

STUDIES IN THE ANATOMY OF SUGARCANE STALK

V. Pith and Cavity Development

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INTRODUCTION

OWING to the scattered arrangement of vascular bundles in the stem of Monocotyledons, the ground tissue cannot be marked off into cortex and pith, homologous to those of a dicot stem. Pith in any plants of the former group, e.g., maize consists of thin-walled parenchymatous matrix in which vascular bundles are embedded. In sugarcane this term is used only when ground tissue consists of loosely packed parenchymatous cells and a few vascular bundles found amongst them and is unable to discharge its function of storing sugar properly.

Occurrence of hollow stems in Angiosperms, especially among the annuals, is quite a common feature both in Monocots and Dicots and the presence of a cavity in them is a means devised by them to meet the peculiar conditions of their growth and development. According to De Bary, cavities within the submerged parts of hydrophilous plants are of great importance, so far as respiration in them is concerned. The extent of development of hollowness in wheat stems materially affected its lodging tendency (Percival, 1921), while Canfield (1923) found cavity formation to be associated with some of the fodder grasses which occurred in moist and sheltered places. But in sugarcane, cavity as well as pith is an undesirable character because both of them not only reduce the sugar content but also lower the yield to the extent to which they develop. Varieties otherwise promising, have at times to be discarded just because they develop or are prone to develop these features in adverse circumstances.

The present paper gives a summarised account of investigations carried on at the Station to study the problem in its various details over a number of years (Khanna, 1933, 1934, 1940, 1941, 1942, 1943, 1944, 1945, 1946, 1947, 1948, 1949, 1950 and 1951).

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II. REVIEW OF LITERATURE

Although both pith and cavity have attracted attention of various workers, so far little precise work as regards their origin, development and the various factors responsible for their formation, has been done. One of the authors (Khanna, 1934) found that varieties developing pith and cavity early in season were not only poorer in the quality of juice, sustaining loss of 7.32 to 17.84% of total sugar which would have been stored provided pith and cavity had not developed, but also deteriorated, when kept cut, more rapidly than those with a solid core. He also noticed that varieties having large cavity appeared to suffer more from dryage in field towards the end of the season than those with none or a small one. In 1941-42, he found the loss in tonnage due to dryage resulting from free circulation of air within cane-stalks, to be as high as 13.7% at harvest in February. Though the girth values of individual stalks were not affected, the cane progressively lost in weight and in the quality of its juice. The yield record of 1933 and 1938 confirmed this finding because the actual weight on harvesting was found to be 30% less than the yield estimated in October (Khanna, 1942). In 1950-51 season when certain factories worked as late as second week of May, Co 453 a highly cavity forming variety lost as much as 27% on weight-basis as against a loss 4-6% in B.O. 11 which normally has a solid core.

That the development of these features is a varietal character, is universally known. Some times it is so characteristic of a variety that it can be used as one of its diagnostic features. For instance, the stalks of Co 331 and Co 299 which resemble to a very great extent, those of B.O. 11 and Co 513 respectively in their outward appearance, can be easily distinguished from them by the presence of a cavity (Khanna and Sharma, unpublished). Another well-known phenomenon is that all the varieties develop pith in the upper internodes when they pass from the vegetative to the reproductive phase.

As regards the factors influencing the extent of development, Mathur (1941, 1942) found that progressive increase in the application of nitrogenous manures, resulted in correspondingly greater amount of pith up to 200 lb. per acre beyond which it became ineffective. Irrigation, on the other hand, was found to retard its formation. At Shahjahanpur, average pithiness fell from 6.5% to 4.7% and 4.5% respectively, when irrigation were increased from 3-5 in number to 9 and 11. At Anakapalle, however, in the same season, no appreciable difference in the amount of pith due to different treatments of manure and irrigation was found to be present. Rege

(1942) found that additional quantity of potash reduced pith formation which was very common in P.O.J. 2878, although ordinarily there did not appear to be any deficiency of this constituent in the soil from the standpoint of plant growth. Dutt and others (1946) found that varieties like Co 213, Co 281, Co 301 and Co 508 which possessed a solid core, transmitted this character to their progeny when they were crossed with such a highly pith-forming variety as P.O.J. 2878. Trivedi (1948) also as a result of the study of progeny of four crosses came to a similar conclusion.

The extent of development of pith and cavity has been estimated in various ways by different workers. Sartorius (1935) measured the solidness of a stalk by a proportional divider and expressed the diameter of pith and cavity in tenths of that of the stalk. Although the method was quick, it suffered from one serious defect in that the length of the cavity or pith was completely left out of consideration. Venkatraman and Ekambaram (1941) suggested that specific gravity of an internode was a fairly reliable index of pith formed within. More recently Lakshmikantham (1946) expressed the volume of pith within an internode as percentage of that of the latter. He determined the volumes of both as if they were cylinders assuming that the internode has the same diameter throughout and that pith extended over its entire length and was of uniform diameter. Obviously the method had very restricted application. Trivedi (1948) improved upon it by splitting open the internodes longitudinally and measuring the length of pith and cavity.

III. MATERIAL AND METHODS

In the initial stages, representative material for these investigations was drawn from different trials carried out at the Station to study the effect of various factors, on the growth and yield of some of the standard canes including Co 313, Co 331 and Co 513 which were distinctly different from one another as regards the formation of pith and cavity. For each variety, a sample usually consisted of 15–20 well-developed non-arrowing and outwardly healthy canes. Presence of pith and cavity was noted after splitting open all the stalks and percentage of internodes so affected was calculated.

In subsequent years, for more detailed work, the length of each successive internode upto the uppermost one (usually 1–3 cm. long) was noted and the internodes were split open along the median diameter* for observation.

* A stalk of sugarcane has two principal diameters, namely (i) the median passing from front to back through the bud and (ii) the lateral from side to side at right angles to the median. The cavity which, in a cross-section, appears from a flattened ellipsoid to a wavy circle in outline, has been found to have its longest axis in the same plane as the median diameter of the stalk.

The extent of development and length of pith and cavity and their location were estimated visually, their length being recorded as a fraction of the length of the internode. The range of development which varies from a small vacuole embedded in the ground tissue to a well formed cavity, covering the entire length of the internode and about $\frac{1}{3}$ of its diameter, was divided into six classes as follows (Pl. XIX, Figs. 2-4 and Pl. XX, Figs. 5-9).

