Aerial Roots of Tibouchina Moricandiana, Baill.

BY

BERTHA CHANDLER, M.A., B.Sc.,

Carnegie Research Scholar in Botany.

With Plate XLVII.

At the Royal Botanic Garden, Edinburgh, a specimen of *Tibouchina Moricandiana* in one of the plant-houses, under conditions of excessive heat and moisture, showed abundant aerial roots. As these roots were somewhat abnormal in appearance, especially with regard to their branching, I have examined them and give here the results, which are of some interest, of my investigation so far as it has been possible to carry it up till now.

The roots arise on the upper branches of the plant, usually from a node, though this is not always the case (see Figs. 1 and 2). In general appearance they are 10 cm. to 15 cm. in length, brownish green in colour, stiff, distinctly transversely wrinkled, and variously branched (Figs. 3 to 9). Usually they show negative geotropism, hanging from the under side of the branches; occasionally they are para-geotropic.

As the roots age, they become constricted at their base, and gradually wither off from the portion nearest the base towards the tip until the whole is withered. This points to a short life and no great functional activity.

To test their capacity it seemed worth while to study their development under soil. Some were therefore cut off from the tree and placed in fibre in a forcing-house. They grew considerably in length, which fact was distinctly noticeable on account of the white colour, but they did not branch.

A shoot was then cut off with aerial roots already developed on it, and was placed so that the roots were plunged in fibre in

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a forcing frame. After a short time, the aerial roots developed as ordinary roots, giving off lateral rootlets, and becoming quite white. In this respect, the roots examined differed in no way in their development from ordinary aerial roots which reach the soil.

The structure of the unbranched portion of the aerial root is normal. The pith is large, a considerable quantity of wood tissue is present, the whole vascular area forming a normal complete ring (Fig. 11). A section of an older portion of the root, as compared with the young one, shows a somewhat smaller pith, more wood tissue, and a very marked cork cambium, with a large development of cork (Fig. 12).

It is noteworthy that in the sections of the older portion the cork cambium consists of a layer of cells rounded, but lengthened in a transverse direction, with two layers of clear cells on either side, more squarish in outline (Fig. 12 *cc.*).

The most interesting feature of these aerial roots is their terminal arrest in growth, and the consequent branching that takes place. The root tip appears to die off after the roots have attained a short length, and the tissues around the apex continuing development, cause a swelling encircling the dead tip after the fashion of a callus cushion (Figs. 3 and 7), and the whole end of the root has a club-like shape with a depression at the end a mm. or more in depth, at the bottom of which is the dead growing point of the root. From the tissues forming the margin of this depression there may sprout a circlet of branch rootlets (Figs. 3 and 7). In other cases the death of the tip of the primary root is followed by what is really a fission of the root. The tissues around the dead tip do not develop symmetrically to form a circular cushion, but on two sides of a median plane, and thus two usually flattened out-growths, equal or unequal in size, develop with the rooted root tip between them at their point of separation (Figs. 6, 10). Or again, from the point where the dead tip was, the whole root may become flattened—opened out, as it were—as a fasciated structure divided at its end into lobes of varying number (Figs. 4, 8).

We have two distinct things to look at here :—

1. The lobes, as I have called them, which arise by the splitting of the end of the original mother root, as is illustrated by Figs. 4, 6, 8, 10.

2. The branch rootlets which arise, as is shown in Figs. 3 and 7, as lateral out-growths from the club-shaped extremity of the root.

Both phenomena are a consequence of the death of the tip of the mother root, which brings about an area of dead tissue in the centre of the end of the root. Around this dead tissue an inner cambium is formed in the pith (Fig. 13 *ic.*), and as the root tissues continue growth to form the swollen end of the root, this inner cambium keeps pace in the formation of tissue as a lining to the central cavity thus produced in the root (Fig. 14 *ic.*). The ultimate destiny of this inner cambium is the point to which I have now to direct special attention.

