and accumulation of sugar in sugarcane at several stages of its growth and development, in order to be able to satisfactorily explain some of their data.

Information in the literature that is available was found to be inadequate to meet their needs. Therefore it was proposed to follow the distribution of the concentration of juice over the entire length of the cane, from the growing point down to its bottom, flush with the surface of the soil.

The results obtained indicated that the concentration in the juice varied not only from top to bottom, but also within each internode and that the variations were very regular, and obviously with a bearing on the physiology of the sugarcane; for this reason, they are presented in this paper, as they might also interest other workers.

Experimental. For the purpose of the present investigation the entire cane was carefully stripped of all its leaves, so that even the most tender internodes at the top, including the growing point, remained intact. The internodes were numbered as follows—the growing point and the closely packed rings of internodes just below it were all numbered together as 1, and the one below it 2, and so on upto "n" towards the bottom of the cane. In the case of the arrowed canes and those in shot blade, the top most internode, distinguishable as such, below the inflorescene or flower primordia, was numbered 1, and the numbering thereafter was the same as in the unarrowed cane.

By means of a sharp cork borer (0·5 cm. dia.) the cane was bored at very short intervals leaving a minimum space between successive borings (vide inset of internode and node in the charts). In this experiment three distinct regions were distinguished in the nodal part of the cane. They are (1) the intercalary meristerm (growth ring), (2) the keim ring (bud and root primordia) and (3) zone of insertion of leaf sheath (leaf scar) (1). Wherever it was possible the cane was bored separately through these regions of the node. In the case of variety Co. 213 (chart 1) the keim ring and the leaf sheath insertion zones were taken together for puncturing. The juice from the core bored out was pressed out and its refractometric brix was read off with Zeiss Hand Refractometer. All the necessary precautions were taken to prevent or minimise errors due to probable rapid evaporation from small quantities of liquids expressed. For this purpose preliminary check

determinations were made with respect to the factors of time and the changing air temperatures.

The results are represented graphically (charts I, II & III). An examination of the data and of the curves goes to indicate, in general, the following. Detailed data have not been included for purposes of brevity of the paper. The graphs in charts show general trends.

1. In the young cane, or in the younger parts of any cane, the concentration of the sap at every point within an internode, is lower than the concentrations in the two nodes at its either end. Between the concentrations in the two terminal nodes of any internode, that in the top node is always of lower magnitude. Their concentration curves are therefore troughs lying below the levels of the concentrations in their two terminal nodes. (Graph 3, internodes 3—7, graph 4, internodes 1—5).

2. The concentration curves of internodes indicate two minima, one at its either end. At the centre or in the upper half of the internode a higher value is located. Of the two minima, the one nearer the bottom node is lower, and corresponds to the intercalary meristerm situated at the base of the internode, and the other minimum of higher magnitude, corresponds to region at and just below the leaf sheath insertion zone. The curves therefore roughly resemble the letter W — with un-equal limbs. (Graph 1).

3. It is noticeable (young canes Co. 223 : graphs 3—5 and Co. 243 : graphs 6—8) that the concentration of juice in any internode commences to increase earlier at its top.

4. As the cane advances in age, the concentrations in both the nodes and the internodes tend to increase The concentrations in all the nodes in a cane rapidly tend to approach a common value, such that the line passing through the points representing their concentrations tends to run parallel to the horizontal axis (graph 2).

5. As the internodes develop, the concentrations within these increase more rapidly. In time, the concentration at every point in the internode moves far above the levels of those at the nodes, such that the curves gradually cease to be troughs and finally assume bell shapes, with every point on the curve situated above the level of the nodal concentrations. In each case a maximum value is located at about the centre of the internode (chart I : graph 2). In this graph, the curves for the three internodes at the top alone are troughs and those for the rest are all inverted and bell shaped.

The various stages of the course of this transformation in shape, from troughs to bell shaped ones, are noticeable in all cases (charts I, II & III).

Taking the cane as a whole, these changes in the shapes of the curves begin to occur earlier and faster in the internodes at its bottom. But within any given internode, irrespective of its location in the cane, similar changes occur, but in the opposite direction, from top downwards.

6. In canes which are more advanced in age (Co. 213 : Chart I), the maximum concentration for the juice in the cane, seems to be located in its

central internodes and in the central portions of individual internodes Previous workers also viz., Went (2), Venkatraman and Rao (3), Viswanath (4), Quintus (5), and Kerr (6) have noticed that as cane matures the maximum tends to travel towards the centre of the cane.

