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Bud and root development of turmeric (*Curcuma longa* L.) rhizome

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Abstract

The structure and organization of axillary bud and adventious root in turmeric (*Curcuma longa*) rhizome was studied. The mother rhizome is bulbous with smaller internodes compared to branches (fingers) which have long internodes. The axillary buds develop from the axile of scale leaf of the rhizome. The secondary branches of the rhizome develop from the primary branches. Roots originate from the intermediate zone of the rhizome. The root apical meristem is of the open type the three sets of structural initials and possess a distinct quiescent centre.

Key words: *Curcuma longa*, rhizome development, turmeric.

Introduction

Though turmeric (*Curcuma longa* L.) is economically an important rhizomatous spice, little attention has been given to study various aspects of its rhizome development. The earlier work were concentrated mainly on general anatomy and morphological aspects such as systematic anatomy of Zingiberaceae (Tomlinson 1956; 1969), root apical organization (Pillai *et al*. 1961), general morphology, growth and branching pattern of ginger and turmeric (Shah & Raju 1975) and vascular pattern of ginger rhizome (Bell 1980). The present paper reports the results of a detailed study of structure and development of shoot apex, axillary bud and root apex of turmeric.

Materials and methods

Rhizomes of *Curcuma longa* L. cvs. Suvarna and Alleppey were planted in pots. The growing shoot apex, as well as rhizomes were collected at 30 day intervals up to maturity (6 months) and fixed in FAA and processed using standard procedures (Johansen 1940). Serial sections were cut at 10 µm thickness and stained with safranin - fast green and haematoxylin - fast green for histological studies (Krishnamoorthy 1988).

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Results and discussion

The turmeric rhizome is sympodially branched, having nodal scale leaves and aerial vegetative leaves. In early stages, the primary fingers show different directions of growth and some of them produce aerial shoots. After 3 months of growth, the bulb has 6-14 nodes and an internodal length of 0.3 to 0.9 cm. The primary and secondary branches have internodes of 0.5 to 2.2 cm length. At maturity, the mother rhizome is bulbous with smaller internodes compared to secondary and tertiary fingers. The fully matured branches are up to the third order. The anatomical and developmental features are alike in both the cultivars and hence the results presented are mainly based on a detailed study of cv. Suvarna.

Transections of the rhizomes show an outer and inner vascular zone. The inner system is more extensive and three-dimensionally very complex. In between them, there is an intermediate zone (Fig. 1A). The adventitious roots originate from this meristematic zone, while the shoots originate from the outer zone.

Shoot apex

The shoot apical meristem of rhizome has the tunica corpus type of configuration. The tunica is two layered. The cell division is mainly anticlinal. The corpus is the region proximal to the tunica, with the cell divisions oriented in all directions. The central region underlying the corpus layer is rib meristem giving rise to files of cells which later become the ground meristem (Fig. 1B). The central region is surrounded by peripheral flank meristem which produces the procambium, cortical region and leaf primordium.

Procambial differentiation

The peripheral flank meristem divide and produce parenchyma cells. Some of the parenchyma cells are distinct from the rest by their shape and deep staining (Fig. 1C). In longitudinal view, these cells show high meristematic activity. This is the primary thickening meristem (PTM), and on further growth, the PTM produces primary vascular bundles. Finally, the collateral vascular bundle with a parenchymatous bundle sheath are found scattered in the ground tissue (Fig. 1D). At lower levels of the developing rhizome, the PTM becomes primarily a root producing meristem that may be close or separated from the central cylinder that consists of individual but interconnected vascular bundles. Secondary growth takes place by means of the secondary thickening meristem (STM). After completing development and when the rhizome has enlarged to maximum size, this meristematic zone is not distinct and a single endodermoid layer takes its place. The volume increase in turmeric is due to the activity of primary growth, limited cambial activity and divisions of the ground parenchyma cells.

Axillary bud

The phyllotaxy in turmeric is opposite. The bud arises exogenously from the axil of the third leaf primordia. The bud meristem protrudes above the surface and the apical meristem is gradually organized - duplicating the pattern found in the shoot apex of mother rhizome (Fig. 2A). The axillary bud develops primary, secondary and tertiary branches. The fingers have long internodes and are slender in nature compared to bulbous mother rhizomes with short internodes.