It will simplify description if we base this upon the case where the mother root splits into two flattened lobes. An examination of one of these lobes when completely formed shows a structure such as is represented in Fig. 21. That is to say, there is similar construction to that of the mother root, save that the whole organ, instead of being cylindric (Figs. 11, 12), is compressed and bilateral. There is a pith, a vascular ring with wood cambium, a cortex, and cork cambium. We have therefore in the case in point two root-organs with complete though compressed root structure, which have arisen by the splitting of one complete cylindric one. How does this come about?

Briefly—the inner cambium (Figs. 13, 14 *ic*) is the tissue through which the half vascular system in each of the lobes formed by the splitting of the mother root is completed as a ring. Reference to Fig. 10 will make clear the process, and transition stages are shown in Figs. 18, 19, 20.

When the tip of the cylindric mother root dies and the root splits, each half has necessarily on its outer convex side half of the cortex of the mother root covering a half of the vascular cylinder, within which lies a part of the pith with a layer of inner cambium and a portion of the cells that have so far been formed by it. Each half-root is then dorsiventral. The inner cambium now develops tissue rapidly to complete the vascular cylinder, and it is clear that in order to do this the cambial cells formed on the originally inner side of this inner cambium will be phlœm elements, those on the originally outer side will be xlyem elements. From this inner cambium the cortex required to complete that of the half-root is also derived, and in it the subsequent cork cambium arises.

We have here, then, an interesting illustration of a pith cambium ultimately becoming continuous with a wood cambium, and developing with it phlœm and xylem tissues in normal sequence, although in order to do so the relative position of these to the pith cambium in its primary position in the root has to be inverted.

What causes the death of the root tip I cannot say. The cells in the centre of the root appear as if injured, and the presence of fungus mycelium has been detected in them. But the material available so far for investigation does not enable me to express an opinion as to whether this mycelium is to be regarded as a stimulating cause in the production of the phenomenon.

Where the lobing at the end of the root has a fasciated character, the method of development is in essential the same as that I have described. The mother root simply opens out unsymmetrically, splitting at the same time along one side, and an obliquely-mouthed depression appears at the base of the fasciated lobes.

In the cases where the circular cushion swelling is formed surrounding the mouth or an apical depression (Figs. 3, 8), the construction of the cushion is on the same lines as that of the transition stage shown in Fig. 18. The trumpet-shaped depression is really the symmetrically opened out root end, lined by an inner cambium producing cells which become cuticularised on the free surface and collapse, and through which mycelium ramifies. In this formation the mother root does not break up into lobes, but there is a formation of branch rootlets in a circlet, as has been already described. I am not yet able to speak with certainty about the origin and development of these rootlets, owing to the failure of material, but there are indications in the structure of the roots I have examined suggesting points of interest for investigation when material serves.

There is nothing to notice particularly in the origin of the aerial roots upon the stem. They come off from the pericycle and pass out in normal fashion (see Fig. 17). But the branch rootlets from the swollen end of the arrested aerial roots offer a problem for solution. In Figs. 14 and 16, at *r* there may be seen in the cortex outside the epidermis small groups of cells which one might take to be the initials of those lateral rootlets. If the suggestion be confirmed we must regard this cortical mass as a callus meristem formed in correlation with the death of the root tip. The decision upon this point must, however, be held over for determination hereafter, as also must be the meaning of certain curious thick-walled cells that are visible in the cortex.

My thanks are due to Professor Bayley Balfour, under whose direction this investigation has been carried out; also to Dr. A. W. Borthwick for many valuable suggestions.

EXPLANATION OF THE FIGURES IN PLATE XLVII.

Illustrating Miss Chandler's Paper on "Aerial Roots in Tibouchina Moricandiana, Baill."

FIG. 1. Aerial roots, *r*, on growing plant.

FIG. 2. Ditto.

FIG. 3. Aerial root swollen at the end and with circlet of branch rootlets.