7. The general trend of the movements of the concentration of the sap is similar in all the varieties irrespective of (a) their ages, (b) the time, in the day, of cutting the canes, and (c) whether the cane is arrowed or unarrowed or is only in shot blade.

8. Comparing graphs (1) and (2), it will be seen that the differences in the shapes of the curves pertaining to individual internodes in the two canes are very striking. In the light of the foregoing, it is obvious that the internodes in the one cane (graph 1) are physiologically very young and are far behind those of the second cane (graph 2). The two canes are of equal ages, having been planted and harvested at the same time under pot culture conditions. In the one case, the cane was manured with castor cake, while the second received no manure.

The differences in the physiological development of canes of equal ages are evidently due to differences in the nutritional conditions under which they are grown. Canes which do not get enough nutrition would seem to tend to finish their life cycle much earlier.

9. The figures in Statement (1) representing the maximum and minimum concentrations within individual internodes clearly point that the concentrations even in the same internode are not uniform and that the differences are very wide.

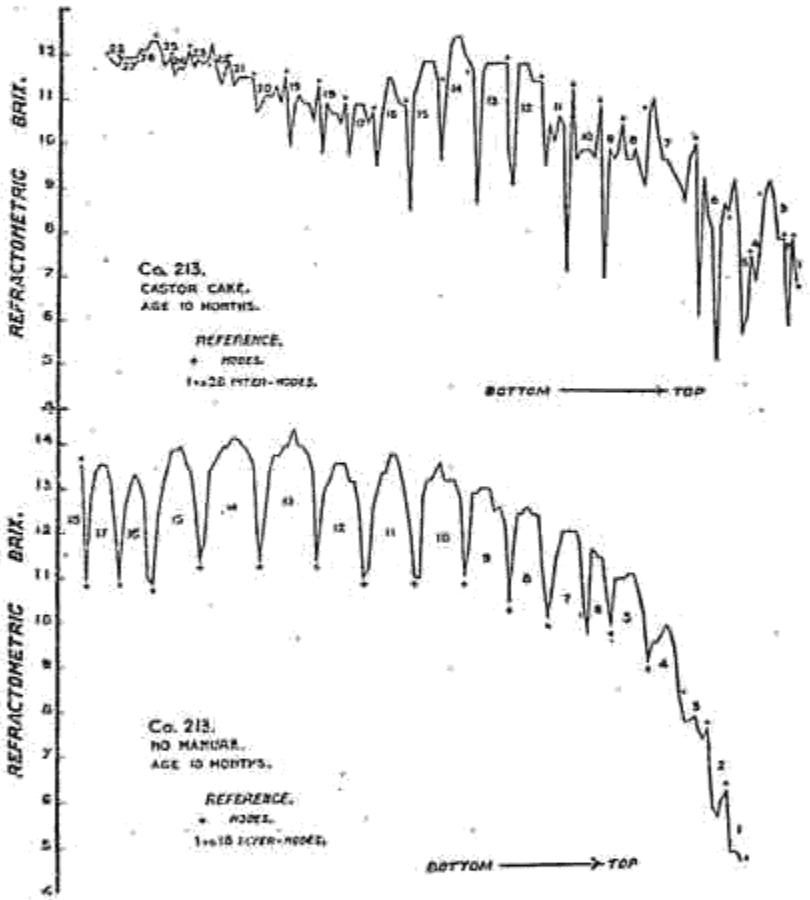
Discussion. In the sugarcane, as in all monocotyledons, the internodes elongate acropetally from bottom upwards, consequent on the activity of the intercalary meristem situated at the base of the internode. Thus the top portions of any internode are the earliest to be formed, and as such, they constitute its older parts, and those at its bottom, the youngest. Traversing from the bottom to the top, the younger internodes are met as we progress upwards. On the other hand, taking each individual internode in the same cane, one meets with progressively older parts laid down in the same direction.

It was indicated by one of us (Varahalu, 7) that at least a certain minimum growth and development of tissues is an essential condition precedent for the commencement of the storage of sugar in sugarcane. In sugarcane therefore this minimum development must be expected to be attained earlier in its bottom internodes, and in the top portions of its individual internodes. Therefore sucrose accumulation should also be expected to commence earlier in these parts. The experimental evidence presented in the paper is in complete accord with what may be expected.

2. The data presented indicated that there are two minima in concentration curves for every internode, and these are situated, one at its either end. This is as may be expected.

