Biosystematic Studies on the Genus *Zingiber* Boehm. in South India

Thesis submitted to the
University of Calicut for the Degree of

DOCTOR OF PHILOSOPHY IN BOTANY

By

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CERTIFICATE

This is to certify that the thesis entitled "**Biosystematic Studies on the Genus *Zingiber* Boehm. in South India**" submitted to the University of Calicut by **Smt. Vasantha. V. A.**, in part fulfillment for the award of the degree of Doctor of Philosophy in Botany is a bonafide record of the research work carried by her under my supervision and guidance. No part of the present work has formed the basis for the award of any other degree or diploma previously.

Dr. M. Sabu

C. U. Campus
31. 03. 2009

DECLARATION

The thesis entitled **"Biosystematic Studies on the Genus *Zingiber* Boehm. in South India"** submitted by me in part-fulfillment for the award of the degree of **Doctor of Philosophy in Botany** has not been submitted earlier, either in part or in full for any degree or diploma of any University and it represents the original work done by me.

C.U. Campus

31. 03.2009

Vasantha V. A.

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CONTENTS

INTRODUCTION

The name *Zingiber* Boehm. was originated from Tamil "*ingiver*" meaning ginger rhizome and the Arab traders spread it to Greece and Rome (Ravindran & Babu, 2005). It is also believed to be originated from Sanskrit word *Singebera* (horn-root) which gave rise to the classical Greek name *Zingiberi* and finally *Zingiber* in Latin.

The genus *Zingiber*, the type genus of the family, belongs to the family Zingiberaceae. The family includes about 53 genera and more than 1200 species, distributed mainly in tropics and sub tropics with the centre of distribution in the Indo-Malayan region but extending through tropical Africa to Central and South America (Kress *et al*., 2002). The genus *Zingiber* is represented by 141 species (Theilade, 1999b; Theilade & Mood 1999) distributed mainly in tropical Asia.

In India the genus was first studied by Roxburgh (1810) and reported 11 species from British India. He classified it under two sections *viz.* Section I- Spikes radical and section II-Spikes terminal, based on the nature of the spike.

Baker (1892) reported 24 species from British India and classified those under 4 sections *viz; Cryptanthium* Horan; *Lampuzium* Horan; *Pleuranthesis* Benth, and *Dymczewiczia* (Horan.) Benth. This infrageneric classification was followed by Schumann (1904) in his monograph on

Zingiberaceae. Fischer (1928) recorded 7 species from the Western Ghats of South India. Jha and Varma (1995) revised the genus in Bihar and Kumar (2001) recorded 7 species from Sikkim. Sabu (2003) revised the genus *Zingiber* in South India and recorded the occurrence of 8 species.

Zingiber species are perennial rhizomatous herbs with tuberous sympodial rhizomes. Aerial shoot is often covered by sheathing leaf bases. The inflorescence is usually a spike or raceme. The flowers are very delicate and fleshy so that in most cases they wither and crumble forming a gummy mass, soon after collection, making it difficult to study floral morphology, unless fresh flowers are readily available. Among *Zingiber*, flowering period is very short and usually associated with rainy season. As most of the members grow in openings or as undergrowth in dense forests, during rainy season, the collection of material is rather difficult. Only one or two flowers open at a time, and it is difficult to detach them from the intact bract. Field notes such as the life cycle, nature of peduncle, colour of the bracts at different stages, colour of labellum are very important. These characters are rarely preserved in the herbarium.

Zingiber is distinct from other genera of the family by the presence of a single anther with a beak or horn-like appendage, which embraces the upper part of the style. The inflorescence usually arises at the base of the leafy stem on a short or long, aerial or subterranean peduncle. The bracts are overlapping; each subtends a non tubular bracteole and a single flower. In many species the bracts are green when young, turning to red in the fruiting stage. The flowers are very delicate and fragile and last only for a few hours. The genus can be recognized in the vegetative stage by the presence of a pulvinus between the base of the petiole and ligule.

In South India, Kerala and western parts of Karnataka have a warm humid climate with heavy rainfall support dense vegetation. This region forms one of the richest floristic regions in the country. Nine species of *Zingiber* occur in South India, they are *Z. capitatum* Roxb. var. *elatum* Roxb., *Z. cernuum* Dalzell, *Z. montanum* (K. D. Koenig) Link ex. Dietr, *Z. neesanum* (J. Graham) Ramamoorthy., *Z. nimmonii* (J. Graham) Dalzell, *Z. officinale* Roscoe, *Z. roseum* (Roxb.) Roscoe., *Z. wightianum* Thwaites., and *Z. zerumbet* (L.) Smith. *Z. wightianum* is endemic and confined mostly to the dense forests at high altitude of Western Ghats. *Z. neesanum* is seen at higher altitudes of Kerala and Karnataka. *Z. roseum* is confined only to Northern Circars and Northern part of Western Ghats in South India. *Z. cernuum* is confined to South India and *Z. nimmonii* in the hilly regions of Western Ghats. *Z. montanum* is mainly distributed in Andhra Pradesh, Karnataka and Goa. *Z. capitatum* var. *elatum* is seen in hill slopes and open grass lands of Karnataka. *Z. officinale* is widely cultivated in all districts of South India whereas *Z. zerumbet* is well distributed throughout India.

The common edible ginger, *Z. officinale* constitute one of the five most important spices of India and about 70% of the total ginger production is confined to Kerala alone. It has been used in Ayurvedic and other natural systems of medicine from time immemorial. In Ayurveda, ginger is used as a carminative and digestive. It is pungent, hot, and anodyne, antirheumatic carminative, cooling, diuretic, and aphrodisiac and promotes digestive power. It is used in the treatment of anorexia, dyspepsia and for the suppression of inflammation. Dry ginger is used in the treatment of asthma, cough, diarrhoea, flatulence, nausea and vomiting (Datta & Mukerji, 1950). It is an important spice extensively used in the preparation of condiments, curries and syrups. The rhizome of *Z. montanum* is given in diarrhoea, also used as a stimulant, carminative, flavouring agent, and also an antidote to snake poison. Rhizome of *Z. officinale* is used for treating cough, bronchitis, asthma, heart, abdominal troubles, piles, elephantiasis, scorpion sting, snake bite, and also as appetizer, stomachic, aphrodisiac, carminative and also used as spice, condiment and preservative. Rhizome of *Z. roseum* is used in cold, cough and rheumatism. *Z. zerumbet* rhizome is given in cough asthma, stomach ache, vermifuge, leprosy and other skin diseases and also used as substitute for true gingers (Prakash & Mehrotra, 1996). The mucilage present in the inflorescence of *Z. zerumbet* is used as shampoo hence known as shampoo ginger. Many varieties of *Z. zerumbet* are now used as ornamental plants (Sabu & Skinner, 2005).

Importance of study

Many species of *Zingiber* are source of indigenous system of medicines, spices, condiments and ornamentals. The genus is less understood taxonomically and biologically as many taxa grow in dense forests especially during monsoon. The flowers last only for a few hours and it is difficult to detach them without damage. Because of the fleshy nature of the rhizome and aerial stem, herbarium preparation is also difficult. The determination of correct identity is necessary for proper utilization and conservation of many species. There are many factors which justify an in depth study of the genus *Zingiber* in South India with respect to their Taxonomy, Morphology, Cytology, Anatomy, Palynology, Chemotaxonomy *etc.* The vulnerability of many of the species and imminent danger of their extinction makes it more urgent.

Objectives

1. To study the diversity of genus *Zingiber* in South India.
2. To carryout biosystematic analysis to find out the relatives of the species.
3. To study the distribution and variation among different taxa in South India.
4. Comparison of collected taxa.
5. Proper characterization of the taxa by anatomical, cytological, palynological, molecular and phytochemical studies.
6. Numerical taxonomic studies using cluster analysis to study interrelationships of taxa.
7. To solve the problem of delimitation of some taxa.

REVIEW OF LITERATURE

The first comprehensive work on the flora of Malabar region was made by Rheede (1678-1693). With the assistance of local physicians he published '*Hortus Malabaricus'* in 12 volumes in Latin in Amsterdam. In which he described 10 species of Zingiberaceae, which includes two species of *Zingiber*, *viz., Z. officinale* as 'inschi', and *Z. zerumbet* as 'Katou-inschi Kua'.

Major contribution to Indian botany was by Roxburgh. His work was published in *Plants of coast of coramandel* (1795-1820) with 300 drawings and descriptions, it also contain *Z. roseum* as *Amomum roseum* Roxb.

Major part of Roxburgh's (1820, 1824) work on Indian botany was incorporated in *Flora Indica.* Part of Roxburgh's manuscript of his *Flora Indica* with addition by Wallich under the title *Flora Indica* edited by William Carey, published posthumously. It includes *Z. officinale*, *Z. zerumbet*, *Z. cassumunar* Roxb., *Z. roseum, Z. ligulatum* Roxb., *Z. rubens* Roxb., *Z. squarrosum* Roxb., *Z. panduratum* Roxb., *Z. capitatum* Roxb., *Z. marginatum* Roxb. and *Z. elatum* Roxb.

Wight (1838–1853) explored the South Indian flora and included 7 genera and 14 species of Zingiberaceae in *Icones Plantarum Indiae orientalis*.

Graham (1839) listed 28 species of Zingiberaceae including 5 species of *Zingiber*, in his *Catalogue of Plants Growing in Bombay*. It includes *Z. cernuum*, *Z. cassumunar*, *Z. nimmonii*, *Z. macrostachyum* and *Z. zerumbet*.

Dalzell and Gibson (1861) worked out the flora of Western parts of India and listed 25 species of Zingiberaceae and it includes 5 species of *Zingiber viz., Z. zerumbet*, *Z. cassumunar*, *Z. nimmonii*, *Z. cernuum*, *Z. macrostachyum* in *Catalogue of plants indigenous to Western India in and near the Bombay Presidency*.

Hooker's *Flora of British India* (1872-1897) is an authentic work on the flora of Indian sub-continent. Baker (1892) explored Scitamineae for the *Flora of British India*. He described 224 species under 18 genera of Zingiberaceae. The genus *Zingiber* includes 24 species, *viz., Z. chrysanthum* Rosc., *Z. rubens*, *Z. roseum*, *Z. nimmonii*, *Z. wightianum*, *Z. barbatum* Wall., *Z. squarrosum, Z. ligulatum*, *Z. cernuum*, *Z. panduratum*, *Z. pardocheilum* Wall., *Z. intermedium* Baker., *Z. officinale*, *Z. griffithii* Baker., *Z. gracile* Jack., *Z. zerumbet*, *Z. cylindricum* Moon., *Z. macrostachyum*, *Z. spectabile* Griff., *Z. cassumunar*, *Z. parishii* Hook, f., *Z. clarkei* King, *Z. capitatum* and *Z. marginatum*.

In present India, 20 species of *Zingiber* occur. They include *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. chrysanthum*, *Z. clarkei*, *Z. intermedium*, *Z. ligulatum*, *Z. marginatum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. odoriferum* Bl., *Z. officinale*, *Z. roseum*, *Z. rubens*, *Z. spectabile*, *Z. squarrosum*, *Z. wightianum*, *Z. zerumbet*, and *Z. parishii*.

Cooke (1907) in *Flora of the Presidency of Bombay*, reported 11 genera and 20 species of gingers with 5 species under the genus *Zingiber viz., Z. cassumunar, Z. cernuum, Z. nimmonii*, *Z. macrostachyum* and *Z. zerumbet.*

Rao (1914) in his *Flowering Plants of Travancore*, gave an enumeration of Zingiberaceae, with 33 species from Kerala. This was nothing more than an inventory of binomials and did not give any key for identification or description.

Bamber (1918) in *Plants of Punjab* reported 10 species under 5 genera of Zingiberaceae and 3 species of *Zingiber viz., Z. cassumunar, Z. officinale* and *Z. zerumbet.*

Fischer (1928) recorded 34 species under 9 genera of Zingiberaceae including 7 species of *Zingiber* in Gamble's (1916–1935) *Flora of Presidency of Madras.* These include *Z. roseum*, *Z. nimmonii*, *Z. wightianum*, *Z. officinale*, *Z. zerumbet*, *Z. macrostachyum* and *Z. cassumunar*.

Ridley (1924) studied the *Flora of Malay Peninsula* and listed 20 genera and 12 species of the genus *viz., Z. spectabile*, *Z. kunstleri* King, *Z. wrayi* Prain, *Z. aromaticum* Valeton, *Z. ottensi* Valeton, *Z. cassumunar*, *Z. chrysostachys* Ridl., *Z. chryseum* Ridl., *Z. citrinum*, *Z. gracile*, *Z. griffithii*, and *Z. puberula* Ridl.

Holttum (1950) made rearrangements in Schumann's sub divisions of the sub family Zingiberoideae and separated the genus *Zingiber* from the tribe Zingibereae and renamed it as Alpinieae and placed the genus *Zingiber* under the tribe Hedychieae. He classified Zingiberaceae into two subfamilies Zingiberoideae and Costoideae, and Zingiberoideae further classified into four tribes Alpinieae, Hedychieae, Globbeae and Zingibereae.

Mitra (1958) studied the monocotyledons of Eastern India and recorded 14 genera under Zingiberaceae and 10 species of *Zingiber viz., Z. capitatum*, *Z. elatum*, *Z. clarkei*, *Z. officinale*, *Z. intermedium*, *Z. zerumbet*, *Z. cassumunar*, *Z. chrysanthum*, *Z. rubens*, and *Z. roseum*.