FIG. 4. Aerial root swollen at the end and with two unequal lobes.

FIG. 5. Aerial root swollen at the end and with one normal branch behind the extremity.

FIG. 6. Aerial root ending in two lobes formed by fusion.

FIG. 7. Aerial root like that in Fig. 3.

FIG. 8. Aerial root spread out in a fasciated manner and ending in three lobes.

FIG. 9. Aerial root, undivided, showing transverse wrinkling.

FIG. 10. Diagrams illustrating arrest and fusion of the aerial root.

A. The primary aerial root, *P*, with pith and vascular system, has been arrested in growth and its tip has died off, whilst the portion behind the tip has grown out as two diverging lobes, S_1 S_2, each with a pith and surrounding vascular system. The cavity formed by the dying out of the root tip and tissue adjacent to it is bounded by an inner cambium (shaded in the figure), from which is formed a portion of the vascular system, V_2 V_2, of each of the divergent lobes, the other portion of their vascular systems, V_1 V_1, being the direct continuation in each case of half of the vascular system of the primary root.

B. Illustrates the same general features as A, but here the end of the primary aerial root dilates to form a wider cavity, and from the edges of this trumpet-like expansion branch rootlets, *r*, arises.

FIG. 11. Aerial root in transverse section, showing normal structure.

FIG. 12. The same at the older stage.

FIG. 13. Aerial root in transverse section, level of A in Fig. 10A, showing beginning of hollowing out of central tissue of roots after death of the tip. Inner cambium, *ic*, beginning to form.

FIG. 14. The same at level E in Fig. 10B. The inner cambium, *ic*, well formed. Cuticularised and collapsing cells formed from inner cambium lining the cavity in root. *r*, possible initials of branch rootlets.

FIG. 15. Further stage of the same. *ic*, inner cambium.

FIG. 16. Portion of 14 more highly magnified, showing possible initials of branch rootlets at *r*, *r*, *r*.

FIG. 17. Normal origination of a rootlet from pericycle.

FIG. 18. Lobe of a split root showing dorsiventral structure. *ic*, inner cambium which afterwards complete the vascular system ring.

FIG. 19. A later stage of features seen in Fig. 18.

FIG. 20. Still later stage than 19.

FIG. 21. Completed lobe resulting from splitting of root. The vascular rings show no difference on the two sides, yet the one side is derived from the vascular ring of the primary aerial root. The other is formed from the inner cambium.

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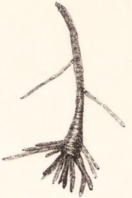

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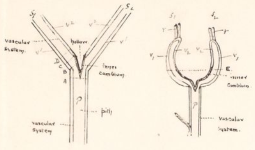

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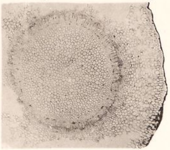

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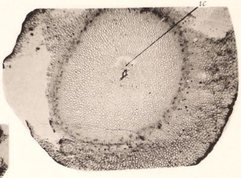

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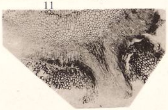

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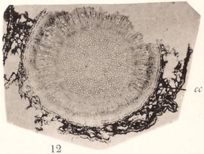

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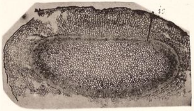

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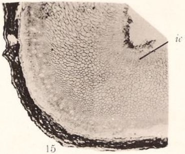

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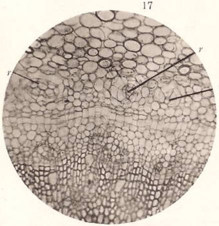

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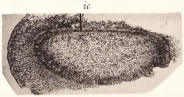

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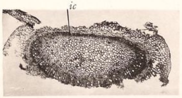

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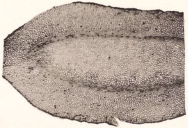

21

Chandler—Aerial Roots of Tibouchina.