THE ANATOMY OF CLIMBING PLANTS

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Introduction.

The plants that climb by means of their stems are known to possess anatomical peculiarities of interest especially of their vascular system. The secondary development of the xylem does not take place in a normal manner but deviates from the ordinary type in many different ways. Such forms of anomalous thickening of the stems of the climbing plants are very well known in plants belonging to Bignoniaceae, Sapindaceae, Convolvulaceae, Leguminosae and many other families. All the different forms of anomalies in the axis of plants have been described by Solereder (11) in his work on the comparative anatomy of Dicotyledons. In spite of a large number of species included in that work, it appeared to the writers that the account was far from being complete and an investigation of the anatomy of the climbing plants of the Bombay presidency might prove profitable.

Since the publication of the work by Solereder (11) not much work has been done on the anatomy of the climbing plants. In 1918 Shirley and Lambert (9) undertook the investigation of the anatomy of climbing plants with a view to determine the family of a plant from examination of its internal structure as is the case with plants of Bignoniaceae and Menispermaceae. They have studied the anatomy of 53 species belonging to 23 different families of the Angiosperms.

Zimmermann (12) has also studied the physiological anatomy of some Cucurbitaceous climbers occurring in East Africa and has made observations on the developments and structure of the various parts of plants.

Similarly Holroyd (3) has also studied the anatomy of some species of Cucurbitaceae. He has studied the conducting system of the stems as these plants show very vigorous growth within a short period.

Sabnis (6) has included a few species of Menispermaceae and Convolvulaceae in his study of the physiological anatomy of the plants of Indian Desert.

Most of the recent work is on the anatomy of the seedlings. Amongst the climbing plants the anatomy of the seedlings of Phaseolus vulgaris has been studied by Harris, Sinnott, Pennypacker and Durham (2) and of Clematis by Smith (10).

Recently Kanga and Dastur (5) in their study of the physiological anatomy of climbing plants have investigated four species of Thunbergia with regard to mechanical tissues.

In this investigation the species that have been examined by the previous workers have been omitted. The plants were collected from the neighbourhood of Bombay, Matheran and Mahableshwar in 1926-27.

The following plants have been investigated:

Menispermaceae :—Cocculus villosus, *DC.*
Cissampelos Pareira, *Linn.*
Tinospora cordifolia, *Miers.*

Capparidaceae :—Cappris horrida, *Linn. f.*

Malphigiaceae —Hiptage Madablota, *Goert.*

Vitaceae :—Vitis elongata, *Wall.*
Vitis lanceolaria, *Wall.*
Vitis latifolia, *Roxb.*

Sapindaceae :— Cardiospermum canescens, *Wall.*

Leguminosae :—Mucuna pruriens, *DC.*
Cannavalia ensiformis, *DC.*
Phaseolus Dalzellii, *T. Cooke.*
Derris uliginosa. *Benth.*
Clitoria Ternatea *Linn.*
Baubinia heterophylla, *Kunth*, *Mim.*
Abrus precatorius, *Linn.*

Oleaceae :—Jasminum Calophyllum, *Wall.*
Jasminum auriculatum, *Vahl.*
Jasminum pubescens, *Willd.*

Apocynaceae :—Chonemorpha macrophylla, *G. Don.*
Beaumontia grandiflora, *Wall.*

Asclepiadaceae :—Marsdenia volubilis, *T. Cooke.*
Daemia extensa, *Br.*

Convolvulaceae :—Porana malabarica, *Clarke.*
Ipomaea carnea, *Jacq.*
Ipomaea obscura, *Ker.*
Ipomaea coccinea, *Linn.*
Ipomaea involucrata, *Beauv.*
Argyreia sepicea, *Dalz.*
Calonyction speciosum, *Chois.*

Aristolochiaceae :—Aristolochia ridicula, *N. E. Br.*
Aristolochia ringens, *Vahl.*
Piperaceae :—Piper trichostachyon, *Cass.*
Euphorbiaceae :—Tragia involucrata, *Linn.*
Liliaceae :—Similax macrophylla, *Roxb.*

Many of the species mentioned above did not possess any peculiarity of structure in spite of their climbing habit and so they are not described or discussed below.

Investigation.

1. Cocculus villosus, *Dc.*

The stem is hairy and bilateral in young stage. The epidermis is thick. The epidermal cells are dark brown in colour. This is due to the presence of tannin as can be seen by Ferrous Sulphate. The wood presents a normal structure in young stage, but in old stem unequal development of wood is seen, greater on the concave side than on the convex side. In the old stem crescent-shaped sclerenchyma bands form more or less a complete ring. Sclerenchyma can be distinguished from the rest of the cortical cells even in the young stem. The development of those sclerenchyma bands is not uniform but unequal. The development of sclerenchyma bands outside the vascular bundles is more vigorous on the concave side than on the convex side. The xylem is characterised by vessels with wide lumina. In the pith region pits are present. (Fig. 1).

