AN ANATOMICAL STUDY OF *TILIACORA ACUMINATA* MIERS.

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1. INTRODUCTION

Tiliacora acuminata (Lam.) Miers. (= *T. racemosa* Colebr.) is a diœcious evergreen climber of the Menispermaceæ, which is known to occur in various parts of India, Burma, Ceylon and Malaya (Brandis, 1874).

The plant is usually seen near hedges and bushy clumps and it frequently climbs over forest trees. The young shoots are green but the older ones are covered with a thin brownish layer of cork. The lenticels are few in number and elongated along the axis of the stem with their margins slightly raised above the general surface. A cross-section of an old stem presents an extremely abnormal appearance, for, instead of a single ring of vascular tissue as is met with in most dicotyledons, we find here a series of concentric rings or large arcs of bundles separated by tangential bands of parenchyma, while in between the bundles of each ring lie the wide interfascicular rays (Figs. 1, 2*a*). Eighteen such rings were counted at the base of a stem, about 8·8 cm. in diameter. Owing to the abundance of fibrous cells in the wood, the stems show a high degree of flexibility and are consequently used in many places for thatching and basket work.

The full grown leaves are 16·5 to 19·0 cm. by 9 to 11 cm. in size, 3- to 5-nerved at the base, ovate, acuminate and cordate, truncate or rounded at the base with undulate margins, and glabrous except on the lower side of the midrib. The petiole is 2·5 to 3·5 cm. in length with its base somewhat flattened and twisted so as to serve as a hook for helping the plant in attaching itself to its support.

The root system consists of a woody tap-root with many branches. The anomaly seen in the stem is also present here (Figs. 2*b* and *c*) and 7 rings of vascular tissue were seen in a root about 4·2 cm. thick. According to Roxburgh (1832, Vol. 3, p. 816) the root is used as a cure for snake-bite.

2. PREVIOUS WORK

A reference to the works of Solereder (1908) and Pfeiffer (1926) shows that anomalous secondary growth has so far been noted in the family Menispermaceæ in the stems and roots of *Abuta*, *Chondrodendron* *Cissampelos*, *Clypea* and *Cocculus* and in the stems only of *Anamirta*, *Anomospermum*, *Chasmanthera*, *Hyperbæna*, *Jateorhiza*, *Menispermum*,

