Phytomorphology, 47(1), pp. 67-75, 1997

HISTOLOGICAL STUDIES ON GINGER RHIZOME (*ZINGIBER OFFICINALE* Rosc.)[1]

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Abstract

The vascular pattern of the underground rhizome of ginger was studied at different stages of development. The internal structure of rhizome showed an inner zone and an outer zone, separated by intermediate layers. Collateral vascular bundles were scattered and more in inner zone. The xylem vessels are with scalariform thickenings and scalariform perforation plates. Libriform fibres or rarely fibre tracheids are met with. The phloem consisted of sieve tubes companion cells, parenchyma and fibres. Oil cells and canals are many. Numerous starch grains, varying in their shape, size and number, were present in both sides of intermediate zone. The rhizome enlargement is by the activity of : (i) primary thickening meristem and procambial cells in the ground parenchyma, (ii) the actively dividing ground parenchyma and (iii) the secondary thickening meristem in which the fusiform and ray initials are discrete. The presence of cambium like layer was an important feature found in ginger.

Key Words : Ginger, *Zingiber officinale*, fusiform and ray initials, vascular pattern, rhizome differentiation.

The developmental anatomy of ginger rhizome is not clearly understood. Earlier studies on ginger gave only the general anatomical features (Solereder & Meyer 1930, Tomlinson 1956), while Pillai et al. (1961) reported on the root apical organization of Zingiberaceae and Shah & Raju (1975) studied the general morphology, growth and branching pattern of ginger and turmeric. Bell (1980) described, the vascular pattern of rhizomatous ginger. Practically no studies were carried out on the developmental morphology and morphogenesis of ginger rhizome. The present aim is to fill the existing gap in our knowledge on the rhizome structure, development and differentiation.

Material and Methods

Rhizomes of ginger were planted in pots. To study the initial stages of rhizome development, samples were collected at 20 day intervals, cut into small pieces and fixed in

1. Received for publication : August 19, 1996.

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The authors are grateful to the Indian Council of Agricultural Research for the grant of an Ad-hoc research scheme on 'Developmental morphology of rhizome of Ginger and Turmeric' and to Dr. K.V. Peter, Director, for providing facilities and encouragement.