2. Cissampelos Pareira, *Linn.*

Like Cocculus villosus, *Dc.* the stem shows a bilateral tendency. The epidermal cells are also of brown colour and have thick epidermis. The brown-coloured secretory sacs are scattered all over the cortex and the pith region. Like Cocculus villosus, *Dc.* the sclerenchyma bands are developed unequally on the concave and convex sides. (Fig. 2). The sclerenchyma can be distinguished even in young stage. An interesting point is the development of secondary trachieds. It appears that a new cambium arises in the pericycle and gives rise to the secondary trachieds which lie in the inside of the sclerenchyma bands. So there is a kind of anomalous secondary thickening in the stem. The xylem is composed of wood vessels with large lumina. Large amount of starch is present in the pith.

3. Tinospora cordifolia, *Miers.*

The climbing organs of the plant are stem and adventitious roots. The plant bears adventitious roots like other plants such as Ficus, etc. These roots ultimately reach the ground. Special storage structures such as tubers, etc., are absent. The adventitious roots originate in the axils of the leaves. The leaves produce abundance of starch which is conducted into the axis after its conversion into sugars by the action of diastase as no starch was found in the adventitious roots. The presence of diastase was tested by experiment.

In this plant the adventitious roots act as passages for the translocation of the photosynthetic products. These adventitious roots after reaching the ground grow in thickness and when sufficiently thick and strong act as the ordinary stem and give out shoots and adventitious roots.

Anatomy of the root is a point of interest. Both the aerial and the underground roots are investigated. With little difference, both agree in their anomalous structures. Chief point of interest is the vascular tissue. In the young stage two xylem groups appear, i.e., the root is diarch (Fig. 7). It becomes tetrarch later on by the appearance of two additional groups of xylem at right angles to the former ones (Fig. 8). These four strands are primary ones. The formation of the secondary xylem takes place and the first groups of secondary xylem appear alternating with the four primary ones. The secondary xylem has elements with wide lumina (Figs. 10*a* and 10*b*). The xylem groups meet in the centre forming a solid cylinder. (Fig. 9). The development of the secondary xylem does not take place uniformly and so at some points the growth is more vigorous than at the other (Figs. 10, 11, 12 and 13). Later on, each of the four xylem groups is divided up into two. Thus the whole xylem is divided up into eight groups (Fig. 13). But side by side a third group of four secondary xylem masses makes its appearance (Figs. 11, 12 and 13). Thus the number of xylem strands is increased to 12 (Fig. 14). So in an old adventitious root which gives rise to fresh shoots, 6 to 12 or more groups of the xylem are noticed (Figs. 11, 12, 13 and 14).

In the underground roots the same phenomenon occurs, except for one difference that the development of the secondary xylem takes place more irregularly than in the aerial adventitious roots and an uneven number of xylem strands is formed.

Another difference lies in the condition of the roots. Some show diarch (Fig. 15), some triarch (Fig. 16) and the rest like the aerial root shows tetrarch conditions.

The fission of the xylem is caused by the dilatation parenchyma.

4. Hiptage Madablota, *Goert.*

It is an extensive climber. The stem is covered with different kinds of hairs. Tannin is present in the majority of cells of both the pith and the cortex. The pith presents heterogeneous nature containing both thick and thin-walled cells. The thick-walled cells are full of tannin. In the old stage below the bark the hard sclerenchymatous cells are present and below that there is a single row of cork cells more or less in a complete ring. The wood is developed unequally, more on one side than on the other. Schenck (7) has described the structure of the stem of Hiptage as normal. Shirley and Lambert (9) have included Hiptage Madablota *Goert* amongt the plants examined by them and have placed it in class 1 normal. According to the present investigation there is a slight unequal development of the wood on the two sides. The side in contact with the support has got more wood than the opposite side.

5. Mucuna pruriens *DC.*

The stem in the young condition is hexagonal but in the old condition becomes oblong. The epidermal cells are thick-walled and dome-shaped. In the cortex as well as in the pith, brown coloured secretory cells are present. The development of the primary wood is regular but the development of the secondary wood is irregular. It is developed more on one side than on the other. The secondary wood has wide lumina. Species of Mucuna are known for the anomalous structure of their stems. Schenck (7) has described the anomalous structure of the axis. The anomaly arises from successive rings of cambium appearing in the pericycle with the phloem islands in the wood. In this species only a strong development of the xylem on the side in contact with the support is found.

