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Towards an Understanding of Perennation in *Curcuma angustifolia* (Zingiberaceae)

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With 12 figures

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Summary

Perennation in *Curcuma angustifolia* is affected by the axillary buds of the corm. The bud grows out into a new corm in the next season. Morphologically the corm is much condensed axis that develops a vascular plexus at the base. From this vascular plexus lower below, a cylinder of radial vascular bundles is organised to continue into a basal root.

Extreme basal root of the corm develops to a depth of two to five inches in the soil where its tips become swollen to form a tuber.

Morphologically, the tuber in *Curcuma angustifolia* is a root and the tuberousness is caused both by the expansion of the ground parenchyma and a dilatation of the stelar portion.

Zusammenfassung

Curcuma angustifolia überdauert mittels Achselknospen. Die Knospe wächst in der nächsten Vegetationsperiode zu einem neuen Sproß aus. Morphologisch stellt der Sproß eine stark verdickte Achse dar. An ihrer Basis bildet sich ein Gefäßgeflecht, von dem sich nach unten ein Zylinder radialer Gefäßbündel in eine Basalwurzel fortsetzt. Die zutiefst am Sproß entspringende Wurzel wächst in eine Tiefe von 5,5—14 cm, wo ihre Spitze knollenförmig anschwillt. Die Knolle von *C. angustifolia* entspricht somit morphologisch einer Wurzel, entstanden durch Vergrößerung des Grundgewebes unter Auseinanderweichen der Gefäßbündel. (Übers. vom Editor).

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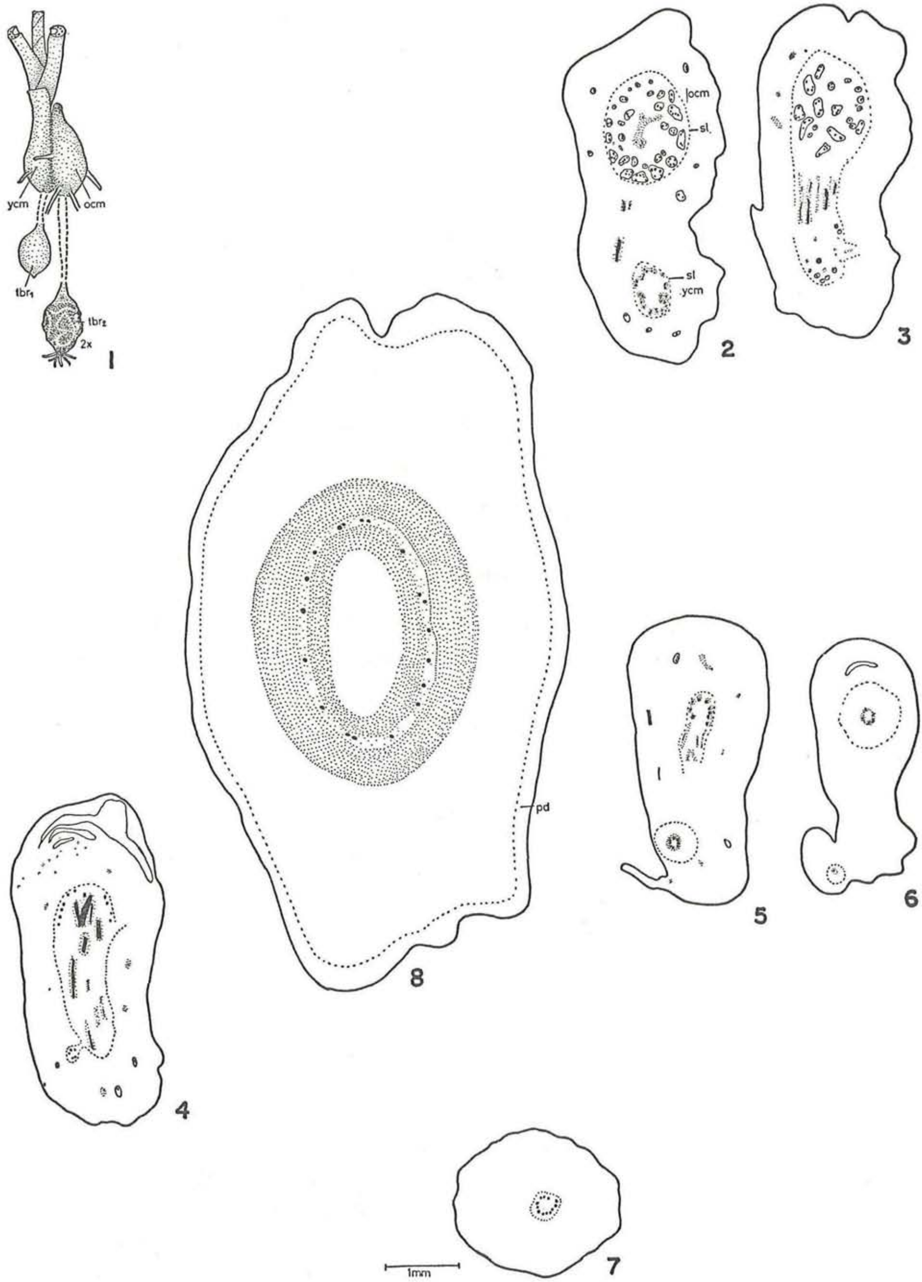