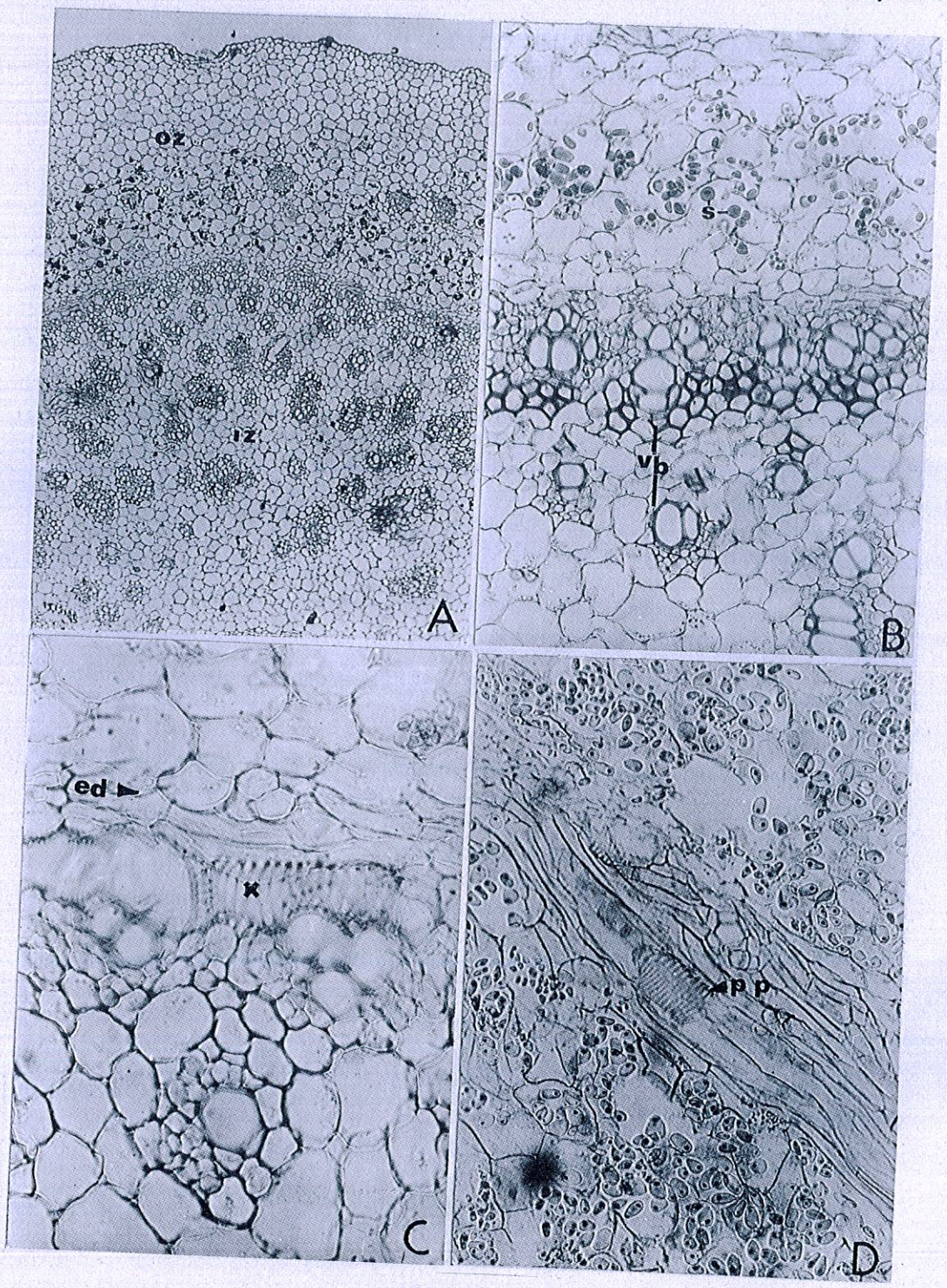

Fig. 1A-D

FAA. The materials were processed for microtomy according to standard procedure (Johansen 1940). For microscopical investigations serial sections were cut at 10 μm and stained in safranin-fastgreen for histological studies and PAS for histochemical studies as per the standard procedure (Krishnamoorthy 1988).

Observations

Ginger stem is sympodially branched. The distal end of each sympodium turns erect to form the aerial shoot; continued growth of the rhizome is by means of lateral buds.

The rhizome axis differs from an aerial axis in morphological features and has a direct bearing on the vascular anatomy. The aerial pseudostem carries leaves. The rhizome bears scale leaves that protect the bud apex. From the rhizome, adventitious roots and lateral bud meristems are originated under appropriate conditions.

The rhizome is the storage organ in ginger. Transection of a rhizome of 10-15mm thickness (early developmental stage) shows a cortex and a wide central cylinder (Fig. 1A). These two regions are separated by a thin walled endodermoidal layer or intermediate layer, resulting in an inner zone and an outer zone. Both have vascular bundles but the inner zone has more. Vascular bundles are collateral, and scattered (Fig. 1B). They are occasionally inverted and irregularly distributed nearer the endodermoidal layer (Fig. 1B). Vessels show scalariform thickening and scalariform perforation plates (Fig. 1C,D). The libriform fibres are highly lignified. Occasionally fibre tracheids are also found (Fig. 2A). The phloem consists of sieve tubes, five to seven companion cells per sieve-tube member, phloem parenchyma and phloem fibres (Fig. 2B).