0 = Absent.

I = A few small isolated vacuoles spaced wide apart.

II = Vacuoles larger in size and closer together: the cavity so formed appearing moniliform in shape and the vacuoles retaining their identity.

III = Cavity tubular and rather narrow with or without thick septa of ground tissue.

IV = Well-developed cavity continuous from node to node: and without vascular strands within it.

V = Same as IV but wider and having vascular strands hanging loose in it, which sometimes form a pseudoseptum giving it an appearance of two parallel cavities.

VI = Maximum development usually covering $\frac{1}{3}$ or more of the diameter of the internode.

The amount of the pith and cavity present in an internode was calculated by multiplying the length of internode with the fraction of this length covered by them and the class to which they belonged. Expressed as a formula it would be as follows:—

$$\text{Amount of pith and cavity} = \text{Length of the internode} \times \text{Fraction of the length of internode covered by pith and cavity} \times \text{Class.}$$

Summation of all the figures for the internodes forming a stalk when divided by its total length, would give the amount of pith and cavity present per unit length and therefore an index for the stalk. As an example one of the stalks of Co 313 studied at harvest is given below (Table I).

The superiority of this method to that followed earlier here would be apparent when the effect of nitrogen derived from different sources, on the

TABLE I

Pith and cavity in Stalk No. 5 of Co 313 at harvest (8-2-1944)

Serial No. of internode	Length of the internode cm.	Pith	Cavity	Length	Location	Class	Amount of pith or cavity
1	4.8	Present	..	Whole	..	I	4.8
2	4.9	..	..	..	..	III	14.7
3	5.5	..	..	..	..	III	16.5
4	5.5	..	Present	..	..	III	16.5
5	8.5	..	..	..	..	II	17.0
6	8.4	..	..	..	..	V	42.0
7	8.5	..	..	..	..	V	42.5
8	8.0	..	..	..	..	III	24.0
9	9.3	..	Present	..	..	III	27.9
10	12.2	..	..	..	..	I	12.2
11	14.8	..	..	$\frac{1}{2}$	Upper	II	14.8
12	12.6	..	..	..	..	..	..
13	12.0	..	Present	$\frac{2}{3}$	Upper	III	24.0
14	11.7	..	..	$\frac{1}{2}$	..	III	17.6
15	12.1	..	..	$\frac{1}{2}$	..	III	18.2
16	12.1	..	..	..	..	..	..
17	11.9	Present	Present	$\frac{1}{2}$	Upper	III	17.9
18	13.6	..	..	..	..	..	..
19	14.8	Present	Present	$\frac{2}{3}$	Upper	II	19.7
20	12.5	..	..	Whole	..	III	37.5
Total for the stalk	205.7						367.8

$$\text{Pith-Cavity Index for the stalk} = \frac{367.8}{205.7} = 1.81$$

development of pith and cavity in Co 313 was studied in 1944-45 (Table II). The differences due to various treatments were significantly different at 1% level when determined by pith-cavity index, whereas those on the basis of percentage of internodes having pith and cavity were found to be significant at 5% level only. Obviously the former method was more accurate and precise than the latter. As regards methods used by other workers, it might be stated that they were not so quick as to be suitable for the collection of data large enough for statistical analysis.

In the ultimate reckoning for a stalk, pith and cavity were treated together, primarily because from economic point of view, the net result of both the features was interference with the storage of sugar.

TABLE II

Comparison of two methods of estimation of pith and cavity in an experiment on the effect of nitrogen derived from different manures on their formation in Co 313 in 1944-45 in Bhograssan

Treatment	Average height of cane examined cm.	Total number of internodes examined	Total number of internodes with pith or cavity	Percentage of internodes with pith or cavity	Pith-cavity index
$F_0C_0A_0$..	218.2	234	132	56.4	1.20
$F_2C_0A_0$..	234.3	208	113	54.2	1.04
$F_0C_2A_0$..	200.5	220	112	50.9	0.79
$F_0C_0A_2$..	202.8	224	105	46.9	0.83
$F_2C_2A_0$..	212.2	242	111	45.9	1.17
$F_2C_0A_2$..	225.3	228	136	59.6	1.20
$F_2C_2A_2$..	219.4	233	145	62.2	1.39
G. Mean ..				53.7	1.09
C. D. at 1% level					0.38
C. D. at 5% level				10.88	0.29

Notes.—1. $F_0C_0A_0$ = No manure : Control.

F_2 = 100 lb. of N per acre as F.Y.M.

C_2 = 100 lb. of N per acre as castor cake.

A_2 = 100 lb. of N per acre as Ammonium sulphate.

F_2C_2 = 200 lb. of N as F.Y.M. and castor cake.

F_2A_2 = 200 lb. of N as F.Y.M. and Ammonium sulphate.

$F_2C_2A_2$ = 300 lb. of N as F.Y.M., castor cake and Ammonium sulphate.

2. Bhograssan is the name of a field with fairly heavy soil.

3. Conclusions : (a) Differences due to various treatments were found to be highly significant in the case of pith-cavity index and significant only in that of the percentage of internodes having pith and cavity. The former method was therefore more accurate and precise than the latter.

At 5% level for percentage of internodes having pith and cavity.

$F_2C_2A_2$, $F_2C_0A_2$, $F_0C_0A_0$, $F_2C_0A_0$, $F_0C_2A_0$, $F_0C_0A_2$, $F_2C_2A_0$

(b) At 5% level for pith-cavity index.

$F_2C_2A_2$, $F_2C_0A_2$, $F_0C_0A_0$, $F_2C_2A_0$, $F_2C_0A_0$, $F_0C_0A_2$, $F_0C_2A_0$

4. Out of seven treatments, four occupy the same position in both the reckonings. One is moved downwards by one and another by two positions. The only major displacement is in the case of $F_2C_2A_0$ which has been pushed forward by three places in the scale of pith-cavity index.

Hand sections of suitable material were made into permanent mounts for the study of the initiation and development of pith and cavity.

