Development of oil cells and ducts in ginger (*Zingiber officinale* Rosc.)

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Abstract

The development, distribution and structure of oil cells, development of secretory ducts and diffusion of oil in ginger rhizomes (*Zingiber officinale*) were studied. Oil cell differentiation initiate from a group of meristematic cells before the development of primary vascular tissue. Oil cells are present in leaf, shoot apex, root apex and are more or less spherical and contain stored volatile oil. The number of oil cells is higher in the apical and nodal regions than in the internodal region and the size of oil cells is dependent on their number. Secretory ducts develops schizogenously and lysigenously. The former type is present in the primary tissues while the latter type is found throughout the developmental stages.

Key words : ginger, oil cells, oil ducts, ontogeny, *Zingiber officinale*.

Introduction

Ginger (*Zingiber officinale* Rosc.) is a perennial rhizomatous plant belonging to the family Zingiberaceae. The members of this family possess oil cells in the rhizome and other plant parts which serve as the site of storage of essential oil and resinous substances imparting a warm pungent taste and flavour to all parts of the plant. Ginger is a major ingredient in traditional medicine of India and ginger oil is used in many pharmaceutical preparations. Oil cells develop close to the meristematic region during the early developmental process. Ducts are found in the ground parenchyma of all the organs, especially in leaf lamina. Oil cells are found with suberized or non suberized walls and each of them contain a refractive globular body (Tomlinson 1969). The present paper describes the mode of development of oil cells and ducts as well as the status of secretion in ginger rhizome.

Materials and methods

Rhizomes of ginger (*var*. Maran) were planted in pots. Newly developed rhizomes with shoot and root apices were fixed in formalin - acetic acid - alcohol mixture (FAA) and were processed for histological studies as per standard procedures (Jenson 1962) and stained with sudan black for lipids (Krishnamoorthy 1988).

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Results and discussion

Oil cell

Oil cells are present in the epidermis or just below the epidermis of leaf, petiole, rhizome and root. In rhizome, oil cell initials are present in the meristematic region. They are more or less spherical and densely stained. Small irregular bodies, cluster of globular drop-like structures and granular structures are seen inside the oil cells (Fig. 1A). The quantity of the cell content seems to vary. Generally oil cells are round to ovoid in leaf tissues and more or less globular in parenchymatous tissues of rhizome. The initiation of oil cells and formation of ducts occurs in the apical parts of shoots and roots and starts much before the initiation of vascular elements. Secretary ducts are formed schizogenously and lysigenously. There are 17.79 cells per unit area in the apical region while in the internodal region there are 2.5 cells per unit area. The oil cell index is higher in the apical region than in the internodal region. But they are larger in the internodal region than in the apical region; an increase in number is followed by decrease in size of oil cell (Table 1).

Table 1. Oil and parenchyma cell dimensions in ginger rhizome

Parameter	Apical region	Internodal region
No. of oil cells/mm²	17.79 ± 3.35	2.50 ± 0.30
No. of parenchyma cells/mm²	25.20 ± 8.70	34.50 ± 9.80
Oil cell index	42.36 ± 15.30	6.70 ± 1.30
Oil cell size (μm)	53.20 ± 1.46	81.70 ± 0.05

Values indicate Mean±SD

Development of ducts

Schizogenous type

This type of secretory duct originates in the intercalary meristem of the developing regions (Fig. 1B). The ducts are initiated by the separation of a group of densely stained meristematic cells through dissolution of middle lamella (Fig 1B). Concurrent separation of the cells leads to the formation of an intercellular space, bordered by parenchymatous cells possessing dense protoplasmic contents (Fig. 1C); these ducts anastomose and appear branched (Fig. 1D). Further separation of the bordering cells along the radial wall leads to widening of the duct lumen.

Lysigenous type

This type of duct formation is more frequently observed in meristematic as well as in mature parts of rhizomes. It takes place in four stages namely, initation, differentiation, secretion and quiescence. These steps are a gradual process which occur acropetally.