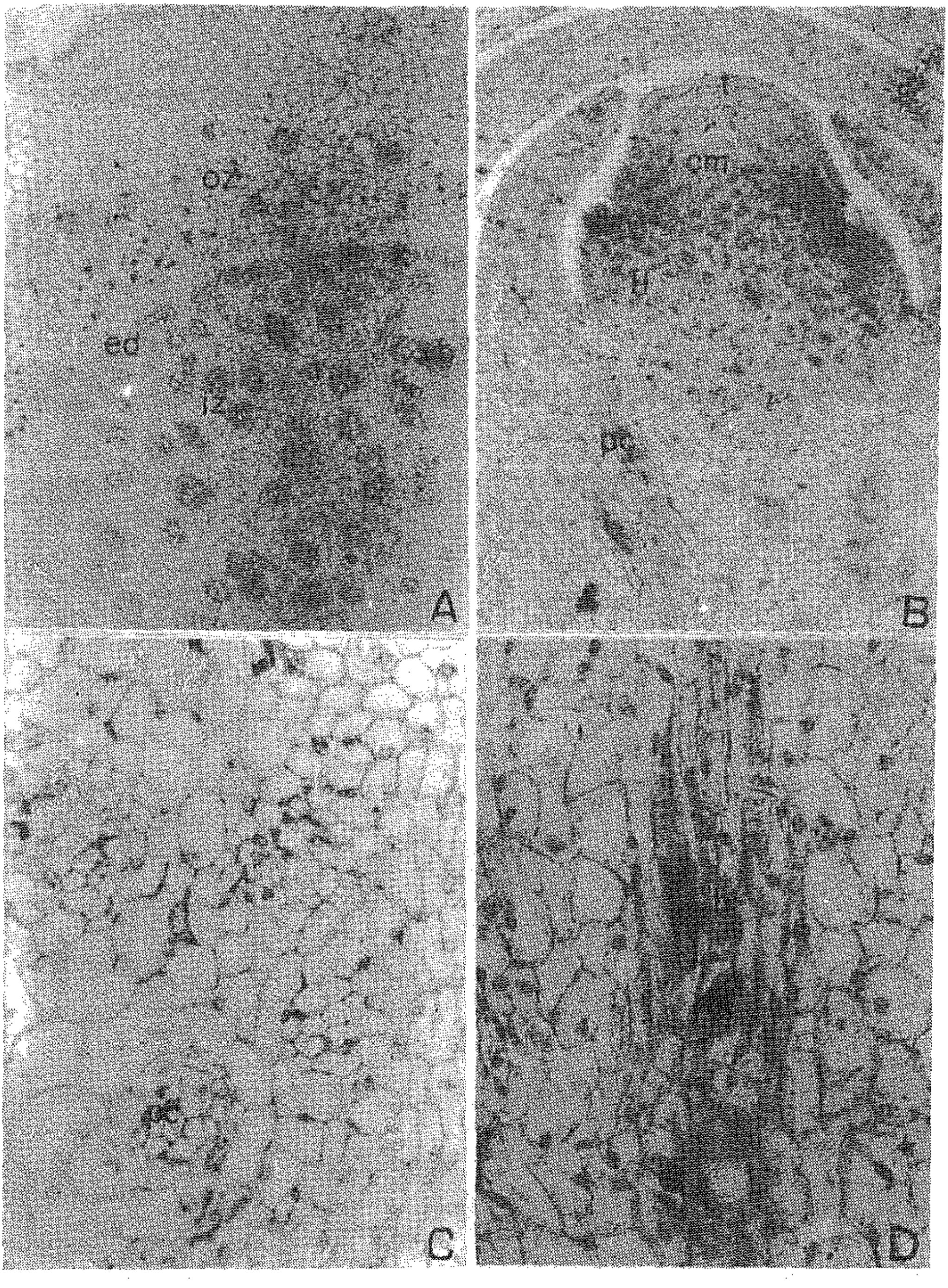

Fig. 1. Anatomy of turmeric rhizome A. TS showing outer zone, inner zone and endodermoid layer (x 50) B. L S showing tunica layers, central meristem and procambial strands (x 200) C. TS of procambial cells (x 200) D. LS showing development of vascular bundles (x 200) (cm-central meristem, ed-endodermoid layer, fl-flank meristem, iz-inner zone, oz-outer zone, pc-procambium, t-tunica, vb-vascular bundle)