6. Phaseolus Dalzellii *T. Cooke.*

The stem is angular and not round. Some of the epidermal cells are dome-shaped. The coloured cells are present all over the stem. At first the development of the wood is normal but later on the secondary wood formation begins. Here the development of the secondary xylem is restricted to two opposite sides. These have wide lumina. The anomaly presented by the stem is of two kinds, an unequal development of the secondary wood and the fission of the secondary xylem (Fig. 3).

According to Solereder (11) anomalies consist either (*a*) in the appearance of successive rings of growth in the pericycle or in the primary cortex, rarely in the bast or (*b*) in the formation of groups of phloem in the tissue of the wood. He clearly states that secondary cleavage of the mass of wood has not been observed. Here in the present investigation the cleavage of the mass of wood is seen in Phaseolus Dalzellii, *T. Cooke.*

Borzi (1) has studied the structure of Phaseolus Caracalla *Linn* which agrees with that of Mucuna in possessing soft bast islands.

7. Jasminum auriculatum, *Vahl.*

The epidermis is very peculiar. It has crumpled folds. The cortical cells contain chloroplasts. Stem is four-sided. The crumpled epidermis is more prominent at the corners than on the sides. In the old stage the cells at the four corners are turned into thick-walled cells and they all combine by the single row of thick-walled cells below the epidermal cells. Further change is seen in the third row of cells. In the young stem it cannot be distinguished from the rest of the cells, but in old it can be distinguished from the rest of the cells from their size and shape. Patches of sclerenchyma are seen strongly developed outside the xylem at the four corners. The development of the wood is unequal, greater on the side in contact with the support than on the opposite side.

The structure of the axis of Jasminum pubescence, *Willd* and Jasminum callophyllum, *Wall,* resembles that of the stem of Jasminum auriculatum, *Vahl.*

Species of Jasminum have been very thoroughly investigated by Kohl (4) and Solereder (11). According to the latter the axis does not show anomalous structure. In this investigation the stem does not show any anomalous structure except the greater development of wood on the side in contact with the support than on the other side.

Many plants belonging to convolvulaceae show anomalous structure in the stem. A true anomalous secondary development of the wood by successive rings of growth is observed in the species of Porana, Ipomoea and Calonyction.

8. Porana Malabarica, *Clarke.*

It is an extensive climber. The stem is hairy. The hairs are not simple but branched. They consist of two cells, i.e., are bicellular. The epidermis is thick. The chloroplasts are present in the row of cells below the epidermal cells. In the old stage hard sclerenchymatous cells are to be seen in the cortex forming more or less a continuous ring. Of those sclerenchyma cells some show the presence of pits. The crystals are seen in the cortex as well as in the pith. The development of the wood is not equal all over and so presents wavy outline. The wood vessels are very big on the peripheral portion below the cortical region. Besides this unequal development of wood there is another anomaly in the stem. A false anomaly arises by the development of the xylem trachieds in the inside of the primary xylem groups (Fig. 4 and 5). The growth in thickness by means of successive rings of cambium as described by H. Schenck (7) is not found here.

9. IPOMAEA OBSCURA, *Ker.*

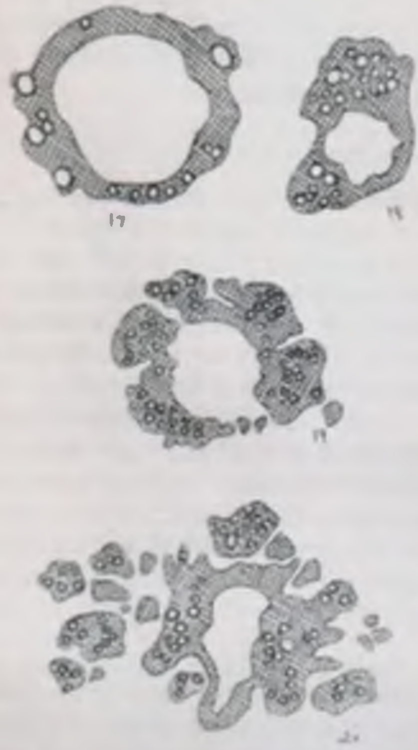
The stem shows the bilateral tendency in the young condition. The epidermis is thick and the epidermal cells are dome-shaped. The epidermis in certain cases shows the primitive stage of the folded epidermis. The cells below the epidermal cells contain chloroplasts. In the mature stem the normal development of the wood is seen but in the older stages an abnormal development is seen. The xylem is divided equally in all directions but later on the development of the xylem is restricted to two sides only. The vigorous development of xylem on those sides ultimately forms a small constriction between the two xylem masses. Of the two xylem masses one that lies on the concave side is more vigorously developed than the other (Fig. 6). The wood lumina are wide. Tyloses are present in the vessels. Some species of Ipomea show anomalous structure in the stem owing to the formation of successive rings of growth. In this case successive rings of growth do appear but the xylem mass is broken up at the centre so that the whole wood is ultimately divided up into two masses in a mature stem. Such kind of behaviour is noticed by Schenck (7) in Merremia umbellata. The unequal development of wood is present.