Initiation and differentiation: In shoot apex, the meristematic cells are arranged in tiers. In between these meristematic cells, prior to the differentiation of vascular elements, certain cells in the cortical zone are distinguishable from other cells by their large size, dense cytoplasm and prominent nucleus (Fig. 1E & 3A). Such cells act as the oil cell mother cell. Anticlinal and periclinal divisions of these cells results in a group of oil cell initials (Figs. 1E & F, 3B-E). Cytoplasmic vacuolation initiates in the oil cell initials at a distance of 420 μm from the shoot apex, and they contain prominent nuclei (Figs. 1F; 3E & F). Subsequently, the surrounding cells also enlarge in size showing cytoplasmic and nuclear disconfigurations (Figs. 1F;
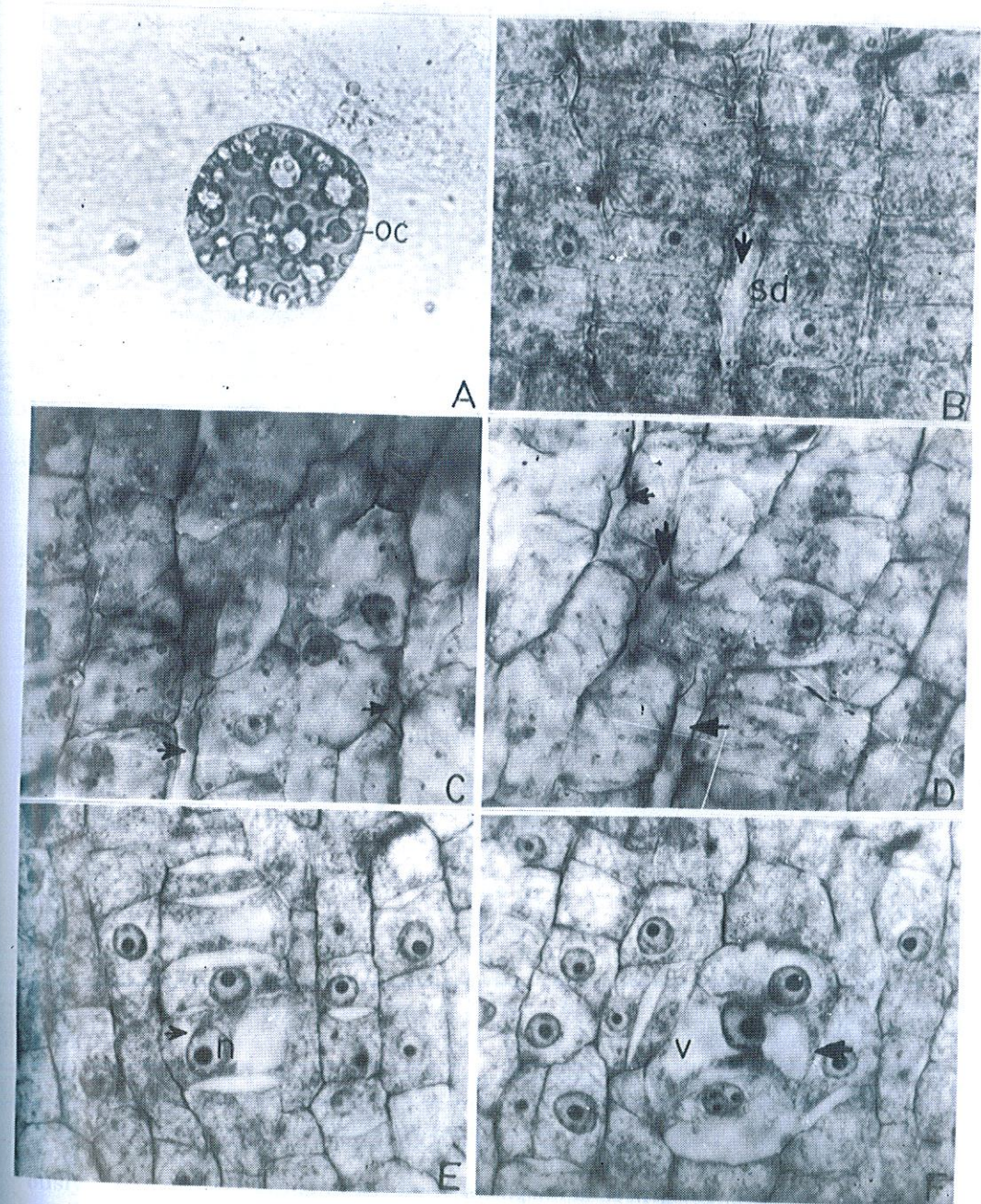
Fig. 1. Schizogenous development of oil cell in ginger rhizome