Duthie (1960), in *Flora of the Upper Gangetic Plain and of the adjacent Siwalik and Sub-Himalayan Tracts*, reported 11 species under 7 genera of Zingiberaceae and 2 species of *Zingiber viz., Z. capitatum* and *Z. officinale.*

Panchaksharappa (1962) studied the two subfamilies, Zingiberoideae and Costoideae of Zingiberaceae and suggested that two subfamilies are distinct and natural groups and the status of Costoideae to be raised to the rank of a family.

Santapau's (1967) contribution is of some significance and he solved many nomenclatural problems concerning Zingiberaceae in *Flora of Khandala* and included 6 species under 5 genera of Zingiberaceae. The genus *Zingiber* includes *two species viz., Z. cernuum* and *Z. macrostachyum*.

Backer and Bakhuizen (1968) in *Flora of Java* listed 53 species under 14 genera of Zingiberaceae. It includes 8 species of *Zingiber viz., Z. purpureum*, *Z. acuminatum* Val*., Z. zerumbet*, *Z. officinale*, *Z. odoriferum*, *Z. ottensii* and *Z. inflexum* Bl.

Burtt (1972) suggested a new classification of the family Zingiberaceae and recognized four tribes *viz.,* Zingibereae, Globbeae, Hedychieae and Alpinieae, Burtt and Smith (1972a) given a key to the subfamilies, tribes and genera of Zingiberaceae. Burtt and Smith (1972b) enumerated the early history of the classification of Zingiberaceae through a chronological study of the key species which are concerned in the typification of the main genera, sub genera and sections. Burtt and Olatunji (1972) suggested advanced reasons for restricting the tribe Zingibereae to the genus *Zingiber* alone and characters distinguishing it from Hedychieae are both morphological and anatomical.

Rao and Verma (1972) studied the Zingiberaceae and Marantaceae of Assam, and reported 70 species under 16 genera in which they included 7 species of *Zingibe*r *viz., Z. chrysanthum*, *Z. rubens*, *Z. intermedium*, *Z. officinale*, *Z. zerumbet*, *Z. cassumunar* and *Z. capitatum*.

Holttum (1974) presented a critical commentary on comparative morphology of Zingiberaceae in Malay Peninsula and suggested that experimental work might throw light on the structure of the condensed lateral cymes and structure of the inflorescence in the family.

Trimen (1898), in *A Hand book to the Flora of Ceylon*, recorded 15 genera of Zingiberaceae and 32 species and *Zingiber* with 4 species *viz., Z. cassumunar*, *Z. cylindricum*, *Z. wightianum* and *Z. zerumbet.*

In *Flora of Hassan District* Ramamoorthy (1976) reported 13 species under 9 genera of Zingiberaceae. In which he listed 3 species of *Zingiber viz., Z. cernuum*, *Z. neesanum*, and *Z. montanum*

Srivastava (1976) in *Flora Gorakhpurensis*, reported 4 species under 3 genera *of* Zingiberaceae and a single species of *Zingiber viz., Z. officinale.*

Burtt (1977) discussed in detail, the nomenclature of turmeric and other Ceylon Zingiberaceae. Burtt and Smith (1976) put forward certain methods for the collection and preservation of the plants of Zingiberaceae.

Oomachan (1977) reported 5 species under 3 genera of Zingiberaceae and a single species of *Zingiber viz., Z. officinale* from Bhopal.

In *Flora of Taiwan*, Moo (1978) listed 23 species under 6 genera of Zingiberaceae and 4 species of *Zingiber viz., Z. zerumbet*, *Z. officinale*, *Z. koshunensis* Hayata ex Moo. and *Z. kawagoii* Hayata.

Nicolson *et al*. (1988) in their interpretation of van Rheed's "*Hortus Malabaricus*" has given scientific names for *Katou-Inschi-Kua* as *Z. zerumbet* and *Inschi* as *Z. officinale*.

Manilal and Sivarajan (1982) in *Flora of Calicut* reported 7 species under 4 genera of Zingiberaceae and 3 species of *Zingiber viz., Z. zerumbet*, *Z. officinale* and *Z. wightianum.* On critical studies the *Z. wightianum* is identified as *Z. cernuum*.

Ghazanfar and Smith (1982) studied *Flora of Pakistan* and listed 5 species under three genera of Zingiberaceae and noted *Z. officinale* in the genus *Zingiber.*

Joseph (1982) in *Flora of Nongpoh and Vicinity*, *East Khasi Hills District*, *Meghalaya* described 15 species under 10 genera of Zingiberaceae and 4 species of *Zingiber viz., Z. chrysanthum*, *Z. capitatum*, *Z. zerumbet* and *Z. cassumunar.*

Deb (1983) studied *The Flora of Tripura* and listed 24 taxa under 9 genera of Zingiberaceae and 3 species of *Zingiber viz., Z. officinale*, *Z. zerumbet* and *Z. rubens.*

Burtt and Smith (1983) listed 38 species under 15 genera of Zingiberaceae and 5 species of *Zingiber viz., Z. cylindricum*, *Z. purpureum*, *Z. zerumbet*, *Z. wightianum* and *Z. officinale* in *Revised Hand book to the Flora of Ceylon*, of Dassanayake and Fosberb.

Balakrishnan (1983) in *Flora of Jowai and vicinity*, *Meghalaya*, described 28 species under 13 genera of Zingiberaceae and listed 3 *Zingiber* species *viz., Z. capitatum*, *Z. rubens* and *Z. purpureum*.

Sharma *et al*. (1984) listed 29 taxa under 10 genera of Zingiberaceae. It includes *Z. capitatum*, *Z. cernuum*, *Z. cylindricum*, *Z. montanum*, *Z. neesanum*, *Z. officinale*, *Z. wightianum* and *Z. zerumbet* from Karnataka.

Chowdhery and Wadhwa (1984) in *Flora of Himachal Pradesh*, listed 12 species under 7 genera of Zingiberaceae, which includes *Z. zerumbet.*

Smith (1988) reviewed the genus *Zingiber* of Borneo. It includes 18 species *viz., Z. officinale*, *Z. pachysiphon* B. L. Burtt & R. M. Sm., *Z. incomptum* B. L. Burtt & R. M. Sm., *Z. longipedunculatum* Ridl., *Z. pseudopungens* R. M. Sm., *Z. purpureum*, *Z. zerumbet*, *Z. martini* R. M. Sm., *Z. puberatum* var. *borneense* R. M. Sm., *Z. acuminatum* var. *borneense* Val., *Z. coloratum* N. E. Br., *Z. albiflorum* R. M. Sm., *Z. leptostachyum* Val., *Z. griffithii*, *Z. odoriferum* Bl. Var. *borneense* Val. and 3 new species whose names were not given.

Nayar *et al*. (1986) in *Flora of Tropical Botanical Garden, Palode,* reported 5 taxa under 5 genera of Zingiberaceae, which includes *Z. zerumbet*.

Rao (1986) in *Flora of Goa*, *Diu*, *Daman*, *Dadra & Nagarhaveli,* reported 6 genera of the family Zingiberaceae and 3 species of *Zingiber viz., Z. cassumunar*, *Z. macrostachyum* and *Z. zerumbet.*

Rao *et al*. (1980) in *Flora of West Godavari District*, *Andhra Pradesh* recorded 8 taxa under 5 genera of Zingiberaceae and 2 species of *Zingiber viz., Z. montanum* and *Z. roseum.*

Rao *et al*. (1986) in *Flora of Sri Kakulam District*, *Andra Pradesh* recorded 8 taxa under 5 genera of Zingiberaceae with *Z. roseum* as a single representative.

Subramanian *et al*. (1987) in *Flora of Palghat* reported 7 species under 6 genera of Zingiberaceae with one species of *Zingiber viz., Z. roseum*.

Karthikeyan *et al.* (1989) in *Flora Indicae Enumeratio-Monocotyledonae,* listed 21 species of *Zingiber*, *viz., Z. capitatum*, *Z. cernuum*, *Z. chrysanthum*, *Z. clarkei*, *Z. elatum*, *Z. capitatum* var. *elatum*, *Z. intermedium*, *Z. ligulatum*, *Z. marginatum*, *Z. neesanum*, *Z. macrostachyum*, *Z. nimmonii*, *Z. officinale*, *Z. purpureum*, *Z. roseum*, *Z. rubens*, *Z. spectabile*, *Z. squarrosum*, *Z. wightianum* and *Z. zerumbet.*

Vajravelu (1990) in *Flora of Palghat District*, reported 13 species of Zingiberaceae under 9 genera with *Z. montanum* and *Z. roseum* under the genus *Zingiber.*

Srivastava and Rao (1994) reported *Z. odoriferum*, a new record for India from Andaman Islands.

Mohanan and Henry (1994) in *Flora of Thiruvananthapuram* reported 8 species under 6 genera of Zingiberaceae and 2 species of *Zingiber viz., Z. zerumbet* and *Z. neesanum.*

Saxena and Brahmam (1995) reported 24 taxa under 7 genera and 5 species of *Zingiber viz., Z. capitatum*, *Z. officinale*, *Z. purpureum*, *Z. rubens* and *Z. zerumbet* from Orissa.

Jain and Prakash (1995) studied the phytogeography and endemism of Zingiberaceae in India, and listed 130 species under 22 genera in which 88 species were endemic to India. It includes 19 species of *Zingiber viz., Z. capitatum*, *Z. cernuum*, *Z. chrysanthum*, *Z. clarkei*, *Z. elatum*, *Z. intermedium*, *Z. ligulatum*, *Z. marginatum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. purpureum*, *Z. cassumunar*, *Z. roseum*, *Z. rubens*, *Z. spectabile*, *Z. squarrosum*, *Z. wightianum*, and *Z. zerumbet*, in which four species viz., *Z. cernuum*, *Z. ligulatum*, *Z. neesanum*, *Z. nimmonii*, are endemic to peninsular India and *Z. clarkei* endemic to eastern Himalaya. *Z. intermedium* and *Z. rubens* are confined to northeastern India, others in tropical Himalaya, North eastern region, South India, and Andaman & Nicobar Islands. *Z. intermedium* is reported as endangered. *Z. officinale* is widely cultivated. It deals with phytogeographical distribution of all Indian Zingiberacean members with position of endemism.

Mudgel and Khanna (1995) in a study of the *flora of Madhya Pradesh* reported *Z. capitatum*, *Z. officinale*, *Z. purpureum*, *Z. roseum* and *Z. rubens.*

Sasidharan and Sivarajan (1996) reported 19 taxa under 9 genera of Zingiberaceae and 4 species of *Zingiber viz., Z. cernuum*, *Z. neesanum*, *Z. wightianum* and *Z. zerumbet* from Thrissur forests.

Sivarajan and Mathew (1996) in *Flora of Nilambur*, reported 15 taxa under 9 genera and 4 species of *Zingiber viz., Z. neesanum*, *Z. roseum*, *Z. officinale*, and *Z. zerumbet*. They reported *Z. roseum* with yellowish green bracts and yellow labellum with purple stripes, but these are the characters of *Z. cernuum*. This may be due to mis-identification. In the present study *Z. roseum* collected from Maradumalli, show labellum as white with red spots and yellow colour at periphery.

In *Illustrations on the Flora of Palani Hills*, Mathew (1996) provided the line drawings of *Z. zerumbet*.

Delin and Larsen (1996) listed 20 genera of Zingiberaceae and 42 species of *Zingiber* in *Flora of China.* In *The Flora of Western Tribal Madhya Pradesh*, *Jodhpur*, Samvatsar (1996), listed 4 taxa under 3 genera of Zingiberaceae. It includes *Z. cernuum*.

Sabu and Mangaly (1996) revised Zingiberaceae of South India and listed 11 genera and 55 species. It includes 7 species of *Zingiber viz., Z. cernuum*, *Z. neesanum*, *Z. officinale*, *Z. montanum*, *Z. roseum*, *Z. wightianum*, and *Z. zerumbet*. Sabu (2003) revised the genus *Zingiber* in South India and described *Z. capitatum* var. *elatum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum*, and *Z. zerumbet* and published a book on *Zingiberaceae and Costaceae of South India* (2006).

Theilade and Mood (1997) from Borneo reported two new species of *Zingiber viz., Z. eborinum* J. Mood & I. Theilade, and *Z. flammeum* I. Theilade & J. Mood. Subsequetly I. Theilade & J. Mood (1997a) described 5 new species from Borneo *viz., Z. vinosum* J. Mood & I Theilade, *Z. lambii* J. Mood & I Theilade, *Z. argenteum* J. Mood & I Theilade, *Z. pendulum* J. Mood & I Theilade, *Z. latifolium* I. Theilade & J. Mood. Theilade (1999) also reported 26 species of *Zingiber* from Thailand. They include *Z. pellitum* Gagnepain, *Z. junceum* Gagnepain, *Z. gramineum* Noronha ex. Blume., *Z. officinale*, *Z. villosum* I. Theilade, *Z. montanum*, *Z. corallinum* Hance., *Z. kerii* Craib, *Z. flavovirens* I. Theilade, *Z. parishii* Hook. f., *Z. peninsulare* I. Theilade, *Z. puberulum* Ridley var. *ovoideum* Holttum, *Z. petiolatum* (Holttum) I. Theilade, *Z. chrysostachys* Ridley., *Z. spectabile* Griffith, *Z. ottensii* Valeton, *Z. zerumbet*, *Z. larsenii* I. Theilade, *Z. barbatum*, *Z. bradleyanum* Craib, *Z. smilesianum* Craib, *Z. rubens*, *Z. wrayii* Ridley, *Z. newmanii* I. Theilade & Mood, *Z. longibracteatum* I. Theilade, *Z. affintegrum* Tong. Theilade and Mood (1999a) further reported 6 new species of *Zingiber* from Borneo *viz., Z. viridiflavum* J. Mood & I Theilade., *Z. chlorobracteatum* J. Mood & I Theilade, *Z. flagelliforme* J. Mood & I. Theilade, *Z. velutinum* J. Mood & I Theilade, *Z. phillippsii* J. Mood &

I. Theilade, *Z. georgei* J. Mood & I Theilade. Theilade and Mood (1999b) reported a new species of *Zingiber*; *viz., Z. collinsii* J. Mood & I Theilade.