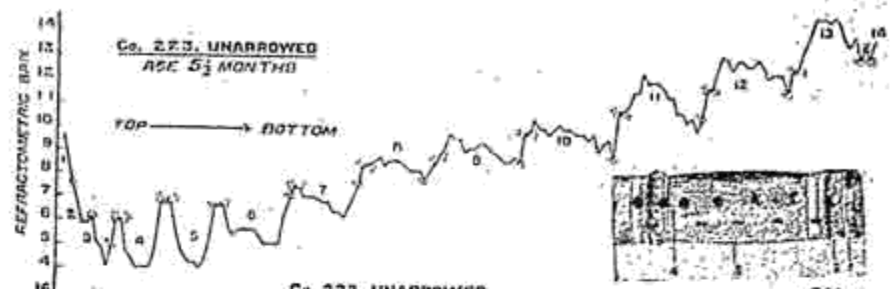
Variations in the Concentration of Juice within Sugarcane.

Graph (1).

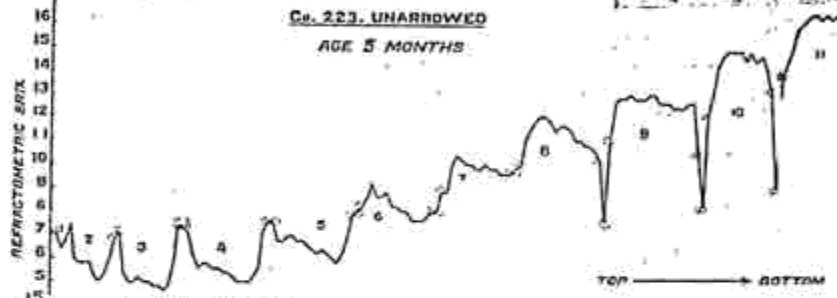


Graph (2).

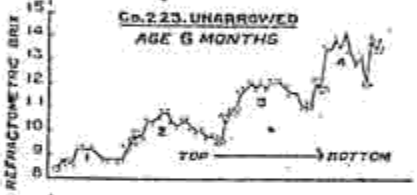
Variations in the Concentration of Juice within Sugarcane



Graph (3).



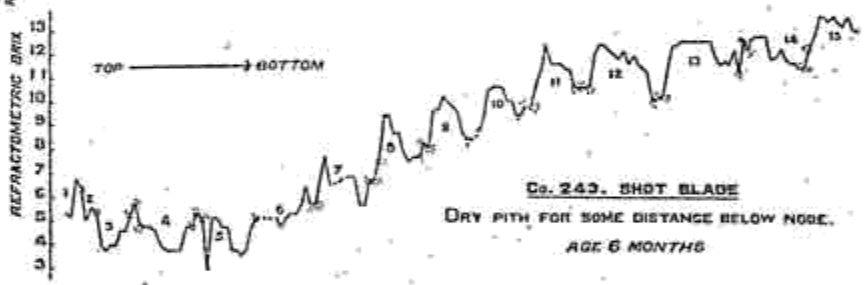
Graph (4).



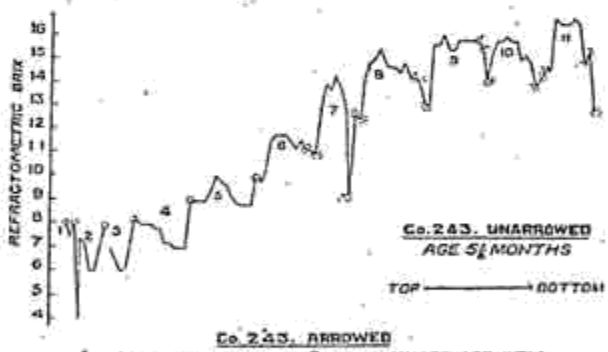
Graph (5).

REFERENCE

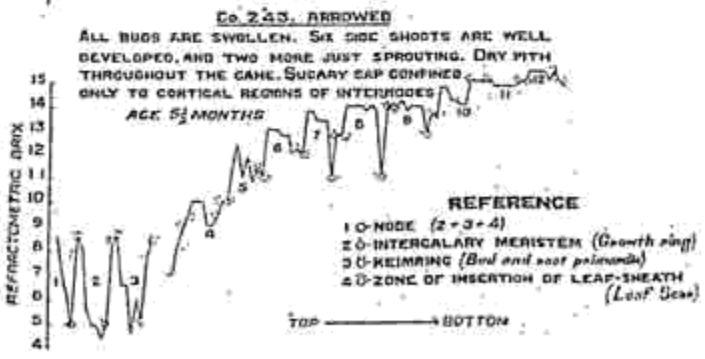
1 ○-NODE (2 + 3 + 4)
2 ◌-INTERCAL RY MERISTEM (*Growth ring*)
3 ◌-KEIMRING (*Bud and root primordia*)
4 ◌-ZONE OF INSERTION OF LEAF-SHEATH (*Leaf Scar*)



Graph (6).