A. Macerated oil cell (x 1000) B-D. Schizogenous development of ducts in intercalary meristematic region (x 1000) E & F. Oil cell mother cell undergoing division (x 1000) (oc-oil duct; n-nucleus; sd-secretory duct; v-vacuole)
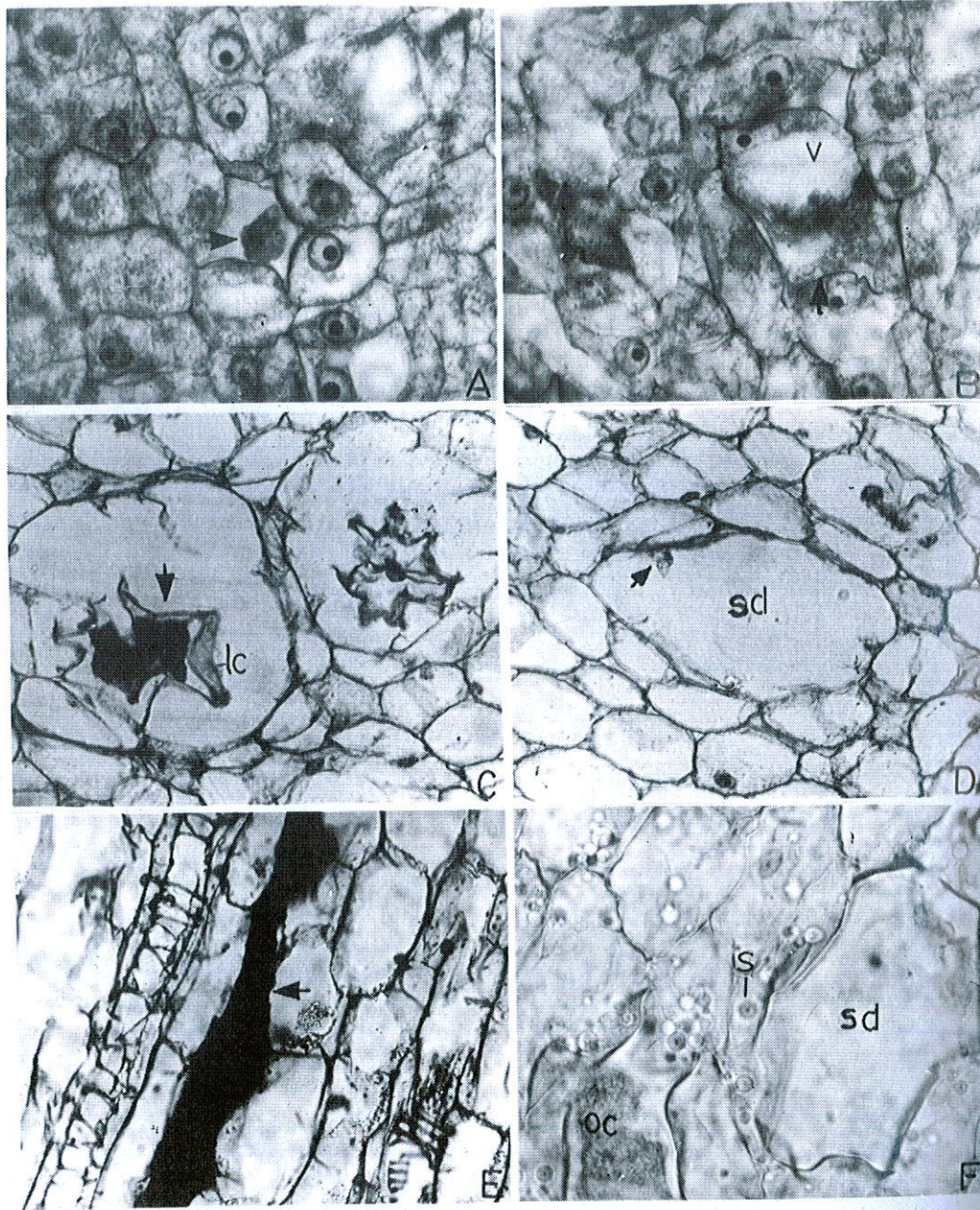
Fig. 2. Lysigenous development of oil cell in ginger rhizome