Srivastava (1998) studied the Zingiberaceae in Andaman and Nicobar Islands and recorded 23 taxa under 10 genera and 5 species of *Zingiber* which includes *Z. odoriferum*, *Z. officinale*, *Z. spectabile*, *Z. squarrosum*, and *Z. zerumbet*.

Hajra *et al.* (1999) in *Flora of great Nicobar Island* reported 3 taxa under 3 genera of Zingiberaceae with *Z. zerumbet* as a single species under *Zingiber*.

Delin *et al*. (2000) described a new species of *Zingiber, Z. neotruncatum* T. L. Wu, K. Larsen & Turland in Chinese and Vietnamese Zingiberaceae.

Kumar (2001) listed the 53 taxa under 13 genera of Zingiberaceae plants from Sikkim. It includes *Zingiber capitatum*, *Z. clarkei*, *Z. chrysanthum*, *Z. rubens*, *Z. officinale*, *Z. zerumbet* and *Z. purpureum.*

Mohanan and Sivadasan (2002) in *Flora of Agasthyamala* recorded 12 taxa under 7 genera of Zingiberaceae and 3 species of *Zingiber viz., Z. neesanum*, *Z. wightianum*, and *Z. zerumbet.*

Kress *et al*. (2002) proposed a new infra-familial classification of the family Zingiberaceae, based on the evidences from molecular data. They recognized four subfamilies: Siphonochiloideae, Tamijioideae, Alpinioideae, Zingiberoideae and genus *Zingiber* is placed under Zingiberoideae.

Behura and Rout (2003) recorded diversity of Zingiberaceae plants in Orissa and included *Z. capitatum*, *Z. cassumunar*, *Z. officinale*, *Z. rubens* and *Z. zerumbet.*

Bhat (2003) in *Flora of Udupi* listed 16 species under 9 genera of Zingiberaceae and 3 species of *Zingiber viz., Z. neesanum*, *Z. officinale* and *Z. zerumbet.*

Manilal (2005) translated *Hortus Malabaricus*, on the plant wealth of Malabar, compiled by the then Dutch Governor of Cochin, Rheede, written in Latin and published from Amsterdam during 1678-1693, to English. Rheede was a keen observer of nature and was fascinated by the vast variety and richness of the local plants. He with the help of local Physicians, Colatt vaidyans, especially Itty Achuden of Carappuram, compiled Malayalam names, medicinal values of the plants, nature of illness, method of preparation of drugs and method of treatments. The book not only gives the socio-cultural conditions in the seventh century of Malabar, but also the ancient traditional ethno-medical knowledge of Malabar Physicians and the plants. It stands as the first comprehensive work on the flora of any tropical region of the world and occupies a pre eminent position in the field of world Botany and the medical traditions of indigenous people.

Nayar *et al.* (2006) enumerated 48 species under 9 genera of Zingiberaceae which includes 6 species of *Zingiber viz., Z. cernuum*, *Z. neesanum*, *Z. purpureum*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet*.

Tripathi and Singh (2006) revised the genus *Zingiber* in Northern India and reported *Z. capitatum*, *Z. chrysanthum*, *Z. rubens*, *Z. intermedium, Z. officinale*, *Z. zerumbet*, and *Z. montanum*.

Anil Kumar *et al*. (2005), in *Flora of Pathanamthitta* recorded 11 species under 5 genera, including 3 species of *Zingiber viz., Z. neesanum*, *Z. wightianum* and *Z. zerumbet.*

Morphology

Shah and Raju (1975) studied growth and branching behaviour of the rhizomes of *Zingiber officinale*, *Curcuma domestica* and *C. amada* Roxb. They noticed that in *Z. officinale*, fully matured branches are up to the fourth order and in the other two are upto the third order. Only *Z. officinale* show aerial shoots with nodes and internodes and negative geotropism and main rhizomes resemble its other branches, while in other two it is bulbous with smaller internodes.

Kam (1977) noted that flower opening in Zingiberaceae is acropetal and involves a ring like open-flower zone moving forward towards the inflorescence.

Bell and Tomlinson (1980) studied morphology and architecture of few rhizomatous plants and suggested that a particular pattern of configuration has certain advantages in substrate exploration and exploitation and they show highly organized and repetitive branching patterns.

Verma and Lal (1984) reported a lateral branch of 1 cm, on the peduncle of *Z. cassumunar* in the experimental garden of Botanical survey of India, Allahabad, Madhya Pradesh.

Mangaly (1989) studied morphology of the ovule and ovular appendages of 13 species under 7 genera of South Indian Zingiberaceae and found that ovular appendages occur in all except *Costus speciosus* and they originate as proliferations from integumental and funicular tissue.

Puri (1989) studied in detail the morphology and evolution of Monocotyledons and suggested that Zingiberaceae, Cannaceae, Musaceae, Cyperaceae, and Gramineae made their appearance in Cretaceous period.

Chirangini and Sharma (2005) studied the *in vitro* propagation and micro rhizome induction in *Zingiber cassumunar*.

Pollination biology

Sakai (2000) studied reproductive phenology of 117 individual plants from 20 taxa of Zingiberaceae and found that they are pollinated by either spider hunters (Nectariniidae), medium sized *Amegilla* bees (Anthophoridae) or small halictid bees (Halictidae). Many ginger species found to be reproduced more than once in a year, and share common pollinators. This may result in segregation of flowering times among species due to competition for pollinators.

Bhattacharya and Mandal (2000) studied the flower morphology, anthesis, pollen production, foraging nature of flower visitors, *in vitro* pollen germination and stigma receptivity of *Bombax ceiba* Linn. (Bombacaceae) and found the flowers as large with numerous stamens which open in post middle night and continue upto the morning. Anther dehisced after flower opening produced 8,8,63,000 pollen grains which are of 3-colporate, with reticulate ornamentation and thick exine. Pollen germination is 95% in 20% sucrose with 500 µg/ml H_3BO_3 solution and stigma receptivity is more at first day after anthesis, and no fruit setting was observed in netted and bagged flower, which strongly indicates that some external agents are required for successful pollination.

Dhamayanthi *et al*. (2003) studied pollen-pistil interactions and found stigmatic and stylar incompatibility exists in ginger cultivars which may contribute to the failure of sexual reproduction.

Zhang *et al.* (2003) studied the reproductive biology of *Alpinia blepherocalyx* from China and found that there are two floral morphs of the plant, which differ in flowering behaviour. Cataflexistylous morph in which the stigma is held erect above the dehiscent anther when anthesis begin in the morning and become curved under the anther at after noon and anaflexistylous morph in which receptive stigma is curved under the indehisecent anther first and moves into a reflexed superior position above the anther as it begins to shed pollen in the afternoon. The cataflexistylous flowers are larger than anaflexistylous flowers, especially in the labellum and corolla tube length; and pollen/ovule ratio of the two floral morphs is significantly different. Cataflexistylous morph has more pollen grains and fewer ovules than the anaflexistylous morph. The floral mechanism found in *Alpinia* appears to reduce self pollination within a flower and among flowers within inflorescences or an individual, thereby increasing pollen available for export to other individuals.

Gao *et al.* (2004) studied pollination ecology of *Curcumorpha longiflora* (Zingiberaceae) by monitoring phenology and flowering behavior, pollinator activity and the quality and quantity of pollination services and pollen germination. They found a new protandrous mechanism with a two day flowering to avoid autogamy and the taxa produce only one flower to keep geitonogamy to a minimum. Germination of pollen grains occurs after 4 hours of pollination shows *C. longiflora* is completely self-compatible. *Bombus* species and *Apis florae* were effective pollinators and active at different stages of the flower.

Deng *et al*. (2004) reported for the first time that the striped squirrel (*Tamiops swinhoei*) as the necter robber from *Alpinia kwangsiensis* T. L. Wu & S. J. Chen. in tropical forests of China.

Sigrist and Sazima (2004) studied the pollination and reproductive biology of 12 species of neotropical Malpigiaceae and found that the species are pollinator dependent and self pollination is limited by herkogamy, protogamy and the stigmatic cuticle and the pollen collecting behaviour of the pollinators favour the rupture of the stigmatic cuticle and deposition of pollen on or inside the stigmas.

Nyine and Pillay (2007) described a quick and reliable method for evaluating pollen quality by germinating banana pollen in sucrose solution and diluted banana nectar. Twenty banana accessions were used to evaluate pollen germination in the two media after 3 hrs. and 24 hrs. 19 genotypes showed significantly higher pollen germination potential (95%), in diluted nectar than in 3% sucrose solution. But certain accessions showed no significant pollen germination in nectar and sucrose. 11 genotypes (55%) showed significant increase in pollen germination by increasing the time of incubation, where as 9 genotypes (45%) were not affected by increase in incubation time. Nectar from different banana clones influenced pollen germination suggesting a genotype effect for pollen germination in *Musa* L.

Cytology and Genetics

Raghavan and Venkatasubban (1943) in their cytological studies of the family Zingiberaceae, worked out chromosome number and morphology of 25 species including *Z. officinale*, *Z. cassumunar* and *Z. zerumbet* and showed that 2n = 22. Sharma and Bhattacharya (1959) worked out Cytology of several members of Zingiberaceae.

Ramachandran (1968) investigated the cytology of 27 species under 11 genera of Zingiberaceae and lowest chromosome number was noted in South Indian plants of this family i.e., 2n = 22 in *Globba ophioglossa*, and in *Zingiber* species, highest 2n = 96 in *G. bulbifera* and found 2n = 25 in *Boesenbergia* and 2n = 21 for *Hitchenia*. He suggested that failure of seed setting in *Z. officinale*, may due to incompatibility and observed structural dihybridity in cultivated *Z. officinale* is by interchanges and inversions and *Z. macrostachyum* also showed evidence of heterozygosity for inversions.

Mahanty (1968) in a cytological study of Zingiberales determined chromosome number of 44 species and stated that the genus *Zingiber* should be included in the tribe Hedychieae. He suggested that haploid number 11 is the original basic number for the whole of Scitamineae and other numbers such as 9, 10, 12, 13, 14, 16 and 17 are secondary in origin.

Pillai *et al*. (1978) studied the flowering behaviour, Cytology and pollen germination in *Zingiber officinale* and found that only 14.5% pollen germinated in artificial medium.

Omanakumari and Mathew (1984) studied Karyomophology of 4 species of *Zingiber*, *viz., Z. officinale*, *Z. zerumbet*, *Z. wightianum* and *Z. macrostachyum*. Karyomorphological data indicate that except *Z. officinale*, where it is relatively symmetrical (IA), all other three species are moderately asymmetrical (2A). Chromosomal evolution show that this is a monobasic genus with x=11. Although the karyotypes of the four species showed general uniformity, in final details recognizable differences were noticed with regard to distribution of secondary constrictions and centromeric positions of a few individual chromosomes and stated that numerical and gross structural changes in Chromosomes have not played any major role in speciation and evolution of the genus.

Pandey and Dobhal (1993) studied 21 collections of *Zingiber officinale* for variability, character associations and path analysis for yield and its 10 component characters. Wide range of variability observed includes rhizome yield per plant was positively associated with plant height, number of fingers per plant, weight of fingers and weight of primary rhizome.

Ekomtramage *et al*. (1996) determined chromosome number of 10 species of Thai Zingiberaceae. Sasikumar *et al*. (1996) developed IISR Varada-a new high yielding ginger variety through germplasm selection. Santos and Cantoria (1996) studied the effect of the aqueous extracts of *Zingiber purpureum* on the mitotic chromosomes of *Allium cepa* L. and found that the extract caused some delay in the emergence of roots from *Allium* seeds and genotoxicity test on the extract using the *Allium* test is negative, indicating the absence of genotoxic constituent.

Das *et al*. (1998) studied the estimation of 4C DNA and karyotype analysis in *Z. officinale* and it revealed that the 4C DNA content and genome volume were positively co-related. Structural alterations in the chromosomes without changes in the numeric chromosome number (2n = 22) caused variations in the DNA amount at cultivar level. Marginal variations in the genome size indicated a close relationship between the cultivars.

Prasad *et al.* (1998) studied 15 cultivars of *Z. officinale* for variability and association of characters among themselves. It revealed that plant height, length of leaf, breadth of leaf, number of primary fingers, length and breadth of rhizome had positive and significant correlation with yield. A negative and significant correlation existed between yield and number of tillers. Raina and Gupta (2001) evaluated 11 cultivars of *Z. officinale* for morphological characters, rhizome yield and quality for cultivation in Jammu region.

Molecular studies

Smith *et al.* (1993) have done the phylogenetic analysis of the Zingiberales based on *rbcL* sequences and found the phylogenetic utility of *rbcL* sequence data for Zingiberals is limited to inter ordinal and intra familial relationships. According to them the order can be divided into two sister groups, one containing the Costaceae and Marantaceae and the other remaining six families; Cannaceae, Zingiberaceae, Heliconiaceae, Lowiaceae, Strelitziaceae, and Musaceae. All recognized families are monophyletic with the exception of Musaceae, which is paraphyletic with the Cannaceae. Clark *et al*. (1993) studied the phylogenetic relationships of the Bromeliflorae–Commeliniflorae-Zingiberiflorae complex of monocots based on *rbcL* sequence comparison.