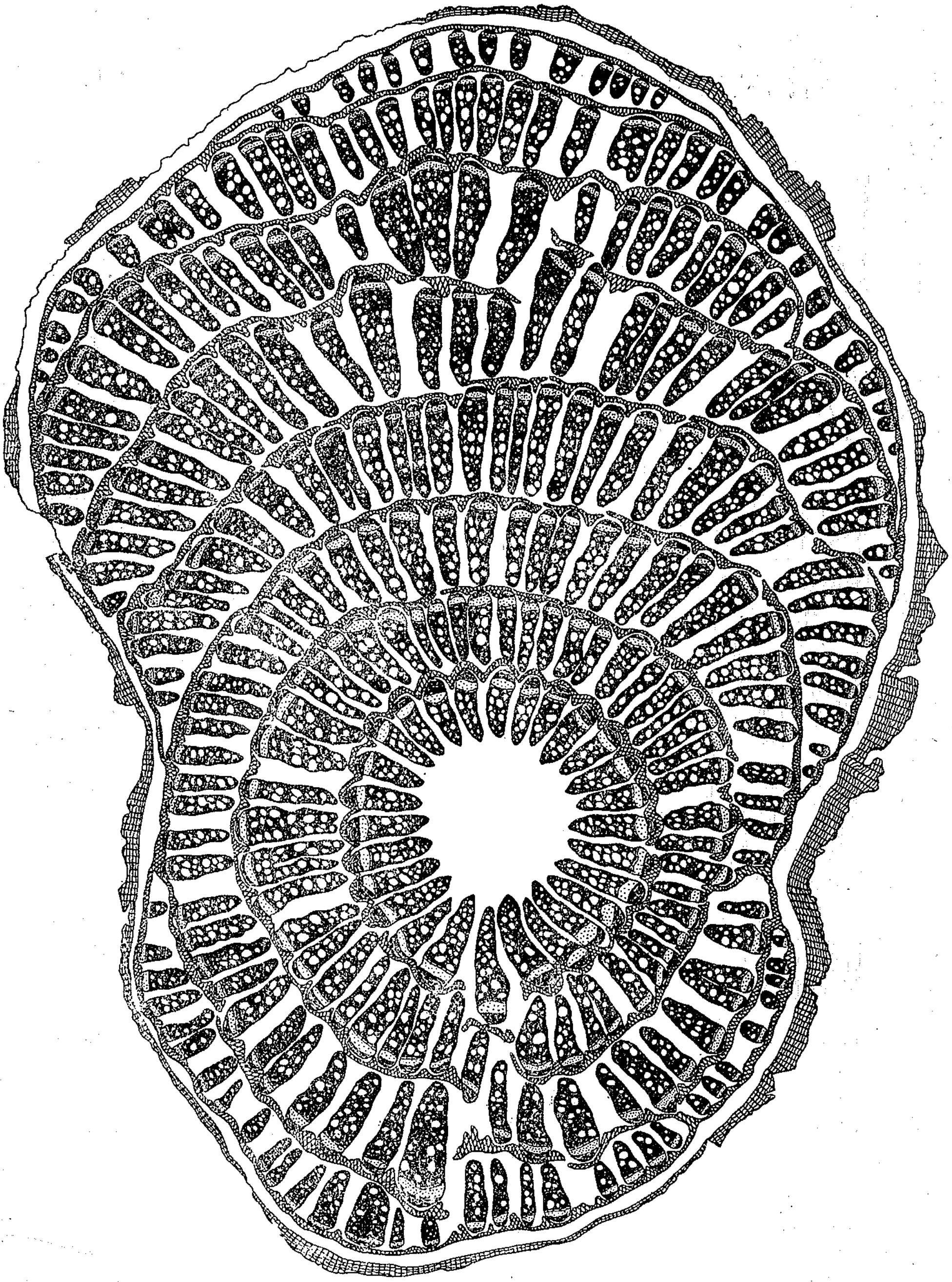

Fig. 1. An outline diagram of t.s. of stem showing anomalous secondary growth. × 9.

Pachygone, *Pericampylus* and *Stephania*. Recently Santos (1931) described it in the stems of *Anamirta cocculus* and *Archangelisia flava* and Maheshwari (1935) has reported it in the stem of *Tiliacora*. No detailed work on the anatomy of the last named plant has, however, yet appeared and this study was undertaken in the hope that it might lead to a clearer idea of the origin of the supernumerary cambial rings which form such a characteristic feature of the stem and root in several plants of the family.

3. MATERIAL AND METHODS

The greater part of the material used in this study was collected locally and fixed in formalin-acetic-alcohol. This was dehydrated, infiltrated and imbedded in paraffin according to the usual methods. Older pieces of the stem and root were first treated with dilute HF. Section were cut between 12 and 25 μ and stained with Safranin and Fast Green. In a few cases Bismarck Brown and Iron-hæmatoxylin were also used for comparison. The oldest stems and roots were cut fresh on a sliding microtome. Mounts of macerated material were also prepared for a study of the shapes and characteristics of the individual cells and the strip method of Priestley, Scott and Malins (1933) was used to make some preparations of the tissues adjacent to the primary cambium[1].

4. THE STEM

Primary Structure.—A cross-section of the stem is roughly circular with some undulations in the younger stages which smoothen out afterwards. The *epidermis* consists of a layer of moderately cutinised cells with occasional stomata. Epidermal hairs are few, occurring only in the youngest regions. They are invariably 2-celled with a short stalk cell which is thick-walled and urn-shaped and a terminal cell which is long, slender and thin-walled. The deposition of cutin is usually seen only on the outer walls but occasionally it extends even to the radial and inner walls of some epidermal cells.

The *cortex* consists of 3–4 layers of collenchymatous cells followed by 4–10 layers of more or less tangentially elongated parenchyma. Chloroplasts are present in both but are more numerous in the outer layers, particularly in the substomatal portions. Solitary thick-walled cells of a fibrous nature are also seen in the cortex but only occasionally and without any definite plan in their arrangement or distribution. "Bitter principle sacs" such as have been noted in *Tinospora* by Santos (1928) were seen in only a few sections.

An *endodermis* is not clearly distinguishable. Many cells of the innermost layer of the cortex which are in contact with the band of sclerenchyma contain rectangular or rhomboidal crystals of calcium oxalate. Due to the lack of a distinct endodermal layer it is not possible to set off the tissues of the stele from the cortex with any

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[1] The designation " primary cambium " is used here to distinguish the cambium of the normal ring of vascular bundles from the subsequently formed " secondary " or " extrafascicular " meristems.

certainty, but by analogy with other menispermaceous stems (see Santos, 1928, 1931), the crescent-shaped arches of sclerenchymatous cells (Fig. 3) which lie outside the vascular ring may be said to belong to the pericycle. The outer of these cells are small and thick-walled and have a narrow lumen while the inner are larger and do not show such a pronounced thickening of their walls. In macerated material the fibres are seen as long and tapering cells with simple slit-like pits on their walls. Next to the sclerenchyma comes a thin-walled parenchymatous tissue, the inner pericycle, composed of 3–5 layers of closely packed polygonal cells which become greatly compressed and flattened in older stages. It is of interest to note that although originally there is a continuous cyclinder of pericyclic fibres, this later becomes ruptured as a result of the increase in girth of the stem ; the interfascicular parenchyma cells intrude however into the gaps and become converted into stone cells thus repairing the broken cylinder.

The *vascular bundles* vary in number from about 20 to 40 and are separated by the medullary rays which are usually 4 to 8 cells wide and consist of radially elongated cells with small intercellular spaces. An increase in the number of bundles may be brought about either by the splitting of the original bundles owing to the formation of secondary vascular rays, or by the production of secondary strands in the interfascicular region. It is frequently seen that the bundles on one side of the stem are larger than those on the opposite side, thus giving it an eccentric appearance which becomes still more pronounced in subsequent stages.

The *pith* occupies a large proportion of the space in a young stem. The cells are large and spherical with prominent inter-cellular spaces at the angles. The peripheral cells are more thick-walled than those in the centre and form a sort of perimedullary zone as is seen in many other dicotyledons (Eames and Macdaniels, 1925, p. 99). Starch grains and calcium oxalate crystals are common.

Secondary Growth.—At a very early stage a fascicular cambium differentiates in each bundle and gives rise to the secondary tissues in the normal manner. There is however no definite inter-fascicular cambium, although some stray tangential divisions are occasionally seen in the cells of the medullary rays. A glance at Figs. 3 and 4 will show that the sclerenchymatous cells of the pericycle invaginate so deeply into the rays that the formation of a continuous cambial ring is hardly possible.