A. Disintegration of nuclear content and darkening of cytoplasm (x 1000) B. Darkening of cell content and vacuole formation (x 1000) C. Darkening and lysing of oil cell (x 400) D. Completely disintegrated central cell (x 400) E. L S of oil duct filled with secretory substances (x 400) F. Matured oil duct and a lysing oil cell (x 400) (lc-lysing cell; oc-oil cells; s-starch grains; sd-secretary duct; v-vacuole)

3E & F). Further development leads to the disintegration of nuclear content of the central cell (Figs. 2A; 3F & G) which stretches towards the intercellular space of the surrounding cells and at this stage darkening of cytoplasm and formation of a large vacuole can also be observed (Figs. 2B; 3H). Later, the central cell disintegrates and the contents spill into the cavity thus formed (Figs. 2C & D; 3I). This process leads to the formation of a duct which can be either articulated or non-articulated type (Fig. 2E), and gets gradually filled up with the cell contents of the lysed cell (Fig. 2E). In some regions the wall dissolves completely but in certain areas the remnant of the wall is seen attached to surrounding cells (Figs. 2C & D). Complete disintegration of central cell leads to the formation of the central duct (Figs. 2C & D). The space released by the disintegrating cell is partly occupied by the enlarging neighbouring cells. This indicates that a lysigenous space is formed devoid of angularity (Figs. 2D & 3H). Once the process of lysogeny of a cell is completed, the adjacent cell also lyse gradually in a basipetal manner causing widening of the duct lumen. These stages are observed inbetween 1500 to 3500 µm from the shoot apex.

Secretion: The differentiated oil cell starts a holocrine type of secretion and expels its contents into the duct. Then the next cell (in acropetal order) gets differentiated into an oil cell and starts the secretory process and elimination of its content followed by lysis. Simultaneously the primary tissues continue to get differentiated into new oil cells and reach the secretory stage, but the secretion and diffusion takes place in basipetal order. The secretions fill the secretory duct in young stages (Fig. 2E)

but the quantity gets reduced gradually and finally the duct seems to be empty (Fig. 2F). From this it is clear that there is diffusion of cell contents through basipetal and radial manner. Once the secretory duct is filled with oil contents (Fig. 2E), further basipetal development leads to its spreading. Oil is mainly transported radially through the intercellular space because during lysigenous duct formation the cell wall undergoes lysis and the cell contents are left back in the intercellular space in contact with the neighbouring cell walls (Fig. 4A). In addition, cell to cell radial movement of oil contents also takes places through plasmodesmata (Fig. 4B) and gets deposited in the form of a black mass inside the cell as well as in the intercellular space (Fig. 4C). These processes make the secretory duct empty during maturation (Fig. 2F). Such secretory stages are noticed about 3250 µm from the shoot tip (around 120 to 160 day old rhizome)