The young rhizome (about 10mm in diameter) shows in cross section an average vessel width of 38.8μm and 1.6 μm wall thicknesses. The fibres have an average width of 12.8μm and 3.2μm wall thicknesses. At maturity, a rhizome with 20 mm diameter (mature rhizome) displays an average of 42.32μm vessel width and 2.02μm wall thicknesses. The length and width of sieve tube member is 76.82 μm and 7.96 μm, respectively, in 10 mm thick rhizome and 80.25 μm and 8.86 μm in 20 mm thick rhizome (Table 1). All these dimensions are gradually increased proportionately with the growth of the plant.

The oil cells and ducts are many in the ground parenchyma (Fig. 4 A,B). The oil canals are formed lysigenously by the disintegration of an entire cell (Fig. 2C). The dimensional changes of oil canals are given in Table 1. Large number of starch grains are found in the cells near the intermediate layer and in ground parenchyma of the central zone and the inner cortical layers (Fig. 1B,D).

Rhizome enlargement in ginger is by the activity of three meristematic zones. Very early in the development of rhizome, a zone of meristematic cells is formed at the base of a young scale leaf primordium of developing rhizome. These meristematic cells develop into

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Fig. 1A-D — (*ed*, endodermoidal layer; *iz*, inner zone; *oz*, outer zone; *pp*, perforation plate; *s*, starch grains; *vb*, vascular bundle; *x*, xylem). **A.** T.s. of ginger rhizome showing a cortex and a wide central cylinder. x 40. **B,C.** T.s. of rhizome showing endodermoidal layer, vascular bundles and inverted xylem elements. **B.** x 200, **C.** x 400. **D.** Section showing scalariform perforation plate and starch grains. x 200.