Rout *et al*. (1998) determined the genetic stability of micropropagated plants of ginger using Random Amplified Polymorphic DNA (RAPD) markers. All RAPD profiles from micropropagated plants were monomorphic and no variation was detected within the micropropagated plants.

Tamura (2007) using *matk* and *rbcL* sequences from 113 genera of 45 families conducted an analysis of major evolutionary relationships in monocotyledons.

Anatomy

Solereder (1908) suggested the methodological employment of the micro-anatomical and micro-chemical characters of the vegetative and reproductive organs in systematic researches.

Bailey (1944), studied the development of vessels in Angiosperms and its significance in morphological research and suggested that vessels have originated independently in five distinct categories Tracheophytes viz. Selaginellales, Filicales, Gnetales; Monocotyledons and Dicotyledons. The irreversible phylogenetic trends in the origin and specialization of vessels are reliable and can be considered in various lines of botanical research.

Cheadle (1953) studied the origin of vessels in monocotyledons and dicotyledons and observed that vessels originated and specialized independently in both. In the dicotyledons vessels arose in secondary xylem, and late metaxylem, metaxylem and protoxylem in succession and specialized in the same sequence. In monocotyledons, vessels originated in roots, stems and leaves in succession and specialized in the same sequence. Vessels appeared in the later formed metaxylem first and later in the earlier formed metaxylem and protoxylem in succession.

Tomlinson (1956) studied 41 species of Zingiberaceae from the point of systematic anatomy. The two subfamilies, Costoideae and Zingiberoideae differ markedly in the anatomy of the lamina, petiole, and sheath, node in aerial stem, hairs and distribution of silica inclusion. The anatomical evidence for the separation of the two subfamilies is supported by evidence from vegetative, floral morphology, geographical distribution, pollen, seedling structure and cytology. The tribes within the Zingiberoideae can be distinguished only in the plane of insertion of the leaves and the type of silica in cell. Individual genus, however frequently show a characteristic anatomy. In1960, in the anatomy of *Phenakospermum* (Musaceae) he revealed that it may possibly be more closely allied to *Strelitzia* than to *Ravenala*. And suggested that the Musaceae have evolved from an ancestor with the vegetative habit of *Phenakospermum* and the inflorescence of *Ravenala.* Tomlinson (1961b) outlined the vegetative morphology of Marantaceae and suggested that there is no clear distinction between the Calatheae and Maranteae, although some of the individual genera may have similar structural diagnostic features. Tomlinson (1962) suggested that information on anatomy and floral morphology in the order Scitamineae makes possible very reasonable taxonomic sub-division and provides a logical explanation of the presumed phylogeny of the order.

Metcalfe (1959) based on anatomical studies have proved that the type of stomata, silica bodies, different pattern of sclerenchyma, leaf epidermis are of diagnostic value at the level of species rather than as indicators of broad taxonomic affinities.

Pillai *et al*. (1961) studied the root apical organization of the members of the Scitamineae. Zingiberaceae exhibit two types of structural configuration, one type has independent initials for cap and plerome and a common protoderm - periblem complex, while the other has common initials for all tissue.

Stebbins and Khush (1961) studied the variation in the organization of the stomatal complex in the leaf epidermis of monocotyledons and its bearing on their phylogeny. Plants with four or more subsidiary cells are common in phanerophytes with hypogeal germination and tropical distribution and plants with two subsidiary cells are primitive plants, hydrophytes or halophytes with tropical or temperate distribution and stomatal complexes without subsidiary cells are almost confined to Liliales. They concluded that the type with many subsidiaries is the most primitive and the other two types have been derived from it independently by reduction of the number of subsidiary cells.

Cheadle (1963) studied vessels in 68 species including 42 genera of Iridaceae from macerations. The vessels in roots are highly specialized except in tribe Aristeae. According to Banerji (1964) the study of the leaf and leaf taxonomy is very useful in identification of a taxon.

Ogura (1964) studied comparative morphology and classification of plants and opined that for natural or phylogenetic classification, it is necessary to assess all characters, not only from the morphological angle but also from cytology, genetics, ecology, biochemistry, geography, geology *etc*.

Dunn *et al*. (1965) studied stomatal patterns in dicotyledons and monocotyledons among 443 species under 152 genera in 96 families and found that the size of stomata in each species of monocotyledon was much more consistent than in the dicotyledons and may be used as a relative reliable character and in dicotyledons it was found to be a poor or inconsistent character.

Cheadle (1968) studied the vessels in Haemodorales, and point out that vessels are generally specialized in the late metaxylem and less so in the early metaxylem. Cheadle (1969) worked out vessels in 65 species of 36 genera of Amaryllidaceae and 6 species in 4 genera of Tecophilaceae and vessels were observed in roots and not in shoot systems and in Tecophilaceae vessels have only scalariform perforation plates.

Metcalfe (1969) classified the family Cyperaceae with the aid of anatomy. Sharma and Mehra (1972) studied the systematic anatomy of 14 species of *Fimbristylis* Vahl (Cyperaceae) and concluded that anatomical characters help in distinguishing the various species includes shape of subsidiary cells in surface view, dermal appendages, outline of blade and stem, adaxial epidermis and aerating canals.

Ghouse and Yunus (1972) worked out a method of preparation of epidermal peels from leaves of gymnosperms by treatment with hot, 60% HNO_3.

Ram and Nayar (1974) recommended a rapid method of obtaining epidermal peels in plants by treatment with Cupric sulphate and Hydrochloric acid. Wagner (1977) surveyed vessel types in monocotyledons and found that Zingiberaceae posses more advanced vessel types in roots than do the other families.

Paliwal and Anand (1978) suggested that features like cuticle, histology, stem anatomy, sieve elements *etc*. alone cannot be employed to raise a system of classification, but they have been of great help where knowledge from other disciplines has either failed or has created doubts.

Gupta and Dutta (1979) studied the concentration of veinlets (V.I) and veinlet terminations (V.T) in simple and pinnate compound leaves to find the order of distribution. The absolute veinlets and veinlet terminations in compound leaf is obtained by adding the absolute V.I and V.T numbers of all the leaflets of a leaf and it is also uniform in many species.

Rajagopal (1979) studied distributional patterns and taxonomic importance of foliar stomata and a new category 'astomatic' is recognized besides the terms epistomatic, hypostomatic and amphistomatic, and suggested that the stomatal distribution pattern along with other epidermal characters can be used as an important taxonomic tool.

Olatunji (1980) worked out the structure and development of stomata in 70 species of Zingiberales and found that paracytic, tricytic, tetracytic and polycytic stomata occur in Zingiberales and tetracytic stomata is common in Zingiberaceae and its mode of development to tetraperigenous.

Bell (1980) described the vascular pattern of stem *Alpinia speciosa* L., which shows scattered vascular bundles in two distinct zones - an inner system and an outer system, separated by a cylinder of undifferentiated tissues called intermediate zone, retaining the features of a meristem. The multiplicity of terminology applied to this zone in literature is classified.

Barthlott (1981) studied the epidermal and seed surface characters of plants and the cellular arrangement, shape of cells, relit of outer cell walls, epicuticular secretions mainly waxes and related substances can be applied in taxonomy.

Gopal *et al*. (1981) studied the epidermal structure and histochemistry of five monocot plants and found thick cuticle, sunken stomata, and low stomatal frequency and mostly closed stomata during day time. But *Tradescantia* spp. exhibits thin cuticle, normal position of guard cells, high stomatal frequency and mostly open stomata during day time.

Pridgeon (1982) surveyed anatomical features of 200 species in 22 genera of subtribe Pleurothallidinae (Orchidaceae) and found that vegetative characters are of diagnostic value and most systematically useful characters are associated with the leaf, trichome, cuticle, epidermis, hypodermis, spiral thickenings and number of vein series.

Dahlgren and Clifford (1982) enumerated the comparative study of vessels of roots, stems and leaves in monocotyledons and stated that Zingiberaceae lack vessels in leaves and roots have vessels with scalariform perforation plates.

Tomlinson and Wilder (1984) studied the systematic anatomy of Cyclanthaceae. Wilder (1985d) studied the anatomy of noncostal portions of lamina in the Cyclanthaceae, and found that stomata in inter ridge areas are most abundant in the abaxial epidermis, which exhibits stomatal bands and four basic kinds of interstomatal bands. He also studied the mesophyll, parenchyma cells, mesophyll fibres and parenchyma like dead cells in noncostal portions of lamina in Cyclanthaceae.

Dannenhoffer *et al*. (1990), studied vascular system of the *Hordeum vulgare* L. and categorized into three bundle types: small, intermediate, and large. Individual longitudinal strands intergrade structurally from one bundle type to another as they descend the leaf. At their distal ends, they have the anatomy of a small bundle. As they descend the leaf, most intergrade into intermediate bundle and then into large bundle types. All strands with large bundle anatomy extend basipetally into the stem. The other longitudinal strands, which do not intergrade structurally into large bundles, do not enter the sheath, but fuse with other longitudinal strands above the junction of the blade with the sheath. And despite the decrease in number of longitudinal bundles entering the sheath, an increase takes place in the total cross sectional area of sieve tubes and treacheary elements.

Bosabalidis *et al.* (1994) studied the ontogeny of the vascular bundles and contiguous tissues in *Zea mays* L. Aiken and Consaul (1995) noticed in the study of anatomical patterns of 30 taxa of *Festuca* of North America and found that the degree of sclerenchyma development varies with the age of a leaf and dryness of the environment and that plants growing on lime stone alvars had leaves with broad heavy brands of sclerenchyma, but the plants grown in an experimental garden developed leaves with small strands of sclerenchyma.

Stern *et al*. (1994) studied anatomy of the thick leaves in *Dendrobium* Section *Rhizobium* (Orchidaceae). Anatomical data support the monophyly of section *Rhizobium*, and the unifacial-leaved species constitute a distinctive clade in within the section.

Remashree *et al*. (1997) carried out histological studies on rhizomes of *Z. officinale* and the vascular patterns showed inner zone and an outer zone separated by intermediate layers. Vascular bundles are collateral and scattered. Starch grains, oil cells and canals were present both sides of intermediate zone. They also noted that the meristematic layer in between the cortex and central cylinder consists of the fusiform and ray initials. Remashree *et al*. (1999) studied development, distribution and structure of oil cells, development of secretory ducts and diffusion of oil in ginger rhizomes. Oil cell differentiation initiate from a group of meristematic cells, and present in leaf, shoot apex, root apex, and contain stored volatile oil. Schizogenously developed ducts were found in primary tissues and lysigenously formed ducts were found throughout the developmental stages.

Hussin *et al*. (2000) studied the leaf anatomy of *Alpinia* from China and noticed that there is interspecific variation in the structure of the leaf midrib and petiole and can be used for species identification. Hussin *et al*. (2001) also studied leaf anatomical variations between species of *Boesenbergia* and *Kaempferia*. Results show that there are variations in the type of stomata, anatomy of midrib, petioles, outlines of leaf margin, hypodermis and trichomes in lamina. Das *et al*. (2004) studied foliar morphology and anatomy of *Curcuma longa*, *C. caesia*, *C. amada* and *Kaempferia galanga* of Zingiberaceae. Macro-as well as micro-morphological and anatomical features of distinctiveness for each species has been revealed so as to contribute towards their taxonomy and pharmacognosy.

Prychild *et al*. (2004) studied distribution and diversity of opaline silica bodies in monocotyledons in a phylogenetic frame work and economic applications of these cell inclusions.

Jayasree (2007) studied morphological and anatomical characters of South Indian Zingiberaceae including 7 taxa of genus *Zingiber*, reported the presence of pulvinus and collenchymatous bundle sheath in the pulvinus as unique feature of the genus.

Maksymowych *et al*. (1983) worked out structure and distribution of vascular bundles in petioles of 28 herbaceous and woody dicotyledons. No single pattern of vascular bundle distribution could be found for both groups of plants. The total number of xylem vessels in herbaceous and woody plant petioles varied between 110–1756 based on anatomical and morphological features.

Kotresha and Seetharam (1995) reported paracytic, anomocytic, tetracytic, and anisocytic stomata in species of *Bauhinia* L.

Palynology

Erdtman (1952) published many extensive studies of different taxa and introduced the technique of pollen preparation by acetolysis.

Vishnu - Mittre (1964) described evolutionary trends in pollen groups and pollen morphology with regards to terminology and the morphology of pollen grains and problems of academic and applied interests which depend upon the co-operation of diverse discipline of science.

Skavarla and Rowley (1970) studied pollen wall of *Canna* and its similarity to the germinal apertures of other pollen. Although the pollen wall of *Canna generalis* Bailey is exceptionally thick, only a minor part of it contains detectable amounts of sporopollenin. According to them, the entire pollen wall of *C. generalis* is similar to the thick intine and thin exine typical for germinal apertures in many pollen grain types.

Southworth (1974) studied the solubility of pollen exine of *Ambrosia trifida* and found that it is insoluble in organic and inorganic acids and bases, lipid solvents and detergents and only soluble in fused Potassium hydroxide in strong solutions and in certain organic bases. The outer exine of gymnosperms and angiosperm pollen dissolves in 2 – aminoethanol.

Kress *et al*. (1978) studied the pollen of *Heliconia* and many of its relatives in the Zingiberales and they are virtually devoid of a conspicuous, protective exine.