IV. OBSERVATIONS AND EXPERIMENTS

A. *Pith and cavity*.—As already stated, pith consists of columns of loosely packed parenchymatous cells, more or less dry or dead or dying depending upon the stage of its development. Vascular bundles within pith which is dull cottony white in colour, appear as opalescent dots when seen in a cross-section of the stalk (Plate XIX, Fig. 1. Co 331), while they are usually cream-coloured and more or less concolorous with matrix in a solid-cored stalk. As disintegration proceeds, the loose parenchyma due to further drying shrinks giving place to a cavity which is therefore more often than not surrounded by pith. Vascular bundles, composed as they are of lignified tissue, and at least a layer of parenchymatous cells surrounding them resist desiccation and are left dangling as strands of tissue in the hollow space so created (Plate XX, Fig. 8). It is not necessary that the formation of a cavity should always be preceded by pith, as was the case in Co 419 (Plate XIX, Fig. 1) in which parenchymatous ground-tissue develops a cavity without undergoing all the stages of pith formation.

B. *Occurrence*.—The fraction of the length of an internode covered by pith and cavity, the number of internodes of a stalk having these features and the class to which they belonged, appeared to be all linked together. In other words, Classes I–VI progressively covered larger amount of storage tissue within an internode and greater number of internodes as well in a stalk. Thus cavity and pith of Class I and II would be found more often than not in the middle portion of internodes while Class III would usually occur in their lower one-third. As regards the number of internodes affected by these three classes, it would show a progressive increase. Classes IV–VI, on the other hand, extended usually from node to node and would be present in much greater number of internodes. A statistical analysis of the extent of development of pith and cavity expressed as pith-cavity index and as percentage of internodes in a stalk having them, showed that the correlation coefficient was significant at 1% level, it being as high as +0.7353, +0.8675 and +0.8710 respectively for Co 313, Co 331 and Co 513 which amongst themselves represented all the three categories of varieties so far as the development of pith and cavity was concerned (Table III).

The correlation found to exist between the extent of development of pith and cavity in an internode and their occurrence in internodes of a stalk was further supported by the results of an experiment, already referred to under 'Material and Methods'. It would appear that of seven treatments

TABLE III
Occurrence of pith and cavity as determined on the basis of their presence in internodes and pith-cavity index and the correlation coefficients between the two methods (Experiment on the effect of N and P in 1945-46)

Sl. No.	Co 313						Co 513					
	N ₁ P ₁		N ₁ P ₀		N ₀ P ₁		N ₀ P ₀		N ₁ P ₁		N ₀ P ₀	
	Percentage of internodes	Pith-cavity Index	Percentage of internodes	Pith-cavity Index	Percentage of internodes	Pith-cavity Index	Percentage of internodes	Pith-cavity Index	Percentage of internodes	Pith-cavity Index	Percentage of internodes	Pith-cavity Index
1	33.3	0.6	56.5	0.9	38.9	0.8	71.4	1.2	96.2	2.5	86.4	2.6
2	62.5	1.7	47.6	1.0	56.0	0.7	54.5	0.7	95.3	2.8	95.8	2.3
3	33.3	0.6	56.5	1.0	30.4	0.4	50.0	0.9	95.9	2.4	87.5	2.0
4	41.2	1.0	67.7	1.0	38.9	0.3	61.1	1.0	90.5	2.4	100.0	4.4
5	38.9	0.7	22.0	0.3	59.1	0.8	17.6	0.3	78.3	2.4	95.2	3.0
6	45.5	0.8	45.0	1.1	75.0	1.2	21.1	0.4	91.0	1.8	95.2	2.6
7	46.2	0.6	30.4	0.4	70.0	1.5	23.8	0.3	95.6	3.0	87.0	1.9
8	61.5	0.9	50.0	0.9	42.1	0.5	42.1	0.9	95.5	2.9	95.5	2.8
9	50.0	0.9	38.1	0.5	52.6	0.9	40.0	0.8	87.5	2.6	95.0	3.0
10	52.2	0.9	23.5	0.5	50.0	1.2	68.4	1.1	90.5	3.0	95.8	2.7
11	64.0	0.9	61.4	1.3	37.5	0.6	69.6	1.0	94.4	3.2	95.7	2.6
12	16.7	0.3	45.8	1.0	47.6	0.8	42.1	0.7	95.0	2.7	95.2	3.2
13	77.3	0.4	65.4	1.3	20.0	0.5	28.6	0.5	80.0	2.5	94.1	2.9
14	63.6	1.0	54.5	1.2	52.6	0.9	45.5	0.7	100.0	3.5	91.0	2.9
15	42.1	0.7	52.2	1.2	35.0	0.7	34.8	0.5	87.5	2.4	81.8	2.7
Correlation coefficient .. +0.7353												
+0.8675												
+0.8710												

Treatments:

N₀P₀ = No nitrogenous nor phosphatic manure.N₀P₁ = + 100 lb. of P₂O₅ per acre applied as triple super.N₁P₀ = 80 lb. of Nitrogen per acre given as Ammonium Sulphate but no phosphatic manure.N₁P₁ = " " + 100 lb. of P₂O₅ per acre applied as triple super.

four occupied, in respect to both, the same position, namely 1st, 2nd, 3rd and 7th, there being only one major displacement (Table II).

Amount of pith and cavity varied from internode to internode within the same stalk. In a non-arrowing stalk of varieties like Co 213 and Co 313 which were prone to develop pith and cavity, the internodes in the lower and middle portions would have cavity often surrounded by pith in varying degrees. Its amount decreased progressively from below upwards in the middle one-third and was more or less completely replaced by pith in a few of the internodes of the upper one-third. The uppermost two-three internodes were, however, completely free of both. In solid-cored varieties, *e.g.*, Co 393 and Co 513 in adverse circumstances, a few vacuoles, however, would make their appearance in the basal internodes. But in the case of an arrowing stalk, formation of pith was greatly enhanced, irrespective of whether a stalk belonged to a solid or cavity-forming variety more so in the latter. Internodes of the upper one-third of such a stalk would have nothing but pith within. In a variety like Co 331 which developed these undesirable features under ordinary conditions of growth, almost all the internodes of arrowing as well as non-arrowing stalks had cavity surrounded by pith. Some times the uppermost one or two of the internodes in non-arrowing stalks did not develop them.

Within a variety, no appreciable difference as regards the development of pith and cavity was found in stalks of the same age. In a highly cavity-forming variety like Co 331, a few of upper internodes of shoots formed late in season would be more or less free of both, whereas those of the earliest to appear would have these undesirable features right upto the top. Similarly when its mother shoots were examined in pre-monsoon period (June-July), the uppermost internode would not show pith and cavity, but the lower ones would have both of them in full measure. It would therefore appear that the age of the stalk as well as that of an internode was one of the important causative factors in a variety where cavity was its common feature.