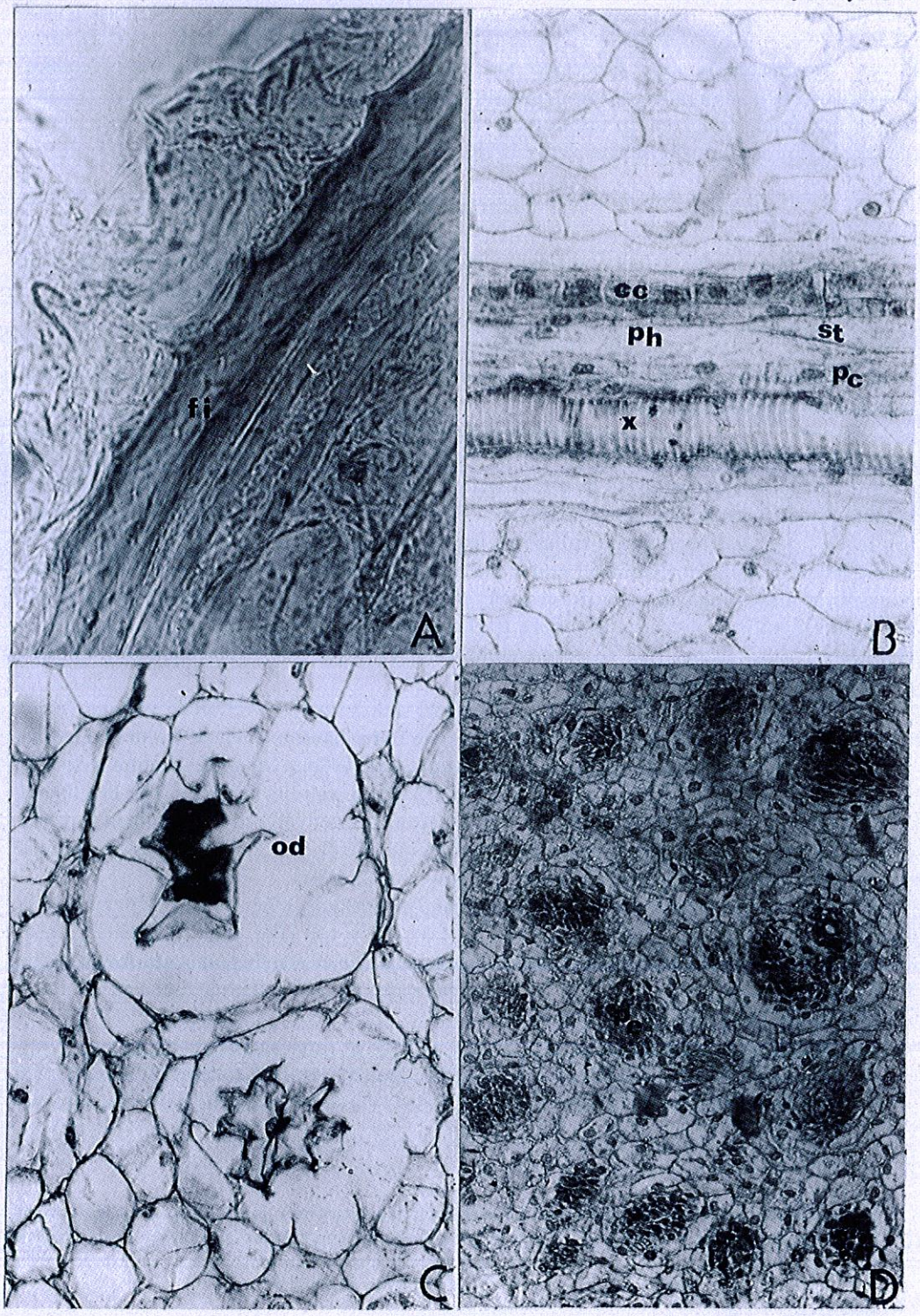

Fig. 2A-D

the primary thickening meristem (PTM) and procambial strands. The meristematic activity is responsible for the initial width increase of the cortex (Fig. 2D). The second type is the actively dividing ground parenchyma and the third type is the secondary thickening meristem (STM) in which fusiform and ray initials are clearly visible (Fig. 3B). STM is observed just below the endodermoidal layer.

At a lower level in the rhizome from the shoot bud apex, the PTM can be still identified. The scattered vascular bundles are developing from the PTM or procambial cells. These groups of cells can be identified by the plane of cell division. (Fig. 2D).

The average tangential dimensions of procambial cells of both young (10 mm) and mature (20 mm) rhizomes showed only slight variation (Table 1), and they can be identified by the plane of division and deep stainability (Fig. 2D). The differentiation of procambial cells into vascular tissue takes place at different stages of rhizome growth (Fig. 3A). This type of growth was observed in many moncots. However, in ginger we observed a special meristematic layer along with the intermediate or endodermoidal layer. This is a cambium-like layer of cells. They are thin walled and consists of two layers (Fig. 3B). In certain loci where vascular bundles develop, these cells are elongated with tapered ends and appear quite similar to the fusiform initials with an average length of 62.34μm and 8.12μm width in mature stages (Table 1, Fig. 3C). Between these fusiform initials some cells show transverse divisions to form ray initials with an average length of 21.36 μm and 17.32μm width in mature rhizomes. (Table 1, Fig. 3C). The presence of a cambium-like layer is an important feature in rhizome development. From this layer inverted and irregularly distributed groups of xylem and phloem are formed along the intermediate layer but it was not observed in the cortex (Fig. 3B). The cells outer and inner to the cambial layers also get filled with starch grains (Fig. 3D). The present study shows that the cambium-like layer is present in rhizome of ginger.

Discussion

Zimmermann & Tomlinson (1972) concluded that the unique and consistent feature of monocotyledonous vascular anatomy was the existence of a well developed inner system, recognized primarily not only on a developmental basis but also on topographic terms as the system was wholly within the central cylinder. In addition, there was often an outer system, largely restricted to the cortex but not always clearly demarcated from the inner system. Bell (1980) pointed out that the tissue at the interface between the cortex and the central cylinder was of particular interest and in many different monocotyledons it was potentially meristematic. This was apparent in the rhizome, the intermediate zone becoming a functional vascular cylinder. Tomlinson (1969) reported that this intermediate layer eventually differentiated as thin walled fibres and proposed the term fibrous layer. The versatility of this tissue and the varying ways in which it may get differentiated has resulted in a multiplicity