As a result of the activity of the fascicular cambium the primary phloem and afterwards even the older secondary phloem cells become crushed and obliterated to form a densely staining cap over the vascular bundles (Fig. 4). It is worthy of note that the sieve plates are not transverse to the longitudinal axis of the sieve tubes but lie at angle of about 45°.

The secondary xylem consists of vessels, fibre-tracheids and wood parenchyma. The vessels are often large enough to be made out with the naked eye. They occur either singly or in groups of two to four. The vessel elements have simple rounded perforations and some of them are provided with tails at one or both ends. Their walls show alternately arranged bordered pits with slit-like apertures which are just included in the border. Fibre-tracheids are abundant and have thick walls with numerous bordered pits having slit-like apertures. The xylem parenchyma cells may be short or elongated and have simple pits with rounded, oval or slit-like openings. The ray cells have simple pits except when they are in contact with vessels or fibre-tracheids in which case the pits are bordered. In tangential sections and strip preparations the rays appear as large more or less homogeneous boat-shaped areas whose lateral cells are particularly rich in calcium oxalate crystals. Short thin-walled "disjunctive parenchyma"[2] cells are also seen although only occasionally. These are wider, having simple rounded or oval pits and short tubular processes.

The older stems usually become eccentric owing to more active growth on one side (Fig. 1). According to Priestley and Tong (1927), Haberlandt (1914, p. 676) and others, such eccentricity in growth may be caused by gravity, mechanical strain, light, moisture, nutrition, temperature, wind, etc., having an unequal influence on the two opposite sides of the stem or root of plants. I have not been able to determine the cause of the eccentricity but the lower side is usually the one which shows more active growth in *Tiliacora* (*cf.* Maheshwari, 1930, on *Boerhaavia*).

Cork formation begins only after a fair amount of secondary growth has taken place. The subepidermal cells undergo some radial elongation followed by tangential divisions which result in the demarcation of the phellogen. The cork cells produced on the outside are more or less rectangular in cross-section and lie in distinct radial rows. The phelloderm, which is produced on the inside, is very narrow and with increase of secondary growth the shape and arrangement of its cells become distorted. Crystals of calcium oxalate are of frequent occurrence and some of the cells become converted into stone cells.

Anomalous Secondary Growth.—The primary cambium becomes inactive after some time (Fig. 4). When this happens, the parenchymatous cells (Fig. 5) lying just outside the sclerenchymatous bands show a radial elongation (Fig. 6) and soon begin to undergo some periclinal divisions, as a result of which the inner cortex becomes converted into a meristematic zone composed of about 4 to 10 layers of cells. A few of the outermost layers of this tissue usually remain undifferentiated and afterwards give rise to another ring of vascular tissue as we shall see later. The next 1 to 3 layers give rise to a ring of stone cells[3] (Fig. 7) and in the remaining portion of the meristem further periclinal and anticlinal divisions now take place at a number of points resulting in the differentiation of groups of phloem cells (Fig. 8) followed

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[2] This name has now replaced the "conjugate parenchyma" of older authors (see Record, 1933, p. 9).

[3] The radial series cannot always be traced outside the stone cells due to the distortion brought about by the inward pressure of the periderm and the outward pressure of the secondary vascular tissue.

internally by some xylem elements (Fig. 9). Some intervening cells between the xylem and phloem continue to retain their meristematic character and form the intrafascicular cambium. As mentioned before, the anomalous growth at first starts in short segments, but it extends laterally to form fairly large arcs of secondary vascular tissue which abut upon the inner ring of bundles (Fig. 10).

Secondary activity in the newly formed ring of bundles is short-lived but another meristem soon arises from the residual cells of the previous one which had been left undifferentiated at its outer edge. The differentiation of stone cells and vascular tissues in this tertiary ring takes place in a manner similar to that already described for the second ring. The subsequent rings originate from the outer cells of their predecessor as in the case of the second and third rings. The production of these supernumerary rings continues for a long time, resulting in the marked polycyclic condition already noted in the beginning of this paper.

The vascular bundles of the anomalous rings are very similar to those of the primary ring except that the former lack all primary xylem and phloem and that the primary ring has on its outside an undulate band composed mainly of fibrous cells while those formed later are overarched by one to three layers of stone cells. Owing to the presence of these sclerenchymatous elements outside every ring of vascular tissue, the pluriseriate nature of the stem is very clear even to the naked eye. The xylem vessels are often found to contain tyloses which are at first thin and bladder-like but later become pitted.

5. THE LEAF

Petiole.—A cross-section of the petiole presents a more or less broad crescent-shaped outline. The cuticular deposit on the epidermis extends even to the radial walls of its cells as in the case of the stem. Epidermal hairs are of the same kind as seen in the stem and are continued on the lower side of the lamina. Next to the epidermis come 3 to 6 layers of compactly arranged collenchymatous cells with chloroplasts. In the inner cortex, which consists mainly of parenchymatous cells, there are also some isolated sclerenchymatous elements with thick walls and a broad lumen. Three leaf traces enter the petiole, all more or less completely surrounded by fibrous sheaths. The median trace divides immediately into three bundles and the other two also branch and anastomose, thus resulting in a total of about 8 to 12 strands arranged in a semicircle. This differs from the condition in *Anamirta*, *Menispermum*, *Cocculus* (Solereder, 1908, p. 41) and *Tinospora* (Santos, 1928) where the bundles are arranged in a circle and the petiole has a more or less rounded outline in a cross-section.