That the extent of development of pith or cavity or both is a varietal feature has been universally recognised. Some varieties, *e.g.*, Co 285 and Co 331, showed consistently a high pith-cavity index year after year while Co 393 and Co 513 were at the bottom of the index-scale (Table IV). Co 213 and Co 313 occupied an intermediate position between the two groups. The cavity-forming varieties were also different from one another in that Co 331 developed both pith and cavity more or less in equal measure whereas in Co 285 and Co 421, pith was the dominant of the two. An extreme case

TABLE IV
Pith-cavity indices of eight sugarcane varieties studied for 6 years from 1941-42 to 1946-47

Time of observa- tion Variety	1941-42*		1942-43		1943-44			1944-45			1945-46			1946-47			Remarks
	Harvest		Harvest	Pre-monsoon	Harvest	Pre-monsoon	Post-monsoon	Harvest	Pre-monsoon	Post-monsoon	Harvest	Pre-monsoon	Post-monsoon	Harvest	Pre-monsoon	Post-monsoon	
Co 213	28.2	28.2	0.83	0.06†	0.41	0.99	0.97	0.05†	0.77	0.37	1.29	2.32	0.97	Cavity dominant in lower in-ternodes Pith more prominent			
Co 285	49.1	33.3	1.59	0.21	..	..	..	0.68	1.92	2.34	0.53	1.40	1.55			
Co 313	59.4	59.4	1.08	0.02†	0.57	0.77	0.67	0.30†	1.17	0.67	1.30	1.37	0.52	Cavity dominant in lower in-ternodes			
Co 331	80.0	80.0	2.37	0.72	1.57	2.52	2.78	1.10	2.70	2.47	1.23	2.54	2.57	Cavity dominant in all inter-nodes			
Co 356	30.9	7.7	..	..	..	..	..	..	..	..	..	..	..	Pith dominant in all internodes, cavity only in the lower ones		
Co 393	2.7	0.0	0.46	0.07†	0.11†	0.35	1.08	0.05†	0.63	0.78	..	..	..	Pith alone present in upper internodes		
Co 421	79.5	48.4	2.40	..	0.53	2.53	2.29	..	..	..	..	..	..	Pith more common than cavity		
Co 513	..	..	..	0.26	0.01†	0.14	0.50	0.00	0.04	0.52	0.39	0.32	0.22	Pith in upper internodes only		
C.D. at 1 %	..	..	0.30	†	0.34	0.28	0.33	†	0.25	0.28	0.28	0.30	0.27			
C.D. at 5 %	..	..	0.40	..	0.45	0.37	0.44	..	0.42	0.37	0.37	0.40	0.35			

* In 1941-42, pith and cavity were noted separately and percentages of internodes having pith and cavity are given in first and second columns respectively.

† These varieties were excluded from the analysis as cavity in most of the canes was practically nil.

‡ Since only two varieties could be analysed, C.D. was not calculated. Co 285 and Co 331 having 0.21 and 0.72 in 1943-44, 0.68 and 1.10 as pith cavity indices in 1944-45 respectively, were obviously different from each other.

in which pith was found in four times as many internodes as cavity, was noted in Co 356. Predominance of pith in this variety appears to have been inherited from its mother, *Sorghum durra* Staff. The presence of one to the exclusion of the other was never met with in a variety which normally forms pith or cavity. In Co 419 a solid-cored variety which did not flower in Bihar, cavity unaccompanied by pith was, however, sometimes met with. On the other hand, Co 393 another solid-cored variety which arrowed rather profusely in certain seasons in this State, developed pith without forming any cavity in upper internodes of even non-flowering stalks.

C. *Origin and Development.*—As already stated, the development of cavity is preceded by the formation of pith which has its origin in intercellular spaces formed schizogenously due to changes in their outline. Just below the growing point, they are polygonal or squarish in shape and so closely packed together that their walls are in tight contact with one another without any space between them. Subsequently when rapid changes take place, they acquire a roundish or oval shape and their walls get separated especially at corners where intercellular spaces, triangular or quadri-angular in outline in a cross-section, are formed (Plate XIX, Fig. 1).

With further increase in the size of cells, these intercellular spaces also enlarge and become distinctly visible under low magnification in an internode (about 1 cm. in diameter and about 2–3 cm. in length) which often bears the standard leaf* of the stalk (Plate XXI, Fig. 2). In a cavity-forming variety, they further increase in size and the central portion acquires a sort of opalescence which slowly turns into cottony dull whiteness as the formation of pith proceeds (Plate XXII, Fig. 5). These various stages of pith-development are found in successive internodes of the same stalk as well.

In a longitudinal section, the intercellular spaces, prior to the appearance of opalescence, would appear as slits between adjacent rows of cells (Plate XXI, Fig. 3). Later on, with the progress of pith formation, cell walls dissociate further and the slits deepen to meet one another. Slowly the space so created between two columns of cells becomes continuous with similar spaces formed between other adjacent columns of cells (Plate XXI, Fig. 4 and Plate XXII, Fig. 5). It is at this stage that the ground tissue appears opalescent. Further large-scale coalescence of these composite spaces which surround columns of cells or a group of such columns, together with the resultant drying of these cells, gives to the central portion of the stalk a dull cottony appearance, so characteristic of pith.

* A standard leaf is one which has the highest visible dewlap or transverse mark.

Being surrounded on all sides by air, parenchymatous cells forming the matrix are cut off from fresh supply of nutrient material, and in due course, they dry up and die. Their walls undergo physical disintegration (Plate XXII, Figs. 6 and 7) and space so created adds to the size of those already present. Term "Cavity" is applied to them when they become large enough to be visible to the naked eye.

Vascular bundles surrounded by the disintegrating parenchyma are, however, able to withstand this general disorganisation of tissues. They hang loose in the cavity-like thin strands and remain functional for long time to come. Parenchymatous cells immediately surrounding them also escape drying and consequent death because they get their requisite nutrition from them (Plate XXII, Fig. 8).