Root apex

The adventitious roots originate endogenously from the intermediate zone. The transection of rhizome reveals that the endodermoid layer and the pericycle become meristematic and undergo periclinal and anticlinal divisions resulting in a group of root initials. The root apex has three sets of structural initials, one each for the root cap and plerome and a common zone for dermatogen and periblem (Fig. 2 B&C). The terminal protective root cap is composed of several layers of parenchymatous cells. The group of undifferentiated inactive cells present at the centre represents the quiescent centre (Fig. 2 C). Active cell divisions occur in the area of cells proximal to the quiescent centre, producing the bulk of the root tissue. This active region, termed the promeristem, represents the part of root apex which is capable of giving rise to all the tissues of the root. The young root axis is more or less clearly separated into central cylinder (plerome) and cortex (periblem). The vascular region is composed of densely staining small cells. The cortex is parenchymatous. During development, the size of the differentiating cortical cells increases considerably before vacuolation becomes evident. The cells of the cortex are very regularly arranged.

The turmeric rhizome consist of a mother rhizome with primary, secondary and tertiary branches (fingers) and their growth in thickness is associated with an outer zone, separated by intermediate layers. The development of meristematic zone peripheral to the vascular cylinder in rhizomes in certain monocotyledons has been known for many years and Guillard (1878) referred to as *meristamiforme*. Rudall (1992) reported that in monocots, there is little or no stem thickening growth but where increase in rhizome or stem thickness does occur, it is initiated at the primary thickening meristem near the vegetative shoot apex. In monocots, the PTM is responsible for primary rhizome or stem thickening, adventitious root production and formation of linkages between the root, rhizomes and leaf vasculature (Rudall 1992).

In certain monocotyledons, Mangin (1882) noted that adventitious roots take their origin from a special meristem formed at the periphery of the central vascular cylinder, which he termed the *couche dictyogene*. He further explained that in one group of monocotyledons, the meristem ceases activity after root initiation. In the second group, the meristem does not lose its activity after initiation of roots but retains it for varying periods of time. In turmeric, the STM is responsible for the initiation of adventitious roots and the evidences available shows that this meristem continuously produces vascular bundles and parenchyma cells in addition to the production of adventitious roots.

Bendixen (1973) observed that roots originate in the pericycle in nutsedge (*Cyperus*) tubers, while Wills *et al.* (1980) found that roots of *C. esculentus* originate in the endodermis. In turmeric, root primorida are initiated in the STM, but the precise cell layer of origin, if only one layer is involved, is difficult to determine. Following initiation and early development, derivatives of the STM are present at the basal end of the root primordium. This tissue is in the form of procambial strands. In the mature rhizome, there are vascular connections between the root and vascular