Ipomaea carnea, *Jacq.*; Ipomaea coccinia, *Linn.*, and Ipomaea involucrata, *Beauv.* :—

The epidermis of all the three species is corrugated and the chloroplasts are present in the cells below the epidermal cells. In Ipomaea involucrata, *Beauv.* the basal part of the hair shows the presence of pits. In all of these unequal development of wood is seen in the old stage. In Ipomaea coccinia, *Linn.* the stem shows a false anomalous structure The formation of the secondary wood is restricted to three points on the normal ring of xylem where secondary xylem develops more vigorously than the remaining portion of the ring.

10. ARGYREIA SERICEA, *Dalz.*

It is an extensive climber. The stem shows the bilateral tendency. The pith presents the dotted appearance and also presents a heterogeneous aspect consisting of thin-walled parenchymatous cells and thick-walled lignified cells. The pits are to be seen in some of the lignified thick-walled cells in the pith. In the pith there are some secretory cells. There is an unequal development of wood in the old stem. Like other species secondary wood with wide lumina originates at several points. Above the ring a more or less continuous ring of sclerenchyma is seen.



Text-Figs. 17–20. Transverse section of the stem of Calonyction speciosum *Chois* showing unequal development of wood and fission of wood.

Fig. 17 × 50, Figs. 18, 19, 20 × 25.

11. Calonyction speciosum, *Chois.*

In the old stage it shows peculiar anomalous structures. Like Ipomaea obscura, *Ker.*, a normal ring of wood develops first. The further development of the wood is not uniform. On two opposite sides only the xylem develops unequally (Figs. 17 and 18). But unlike Ipomoea obscura, *Ker.* fission of the xylem mass takes place. This fission of the xylem mass is brought about by the parenchymatous cells penetrating into the xylem (Figs. 19–20). These parenchymatous cells are full of starch grains. Here the fission is not regular but irregular. On account of this irregular fission of the xylem the xylem masses are seen scattered throughout the cortex (Fig. 20). Both the types of anomaly true and false are found in the stem. The formation of the secondary xylem is restricted at some points on the normal ring as in Ipomoea Coccinia, *Linn.* and the cleavage of xylem mass takes place. Schober (8) has observed a different kind of anomaly in Calonyction speciosum, *Choisy* where the formation of successive rings of growth takes place.

12. Piper trichostachyon, *Cass.*

It is a stout extensive woody climber which climbs by means of adventitious roots which are produced at the nodes. The epidermis is very thick. The epidermal cells contain brown colouring matter. The secretory cells are present both in the cortex and in the pith. Two kinds of vascular bundles are present, a normal ring of vascular bundles with medullary bundles in the pith. Below the fourth layer from the epidermal cells a more or less continuous sclerenchymatous ring is formed. Another sclerenchymatous zone is present inside the normal ring having an undulated and wavy form. The cells in the pith present a dotted appearance due to the deposit of thickening material at some points. On either side of the xylem and the phloem of the medullary bundles in the pith a band of sclerenchyma is formed. Later, the bundles of the cortical region grow in thickness. At the same time another, i.e., a third sclerenchymatous ring is formed, undulated like the one that is formed inside the normal ring and thus the wood is surrounded by sclerenchymatous rings on both the sides. The cortical bundles unite in the form of a ring showing greater development of wood on the concave side than on the convex side. Also a third row of vascular bundles originate between the cortical and pith bundles.

Piper nigrum, *Linn.*, has been examined by Shirley and Lambert(9) and it is put in their class polycycla. The oldest vascular bundles lie in the pith and another ring of bundles arises from a fresh cambium. The chief peculiarity lies in the unequal development of the secondary xylem. On the concave side it is strongly developed while on the convex it is absent.

13. Tragia involucrata, *Linn.*

It is a stinging climber. The stem is covered by different kinds of hairs. In the basal portion of the hairs pits are to be seen. The wood is very peculiar. In the old stem it is horse-shoe-shaped. The development is greater on the concave side than on the convex side. The wood presents an anomalous structure. The secondary wood undergoes fission. The fission of the wood is by means of dilatation of parenchyma. Like Tinospora Cordifolia, *Miers* fission is not regular but it is irregular and both the types radial and tangential are noticed.