Quiescence: In the mature rhizome, the ground parenchyma do not undergo further cell division and differentiation into a duct. In this stage, the cells adjacent to the duct become storage cells, containing numerous starch grains and possessing large vacuoles (Figs. 2F & 3I). Empty cell or cells with distorted cytoplasm appear in certain areas along the duct lumen (Figs. 2F & 3I), forming the channel for secretory substances. Quiescence and secretory stages are visible from third month onwards after planting. In ginger, oil cells are present in all the plant organs. The difference between a meristematic cell and oil cell initial is quite distinct and the nature of development of oil duct is schizogenous in primary tissues and further development is both schizo-and lysigenously. Babu (1985) reported schizo-lysigenous
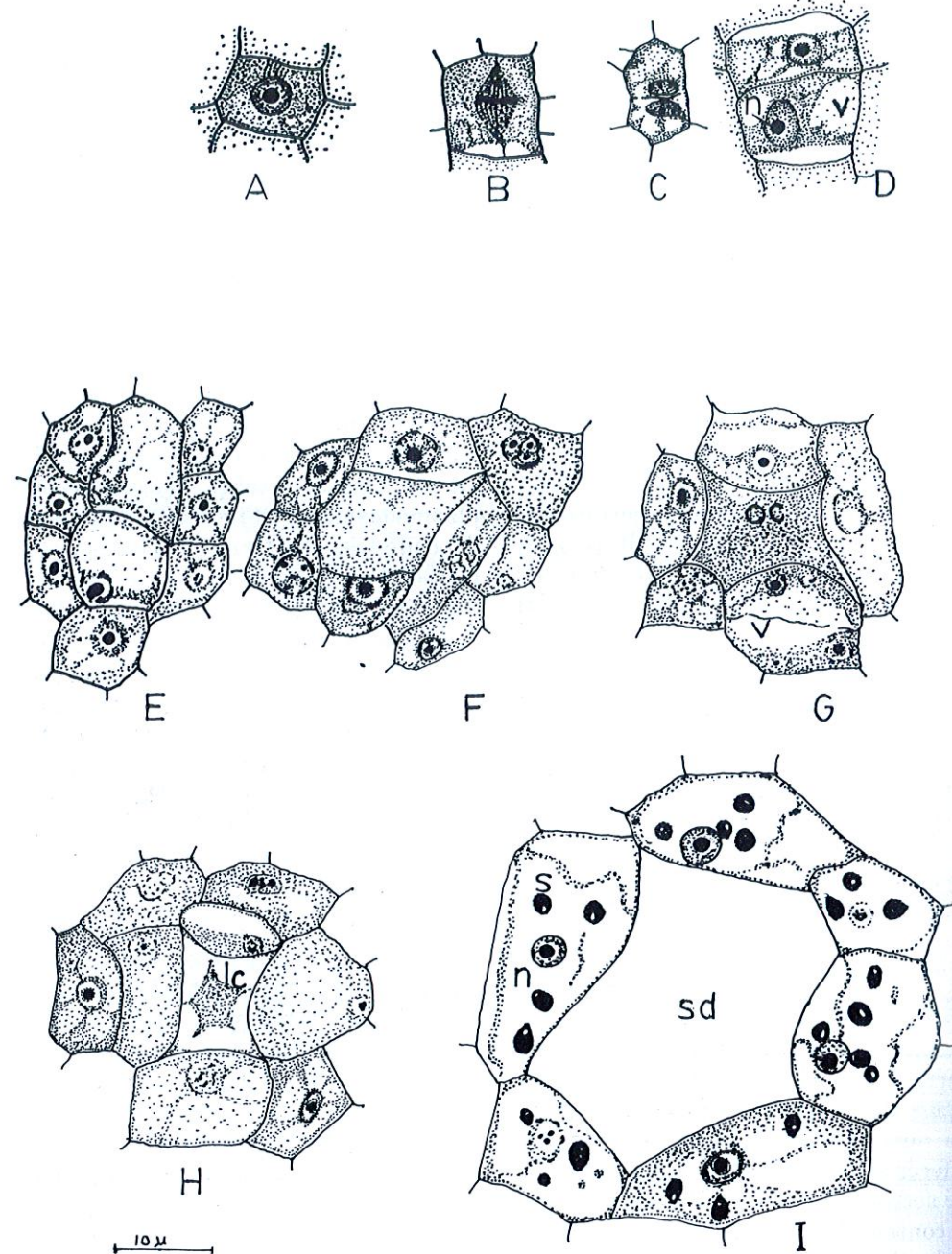
Fig. 3. Lysigenous development of oil cell in ginger rhizome (continued)