Stone *et al*. (1979) observed that pollen of *Heliconia* and most of its Zingiberaceous relatives are destroyed by the standard acetolysis preparation and the fragility of the grain is the result of the weak exine development and sporopollenin deposition. According to Zavada (1983) pollen morphology of Zingiberaceae is poorly understood and several taxa remain palynologically unknown.

Kress and Stone (1983) studied pollen morphology of 27 species of *Heliconia.* Pollen of species with erect inflorescence has many character states in common with pollen of pendent species. Among the species with pendent inflorescences four groups can be distinguished by pollen features.

Zavada (1983) studied the comparative morphology of monocot pollen and evolutionary trends of aperture and wall and suggested that the evolutionary trends of pollen apertures and wall structure in the monocot is parallel to those proposed by Walker (1976) in dicots. Pollen of

Zingiberaceae is generally inaperturate except in *Zingiber,* where it is monosulcate and exine sculpture is spinulose or psilate.

Stone (1987) found that *Sassafras* and *Heliconia* have inaperturate pollen with a highly reduced exine and thick channeled intine. The ontogenetic basis for this wide spread convergence in pollen structures is simply a reduction or deletion of exine and a correlated elaboration of intine deposition.

Meerow and Dehgan (1988) studied pollen morphology of Eucharideae (Amaryllidaceae) and found that Pollen grains are elliptic monosulcate, semitectate - columellate and reticulate.

Liang (1988) studied pollen types and their significance in taxonomy in 8 species of *Zingiber*. The species of sections *Zingiber* and *Dymczewiczia* showed spherical grains with cerebroid sculpturing while pollen of section *Cryptanthium* with spiro-striate sculpturing.

Mangaly and Nayar (1990) studied palynology of 21 species of Zingiberaceae of South India. It includes *Alpinia* Roxb., *Amomum* Roxb., *Boesenbergia* (Wall.) Kuntze, *Costus* L,, *Curcuma* L., *Elettaria* Maton, *Globba* L., *Hedychium* Koenig and *Zingiber*. Exine is absent only in *Kaempferia* L. Pollen grains are spheroidal in *Globba ophioglossa* Wight and inaperturate except in *Curcuma* and *Zingiber*, where grain is ellipsoid and sulcate. A lamellated intine occurs in all, and it is thinner at the aperture region in *Curcuma, Costus* and *Zingiber*. They found that *Alpinia*, *Amomum*, *Boesenbergia*, *kaempferia* and *Zingiber* constitute one group and *Elettaria*, *Hedychium* and *Costus* constitute another palynologically.

Kronestedt and Rowley (1989) studied the pollen grain development and tapetal changes in *Strelitzia reginae* (Strelitziaceae). The proexine that forms within the callosic envelope before the end of the microspore tetrad period is thick (1µm) and exceptionally complex. It has components equitable with tectum, columellae and a nexine that includes lamellar zones. All these components persists in the exine though late in development they become difficult to recognize because the exine is reduced in thickness, apparently by stretching to a maximum of 0.2 µm. *Strelitzia* is an example of an exine template with receptors for sporopollenin that is not maintained during development.

Yunus (1990) examined pollen surface configuration of 13 species under 4 genera of the family Malpighiaceae using SEM. Periporate pollen occurs in all the taxa except *Tristellateria australasiae* A. Rich., which has been considered as advanced than the primitive tricolporate condition.

Ambwani and Kumar (1993) worked out pollen morphology of three species of *Pseudophoenix* (Arecaceae) viz., *P. vinifera* (Mart) Becc., *P. ekmanii* Burret., and *P. sargentii* H. Wendl. ex Sarg. under Scanning Electron Microscope and found that in *P. vinifera* pollen is bisulcate, trochotomus, sulcus completely extends up to the margin and has larger pollen than other two, but trichotomonosulcate aperture doesnot extend along the total radius of the pollen. The aperture in *P. sargentti* is of uniform width but becomes narrow in the central part in the pollen of *P. ekmanii*. On the basis of the pollen morphology different species of *Pseudophenix* can be distinguished.

Poston and Nowicke (1993) studied pollen morphology, trichome types and relationships of the Gronovioideae (Loasaceae) with the help of LM, SEM, TEM and closely related species *Gronovia*, *Fuerteria* and *Cevallia* were distinguished by pollen characters as well as specialized trichome types.

Theilade *et al*. (1993) have found two types of pollen grains in genus *Zingiber*; i.e., ellipsoid with spiro-striate sculpturing and spheroidal with cerebroid sculpturing. So on the basis of pollen morphology the section *Dymczewiczia* should be included in section *Zingiber* which shows same pollen characters.

Theilade and Theilade (1996) noticed that in *Zingiber spectabile*, microspores develops a thick primexine whereas the mature pollen exhibits an extremely thin and discontinuous exine. The development of a channeled intine was initiated after the disintegration of the callose wall, when the microspores had entered the free stage. It reached maximum thickness in the late microspore period after which it decreased in thickness. A thin inner intine was found and an electron dense material appeared in the channels of the outer intine. Thus the general pattern of sporoderm development is similar to that observed in other members of Zingiberales.

Nayar (1996) studied the pollen morphology of Zingiberiflorae with particular reference to the nature of the pollen wall in 29 species of Zingiberales and showed that the characteristic medine in this group is in fact the modified inner most region of exine and the protoplasmic membrane layer is the true intine. Distinct apertures occur in the medine layer and the "protoplasmic membrane" layer of majority of taxa, so that they cannot be classified inaperturate. Evolutionary trends in apertural condition were also are discussed.

Kirpes *et al*. (1996) studied the systematic significance of pollen arrangement in microsporangia of Poaceae and Cyperaceae.

Rudall *et al.* (1997) studied cladistic analysis of *rbc*L sequences and found that it supports the interpretation of simultaneous microsporogenesis for Asparagales and in higher Asparagoid clad microsporogenesis is entirely successive; and lower asparagoids it is mainly simultaneous. The trichotomonosulcate pollen, a characteristic feature of lower Asparagoid clade is associated with simultaneous microsporogenesis and trichotomonosulcate pollen with the DNA tree can be taken as an indication of the reliability of both for taxonomic revision of family limits.

Christine *et al*. (1996) conducted a survey to determine the taxonomic distribution and possible phylogenetic significance of pollen arrangement. In a small number of taxa in Poaceae and Cyperaceae, a single, uniseriate cylinder of pollen grains is arranged in the anther locule such that each grain is in contact with the tapetum.

Furness and Rudall (1999) recognized two types of microsporogenesis among monocotyledons *viz*; successive and simultaneous. Successive and simultaneous microsporogenesis is predominant though intermediate also occur. Successive microsporogenesis is present in Zingiberaceae. Furness and Rudall (2001) studied the importance of pollen and anther characters like tapetum type, microsporogenesis and inaperturate pollen in higher level systematic of monocotyledons.

Wichelen *et al.* (1999) studied the systematic value of pollen grains in Cyperaceae by LM and SEM. Sclerioideae and Caricoideae show a similar pollen grain type while in the Cyperoideae a different pollen grain types were found.

Kosenko (1999) studied pollen morphology and taxonomy of 34 species and 7 genera of Liliaceae. The genera *Tulipa* and *Lilium* are heterogenous in both aperture type and exine ornamentation. The other genera are homogenous in possessing a single longitudinal aperture. Pollen morphological data support the division of the family.

Ahmad *et al*. (2001) discussed difference in morphological characters and its taxonomic implications in pollen of 13 species of Guttiferae in which pollen grain characters like shape, aperture, exine ornamentation and puncta are considered.

Cooper *et al*. (2000) reported aperture like region on the pollen grain of some species of *Callitriche*. Harley and Baker (2001), studied pollen aperture morphology in Arecaceae and cladistic analysis of Arecaceae have worked out.

Dhamayanthi *et al*. (2003) studied the structure and development of male and female gametophytes of *Z. officinale* and found that stigmatic and stylar incompatibility was predominant in ginger cultivars and the failure of sexual reproduction may be due to the stigmatic and stylar incompatibility.

Wang *et al*. (2004) studied 37 species of family Zingiberaceae and found 33 had starchy pollen and 4 species without starch and only one species with lipid. Wang *et al*. (2005), while studying self pollination by sliding pollen in *Caulokaempferia coenobialis* K. Larsen. (Zingiberaceae) noticed that pollen grain being held together by pollen connecting threads and this is the first report of such threads in the Zingiberaceae. Wang *et al*. (2005) studied self pollination by sliding pollen in *Caulokaempferia coenobialis* (Zingiberaceae), which produces few consequently opening bright yellow flowers that are 3 cm long and oriented parallel to the ground. At the time of anther dehiscence each pollen sac releases a drop of pollen onto the horizontally oriented style, and the two drops then emerge to form an oily film that slowly flows toward the stigma, carrying out self pollination. The automatic selfing by pollen that reaches the stigma about 9 hrs. after the onset of anthesis apparently constitute a case of delayed selfing, providing reproductive reassurance in situations of low pollinator visitation.

Friis *et al.* (2004) reported characters like inaperturate, striate, pollen of *Mayor portugallica* from the early cretaceous of Torris Vedras in the Western Portuguese Basin. It forms strong evidence on the emergence of monocotyledons from the early cretaceous. Among monocots inaperturate pollen with predominant striae occur in both Araceae and Zingiberaceae.

Zona (2001) examined pollen from 149 taxa of Commelinoid monocots qualitatively for starch as the primary storage product and found that starchy pollen appears to be a characteristic feature.

Harley and Baker (2001) studied pollen aperture morphology in Arecaceae with emphasis on phylogeny found that majority of species have monsosulcate pollen, 17 aperture types and 13 exine type with both successive and simultaneous cytokinesis.

Mondal (1987) studied the morphology of some species of *Desmodium* Desv. from different phytogeographical regions of India, with the view to estimate the variation in palynological characters with the variable ecological conditions of the plant.

Phytochemistry

Mathai (1975) studied seasonal accumulation of chemical constituent in seven *Z. officinale* varieties and trends in oleoresin accumulation using Ethyl alcohol and Acetone as solvents. Varieties exhibited a reduction in the amount of oleoresin with increase in maturity and alcohol showed better oleoresin extraction capacity than acetone.

Oliveros (1996) worked out the main constituent of the volatile oil of *Z. purpureum*. Terpinen 4-0l is most stable at pH 7 and temperature ranging from 23^{o}C-60^{o}C. Zingisol and zingiment have the antibacterial and antifungal activities and it can be used as an alternative medication in cases were skin infection are caused by strains that have developed resistance to antibiotics available in the market. Volatile oil from rhizome contains terpinen-4-ol, which is used as folk medicine for the treatment of asthma, rheumatism, diarrhoea, cough and skin diseases.

Sreekumar *et al*. (1999) developed a new commercially viable technology for recovery of ginger oil with fresh flavour from fresh rhizomes of *Z. officinale.*

Bordoloi (1998) studied essential oils of the leaf and rhizome of *Z. officinale* by gas chromatography and found the major compounds such as Zingiberene (16.05%) and geranial (12.50%) geranyl acetate (11.42%) geraniol (9.05%) in rhizome and 14-hydroxy–9–epi-(E) caryophyllene (35.74%) geranyl acetate (10.60%) geranil (0.2%), geranial (8.78%) Caryophyllene oxide (8.60%) in leaf while sesquiphellandrene (6.11%), bisabolene (5.50%), camphene (5.46%) and (E, E)-9 farnesene (5.00%) are found in rhizome oil only.

Nishimura (2001) studied the fresh rhizomes of *Z. officinale* using multidimensional GC system in Japan and revealed that linalool, 4-terpineol, isoborneol and borneol are present.

Fakim *et al*. (2002) studied the chemical composition of the essential oils obtained from the hydrodistillation of the rhizomes of *Z. officinale*, *Hedychium coccineum* (Buch-Ham.) *ex* Smith, *H. flavescens* Carey *ex* Roscoe and *H. coronarium* Koenig by GC and GC/MS. Oil of *Z. officinale* was characterized by the presence of geranial (16.3%), neral (10.3%), zingiberene (9.5%), β-sequiphellandrene (6.3%), and ar-curcumene (5.1%).

Pino *et al*. (2004) studied the chemical composition of the essential oil obtained from the rhizomes of *Z. officinale* by combined GC and GC/MS. The oil was characterized by the presence of ar-curcumene, zingiberene, β-bisabolene and cadina-1, 4 diene.

Sabulal *et al*. (2006) isolated oil from the rhizomes of *Z. nimmonii* and studied GC and GC-MS analysis. Major oil constituents are β-caryophyllene and α-humulene (α-caryophyllene as of isocaryophyllene. Oil contained 71.2% sesquiterpenes, 14.2% oxygenated sesquiterpenes, 8.9% monoterpenes, and 1.9% oxygenated monoterpenes and 1.3% non-terpenoid constituents. The oil also showed inhibitory activity against certain fungi and bacteria. Sabulal *et al*. (2007) worked out the oil constituents of *Z. neesanum* by GC and GC-MS. Major compounds are phenylbutanoids (E)-1-(3', 4'-dimethoxy phenyl) butadiene an anti inflammatory compound, (E)-1-(3'4'-dimethoxy phenyl) but-1-ene and (E)-β-ocimene, β-pinene and linalool are major terpenoid constituents of rhizome oil.

Phenetics

Sneath and Sokal (1973) enumerated a new method for classification of organisms based on similarities and can be utilized in clustering and to establish a phylogenetic or diagnostic system and many other fields of endeavour.