The pith consists of fairly large spherical cells with small intercellular spaces. Many of the cells contain calcium oxalate dust.

Lamina.—The leaf is bifacial. In a cross-section of the lamina the upper epidermis is seen to consist of tabular or squarish cells whose outer walls are slightly convex but not so heavily cutinised as those of the stem or petiole. The mesophyll consists of a single layer of palisade tissue followed by the irregularly shaped cells of the spongy parenchyma which are interspersed with large air spaces. Each vein consists of a small vascular bundle surrounded by a fibrous sheath which extends both inward and downward as to some close to the epidermal layers. The cells of the sheath occasionally show small rhomboidal crystals of calcium oxalate. In some plants of the family, Solereder (1908, p. 815) and Santos (1928) record the presence of large rhomboidal crystals in the epidermal layers, which serve as a 'regular armour' : but I was unable to find them in either the lower or the upper epidermis of *Tiliacora acuminata.* Stomata were seen only on the lower surface.

The midrib is conspicuous on account of the local convexity of the leaf tissues in this region. As seen in a transverse section the epidermal cells on both sides of the midrib are usually polygonal and more thick-walled than those on the sides. Just below the epidermis, on either side of the lamina, there are 1 to 3 layers of collenchymatous cells those on the lower side being somewhat larger. They frequently contain crystals of calcium oxalate. Next to the collenchymatous tissue is the parenchyma with occasional stone cells which are more frequent in the basal part of the leaf.

The number of vascular bundles composing the midrib depends on the size of the leaf and the distance from the base at which the section is taken. The largest number (about 13) is seen at the base of the lamina, from where they pass off towards the right and left until there is only one bundle left in the distal portion of the midrib.

6. THE ROOT

Primary Structure.—A cross-section of the young root is more or less circular in outline and shows the usual piliferous layer, cortex and stele. Suberisation of the outer walls of the epidermis begins soon after the root hairs have ceased to function and extends even to layer below it. The cortex consists of about 3 to 6 layers of large polygonal cells which are often full of fungal hyphæ[4] (Fig. 11). The innermost layer forms an indistinct endodermis, sometimes easily recognisable by the Casparian strips on its radial walls which are more easily seen opposite to the primary phloem strands. Inside the endodermis there is a single layer of pericycle. The stele is usually diarch but sometimes triarch, and the primary xylem elements meet in the centre to form a "xylem plate" (Figs. 11, 13). It is only in a few roots that some small parenchymatous cells resembling those of a pith were seen in the centre but even these become lignified in later stages. In some cases they were found to contain starch grains. Some of the cells immediately outside the primary phloem and perhaps belonging to it become lignified and form fibres.

Secondary Structure.—Secondary growth begins early by the usual differentiation of cambial segments below the primary phloem bundles

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[4] I am indebted to Dr. B. B. Mundkur (New Delhi) and Dr. K. Bagchee (Dehradun) for the information that a mycorrhiza is so far unknown in the Menispermaceæ.

and their subsequent extension resulting in a complete cambial cylinder. The secondary xylem elements extend so close to the primary xylem that in later stages it is difficult to demarcate the latter. Opposite to the primary xylem groups the cambium cuts off only parenchymatous tissue resulting in two (three, when the root is triarch) broad medullary rays, which divide the secondary vascular tissues into large semicircular segments. Very soon additional vascular rays originate inside each segment which is consequently split up into separate bundles of which as many as 15 may be seen in later stages.

The structure of the secondary vascular bundles is very similar to those of the stem. Tyloses are frequently present in the vessels. As secondary growth proceeds, the primary phloem cells become flattened and crushed, and a one to two-layered ring of sclerenchymatous elements appears at the periphery of the secondary vascular bundles.

Very soon after the vascular cambium has begun its activity a phellogen differentiates in the pericycle. It cuts off 7–10 layers of phellem towards the outside but much less of phelloderm. Here and there inside the former are seen some thick-walled elements which have a mechanical function. With the development of the cork, all the tissues outside it (*i.e.*, the cortex and the epidermis) die and are sloughed off.

Anomalous Secondary Growth.—The abnormal growth starts in the roots from the pericyclic cells internal to the phellogen, which first elongate radially and then divide periclinally to form a zone of meristematic cells, 8 to 10 cells wide. As in the stem, isolated patches of phloem and xylem separated by a cambium are differentiated inside it. On the outside of the meristematic zone there differentiates a layer or two of sclerenchymatous cells which often contain calcium oxalate crystals and further outward (as in the stem) a few layers of the meristem are left over to form the precursors of the next anomalous ring. Other rings (Fig. 12) are produced similarly in centrifugal succession from the residual cells of the previous meristem left over immediately outside the layer of stone cells.

7. DISCUSSION

Anomalous thickening in plants, characterised by the production of additional complete or partial extrafascicular cambial cylinders, is observed in lianes as well as non-lianes. As regards the modes of origin of the anomalous rings, Solereder (1908, p. 1164–65) divides the dicotyledonous families into two groups :—

(i) Those in which the secondary meristem arises either in the inner cortex or occasionally even in the endodermis : Capparideæ, Caryophylleæ, Compositæ, Cucurbitaceæ, Menispermaceæ, Plumbagineæ Umbelliferæ and Verbenaceæ.