A. Oil mother cell B-D. Divisions occuring in the oil cell mother cell E. Nuclear disintegration of central cell F. Nuclear disintegration (note the deformed wall) G. Cytoplasmic condensation H. Darkening of cell content and increase in vacuolations I. Mature oil duct with scanty cytoplasm (lc-lysing cell; oc-oil cell; s-starch grains; sc-secretory duct; v-vacuole)
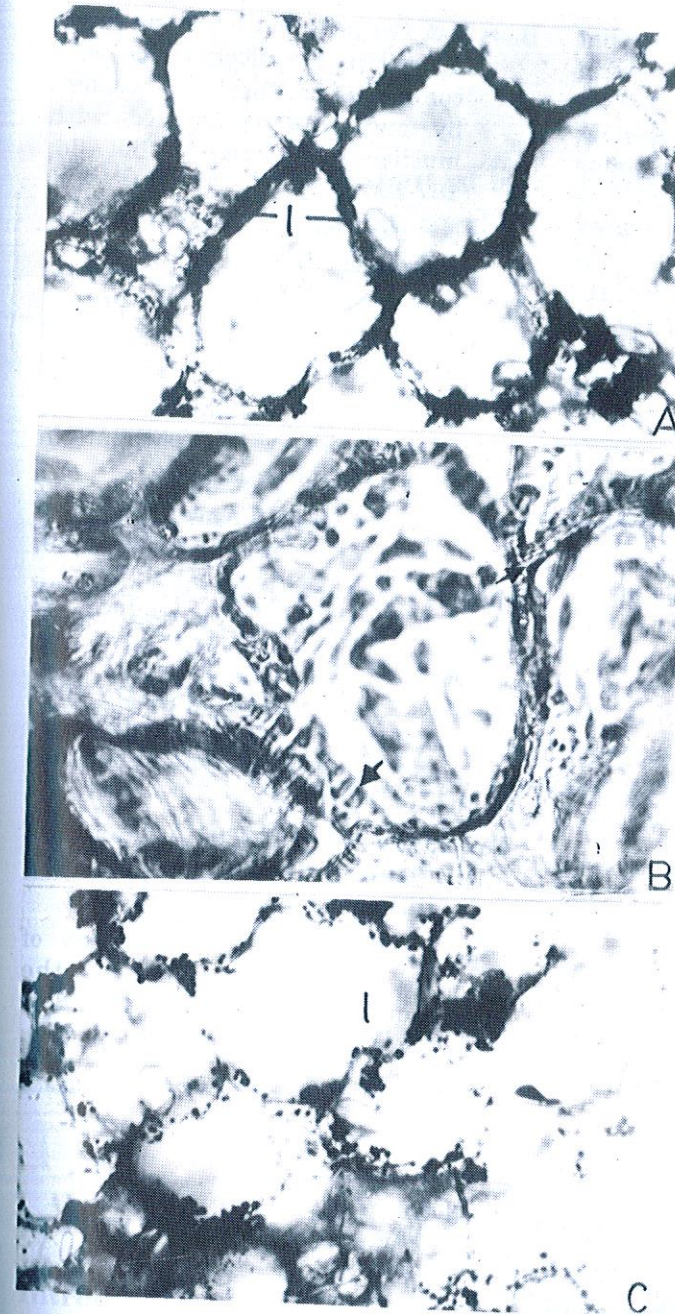
Fig. 4. Lipid deposition in oil cells of ginger rhizome

A. Deposition of lipids in the intercellular space in the form of black mass (x 400) B. Plasmodesmatal connection (arrow) between cells (x 400) C. Deposition of lipid inside the cell in the form of black dots (x 400) (l-lipid)

development in *Vateria indica* and *Parthenium argentatum*. In *Anacardium* sp., *Rhus* sp. and *Coctinus* sp., the duct initiates schizogenously and enlarge lysigenously, thus forming a schizo-lysigenous duct (Langerheim 1969; Paula & Alvea 1973). Lysigenous intercellular spaces are larger in water plants and in the root of some monocotyledons (Fahn 1990). The manner of initiation and early development of a duct is generally by (1) separation of cell walls that were previously in contact with each other (schizogenous) (2) break down of certain cells through autolytic enzyme action (lysigenous) and (3) by a combination of both these process (Metcalfe & Chalk 1983). In ginger, both the types of duct formation were observed.

In the case of monocotyledons, Tomlinson (1969) reported the presence of oil cells in Zingiberaceae but not the mode of differentiation of oil cavity. Venning (1948) studied different plant organs of various species and came to the conclusion that in the shoot of *Spondias dulsis*, the ducts are formed schizo-lysigenously and stated that in different organs of the same species e.g. mango, the ducts develop in different ways. The present

observations lead to the conclusion that the oil ducts are formed in two ways in ginger. The cavities observed in meristematic regions are of schizogenous type while those observed in both young and mature regions throughout the growing period are of lysigenous type. The initiation and differentiation of ducts occur almost at 420 μm from the shoot or root tips. In ginger, rhizome is the storage organ and possesses numerous oil cells, oil canals and starch grains. Since oil and fats are important reserve materials, these secretory processes are of great taxonomic significance (Metcalfe & Chalk 1983; Bass & Gregory 1985; Fahn 1990).

Acknowledgements

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