Figs. 1—8. *Curcuma angustifolia*. — Diagram showing twin corms and the tuber (1), cross section of the twin corms, old (ocm) and new (ycm) at successively lower levels from top to base showing a change from stem to root structure of the vascular tissue (2—6). Out line diagram of a transverse section through top of the root tuber (7), and middle region of the same root tuber (8).

Introduction

Studies on the perennation have been made by several workers among the members of the *Liliaceae* (Rimbach 1897, Church 1919), but no attempt has so far been made to investigate the perennation habit in the family *Zingiberaceae*, though studies on the rhizome have repeatedly been made (Futterer 1896, Tomlinson 1969, Chakravorti 1939). Moreover, anatomy of the root tuber also seems to be uninvestigated at least in *Curcuma angustifolia*.

Material and Methods

The material was collected locally from Govindgarh Dist. Rewa (M. P.) India and was fixed in F. A. A. on the spot. Usual methods of dehydration through tertiary butyl alcohol-liquid paraffin series and embedding in paraffin wax were employed. Serial transverse sections were taken at a thickness of 10 micron and staining was done with erythrosin crystal violet combination.

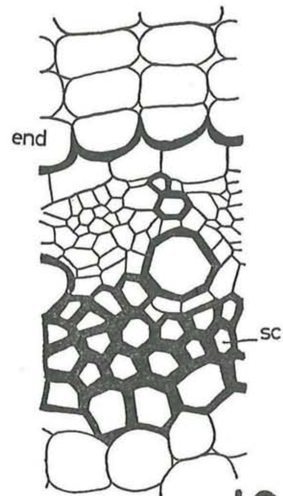
For understanding a better perspective a thick hand section of the cleared twin corm was also taken.

Observations

In *Curcuma angustifolia* a single vertically elongated corm like structure forms the subterranean axis and only one plant is produced in the season by the apical bud of the corm. To understand the mode of branching in the corm and the production of new plants in the succeeding year, it was thought desirable to collect the earliest stages of the plants in the beginning of the rainy season. The search of young plants was further motivated by the chances of getting seedling of the plants in nature, as the seeds failed to germinate in the laboratory.

The young plants, showing their first leaves in juvenile stage above ground, were uprooted carefully and washed to show the origin of the plants. It was surprising to find that, in all cases, an old corm was found associated with the basal part of the young plant laterally (Fig. 1). The old corm (ocm) was dark brown in colour and at the base continued into a thick root that had swelled at the tip to form a tuber (Fig. 1, tbr_2). The tuber was black in colour and shrivelled, with a tuft of fine roots at the base. To the lateral side of such an corm was attached a young, whitish corm (Fig. 1, ycm) that continued up into a rosette of young leaves and basally produced a thick root that terminated into a young whitish tuber (Fig. 1, tbr_1). Obviously, all the new plants are produced by the surviving corms of the preceeding year, as no seedling could be obtained despite intensive search of the whole area.