It might, therefore, be stated that cavity which in the ultimate analysis has its origin in innumerable minute intercellular spaces and develops through further separation of cell walls brought about by increase in size and change in shape of cells is schizogenous in origin and 'pith' is just an intermediary stage between the microscopic intercellular spaces and a cavity visible to the naked eye. Where the amount of storage tissue involved is not large, as is the case in Co 419 (Plate XIX, Fig. 1), 'pith' stage is omitted. Also their development was a continuous process which was initiated with the formation of intercellular spaces in all varieties but was arrested at its different stages of development, depending upon the various factors internal as well as external. Thus in Co 513, it was not allowed to proceed beyond the initial stage of intercellular spaces which are a normal feature of all plant tissues. Co 419 represented the next stage where these intercellular spaces became sufficiently large to interfere with uniform diffusion of light from a smoothly cut surface with the result that they gave an opalescent appearance to the ground tissue. In Co 356 the enlargement of these spaces was carried still further to convert the matrix into cottony white pith. It reached its maximum development in Co 331 in which there was physical disintegration of cell walls to form a cavity due to desiccation.

V. SUMMARY

1. Owing to the scattered arrangements of vascular bundles in monocotyledonous stem, there is no pith homologous to that found in Dicots. Cavity in stem, however, is a normal feature in some hydrophilous or shade-loving plants of both the groups.

2. In sugarcane, pith has acquired a specific meaning and together with cavity is an undesirable feature as both of them affect the economic value of the stalk. In a pith and cavity-forming variety, it not only suffers

in weight and quality of juice, in the standing crop, but also deteriorates more rapidly during transit and storage compared to a solid-cored variety.

3. Development of pith and cavity to a great extent is a varietal feature the magnitude of which has been found to vary with several external factors. Their precise role is little understood. Nor is there any unanimity as regards the methodology of their estimation.

4. The development of pith and cavity is traced from the initial stage of intercellular spaces right up to the formation of a large cavity which is therefore schizogenous in origin.

5. A precise method for the proper estimation of their magnitude is given. The estimate so made was found to be highly correlated with the number of internodes having pith and cavity, the correlation coefficient for Co 313, Co 331 and Co 513 respectively being $+0.7355$, $+0.8675$ and $+0.8710$.

6. Co 331 and Co 513 were respectively the greatest and the least cavity-forming varieties among those studied, while Co 213 and Co 313 occupied an intermediate position. Co 285 also formed large cavities which were accompanied by more of pith than in Co 331. Co 356 and Co 421 were more akin to Co 285 as the formation of pith dominated in them also. Co 393 and Co 419 were solid-cored. Arrowing always produced pith in upper internodes even in solid-cored varieties as well.

VI. ACKNOWLEDGEMENTS

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EXPLANATION OF PLATES

PLATES XIX AND XX

Figs. 1-9.—Fig. 1. Co 331 shows the formation of pith which is cottony white in appearance with tiny islands representing vascular bundles and living parenchymatous tissue surrounding them. In Co 419, a minute cavity has developed without being preceded by the formation of pith. Figs. 2-9 show the various classes of pith-cavity development. Fig. 2. Class 0; Fig. 3, Class 1; Fig. 4, Class 2; Fig. 5, Class 3 with septa; Fig. 6, Class 3 without septum; Fig. 7, Class 4; Fig. 8, Class 5 and Fig. 9, Class 6.

(Photographs not to the same scale)

PLATES XXI AND XXII

Figs. 1-8.—Showing various stages in the formation of pith and cavity. Fig. 1. T.S. of parenchymatous tissue showing intercellular spaces; the initial stage. Fig. 2. T.S. of parenchymatous tissue which has acquired opalescence due to the presence of air in the enlarged intercellular spaces. Fig. 3. L.S. of the initial stage. Intercellular spaces appear as slits between columns of cells. Fig. 4. L.S. of opalescent stage. Slits have deepened and joined together. Fig. 5. T.S. of parenchymatous tissue which is cottony white in appearance. Cells have started collapsing; the 'pith' stage. Fig. 6. T.S. of the next stage in which the cell-walls are disintegrating. Fig. 7. A magnified portion of Fig. 6. Fig. 8. T.S. of a vascular bundle surrounded by living parenchymatous cells.

(Magnifications: Figs. 1 and 2, $\times 35$; Figs. 3 and 8, $\times 90$; Figs. 4 and 6, $\times 20$; Figs. 5 and 7, $\times 50$).