Sahu (1991) studied 21 taxa of *Vernonia* in India by numerical analysis. 27 characters were studied of which 15 are qualitative and others quantitative. Cluster analysis shows that the species fall under four different groups.

Gajurel *et al.* (2002) studied 32 characters of 18 taxa of *Piper* occurring in Arunachal Pradesh by cluster analysis. It was carried out using weighted pair group percent disagreement, and dendrogram was constructed. It revealed that the species of the region fall under 6 distinct clusters under two broad sections each consists of 3 clusters. Species of each cluster show close inter-specific relationship with more than 50% similarity among them, and the result indicated that the species of Indian *Piper* could be grouped into two sub-generic sections.

Pharmacognosy

Datta and Mukerji (1950) studied pharmacognosy of Indian root and rhizome drugs including *Curcuma*, *Alpinia galanga* (L.) Sw. and *Z. officinale*. They have a stimulant and carminative effect and can be given in dyspepsia and flatulent colic. A hot infusion of ginger known as ginger tea is considered to have diaphoretic effect upon colds.

Prakash and Mehrotra (1996) discussed the importance of rhizome of *Z. officinale* for cough, bronchitis, asthma, heart, abdominal troubles, piles, elephantiasis, scorpion sting, snake bite, appetizer, stomachic, aphrodisiac, carminative and its uses as spice, condiment and preservative. Rhizome of *Z. montanum* is given in diarrhoea, colic etc. and can also be used as a stimulant, carminative, flavoring agent and an antidote to snake bite. Rhizome of *Z. roseum* is used in cold, cough and rheumatism. *Z. zerumbet* rhizome is given in cough, asthma, stomach ache, vermifuge, leprosy and other skin diseases and also used as substitute for true gingers. Jain and Shukla (1996), studied psychoactivity among zingiberaceous genera like *Kaempferia galanga* L. and *Z. officinale*.

Suvachittanont and Kasisadapan (1996) noticed the ability of ginger to remove or inhibit the production of superoxide free-radical by superoxide dismutase (SOD) enzyme present in young, old, cooked or raw, freeze or dried powder.

Srivastava (2003) conducted pharmacognostic studies on *Z. zerumbet* and found that the plant can be employed to cure various diseases and possess a number of biological activities

Thankamani *et al.* (2005) described the medicinal uses of chillies, ginger and turmeric.

Kuruvilla *et al.* (2004) described the uses of *Z. officinale*, as great natural preservative, digestive, relieving nausea and vomiting associated with pregnancy, low blood pressure and useful in keeping cholesterol levels under control, antinflammatory and also remedy for influenza.

Ethnobotany

Joshi (1989) described an account of the plants used in ethnomedicine, which includes *Z. officinale.* Brahmam and Saxena (1990) in ethnobotanical studies in Gandhamardan hills of Orissa noted *Z. capitatum* and *Z. montanum* are used as folk medicines.

Borthakur (1993) reported 13 native plant remedies used among different ethnic groups of Assam, includes *Z. officinale* to relieve labour pain and to facilitate child birth. Jain (1995) studied ethnobotanical diversity among zingibers in India.

Riswan and Setyowati (1996) studied traditional uses and distribution of genera and species of Zingiberaceae in Indonesia based on field and literature survey.

Sen and Batra (1997) in the study of Ethno-medico-botany of household remedies of Phagi and Tehsil of Jaipur district of Rajasthan noticed *Z. officinale* as remedy for abdominal pain and vomiting.

Rajendran *et al*. (1997) while studying rare and noteworthy plants of the Eastern Ghats in Andhra Pradesh reported the use of *Z. zerumbet* by the tribes for muscle pain and stomach pain.

Yusuf *et al*. (2002) studied the ethnobotanical uses of zingibers in Bangladesh *viz., Z. officinale, Z. purpureum* and *Z. zerumbet.*

Sabu and Skinner (2005) gave an account of other economically important species of *Zingiber* besides *Z. officinale*.

AREA OF STUDY

The present study area covers the states Andhra Pradesh, Karnataka, Goa, Tamil Nadu, Kerala and Union territories of Mahe and Pondicherry (Plate.1). The region stretches between 8^{o} and 18^{o}N latitude and east-west between 72^{o} and 8^{o}E longitudes. Geographically it can be divided into 4 major divisions 1) the mountain region in the east and west. 2) The undulating midlands with hillocks. 3) The northern plains and 4) the sloping coastal strips. The area consists of a wide variety of habitat, laterite hills and valleys, swamps, marshy low lands, sandy sea coasts, fresh water rivers, ponds, back waters and harbours diverse types of vegetation. The Peninsular India is flanked by the Bay of Bengal on the east, the Arabian Sea on the west and the Indian Ocean on the south.

Western Ghats and Eastern Ghats comprise the main mountain systems in South India. Western Ghats runs along the western border of the Deccan Plateau, about 1600 km long, with an average height of 1200 meters. It forms a barrier against North west monsoon, which helps to precipitate on the west coast. South-west monsoon and North-east monsoon form the two rain-bearing winds. South-west monsoon is dominant over Kerala and Karnataka. North-east monsoon is comparatively weaker in southern states. Before the south-west monsoon, there are intermittent rains in April-May. Rhizomes start producing vegetative shoots during the onset of the monsoon.

Climate

The climate of India may be broadly described as tropical monsoon type. The meteorological department of India recognizes four seasons *viz.* 1) summer 2) monsoon 3) post monsoon and 4) winter (Murthy *et al*. 1996).

Summer Season

The summer season prevails March to May, during this season most of the lakes and rivers in the Peninsular India either dry or shrink. Average temperature around is 32-40˚C. During this period most of the gingers remain under the soil as rhizomes.

Monsoon

The south-west monsoon winds enter the South Indian Sea towards the end of May or the beginning of June. It divides into Arabian Sea branch and Bay of Bengal branch. The Arabian Sea branch of the South-west monsoon first hits the Western Ghats of the coastal states. This branch of the monsoon moves northwards along Western Ghats giving rain to the coastal areas West of Western Ghats. The Eastern parts of the Western Ghats do not receive much rain from this monsoon as the wind does not cross the Western Ghats. The Bay of Bengal branch of South-west monsoon causes rain to North-east India. It gives heavy rains in the coastal and the Western Ghats. During this season, cloudy skies cause temperature to fall a little, but humidity rises to its maximum for the year. In *Zingiber* flowering period is very short and associated with rainy season. Flowering takes place along the onset of south-west monsoon in *Z. cernuum*, *Z. zerumbet*, *Z. nimmonii*, *Z. neesanum, Z. montanum* and *Z. roseum* and in *Z. officinale* in between September-November*. Z. capitatum* var. *elatum and Z. wightianum* flowers during the south-east monsoon and subsequently fruiting also occur.

Post-monsoon

The south-west monsoon begins to withdraw from India by the first week of October. The retreating South West Monsoon winds are replaced by North-east monsoon winds. Around September, with the Sun fast retreating South, the Northern land mass of the Indian sub continent begins to build over northern India. The Indian Ocean and its surrounding atmosphere still hold its heat. This causes cold wind to sweep down from Himalayas and Indo-Gangetic plain towards the vast spans of the Indian Ocean South of the Deccan Peninsula. This is known as the North-east Monsoon or retreating Monsoon.

Winter

Winter commences more or less by the end of November and continues till the end of February. Once the Monsoon subsides, average temperatures gradually fall across India. In South India somewhat cooler weather prevails and temperature reaches 16˚ C-10 ˚C. The Western Ghats including the Nilgiri Range, the temperature fall below freezing. In the coastal areas, the Indian Ocean exerts a strong moderating influence on the weather.

Temperature

Temperature is the intensity of heat and it decrease from equator to poles. The factors such as latitude, altitude, humidity and winds have influence on the temperature. In coastal areas Bombay on the West Coast has an average temperature of 30.5^{o} C, while Chennai on the east coast goes up to 33.4^{o} C. The effect of altitude varies with conditions; a rise in the hills of 1000 m, there is roughly a fall of 6^{o} C in temperature. Thus hill stations, coastal areas and plateau regions have differencing temperature conditions. The mean maximum temperature during coldest months of December to January is about 27^{o} C and minimum 24^{o} C in the extreme south. In summer season it is around 40^{o} C.

MATERIALS AND METHODS

Taxonomy

All taxa under the study were collected from different regions of South India. Field observations such as habitat, frequency, association of vegetation, habit, colour and odour of plants and plane of distichy of leaves were noted in the field book. Underground parts such as rhizome, roots and root tubers were collected. The rhizomes and plants from different collection area were planted in the Calicut University Botanical Garden for continued observations. Vegetation and flowering twigs were pickled in 50% Formaldehyde-Acetic acid-Alcohol solution (FAA) in the field and stored for further studies. Specimens were identified with the help of Floras, Revisions and Monographs and also referred to experts for accurate identification. Drawings were prepared with the help of Camera Lucida. The nomenclatural corrections were made according to latest ICBN (Mc Neill, 2006) and for abbreviation of periodicals, the BPH (Lawrence, 1968) is followed. Brumitt and Powell (1992) is followed for the abbreviation of authors. The types and authentic materials available in Central National Herbarium (CAL), Kolkata and Madras Herbarium (MH) at Coimbatore were studied. A full set of voucher specimens used for this investigation is deposited in the Herbarium of Calicut University (CALI).

Morphology

Plants and rhizomes from different locations were planted in Botanical garden for morphological study. Rhizomes start growing with the onset of South-west Monsoon. Flowering period is very short from May to December, and associated with rainy season. Habit, nature of spike, flower, leaves, ligule, and trichomes were noted, close observations were made by a hand lens. Under ground parts such as rhizome, roots, root tubers were taken out after flowering and fruiting period. Nature of the rhizome, colour, and size were noted. Plant parts were pickled in 40% formaldehyde for further observations.

Anatomy

Specimens of 9 species of *Zingiber* and samples / accessions from different locations were studied. Plant parts like epidermis of leaves, foliar anatomy of stem, rhizome, and root were studied (fig. 1). Fifth leaf from the tip is taken for the study. Middle portion of the leaves were taken for the preparation of epidermal peelings with the help of scalpel. Characters like size and shape of epidermal cells, stomata, trichomes, etc. were observed with Magnus MLX, Compound microscope with magnifications 10x, 40x and 100x. Ocular micrometer was used for all measurements and calculations were made by calibrating with stage micrometer. Stomatal Index was calculated (Salisbury, 1927) on the basis of average value from 10 readings.

$$\text{Stomatal Index} = \frac{\text{No. of Stomata}}{\text{No. of Stomata + Epidermal Cells}} \times 100$$

Free hand sections of the leaf sheath, pulvinus, midrib, lamina and leaf margins were taken for anatomical studies. Sections were stained with safranine and observed under microscope for details. Sections of stem were taken from 5 cm above the ground level. Rhizome sections were stained in safranine and the occurrence of starch grains, their size, shape and oil cells were studied. In roots, nature of the cortex, presence of starch grains and other inclusions were noticed. To study the xylem elements, maceration of stem, root, petiole, and rhizome were done according to Jeffrey's method (Johansen, 1940).

Photographs of epidermis (both adaxial and abaxial), transverse section of leaf, margin, pulvinus, midrib, leaf sheath, stem, rhizome and roots were taken with the help of Nikon Trinocular Microscope Eclipse-E-100. Image analyzer and Sony Digital camera (DSC 7.6) attached to Zeiss stemi DV4 Stereo microscope.

Stomatal development

Young developing leaves were collected for study of stomatal development. The young leaves, which were rolled inside the concentric layers of leaf sheaths, were dissected out after slashing the stem into longitudinal halves. Small portions of the young leaves were cut and fixed in alcohol-acetic acid-mixture (3:1) for six hours. The leaves were crushed on a slide and mounted in 1% acetocarmine solution and warmed on a hot plate.

When cooled, the slides were sealed with nail varnish and observed after 4-6 hours. Drawings were made using camera lucida attached to a trinocular compound microscope (Olympus CX21FS 1 model).

Cytology

Root tips of 8 species were taken for cytological studies. Roots were obtained between 10.30-12.30 a. m. Roots were pretreated in a saturated aqueous solution of Para-dichloro benzene (Sharma & Mookerjee, 1955) for two hours at 6-8^{o} C. Then they were fixed in (3:1) acetic-alcohol for 45 minutes. The materials were then hydrolyzed and stained in a mixture of 2% Acetocarmine-Haematoxylin (9:1) by heating over a flame for a few seconds. Smearing was done in 1% acetocarmine solution and slides were sealed with paraffin. They were observed under Trinocular compound microscope. Photographs were taken with Nokia camera (model Nikon COOLPIX 5000) attached to Compound microscope (Olympus CX21FS 1 model).

Palynology

Flowers of plants from different locations were collected for pollen studies. As the flowers are fleshy and very delicate, they wither and crumble very soon after collection, rendering them unsatisfactory for pollen studies. Excised anthers were preserved in the labelled vials at the time of collection itself. Anthers were preserved in Formalin-acetic-alcohol or directly in 70% Ethyl alcohol. Direct mounting method was adopted since common acetolysis method was found unsuitable. The pollen wall of *Zingiber* is non-resistant to acetolysis and dissolves off when treated with the acetolysis mixture. Before standardizing the direct mounting method as described above, test experiments were conducted to prepare the pollen materials by acetolysis method (Erdtman 1952, 1966). Preparations were also made after treatment with 70% ethyl alcohol and staining with safranine. The pollen wall did not take any appreciable stain, so staining with safranine was not found to have the desired effect on pollen wall for observation.