(ii) Those in which the place of origin lies deeper, either in the pericycle or even in the phloem of the original vascular ring : Amaranthaceæ, Ampelidaceæ, Bignoniaceæ, Buxaceæ, Cæsalpinieæ, Candolleaceæ (?), Cappárideæ, Chenopodiaceæ, Compositæ, Convolvulaceæ, Cucurbitaceæ, Dilleniaceæ, Euphorbiaceæ, Ficoideæ, Hippocrateaceæ, Icacineæ, Illecebraceæ, Labiatæ, Loranthaceæ, Nyctaginaceæ, Olacineæ, Phytolaccaceæ, Plumbagineæ, Polygaleæ, Rhamneæ (?), Rubiaceæ and Sapindaceæ.

In addition to the above families Pfeiffer (1926) mentions the same abnormality in the Acanthaceæ, Vochysiaceæ, Cruciferæ, and with some doubt in the Loganiaceæ, and Stylidiaceæ. A similar anomaly is met with among the Gymnosperms in the Cycadaceæ and Gnetaceæ.

As regards the Menispermaceæ, Maheu (quoted in Solereder, 1908, p. 818) reported that the anomalous rings may originate in any of the following tissues :—

(*a*) Cortex (*Menispermum*).

(*b*) Endodermis (*Abuta rufescens*, *Chondrodendron tomentosum*, *C. platyphyllum* and *Cocculus laurifolius*).

(*c*) Pericycle (*Cocculus læba*, *Cissampelos pareira*).

(*d*) The region immediately external to the phloem of the normal ring of bundles (*Abuta selloana*, *Anomospermum grandifolium*, *Cocculus platyphyllus* and *Cissampelos mauritiana*).

Pfeiffer (1926, p. 164) remarks however that Maheu's observations, which were made almost entirely on herbarium material, are not quite reliable, and suggests further work on fresh material. The only recent paper on the subject is by Santos (1931) who found that in the stems of *Archangelisia flava* and *Anamirta cocculus* the abnormal rings are formed by successively produced cambial layers differentiating in the primary cortex. Should this be so and the cambia continue to arise from the cortical cells in centrifugal succession, a time will eventually arrive when the cortex would be used up altogether. In *Tiliacora acuminata* only about 12–14 layers of cells are found in the primary cortex, but a cross-section of a thick stem already showed as many as 17 anomalous rings and there was no indication that the abnormal growth had come to an end. It was this that prompted me to make a closer study of the origin of the anomaly and compare my observations with those of other recent authors. In the stem of *Boerhaavia diffusa* (Maheshwari, 1930) and the root of *Beta vulgaris* (Artschwager, 1926), the supplementary rings of vascular tissue do not arise *de novo*, but their origin has been traced back to the normal cambial ring. Joshi (1931, 1937) supported this in the case of *Alternanthera sessilis* and other Amarantaceæ and Chenopodiaceæ and there seems to be no doubt that the supernumerary vascular rings found in the Centrospermales are in direct lineage with the first extrafascicular cambium.

My observations on *Tiliacora acuminata* correspond with those of the above authors and are at variance with the results obtained by Santos (1931). Briefly, there is at first a single ring of vascular bundles in the stem, separated from each other by broad medullary rays. The cambium in these bundles becomes inactive after a time and a new extrafascicular cambium arises in the cells lying immediately outside the pericycle. This gives rise to a broad zone of meristematic cells a few layers of which lying at the periphery remain undifferentiated for the present; the next 1–3 layers give rise to stone cells and the rest undergo further divisions to produce a ring of secondary vascular bundles. Now, after a brief period of secondary growth in these bundles, the two or three layers of undifferentiated cells left over outside the ring of stone cells begin active divisions and behave in the same way as the first meristem. This process repeats itself several times, giving a pluriseriate character to the stem. The same anomaly occurs in the root with this difference that here the secondary cambium and the phellogen both originate in the pericycle.

It is worthy of note that two different types of secondary growth occur in the family Menispermaceæ. A few genera like *Tinospora* (Santos, 1928) show only the normal type, while others (see list on p. 2) are characterised by the formation of successive rings of centrifugally differentiated vascular bundles. A study of the published data on the habit of the plants seems to indicate that the difference is not related to the environment.

Whether this condition is the result of parallel development or whether one of the two conditions is derived from the other is therefore difficult to say in the present state of our knowledge of the morphology and cytology of the plants belonging to this family.

8. SUMMARY

1. A cross-section of the young stem of *Tiliacora acuminata* shows a normal ring of vascular bundles separated by broad medullary rays. An interfascicular cambium is inactive or absent. The pericycle consists of a ring of sclerenchymatous elements made up of arcs of fibres capping each vascular bundle. A well-differentiated endodermis is absent.

2. Older stems show a series of concentric rings of vascular bundles (18 rings were counted in a stem 8·8 cm. thick), separated by wide rays and tangential bands of stone cells and thin-walled parenchyma.

3. Sections cut at different levels of the stem show that after a while the normal fascicular cambia of the primary ring of bundles become inactive and an extrafascicular meristem originates from the cortical cells lying immediately outside the pericycle. A few of the outermost layers of this meristem remain undifferentiated, the next 1–3 layers give rise to stone cells, and the rest differentiate into a secondary ring of vascular bundles separated by broad rays of parenchymatous cells. After a time the activity of the cambia in these bundles also ceases and a second meristem arises from the undifferentiated cells of the first one left over outside the stone cells. This process is repeated so as to give rise to a large number of anomalous rings of vascular bundles arising in centrifugal succession.