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Fig. 2A-D — (*cc*, companion cells; *fi*, fiber; *od*, oil ducts; *Pc*, procambium; *Pl*, phloem; *st*, sieve tube; *x*, xylem). **A.** Libriform fibre. x 400. **B.** L.s. of rhizome showing xylem and phloem elements. x 200. **C.** Section showing lysigenous development of oil ducts. x 400. **D.** T.s. of rhizome showing procambial groups. x 200.

TABLE 1 — DIMENSIONS OF PROCAMBIUM, CAMBIUM, XYLEM, FIBRE, PHLOEM AND OIL CANAL (MEASUREMENTS IN μm)

Diameters of Rhizome	Procambial Cells		Cambium				Xylem, Vessel Members		Fibre		Phloem		Oil Canal
			Fusiform Cells		Ray Cells						Sieve Tube Members		
	Length	Width	Length	Width	Length	Width	Width	Wall Thickness	Width	Wall Thickness	Length	Width	Diameter
Young rhizome (10mm) Range	14.49-27.6	4.6-17.3	46-71.3	6.21-8.73	11.5-24.5	4.83-8.73	18.4-48.3	1.15-1.84	10.1-13.3	1.5-4.8	57.5-103.5	5.29-10.35	51.03-78-08
Mean	19.20	16.06	59.94	7.62	18.70	5.1.39	36.8	1.61	12.8	3.2	76.82	7.96	60.78
Sd	±3.523	±0.834	±17.663	±0.762	±5.384	±0.810	±10.62	±0.345	±0.42	±0.01	±13.28	±1.662	±5.28
Matured rhizome (20 mm) Range	16.62-39.8	4.9-8.3	49.32-80.38	7.21-9.32	13.5-28.3	4.96-9.38	14.98-60.38	1.89-2.32	12-20.75	2.3-5.3	60.7-120.5	16.28-12.35	55-78.02
Mean	22.30	6.91	62.35	8.12	21.36	7.32	45.32	2.02	18.3	4.2	80.25	8.86	63.78
Sd	±4.321	±0.78	±6.23	±0.82	±5.32	±1.23	±8.92	±0.238	±2.38	±0.02	±10.326	±1.872	±8.032