After preservation in 70% alcohol it was further subjected to ethanol dehydration series for 30 minutes, two changes in 90% alcohol and also in absolute alcohol. Then it was subjected to critical point drying by using Model 03E-1210, Hitachi make HCP-2. Then it was coated with Gold-Palladium in Hitachi make ion sputter E-1010 (with Au - Pd target assembly). Photographs of pollen grains were taken with Scanning electron microscope of Hitachi make S-2400.

Phytochemistry

The fresh rhizomes were washed thoroughly, sliced into small pieces, dried under shade, weighted and subjected to hydro-distillation in a Clevenger- type apparatus for 4-5 hrs. The steam volatile oil that condensed with graduated arm of the apparatus was measured and collected. The percentage of yield of the oil was calculated on dry weight basis *i.e.*, oil yield in ml/100 g of dried rhizomes. The collected oil was dried over anhydrous Sodium sulphate and stored at 4-5^{o}C in a refrigerator for further analysis.

Oil stored was subjected to Gas chromatography and Mass spectrometry (GC-MS) for identifying and quantifying target compounds at trace levels (Sabulal et al., 2007). It was performed into D-DB_5 (USA) at 75 eV and 250°C. The column conditions used were HP_5 (HDB_5) fused silica capillary 0.32 mm x 30 m with film thickness, 0.25 μm. The carrier gas was Helium and length of the column was 30 m, flow rate 15 ml/min. The temperature programmed was initially 60°C for 1 minute and then heated at the rate of 3°C to 280°C. Running time was 73.33 min. The components were ascertained with the help of Wiley Library 275 combined with the analyzer.

Molecular studies

RbcL (ribulose 1, 5- biphosphate carboxylase/ oxygenase) is a gene located in the chloroplast of photosynthetic organisms. It codes for large subunit of the protein rubisco, and its sequence has been used in plant phylogenetics.

Tender leaves of *Zingiber* species from different locations in South India were used for the studies. Cellular genomic DNA was isolated from 100 mg of tender leaf tissues using the GenElute™ plant genomic DNA Kit (Sigma, USA) following manufacturer's instructions.

About 1 μl of the genomic DNA isolated from 100 mg of leaf tissues were subjected to electrophoresis (Electrophoresis is the motion of dispersed particles relative to a fluid under the influence of an electric field that is space uniform) on a 0.8% agarose gel containing 500 ng/ μl of Ethidium bromide. After the electrophoresis, the gel was viewed over a UV Transilluminator (Bio Imagine Systems), for viewing DNA / RNA in agarose gels stained with Ethium bromide, and the quality and quantity of the DNA was assessed by comparison with a sample of known DNA concentration. The DNA was diluted to 10 ng/μl and stored at 4° C as working solution while the stock DNA was stored at -20° C in aliquots (a portion of a total amount of solution).

Oligonucleotide primers, which consist of a short polymer of two to twenty nucleotides, were designated for PCR amplification (polymerase chain reaction) of the corresponding sequences from *Zingiber* species. PCR amplification is a technique for amplifying DNA sequences *in vitro* by separating the DNA into two strands and incubating with oligonucleotide primers and DNA polymerase. A specific sequence of DNA can be amplified by as many as one billion times. The sequence of forward primer designated rbclF was: ATGTCACCACAAACAGAAACTAAAGCAAGT while that of reverse primer designated rbclR was: CTTCACAAGCAGCAGCTAGT TCAGGACTCC. PCR amplification was carried out in a final volume of 20 μl containing 20 ng of template DNA, lX Gene Amp buffer (100 mM Tris HCl pH – 8.3; 500 mM Mg $^{2+}$.) 20 pmoles primer and 1.5 U of AmpliTaq Gold DNA polymerase (Applied Biosystems) enzyme. Tubes containing all the reaction components except primer were included as a control for each reaction.

The PCR amplification products were loaded onto 1.2% agarose gels with 1 Kb ladder (Bangalore Genei) as the molecular standard marker. The gels were viewed in UV transilluminator and image captured using a GelDoc system (G: Box, Syngene, UK). The amplified products were cut from the gel under the UV transilluminator.

DNA band was eluted from gel using GFX™ PCR DNA and Gel Band Purification kit (Amersham Biosciences) following manufacturers instructions. Quality and quantity of the eluted DNA were checked by electrophoresis on 1% agarose gel. The DNA bands were visualized under UV transilluminator.

PCR product was directly sequenced based on Sangers's Dideoxy Chain Termination method. Sequencing was carried out in ABI 310 Automated Sequencer (Applied biosystems, Perkin Elmer) using the ABI 310 PRISM Big Dye Terminator Cycle Sequencing Ready Reaction Kit, version 3.0 (ABI, Perkin Elmer). The sequencing reaction was carried out in a final volume of 20 μl with 3 μl 5X buffer, 100 ng of the DNA, 20 pmole primer (either forward or reverse), 1 μl Ready Reaction mix and sterile water to make up the volume. Sequencing reaction was carried out in Mastercycler Gradient eps (Eppendorf, Germany) with the following conditions; an initial denaturation step at 96°C for 2 minutes followed by 25 cycles of 96°C for 30 seconds, 58°C for 20 seconds, and 60°C for 4 minutes with a thermal ramp of 1°C/second.

Post reaction clean up was carried out before loading samples into the automated sequencer. For this, the entire reaction was transferred to 1.5 ml microfuge tube containing 50 μl of 95% ethanol and 2 μl 3M sodium acetate (pH–4.6) and 2 μl 125 mM EDTA. Contents were mixed by gently inverting tubes and incubated for 15 minutes at room temperature for precipitation of the extended products. The tubes were centrifuged at maximum speed (around 9000x g) for 20 minutes (Rota 4R- V/FM, Plasto crafts). The supernatant was aspirated off and the pellet was washed with 250 μl of 70% ethanol and centrifuged at maximum speed for 5 minutes. Supernatant was carefully aspirated off and after drying under vacuum, the pellet was suspended in Template Suppression Reagent (TSR), heat denatured and run in ABI 310 Genetic Analyser using the module seq POP6 (1ml) E. Sequencing data was normalized using the matrix standard and electropherogram was analysed using the program Chromas 1.45.

The sequences obtained were subjected to GenBank searches with BLAST algorithm (Altschul *et al*, 1990) to confirm their identity. The translated sequences were aligned with CLUSTALW (Thompson *et al*, 1997). Distance trees were built by the Neighbor-joining method implemented in MEGA version 4 (Tamura *et al*, 2007). Robustness of clustering was checked by bootstrapping (Felsentein, 1985) 1000 replicates.

Pollination biology

Field observations were made during flowering season for the study of pollination biology. Flowers were surveyed for visitors behaviour at different times of the day. Insects were identified with the help of Zoology Department, Calicut University. Pollen grains were observed by Compound Microscope (Olympus CX21FS 1 model).

To study pollen viability, fresh pollen samples were collected from the plants from the field. 3-(4, 5–Dimethyl thiazol–2-yl)–2, 5,-diphenyl tetrazolium bromide (MTT) is used to test for the presence of dehydrogenese in the pollen. MTT is dissolved in 5% sucrose solution and strained through a filter paper. Pollen samples were placed in a drop of this reagent and set to dry on a microscope slide. Dark purple brown staining indicates the presence of dehydrogenase, which is a sign of pollen viability.

Phenetics

Nine taxa (Operational Taxonomic Units), Sneath & Sokal (1973) of genus *Zingiber* of South India were considered for this study and their code numbers are given in Table-11. Forty one characters from morphology, anatomy, palynology, and phytochemistry, which showed significant variations among the OTUs were considered. For the selection characters the guide lines suggested by Sneath and Sokal (1973) was adopted. The methodology adopted by Sahu (1991) and Gajurel *et al.* (2002) were used for cluster analysis except that Unweighted Pair Group Method with

Arithmetic mean (UPGMA) was used as algorithm here instead of Weighted Pair Group Method with Arithmetic mean (WPGMA). The characters used and their states are given in Table-12. The qualitative characters were directly converted to numerical code using different codes for different character states (Table-13). For comparison and calculation, all the 41 characters were tabulated against the 9 OTUs using character codes (Table-14). This tabulated data were used to generate dendrogram using the statistical package STATISTICA version 5.0 loaded in a personal computer. The dendrogram generated using the test percent disagreement was found suitable for the clustering of the OTUs where 7 distinct clusters of the 9 OTU's.

Presentation of data

The introductory part of this work begins with the general features of the genus *Zingiber* and the importance of biosystematic study. This is followed by the detailed analysis of the earlier works related to the genus in particular and others in general are dealt with and it is followed by salient features of the area of study. Materials and methods relevent to all disciplines of the work were given as a separate chapter.

The studies of different diciplines such as comparative morphology, morphology of rhizomes, anatomy, phytochemistry, palynology, molecular studies, cytology, pollination biology, systematic treatment and phenetics are given as separate chapters and each one is followed by result and discussion.

In the systematic part, subfamilies and tribes recognized by Kress *et al.* (2002) represent natural groups and are world wide in scope and hence this classification is accepted in the present treatment. Species are arranged alphabetically and for each species, description, distribution, ecology and details of species studies are given. A list of specimens examined is given at the end of each species. Phenetics is given at the end considering all relevant characters studied. A total of 44 plates and 28 figures are provided. The figures include taxonomy, anatomy and phytochemistry.

COMPARATIVE MORPHOLOGY

The genus *Zingiber* is characterized by medium sized herbs with about 0.6-2 m tall, having long, creeping, or stout and fleshy subterranean rhizomes. Each branch of the rhizome typically turns upwards, which later on emerges into an erect leafy shoot. The base of the leafy shoot is covered by several leaf sheaths without properly developed blades, followed by distichously arranged normal leaves. Each leaf sheath is terminated at the apex by a membranous ligule and continues upward as a narrowed stalk like portion and finally the leaf blade. Plane of distichy of leaves is parallel to rhizome. The petiole is swollen and forms a pulvinus. Inflorescence is developed on a separate shoot directly from the rhizome, with short or long peduncle, rarely terminal also occurs. The peduncle is covered by sterile sheaths. The whole inflorescence often looks like a cone and each bract subtends a single flower. The bracts are red or with yellow tinge or green when young, turning red in the fruiting stage. Flowers are usually ephemeral, only lasting for a few hours. Lip is 3-lobed and forms most attractive part of the flowers. The unique character of the genus is the stamen i.e, the long-curved beak or horn-like appendage on the anther.

Distribution

Majority of the species are distributed in tropical areas, in dense forests, and grasslands at high altitudes. Some species grow in plains at lower elevations. About 141 species, widely distributed throughout India, Malaysia, Queensland, Japan, East India, Java, New Guinea, Thailand, Myanmar, Kampuchea, Cambodia, Laos, Philippines, China, Sri Lanka etc. Sabu (2003) reported 8 species from South India, Sharma *et al*. (1984) reported the occurrence of *Z .capitatum* var. *elatum* in Karnataka now it has been collected from Warangal. It was reported from Bengal and Bihar by Jha and Varma (1995). *Z. montanum* is distributed throughout in India, Malay Peninsula and Sri Lanka. In South India it is reported from Andhra Pradesh, Karnataka, Kerala and Tamil Nadu. *Z. neesanum* is endemic to peninsular India. It is reported from Andra Pradesh, Maharashtra, Karnataka and Kerala. The *Z. cernuum* and *Z. nimmonii* are endemic to peninsular India. *Z. nimmonii* is reported from hilly regions of Western Ghats of Maharashtra, Karnataka, Kerala and Tamil Nadu where as *Z. cernuum* is reported from plains as well as mountains of Kerala, Karnataka, Tamil Nadu, and Maharashtra. *Z. officinale* is cultivated in tropical countries throughout the world. Dahlgren *et al.* (1985), considered it to be originated in eastern India. In South India, though it is widely cultivated in all districts some wild forms occur in the evergreen forests of Kerala. *Z. roseum* is endemic to India and is reported from Northern Circars and Western Ghats. *Z. wightianum* occurs in Southern peninsular India and Sri Lanka. *Z. zerumbet* is widely distributed throughout India, Thailand, Malay Peninsula and other tropical countries. It is considered as a native of India (Holttum, 1950).

Habitat

Plants are distributed mainly in tropics and sub-tropics as undergrowth in dense forests and shady cool places in the openings. The richest floristic regions in South India are Kerala, western parts of Karnataka and Maharashtra. On account of the geographic location, Kerala and the Western parts of Karnataka have a warm and humid climate with heavy rainfall, and support dense vegetation. *Z. wightianum* has a very restricted distribution confined only to specific regions of Western Ghats like Anamalai hills, whereas *Z. neesanum* shows much wider distribution along the Western Ghats at high altitudes. *Z. cernuum*, *Z. nimmonii* and *Z. zerumbet* are evenly distributed in plains as well as on mountains. *Z. montanum* is mostly confined to the drier areas of Karnataka, Goa, etc. *Z. roseum* is confined to the Orissa, Karnataka, and Central Deccan plateau mostly in Chattisgarh, Andhra Pradesh, and Madhya Pradesh.