Graph (7).



Graph (8).

It is well known that when supplies of sugar and other labile food material increase within a plant or in any part thereof, quicker differentiation of tissues and rapid thickening of the walls is stimulated, with the ultimate result that the tissues tend to lose their plasticity and become merely mechanical units of the plant.

In the regions of the leaf sheath insertion, labile food materials synthesized in the leaves, find entrance into the cane continuously in larger quantities. As such it should be expected that both the water content and the concentration of the juice extractable from this region and from regions just subjacent to it, should gradually tend to fall to a minimum. This is what was observed.

Again, as the meristematic tissue at the base of the internode is constantly utilising large quantities of water and food to meet its high energy requirements for the production of newer cells, there can naturally be expected only a balance of minimum of concentration of sugars at this end of the internode, and this is so. This latter minimum is also the lower of the two minima.

3. As the lower portions of the internode above the intercalary meristem are, at any instant, comparatively younger than those in the top portions of the same internode, the speed of increase in the concentration of the juice in these portions should also be expected to be slow. The experimental data actually indicated this. The portions of the curves pertaining to this region are the last to cross and go above the level of the nodal concentration.

4. Further as the top portions of the internode are older and tend to get continually more woody earlier, and those towards the bottom are young, and as these relative positions hold, at any instant, in all internodes, it can easily be realised that the maximum concentration in the sap within any internode should occur at about its centre or just above it. The data, presented, as was already seen, bear out this.

5. The observation that "as cane matures the maximum for the concentration of its juice tends to travel towards the centre of the cane," can also be explained on just similar considerations.

Taking the cane as a whole, which is mature or is approaching maturity, it contains towards its bottom, internodes which are older and more woody and so with lower concentration of juice. Again, towards its top it contains internodes which are young and still growing and for this reason they also contain lower concentrations. Thus the picture here is just similar to what obtains in any one of the individual internodes, but with this difference, that the location and the direction of the young and the older portions are reversed in this case.

Therefore as in any internode, so in any mature cane, it should be expected that the maximum concentration of juice should seem to be located in its central internodes, which are neither too young, nor too old.

While this seems to be the most plausible explanation, a yet another possibility contributing to this end also seems to operate. As will be shown in a subsequent communication, the curves for the development of the leaves, their dry matter as well as their functioning surface areas, indicate maxima in the regions of those leaves which are attached to the nodes situated in the second and the third quarters of any cane. It may therefore be expected that due to this cause also comparatively greater quantities of sugars might be enabled to be stored within the internodes to which the leaves pertain.

In any case the apparent travelling of the maximum towards the centre of the cane seems to mark only a stage in the normal physiological development of the cane.

6. Considerations in the paper should also lead to another possibility. When the whole cane becomes fully mature and tends toward over-ripening, the bell shaped curves in all internodes should gradually tend to flatten out until the new curves become parallel to the horizontal axis, as each internode loses its plasticity and becomes more woody. This is being verified by further work.

Summary. 1. The distribution of concentration in the sap of sugarcane over its entire length from its growing point down to its bottom was followed with the aid of hand refractometer. The canes selected were of ages 5, 5½, 6 and 10 months. They include canes which are (1) unarrowed, (ii) arrowed, (iii) which are in shot blade and (iv) those which are treated with and without manure. They also included canes which were cut at different parts of the day and night. For purposes of this study three distinct regions were distinguised at the nodal parts. They are (i) intercalary meristem (growth ring), (ii) Keim ring (bud and root primordia), and (iii) leaf sheath insertion zone (leaf scar).

2. The distribution and the mode of accumulation of sugar in juice during the development of cane towards its maturity follows a regular sequence which is interesting from the point of view of the physiology of sugarcane.

3. The forms of concentration curves and the character of the several changes in form which they undergo are similar in all cases, irrespective of the time of cutting the cane, and whether it is arrowed or unarrowed, manured or unmanured, or whether it is only in shot blade.