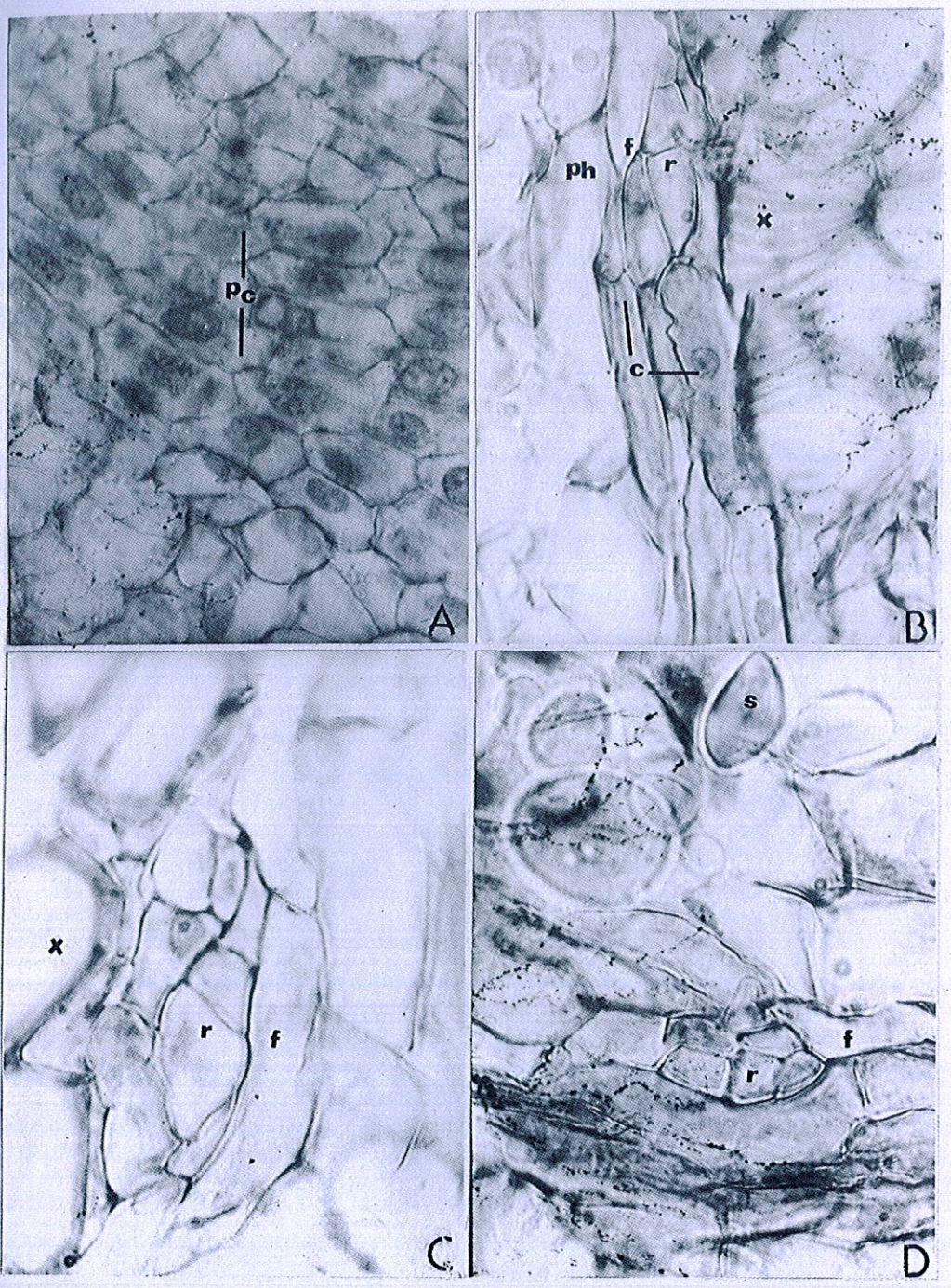

Fig. 3A-D — (*c*, cambium; *f*, fusiform initials; *Pc*, procambium; *Ph*, phloem; *r*, ray initials; *s*, starch grains; *x*, xylem). **A.** L.s. of rhizome showing formation of cambium. **B.** Long fusiform cells and short ray initials cells. x 800. **C.** L.s. of rhizome showing endodermoidal region with fusiform and ray initials. x 800. **D.** L.s. showing starch grains and cambial layers. x 800.

of names given to it by different authors. In the present study we prefer to retain the term intermediate zone in line with Petersen (1892). Scahacht (1852) and de Bary (1877) used the term cambial ring and cambial like instead of the term intermediate zone. Sargent & Arber (1915) reported that the roots are originating from the intermediate layer so they termed the layer as root plate. Coetxee (1976) coined the term cambial band besides the intermediate layer. Kumar (1973) described that in certain Zingiberaceae a meristematic, cambium- like zone was present that separated the outer and inner system. In ginger, the present authors could observe fusiform and ray initials, but it is not persistent for long, so termed it as cambium-like layer.