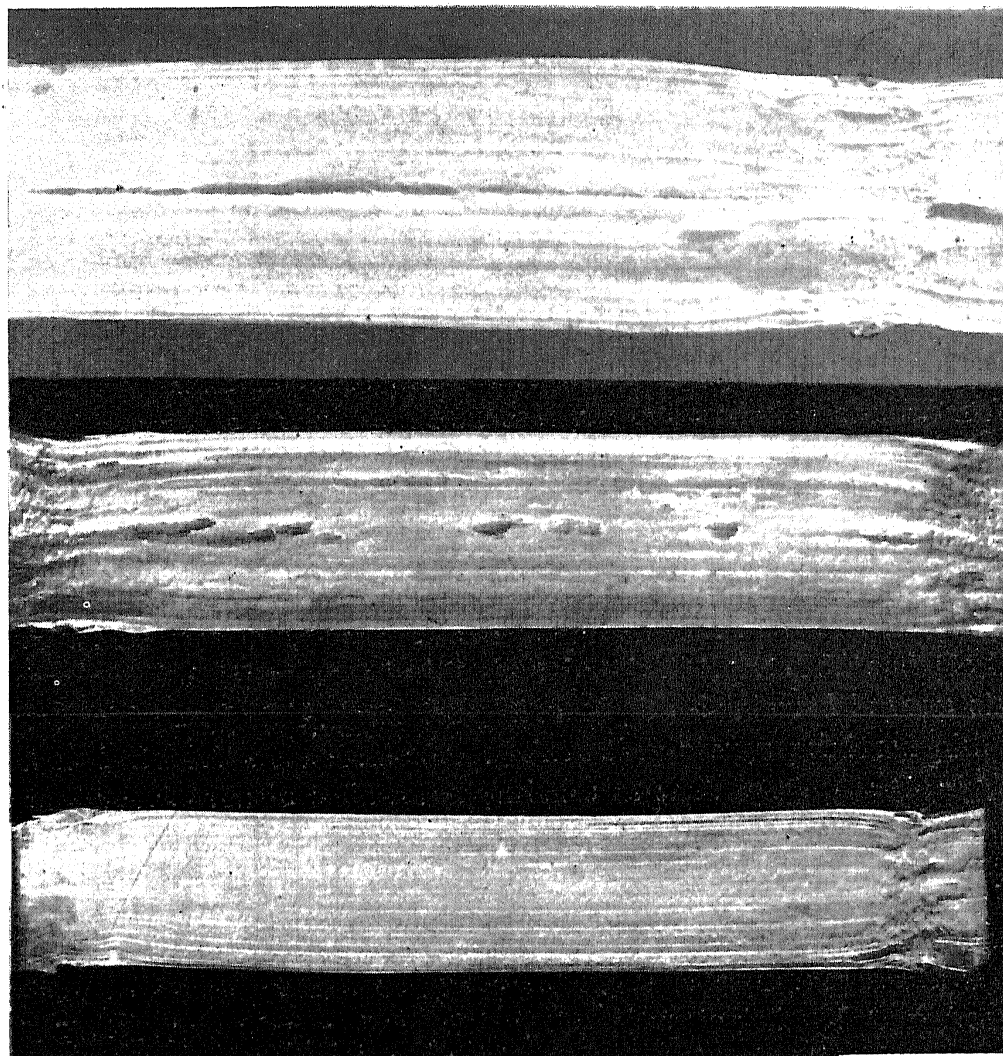


FIG. 4

FIG. 3

FIG. 2

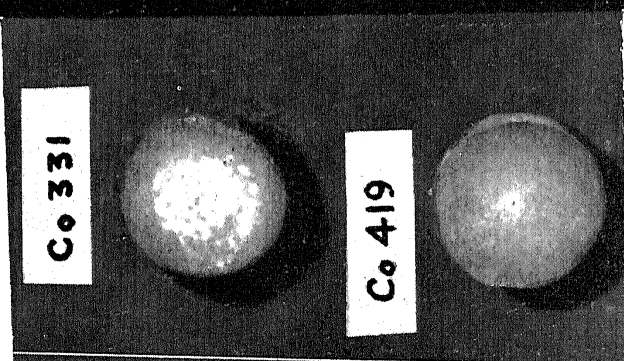
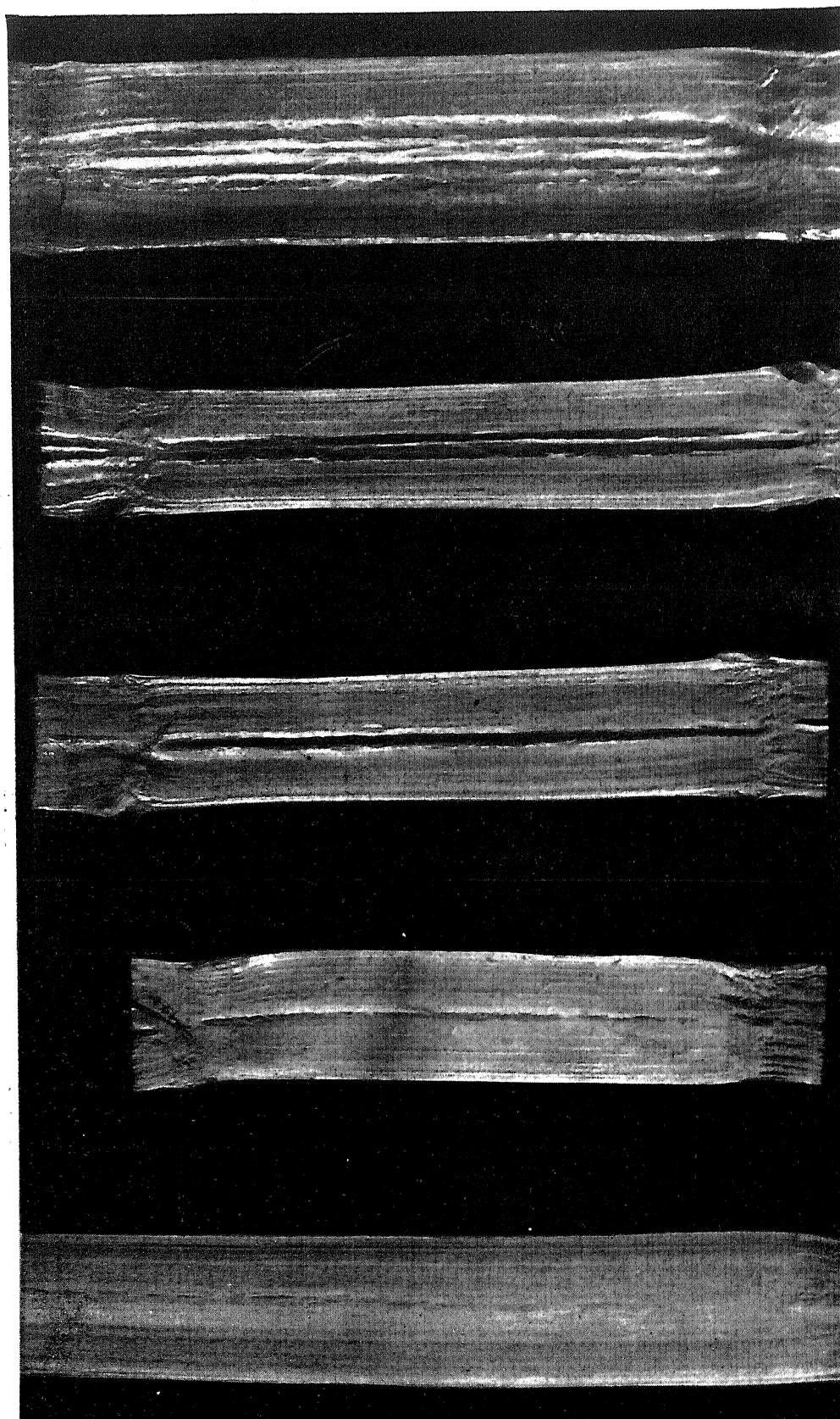