4. There is a well-marked eccentricity in the stems, the lower side showing greater growth and a larger number of anomalous rings (or their segments) than the upper.

5. Three leaf-traces enter the petiole, but they further split and anastomose in their course so that there is no constancy in their number and 8 to 12 bundles may be seen in a cross-section of the petiole.

6. The lamina shows the usual structure of a mesophytic dicotyledonous leaf with the stomata confined to the lower surface. The midrib has about a dozen bundles at the base but these pass out right and left and ultimately only a single bundle is seen at its distal end.

7. The root is usually diarch but sometimes triarch. The cortical cells are often full of fungal hyphæ. Cork formation takes place in the pericycle, and after the production of the first and normal ring of secondary vascular tissues a new cambium arises from the pericyclic cells internal to the periderm and gives rise to an additional ring of vascular bundles outside the first one. As in the stem, there is a centrifugal succession of such rings of vascular tissue which gives a pluriseriate appearance to the mature roots.

8. Crystals of calcium oxalate are found in all parts of the plant.

9. ACKNOWLEDGMENTS

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EXPLANATION OF PLATES

PLATE VII

Fig. 2*a*. Transversely cut surface of a thick stem showing the supernumerary rings of vascular tissues; *b* & *c*. Cross and longitudinal sections of the root to show the same anomaly. ×½.

Fig. 3. T.s. of portion of a young stem. ×70.

Fig. 4. T.s. of a part of stem showing the approximate stage after which anomalous growth starts. ×70.

PLATE VIII

Fig. 5. T.s. of a portion of young stem showing the epidermis, cortex, and the sclerenchymatous pericycle. ×290.

Fig. 6. Part of an older stem showing the origin of extra-fascicular cambium. Note the radial elongation and periclinal divisions in the inner cortical cells. ×290.

Fig. 7. The meristematic zone is well established and a band of stone cells is being differentiated at its periphery. Note that a few cells of the meristem are left over at the outer edge of the stone cells. The radial rows are especially clear towards the left. ×220.

Fig. 8. Later stage showing the differentiation of a group of phloem cells from the meristem. ×220.

Fig. 9. Still later stage showing the differentiation of a vascular bundle consisting of both xylem and phloem. ×220.

Fig. 10. Portion of t.s. of a stem showing the inner or normal and the outer or abnormal ring of vascular tissue. ×37.

PLATE IX

Fig. 11. T.s. of a young root showing the primary xylem plate. Note fungal hyphæ in the cortical cells. ×212.

Fig. 12. T.s. of an old root showing the anomaly. ×6.

Fig. 13. T.s. of the central portion of an old root showing primary xylem and part of secondary xylem and medullary rays. ×190.