4. The concentration of juice is not strictly uniform, either in the whole cane or in any of its internodes. But as the cane matures, or advances in age, the differences in the average concentration of juice in successive internodes tend to get considerably narrowed down.

5. In the internodes, beyond certain stages in their development, there occurs maximum concentration about their central parts, and two minima, one at either end of each internode. One of the two minima corresponds to the intercalary meristematic zone at the base of the internode and

the other to the zone of leaf sheath insertion at its top. The former is the lower of the two minima.

6. In a young cane and in the younger parts of a developed cane, the concentrations at all points within an internode are lower than those in the keim ring and the leaf sheath insertion zones. The concentration curves are troughs lying below the levels of the nodal concentrations.

7. But with advance in age, the concentration in both the nodes and the internodes, gradually increases, those in the nodes, all tend to become equal and attain a stationary level. Within any internode the concentrations at all points in it gradually increase beyond those in the nodes, and continue to do so, such that in time, the forms of their curves get completely inverted. They change their shapes from troughs, lying entirely below the level of the nodal concentrations, to bell shaped ones, with every point on them being far above the concentrations in the nodes. The rate of this change however varies from point to point in the internode. The change is very gradual and commences earlier from the top of the internode. All the possible intermediate transitional stages through which the curves pass in the process leading to their complete and the final inversion are illustrated.

8. Taking the cane as a whole the concentration in it commences to increase earlier at its bottom, but taking each internode in it individually, the increase occurs earlier at its top. With advance in age, the concentration in both gets to be maximum in their central parts.

9. Manuring seems to keep the cane physiologically much younger than the one which is of equal age, but which received no manure.

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STATEMENT 1. Maximum and Minimum concentrations (Brix) in successive Internodes of canes.

CO. 223. Unarrowed cut at 12-30 A. M. midnight. Brix.			CO. 223. Unarrowed cut at 3 P. M. Brix.			CO. 243. Unarrowed cut at 2-30 P. M. Brix.			Co. 213. Unarrowed. No Manure cut at 10 A. M. Brix			Co. 213. Unarrowed manured with castor cake. cut at 10 A. M. Brix.		
Max.	Min.	Diff.	Max.	Min.	Diff.	Max.	Min.	Diff.	Max.	Min.	Diff.	Max.	Min.	Diff.
5·8	5·8	0·00	6·8	6·4	0·4	7·4	7·4	0·0	5·8	5·4	0·4	8·4	7·0	1·4
5·0	4·0	1·00	6·0	5·0	1·0	8·0	6·0	2·0	7·8	7·2	0·6	6·8	6·0	0·8
4·8	4·0	0·80	5·8	4·6	1·2	7·2	6·0	1·2	9·8	8·2	1·6	8·4	4·8	3·6
5·6	4·0	1·60	7·2	5·0	2·2	7·8	7·0	0·8	11·0	10·0	1·0	8·4	4·2	4·2
6·2	5·0	1·20	7·0	5·8	1·2	10·0	8·8	1·2	11·6	9·6	2·0	10·2	7·8	2·4
7·4	6·2	1·20	9·2	7·6	1·6	11·8	10·2	1·6	12·0	10·6	1·4	9·0	8·2	0·8
8·8	7·7	1·00	10·4	9·6	0·8	14·2	13·0	1·2	12·6	11·0	1·6			
9·8	8·8	1·20	12·0	10·6	2·6	15·6	14·4	1·2	13·0	11·6	1·4	9·0	6·0	3·0
10·4	9·0	1·40	13·0	12·4	0·6	16·0	13·2	2·8	13·6	11·0	2·6	9·0	8·8	0·2
12·0	10·0	2·40	14·8	13·0	1·8	16·2	15·2	1·0	13·8	11·2	2·6	9·6	6·2	3·4
13·2	12·4	0·80	16·2	14·0	1·6	17·4	14·8	2·2	13·6	12·6	2·0	11·0	7·8	3·2
14·8	13·4	1·40							14·4	12·6	1·8	11·6	8·8	2·8
									14·2	11·8	2·4	11·0	7·6	3·4
									14·0	11·4	2·6	10·6	8·6	2·0
									13·6	11·0	2·6	10·0	8·8	1·2
												10·0	8·8	1·2
												10·2	9·0	1·2
												10·4	10·0	0·4
												10·6	10·4	0·2
												11·2	10·4	0·8
												11·0	10·8	0·2
												10·8	10·6	0·2
												11·2	11·8	0·4
												11·4	11·2	0·2
												11·0	11·0	0·2
												11·0	10·8	0·2