FIG. 1



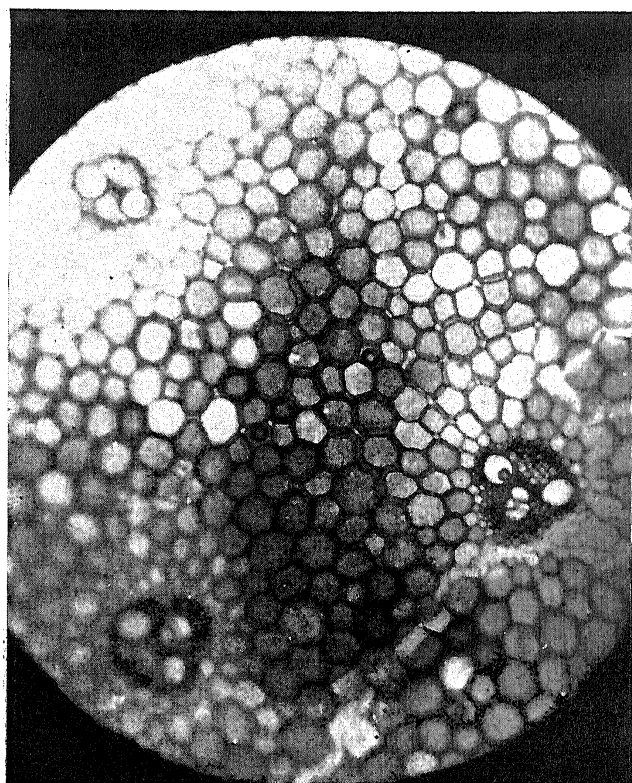


FIG. 1

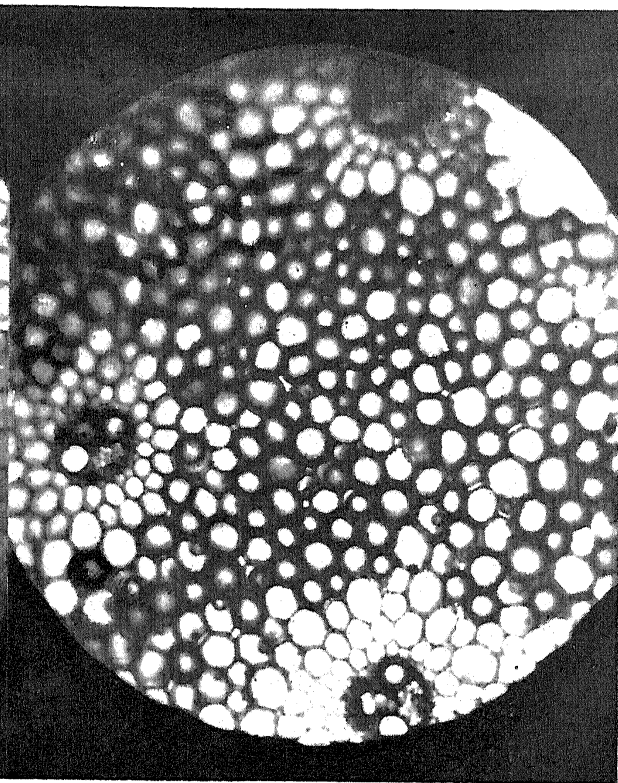


FIG. 2

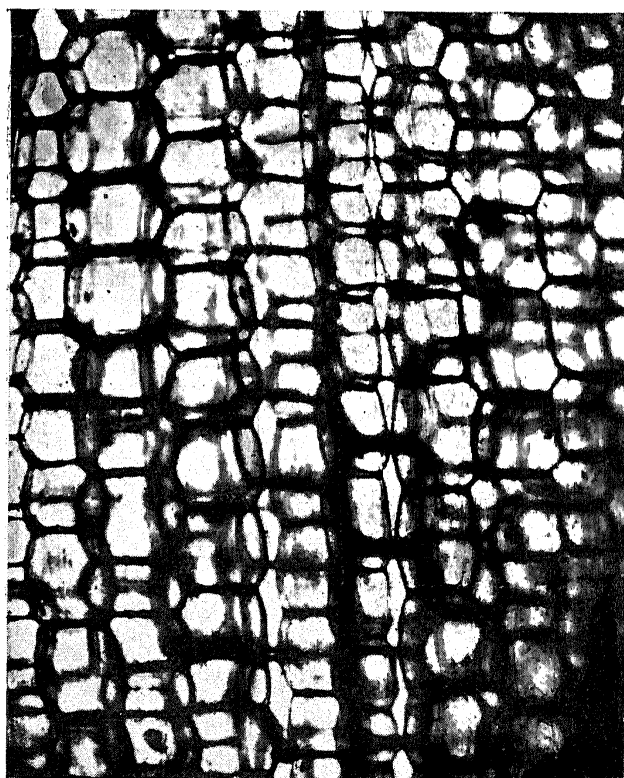


FIG. 3

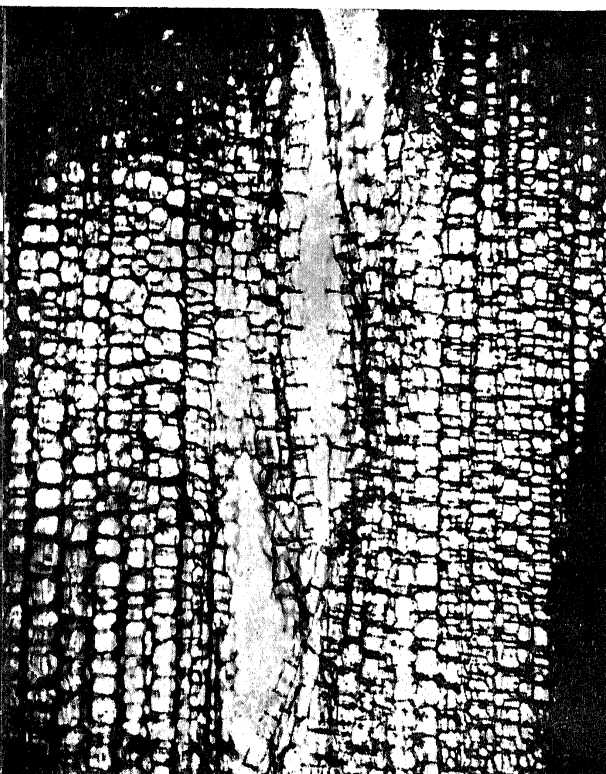