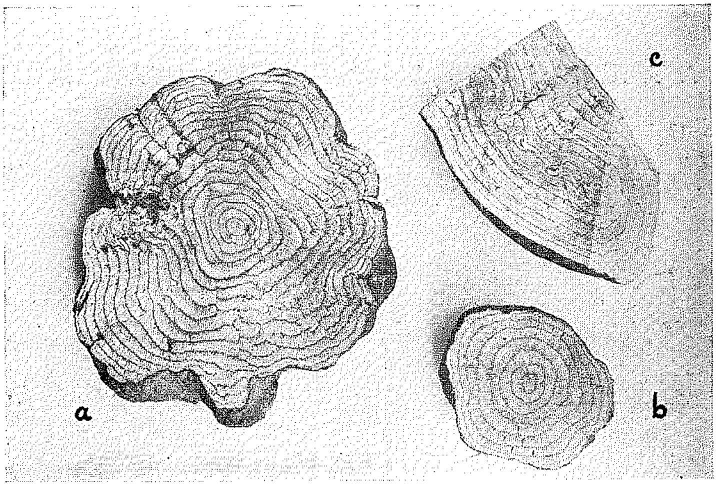

FIG. 2

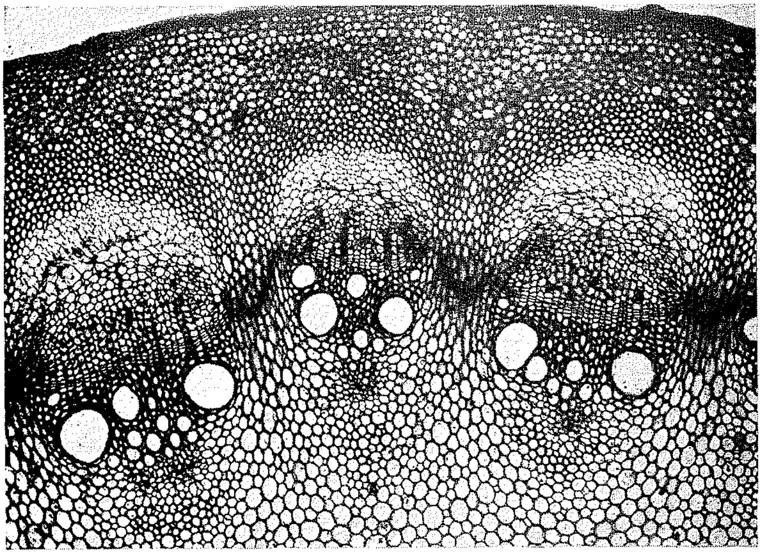

FIG. 3

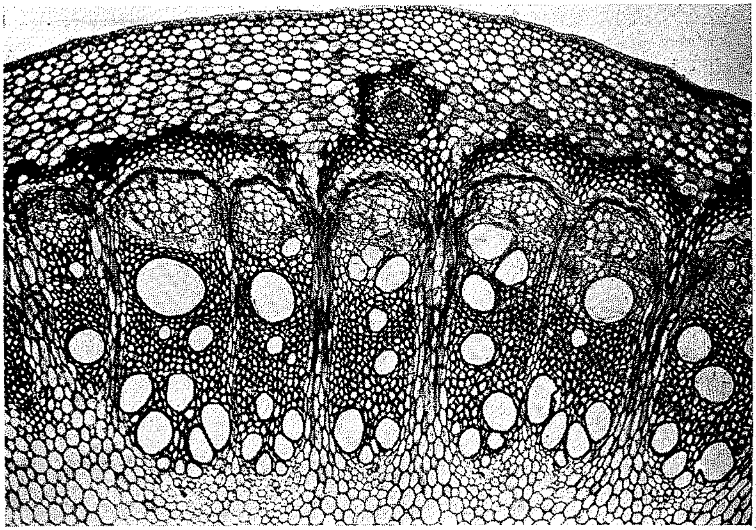

FIG. 4

BALWANT SINGH—

AN ANATOMICAL STUDY OF TILIACORA ACUMINATA ***MIERS***

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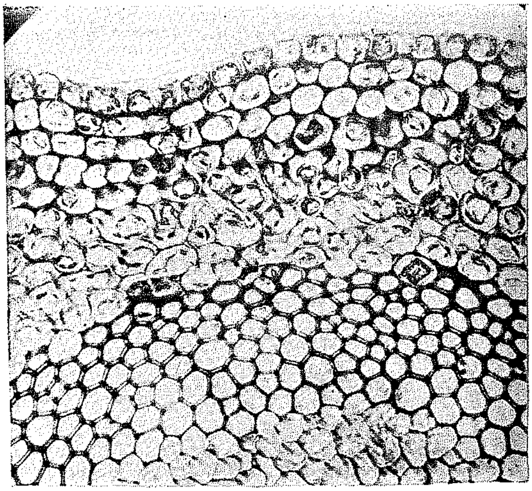


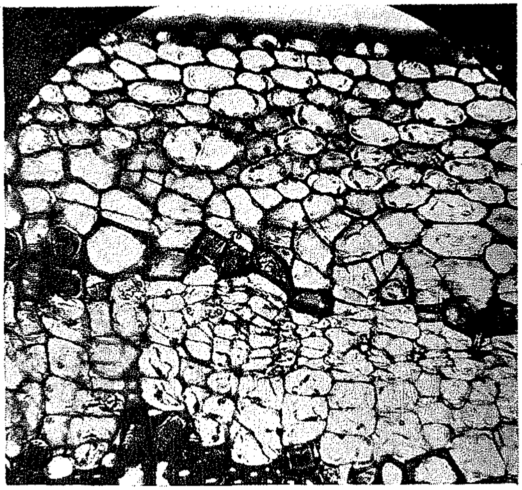
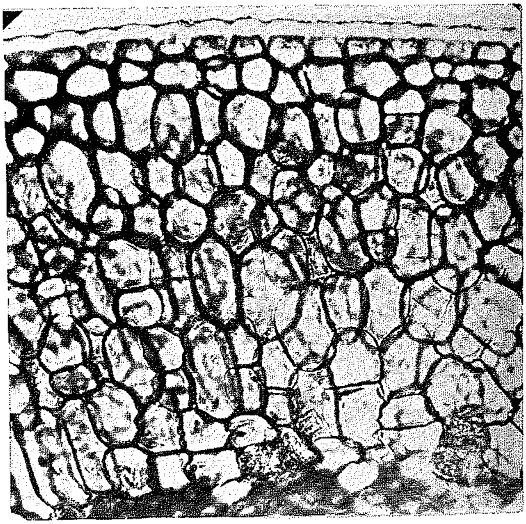


FIG. 8

. 6



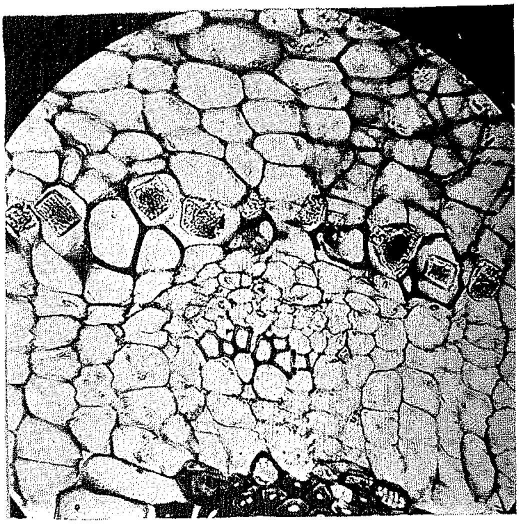
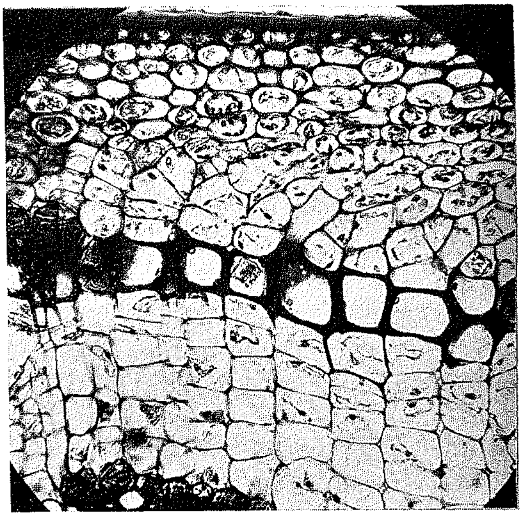