Such twin corms were dehydrated and embedded in paraffin for sectioning as usual. A transection of such twin corms from the top shows two separate axes (Fig. 2). The larger figure (Ocm) is the corm of the preceeding



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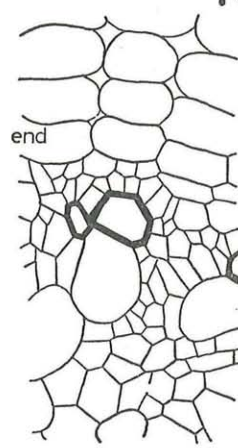

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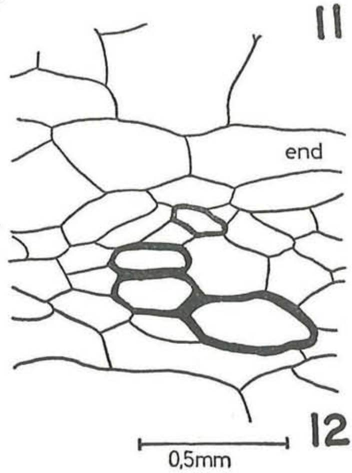

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Figs. 9—12. *Curcuma angustifolia.* — A longisection of twin corms showing its vasculature (9), a portion of the stelat region of a root tuber through top (10), and a sector of the stelar region of the same through middle (11, 12).

year and the smaller one (ycm) is that of succeeding year (Fig. 2). The sections exhibit vascular structure of a typical stem. As in stem, two vascular systems, the central and the peripheral, are separated by a zone of thin walled cells (Fig. 2, sl). The section also shows fusion of the two axes into a common ground tissue, but the two central vascular cylinders of the two axes are separate, although the peripheral system of the two exhibit anastomosis (Fig. 2). Gradually below, the two cylinders become connected through sharply diverging vascular strands of the two cylinders and also through a vascular bridge, which too possesses the structure of an axis (Fig. 3). A lateral root in transection, is seen in figure 3 about to fuse with the vascular tissue (central cylinder) of the new corm. Striking changes in the configuration of the vascular strands occur immediately below. The vascular tissue of the two corms exhibit profuse anastomosis forming a vascular plexus (Fig. 4). Immediately below, the strands found scattered in the central cylinders sharply diverge out along respective directions to align themselves along the separation zone of thin walled cells (Fig. 4). Ultimately, all the bundles come to lie in a circle along the separation zone. The number of bundle is, however, reduced by anastomosis. During this process, the differentiation of protoxylem poles, which was centripetal above, changes to centrifugal through lateral. Thus the bundles become exarch and aligned in a ring giving rise to the typical root anatomy (Fig. 6). The separation zone of the axis merges in the root with the pericycle, and probably also with the endodermis, of the latter. The peripheral vascular system ends blindly in the tissue, that sorrounds the root for some distance forming a sheath.

The young corm, during further development, produces scale leaves and axillary buds, and finally the apical bud starts differentiating foliage leaves. The corm forms three to four nodes before the apical bud differentiates foliage leaves.

A better perspective of the whole, otherwise complicated, structure can be had from a cleared thick longitudinal slice of the corms, as represented in figure 9. The old corm is shown on the right, while the young one is to the left in the figure. In both the corms, thick dashes (Fig. 9, sl) indicate the line of demarcation between the outer and the inner vascular systems. The different vascular tissues in the central region follow a highly oblique or even horizontal course due to extremely shortened internodes. The bundles of the outer cylinder traverse, more or less, straight downwards. The young corm is connected to the old one by means of a short connecting tissue traversed by vascular bundles (Fig. 9, ctr). It may, however, be noted that vascular tissues of the both the outer and the inner cylinders are contributing to the supply of the connecting branch. Axillary buds are produced and are shown here in both the corms (Fig. 9, axb). The axillary buds receive supplies from the vascular tissues of both the outer and the inner cylinder. The growing terminal bud of the young corm is also seen in the figure (Fig. 9, trb). The mid-vein bundles of the leaves diverge sharply in at the nodes and enter obliquely the central cylinder, wherein they follow an extended oblique course down to fuse with other bundles along the opposite side, two to three nodes below (Fig. 9, ltr).