According to Solereder (11) the anomaly presented by the axis of Euphorbiaceae are of four different types.

1. Intraxylary phloem.
2. Secondary bundles of wood and bast in the parenchymatous pericycle.
3. Interxylary phloem.
4. Medullary vascular bundles.

The present investigation presents one more type of anomaly to be found in the axis of Euphorbiaceae and that is the fission of xylem by dilatation of parenchyma.

In the plants described above the main anatomical feature is the unequal development of the secondary xylem. The secondary xylem is not formed equally surrounding the primary xylem, but the growth of the secondary xylem takes place unequally in different ways. In some cases the development of the xylem is more vigorous at one point than at the other. In some cases, the secondary xylem does not develop at all over a greater portion of the vascular ring. In other cases, the secondary xylem is broken up into small groups at certain points outside the ring.

It appears that the development of the wood or any other mechanical tissue such as sclerenchymatous bands is more vigorous on the concave side than on the convex or lateral sides. This appears to be a usual feature of the climbing stems and it is clearly shown by the stem of the plants described above.

Shirley and Lambert (9) from their study of the stems of climbing plants have come to the conclusion that the anomalous structure of the stem helps the conduction of the food materials in the bast. This appears to be an unsound conclusion. Very probably the anomalous structure of the axis is caused by the mechanical requirements and the pressure exerted on the climbing stem by the growth in thickness of the support may cause abnormal growth of the tissues under pressure. The greater development of the wood on the side in contact with the support points to the same conclusion that a kind of mechanical girder is provided on the concave side to bear the strain of compression.

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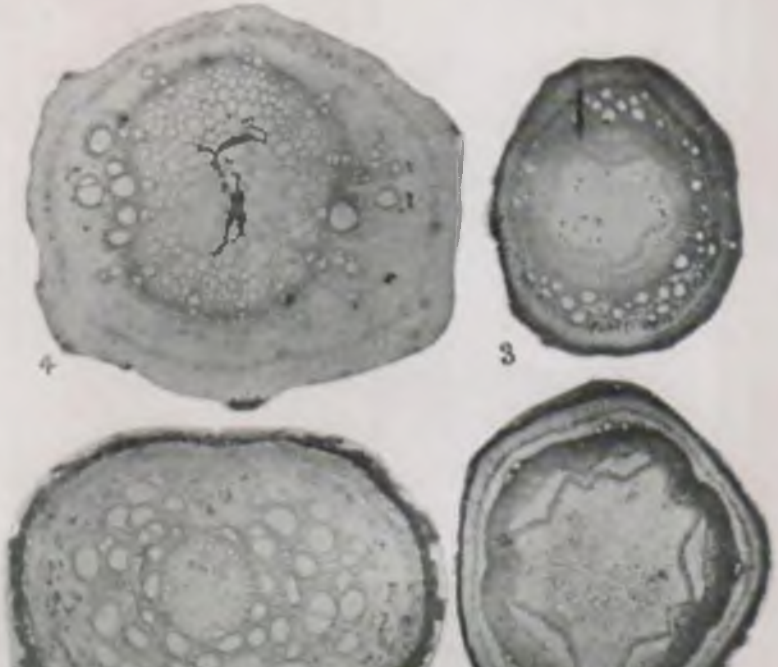
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Explanation of Figures.

Fig. 1. Transverse section of the old stem of Cocculus villosus, *DC*, showing unequal development of wood and sclerenchyma band. × 50.

Fig. 2. Transverse section of the old stem of Cissampelos pereira, *Linn*, showing unequal development of wood. × 50.

Fig. 3. Transverse section of the stem of Phaseolus Dalzellii, *T. Cooke*, showing unequal development of wood and the fission of wood. × 50.

Figs. 4-5. Transverse section of the stem of Porana malabarica, *C. B. Clarke*, showing anomalous structure.

Fig. 6. Transverse section of the stem of Ipomaea obscura, *Ker.* showing anomalous structure of wood.

Figs. 7-14. Transverse section of the adventitious root of Tinospora cordifolia, *Miers*, showing different stages of development and fission of wood.

Fig. 7 × 50. Figs. 8. 10a, 10b, 11, 12 and 13 × 25, Fig. 9 × 37½. Fig. 14 × 12½.

Fig. 15. Transverse section of the underground root of Tinospora cordifolia, *Miers*, showing diarch condition. × 50.

Fig. 16. Transverse section of the underground root of Tinospora cordifolia. *Miers* showing triarch condition. × 25.