FIG. 9

. 7



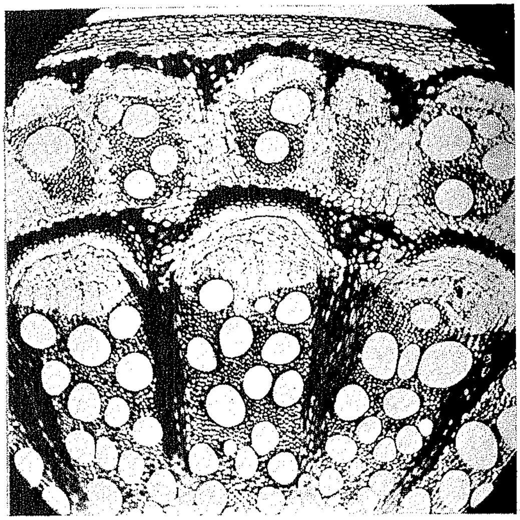


FIG. 10

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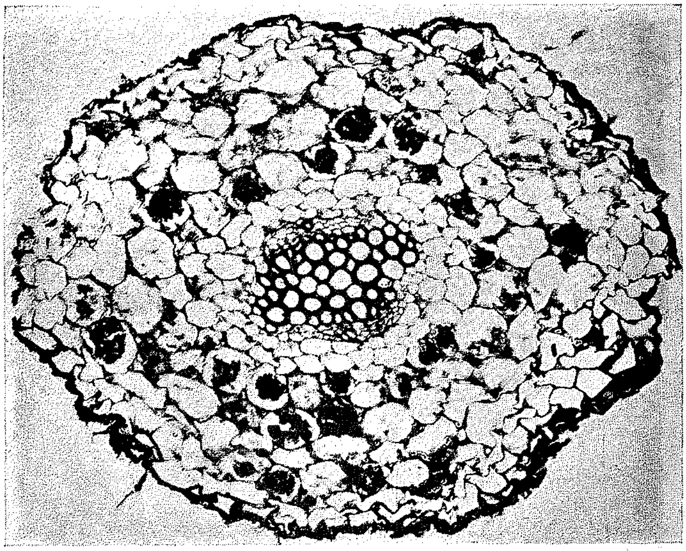

FIG. 11

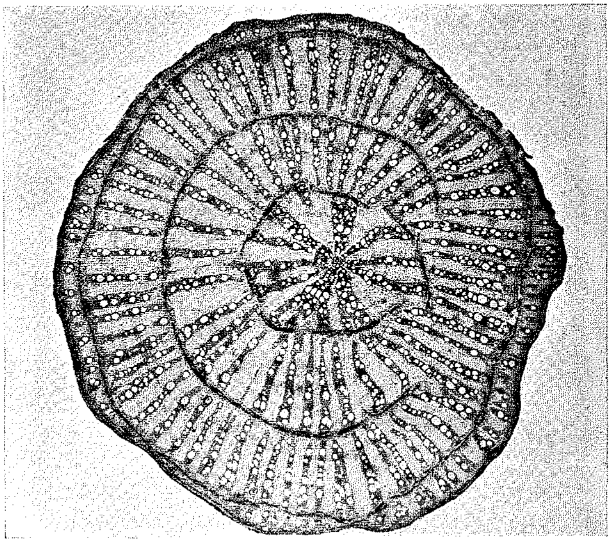

FIG. 12

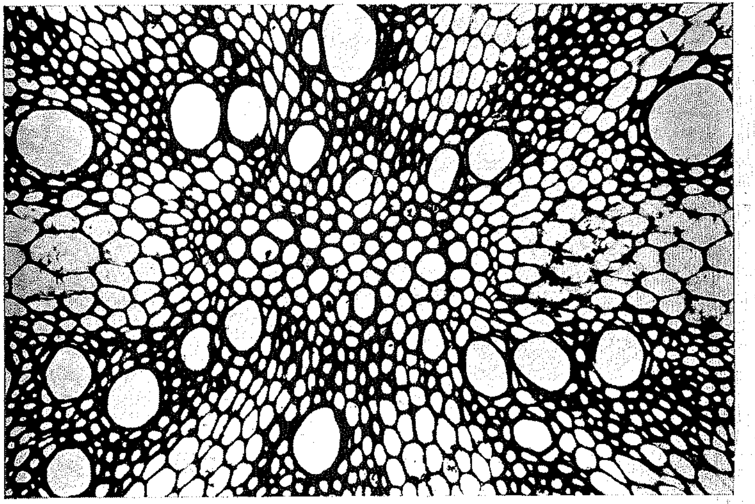

FIG. 13

BALWANT SINGH—

AN ANATOMICAL STUDY OF TILIACORA ACUMINATA *MIERS.*