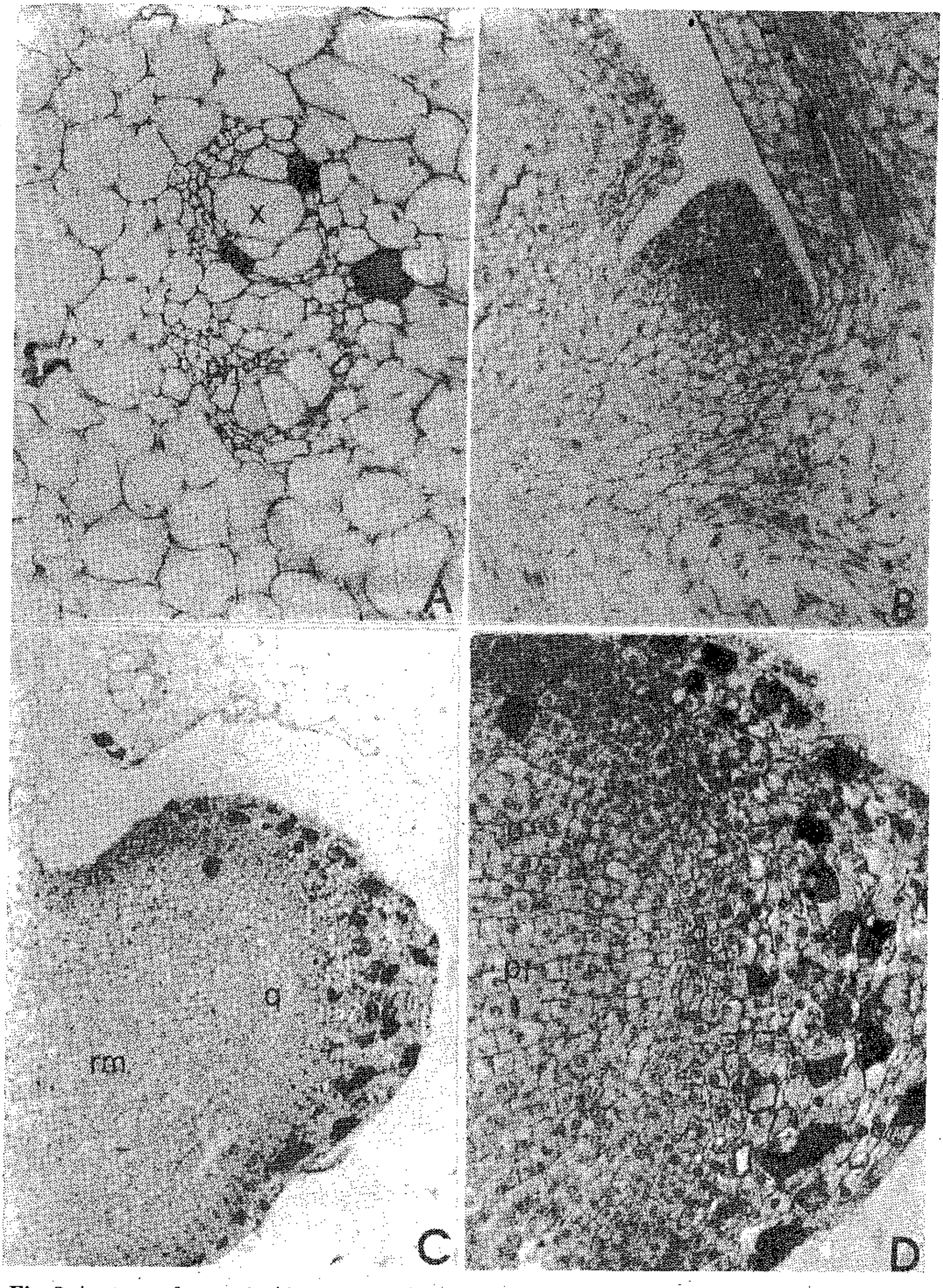

Fig. 2. Anatomy of turmeric rhizome A. TS showing collateral vascular bundle (x 400) B. L S of axillary bud (x 200) C. LS of root apex (x 200) D. L S of root apex showing separate sets of initials, quiescent centre and root cap (x 400) (ax-axillary bud, p-periblem, ph-phloem, pl-plerome, q-quiescent centre, rc-root cap, vb-vascular bundle, x-xylem).

network of the rhizome. The STM of the basal bulb give rise to roots as well as to encircling strands of procambium and to parenchymatous sectors. The procambial strands, in addition to vascularizing roots and rhizome primordia, form vascular bundles that encircle the axis of the basal bulb. At mature levels of the basal bulb, an endodermoid layer encloses a fully mature zone of irregularly arranged vascular bundles. The cell walls become very thick and lignified but in the absence of casparian strips, the layer should be referred to as endodermoid layer (Gifford & Bayer 1995). The root apex possess a quiescent centre at the root tip with the meristematic zone composed of actively dividing cells around and behind it. The quiescent centre is a reservoir of cells relatively resistant to damage because of their inactivity, and they are the permanent source of the active initials (Clowes 1963).

The PTM ceases activity at a short distance behind the apex. Further increase in rhizome thickness takes place by the STM. In the present study, the PTM and STM develop separately and they are discontinuous. The PTM and STM are reported to be longitudinally discontinuous in *Yucca whipplei* Torr. (Diggle & De Mason 1983). The fundamental tissues also divide and redivide leading to enlargement of the rhizome. The shoot apex, root apex and primary growth of turmeric by different meristems such as short living cambium, secondary thickening meristem and contribution of ground meristem have been studied for the first time in this study.

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