FIG. 4

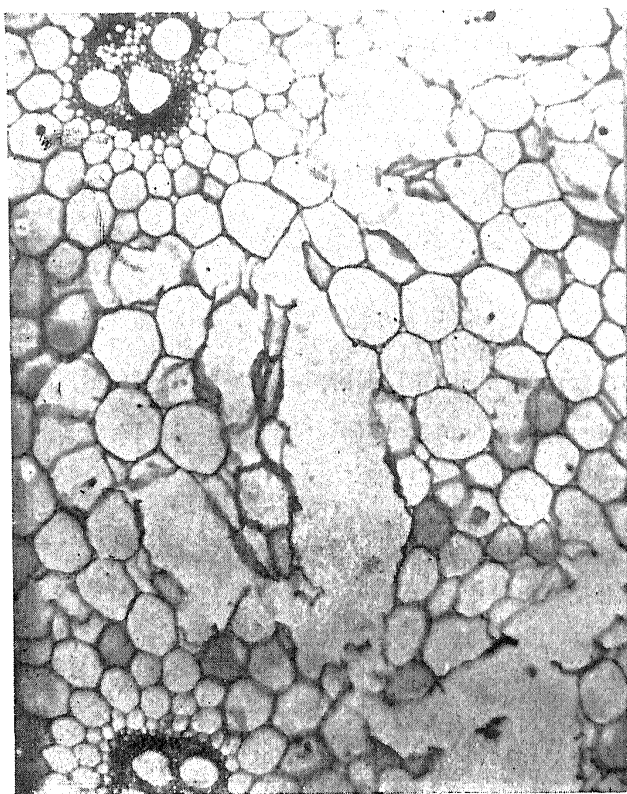


FIG. 5

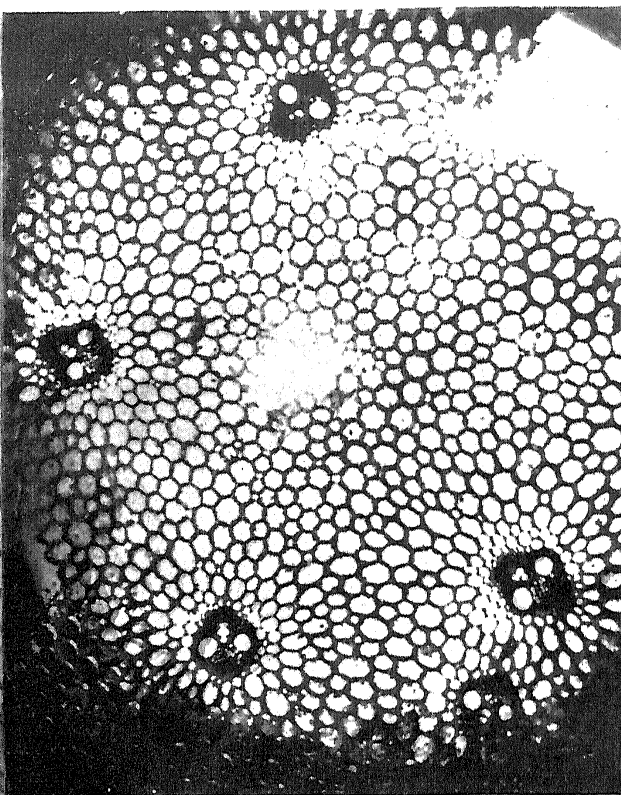


FIG. 6

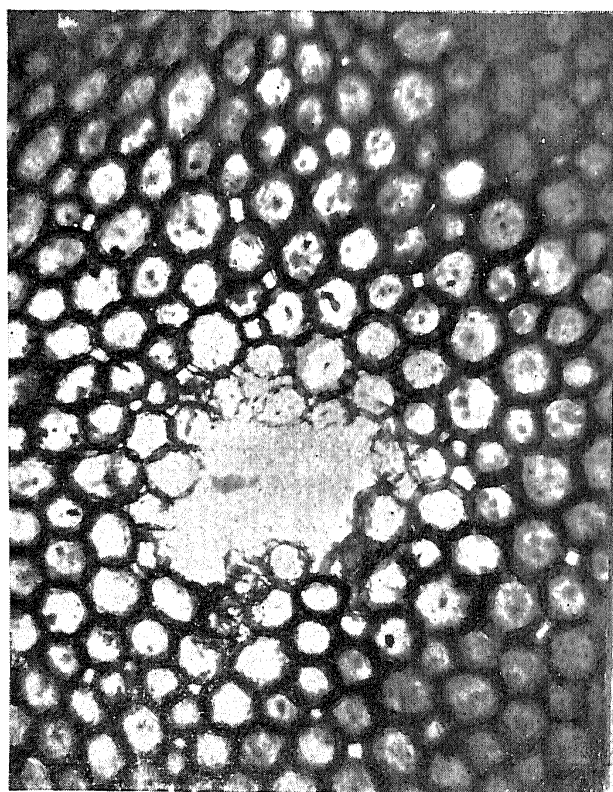


FIG. 7

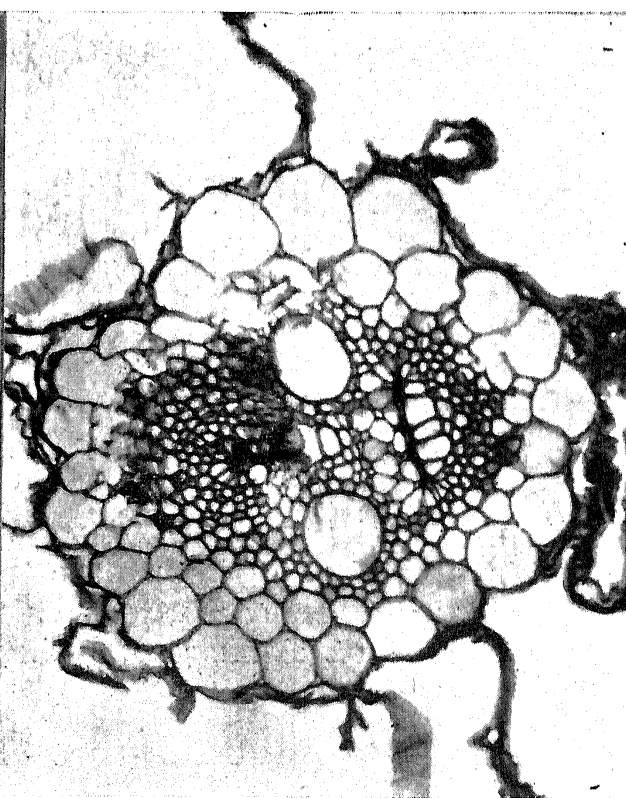


FIG. 8