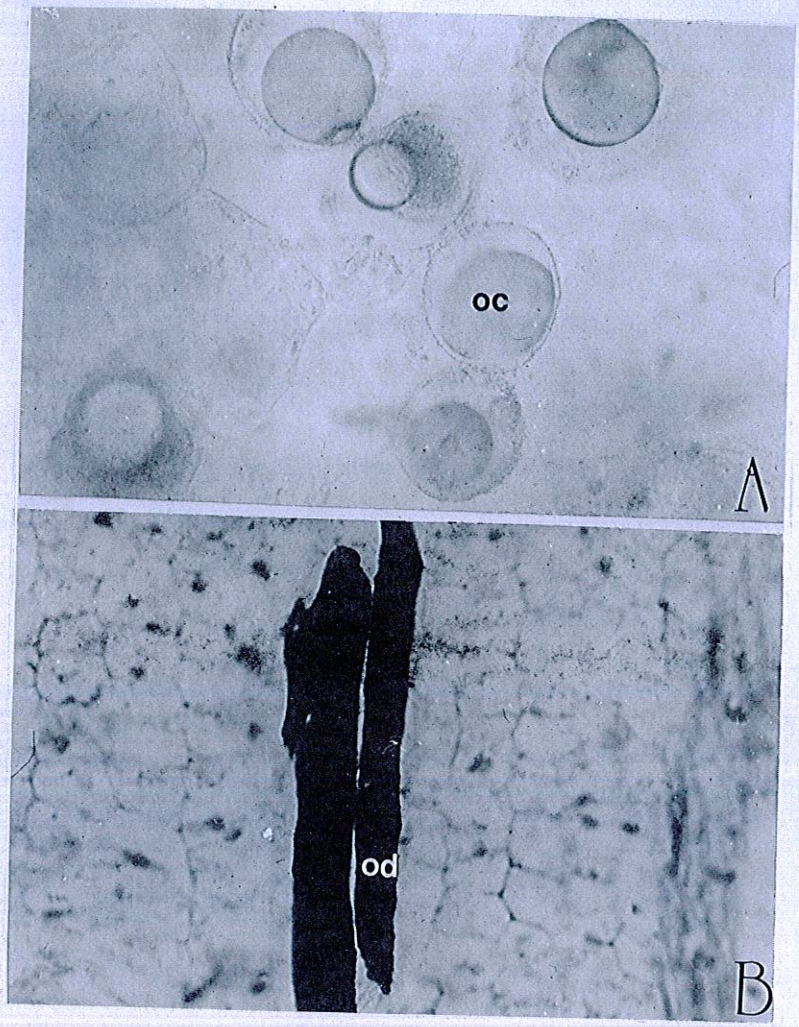

Fig. 4 A,B — (*oc*, oil cell; *od*, oil duct). **A.** Oil cells. x 400. **B.** L.s showing oil canal. x 400.

The earlier workers had given many terms to the potentially meristematic layer but none of them pointed out the essential features of the fusiform and ray initials of cambium. The present authors succeeded in showing photographic evidence of fusiform and ray initials to justify the term intermediate cambium-like layers.

Zimmermann & Tomlinson (1970) reported that in *Dracaena* the cortical system can develop by means of meristematic activity of an intermediate zone. Between the inner system and the secondary tissue of *Dracaena* lies the 'cambium' from which the secondary tissue differentiates as a continuation of the primary. The growth in thickness of rhizome inNutsedge is caused by the cell division and enlargement in the inner and outer zone (Esau 1977). In the same species Gifford & Bayer (1995) reported that the rhizome development is by means of primary and secondary thickening meristem. In ginger the present authors found that the girth increase in rhizome is by means of the initial divisive activity of the procambial cells, meristemosity of cambium-like cells, and of ground parenchyma. The first is by tangential and radial divisions for a short span, the second for still more prolonged time by way of orderly divisions of fusiform and ray initials, and third by multiplane cell-divisions for prolonged duration. From the Table 1 it is clear that the dimensions of procambium, cambium, xylem and phloem have increased proportionately with the growth.

Transections of ginger rhizome showed, that starch accumulates in cells situated near the loci of cambium-like zone, xylem and phloem. These cells may be the primary sink for starch. The enzymes responsible for the conversion of sugar to starch could be more in these regions. However, more studies are to be conducted on the biochemical reactions in these cell layers.

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