Roots are produced adventitiously and receive supplies from the vascular tissue lying along the separation zone (Fig. 9, rt).

The Tuber:

It has already been mentioned that the extreme basal root of the corm develops to a depth of two to five inches in the soil where its tip become swollen to form a tuber (Fig. 9).

A transection through the proximal region of the root tuber shows a wide parenchymatous cortex a comparatively smaller stelar region (Fig. 7). The stele is anatomically of a typical root (Fig. 10). The endodermal cells (end) have the characteristic thickening along the inner tangential and radial walls. However, there is a continous band of sclerenchyma (sc) on the inner side of the metaxylem ring, enclosing a narrow parenchymatous region of the pith (Fig. 10).

A transection passing through the middle of the tuber (Fig. 8) is peculiar in showing a wide cortex and a large pith (Fig. 8). The vascular ring widens considerably and is represented as a narrow ring of smaller starch free cell layers in a continous ring (Fig. 8). The large cells of the cortex without, including the endodermis and the pith cells with in this vascular ring are heavily filled with starch grains, making the vascular region more conspicous. The endodermis lacks the usual thickening along the radial and inner tangential walls of the constituent cells, which, however, are comparatively enlarged (Figs. 11, 12) end.

Anatomically, the vascular region is that of a typical root, although the xylem poles show a corresponding increase in number. The cortex, in this region, is composed of three zones, the outer most zone is the periderm (Fig. 8, pd), the middle is wholly parenchymatous without starch grains, and the inner is storage in nature, consisting of large parenchyma cells heavilly filled with large starch grains. Similarly, the pith which lacks any sclerenchyma tissue, is composed of two regions; the outer region with storage parenchyma similar to inner cortex, and the inner central region of wholly parenchymatous cells without starch (Fig. 8).

Discussion

While tracing the continuity of the axial vascular tissue with that of the root through serial transverse sections, it was observed that as the base of the axis is approached, the bundles of the inner cylinder anastomose diagonally to form a vascular plexus. In doing so, all the bundles of the axis align themselves along the separation layer in a ring. It is here that the bundles twist and rearrange into radial strands to continue down into the root. It may be recalled that vascular plates are common in the seedlings of monocotyledons (ARBER 1915, 1961, HEYWARD 1938, BOYD 1930, 1932) and that a simple reorientation and rearrangement of the vascular tissues occurs in the hypocotyl to give rise to the vascular structure of the root in *Costus speciosus* (BOYD 1930). Considered in this light, the change from axial to root vasculature in the corm of *Curcuma angustifolia* is much like the vascular transition in seedlings.

The root tubers of certain monocotyledons have been described by ARBER (1961). She has described three types of root tubers depending upon the part of the root playing the major role in tuberization. The cortex of the root may be exagerated to develop the tuberousness as in *Roscoea cautleoides* GAGNEP (*Zingiberaceae*), and *Triglochin procera* R. Br., or else the stelar region may become considerably extended to produce the tuber as in *Hemerocallis fulva* I. and *Asphodelus ramosus* L. The third type is recorded in *Dioscorea discolor* hort., where the hypertrophy of the stelar tissue results in the scattered vascular tissue. The tuber in *Curcuma angustifolia* as has been revealed during the present study, falls under the second category where the tuberousness is mainly due to extended stelar region. It also confirms the observations of ARBER (1961) on *Hemerocallis* and *Asphodelus*, that during tuberisation, the endodermal cells loose their characterstic thickening and, that the sclerotic conjunctive tissue present along the xylem in roots is totally lost in the tuber. The tuberisation is largely due to expansion of the pith. The xylem poles were also observed to increase slightly in number, from 14 in root to 21 in the tuber. In this respect, it resembles the condition in *Triglochin procera* where also an increase in the number of xylem strands has been recorded.

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