Rhizome

Rhizome is an underground stem modified for the vegetative propagation and storage of food materials. Rhizome may be short or long or subterranean. These interconnected rhizomes form a series known as a sympodium. It has nodes with scale leaves and internodes. Axillary buds are present in the nodes. The aerial shoot developed from the apical bud has many nodes and inter nodes. The primary branches may be two, three or four. The subsequent development of secondary, tertiary and quaternary branches are on the abaxial side of the respective branches. The young rhizome and axillary buds are ensheathed and protected by scale leaves. Rhizomes are more or less fleshy, remain dormant during dry season and regain into life just after rain. Rhizomes are aromatic and variously coloured. In *Z. capitatum* var. *elatum* rhizome is thick, light yellow and produce many fusiform root tubers. The rhizome is deep yellow, aromatic and with many tubers in *Z. montanum*. It is small, light yellow inside with many fleshy, fusiform, white root tubers in *Z. neesanum*. Rhizomes of *Z. cernuum* and *Z. nimmonii* are small, fleshy, strongly aromatic, purplish–lilac in peripheral region and pale yellow at the centre, bearing ovoid fleshy root tubers. In the case of *Z. officinale*, rhizome is thick, fleshy, grayish-yellow within, with pungent smell. In *Z. roseum* rhizome is thick, fleshy, and white to pale yellow within. Tubers are rare in *Z. wightianum* and the rhizome is stoloniferous, cylindrical, thick, and fleshy with many fleshy roots. Light yellow rhizome is present in *Z. zerumbet* and bears root and root tubers but comparatively fewer than *Z. neesanum*.

Roots

The roots may be fibrous and fleshy. When young, many roots grow out from the base of the sprouts. These roots are thin and have root hairs. As plant grows further, several fleshy roots of indefinite growth are produced from the lower nodes. In *Z. cernuum*, *Z. nimmonii*, *Z. capitatum* var. *elatum, Z. montanum* and *Z. neesanum* root tubers are present at tip of the roots. They are white to yellow, 1-4 cm long, fusiform, spindle-shaped, ovate or oblong.

Aerial Shoot

The leaf shoot, 1-2.5 m tall, erect with the apex curving over. Shoot bears a number of two-ranked leaf blades which spread more or less horizontally. The lowest blades are shorter and largest leaves are those rather above the middle of the leaf bearing part. Aerial stem is usually covered by the leaf sheaths. The base of the leafy shoot is covered by several leaf sheaths without properly developed blades. The leaves of different species vary in size. *Z. capitatum* var. *elatum* bears terminal inflorescence. In all others the inflorescence is on a separate shoot which is a short or long elongated spike.

Leaves

Leaves are distichous, and plane of distichy is parallel to rhizome. Base of the petiole is swollen and pulvinus-like. Ligule present at the upper margin of the sheath is usually membranous, short or long, entire, or shortly or deeply bilobed. Size of the ligule also varies. It is 2-3.5 cm long in *Z. zerumbet.* Smallest ligule 2 mm is present in *Z. montanum.* Lamina is linear, lanceolate with acute tip in *Z. montanum* and *Z. neesanum*. In *Z. capitatum* var. *elatum* the leaves are linear and recurved whereas in *Z. officinale*, leaves are linear, narrowly lanceolate and acuminate. It is oblong lanceolate in *Z. cernuum*, *Z. nimmonii*, *Z. roseum*, *Z. wightianum and Z. zerumbet.* Leaves have a sheath below, which encircles the stem and it is open. They are generally thin, sometimes fleshy and hairy. Hairs are present usually on lower surface, they are unicellular, simple, and the base is often swollen (Tomlinson, 1962). Venation is generally pinnate to parallel with a prominent midvein and slightly arching, convergent lateral veins.

Inflorescence

Inflorescence is a spike which is terminal or on a separate shoot arising directly from the rhizome or from the base of the pseudo stem. It is terminal in *Z. capitatum* var. *elatum* where as in all other South Indian zingibers inflorescence is produced as a separate spike. It is cylindrical, globose or sub-globose and arises directly from rhizome in *Z. cernuum*, *Z. neesanum*, *Z. nimmonii, Z. wightianum* and *Z. roseum.* The spike is dark greenish red and partly immersed in soil as in *Z. wightianum*. In *Z. roseum*, the inflorescence is globose, rounded at tip, partially buried in soil, and dark purple in colour. In, *Z. nimmonii* the spike is sub-globose, with purple bracts. In *Z. cernuum* bracts are green, with red streaks. Peduncle may be short or long and it is ensheathed by two ranked sterile bracts. The spike has closely overlapping bracts, each with a single flower and the whole inflorescence has a cone-like appearance. In many species the bracts are green when young, turning to red in the fruiting stage. Rarely deep red, yellow and white bracts are also present, *Z. citrinum*. The flowers are usually very delicate, fragile and last only for a few hours. Size of peduncle varies from 10-50 cm long in *Z. zerumbet* and 15-45 cm in species like *Z. montanum, Z. neesanum* and *Z. officinale*. A very short peduncle is present and it varies from 0.5 to 3 cm in *Z. cernuum, Z. roseum* and

Z. wightianum, and it is 9.5 – 10 cm in *Z. nimmonii*. Shape of the spike varies considerably, cylindrical with tapering narrow apex in *Z. neesanum*, ovoid with acute apex in *Z. montanum*, and ovoid with rounded apex in *Z. zerumbet*. Spike is sub-globose and is partially buried in soil in *Z. nimmonii, Z. roseum* and *Z. wightianum*. Size of the spike varies from 4-6 cm in *Z. roseum* and 13-15 cm in *Z. capitatum* var. *elatum*. In *Z. officinale, Z. neesanum*, *Z. capitatum*, the flower opens in the evening about 3-5 p. m. One to two flowers are produced at a time in *Z. officinale* and *Z. neesanum*, whereas 4-6 flowers are seen in *Z. capitatum* var. *elatum*. In others like *Z. zerumbet, Z. cernuum, Z. nimmonii, Z. wightianum, Z. roseum,* and *Z. montanum* 1-2 flowers occur and opens early in the morning i. e., about 5-7 a. m. 2-4 inflorescences are produced at a time in *Z. cernuum*, *Z.* nimmonii, *Z. neesanum*, *Z. officinale* and *Z. zerumbet.* Holttum (1950) believed that the basic inflorescence unit in Zingiberaceae consists of axillary monochasial cymes and each branch with a terminal flower. A single flower in each bract is considered as derived.

Bracts

Inflorescence consists of a rachis bearing primary bracts, which are large, broadly ovate, or lanceolate, brightly coloured when old, apices closely imbricating and spirally arranged. It is lanceolate in *Z. cernuum*, *Z. nimmonii*, *Z. roseum*, and *Z. wightianum.* Bracts are green or with red margin in *Z. capitatum* var. *elatum* and green in *Z. zerumbet* when young and turn to red at fruiting stage. It is purple red in *Z. neesanum* and greenish–brown in *Z. montanum*, light green with red towards tip in *Z. cernuum,* dark purple in *Z. roseum.* It is light pink to purple in *Z. nimmonii.* Bracts are green with purple streaks in *Z. wightianum*. A single flower is present in the axil of each bract. Size ranges from 2.5 x 5 cm, outer surface hairy and inner glabrous. Largest 4.1-4.3 x .8-.9 cm in *Z. wightianum* and smallest is seen in *Z. officinale* with 2.3-2.4 x 2.1-2.7 cm.

In *Z. capitatum* var. *elatum* bracts are green with red margins and white below, 3.3- 3.8 x 1-1.5 cm and pubescent. In *Z. montanum* bracts 3-4.2 x 2.4-4.8 cm, broadly ovate, greenish brown, inner glabrous, outer densely pubescent. Bracts are ovate, lanceolate, tip acute, reddish green, pale towards base, inner glabrous outer pubescent and 3.2-3.6 x 2-2.8 cm in *Z. neesanum.* In *Z. cernuum,* bracts many 3-4 x 1 cm, lanceolate greenish yellow, with red streaks, outer pubescent and inner glabrous. In *Z. nimmonii* bracts many, 4.2–4.4 x 1.2 cm, colour ranges from light pink to dark purple. It is green, glabrous inside, outer hairy, 2.3–2.4 x 2.1-2.7. In *Z. officinale* and in *Z. roseum* 3.3-3.8 x 0.9–1.2 cm, lanceolate, outer pubescent and inner glabrous, light green with red streaks towards tip. In *Z. wightianum*, bracts 4.1-4.3 x 0.8-0.9 cm, lanceolate, acuminate, greenish red and tip curved. Bracts closely imbricating, 3-3.7 x 2-2.9 cm, ovate to obovate, green, white towards base, outer densely pubescent, margin membranous in *Z. zerumbet*.

Bracteoles

The bracteole faces towards fertile bract which is thin, narrower than the bract, usually persisting and enclosing the fruit and split to the base, generally light green, in *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. nimmonii*; creamy white in *Z. officinale* white with red spots towards tip. Bracteoles greenish red, margin smooth, size 3.2-3.4 x .9.5-10.5 mm in *Z. wightianum*. It is 2-3 x 1-1.6 cm in *Z. neesanum*, pale yellow with red streaks. Tip of the bracteole 3-toothed and size varies with species.

Flowers

Flowers are bisexual, fragile, ephemeral and zygomorphic, trimerous, dichlamydous, epigynous and highly specialized. The size of the flowers ranges from 4.8-5.2 cm long and yellow in *Z. capitatum* var. *elatum*, 7.3-7.5 cm and yellow in *Z. montanum*, 5.5-5.8 cm, yellow in *Z. zerumbet*, flower 5.5-5.8 cm, labellum yellow with purple spots in *Z. cernuum*, 4.3-5 cm long labellum white with purple streaks in *Z. neesanum*, 7.5-7.7 cm long yellow with purple spotted labellum in *Z. nimmonii*, 4.2-4.5 cm long with red with yellow spots in *Z. officinale*, 6.2-6.8 cm long, labellum white with red and yellow spots in *Z. roseum*, and 6.1-6.4 cm long in *Z. wightianum*.

The structure of flowers is based on the ancestral liliferous type of 3 sepals, 3 petals, 3+3 stamens and a gynoecium of 3 locules. The calyx is tubular with three teeth. The corolla consists of a narrow corolla tube and three sub equal corolla lobes, of which dorsal one is large and the two lateral lobes narrow and slightly different in shape. Labellum or lip is large and forms most conspicuous part of the flower. The labellum in *Zingiber* is actually formed from 3 modified sterile stamens in contrast to the orchid lip, which is a true petal. The two lateral stamens are transformed into Petal like structure.

The flower has an inferior trilocular ovary with many ovules on axile placenta. On top of the ovary there are two styloidial nectariferous glands called as epigynous glands.

One functional stamen is present and it belongs to the outer whorl. The two adjacent stamens are not seen in *Zingiber*. The three stamens of the inner whorl represent labellum or lip. Several theories have been proposed by various scientists regarding the origin of the zingiberaceous labellum.

1. Robert Brown (1830) suggested that the labellum represents the single outer stamen only and the two inner ones develop into stylodes. The stylodes are late developments in the ontogeny of the flower and the vascular tissue gives no support to the theory of their staminal origin.

2. According to Lestiboudois (1841) and Eichler (1875) the lip represents the two stamens of the inner whorl and the intermediate are of the outer whorl being entirely aborted. This theory is supported by the bilobed nature of the labellum.

3. Schumann (1904) suggested that in some genera the two inner staminoides form the lip (e.g., *Hedychium* and *Kaempferia*) where the lip is lobed and in other cases the single outer stamen forms the lip (eg: *Alpinia* where the lip is not bilobed).

4. After examining the vascular strands to the various parts of the flower Costerus (1915) stated that the labellum consisted of a combination of all three stamens. The middle one is sometimes strongly developed or reduced. In *Zingiber* the vascular strand corresponding to the single stamen of the outer whorl is quite lacking.

The theory of Costerus explains the existence of the broad, trilobate lips of some alpinias and the bilobed lips of other genera.

The structure of the functional stamen is normal. A characteristic feature of the stamen is the apical extension of connective into beaked anther crest. An interesting feature of the stamen is the way in which it holds the style between the swollen pollen sacs.

Calyx and corolla

Calyx is tubular, cylindrical, thin and shorter than bracteoles. Corolla tube is cylindrical, slender, as long as bract, corolla lobes 3, unequal, dorsal lobe is broader than the other two lateral lobes. Lateral lobes erect, narrowed to the tip, edges inflexed, linear lanceolate, present below the labellum, white or cream coloured.

Calyx 1.2-1.4x1-1.2 cm, unequally 3-toothed, white, membranous, apex truncate, hairs on margin in *Z. capitatum* var. *elatum* and corolla tube cylindrical 1.5 cm long, light yellow. In *Z. montanum* calyx 1.5-1.8 x 0.7-1.2 cm, white, unilaterally split, hairs more towards lower region and corolla tube 3 cm long, and light yellow. Calyx 2.3 cm long, hairs absent, 3-toothed, deeply notched, and corolla tube slender, cylindrical, white 2.2-2.9 cm long, longer than bracts in *Z. neesanum.* In *Z. cernuum* calyx is tubular, 1.6-2 x 0.8 cm long, pale yellow, 3-toothed, outer sparsely pubescent and unilaterally split, corolla tube, 4-4.5 cm long, yellow and slender. In *Z. nimmonii*, calyx is tubular 1.8 x 0.5 cm, tip shortly 3-lobed, unilaterally split 9 mm deep, white, densely pubescent, corolla tube slender 4.3 cm, cream colour, and hairy towards base. In *Z. officinale,* calyx 1-1.2 x 0.8 cm, tubular, hyaline, white, hairs absent, teeth not prominent, unilaterally split, and corolla, tube 2.5 cm and pale yellow. In *Z. roseum*, calyx tubular, membranous, 3-toothed, 1.7-0.9 cm long, white, hairy towards base unilaterally split, corolla tube slender, white 3.5 cm long, sparsely pubescent. In *Z. wightianum*, calyx is 2-2.1 cm long, slightly 3-toothed, unilaterally split 1-1.1 cm deep, light yellow, hairs more at lower side and corolla tube 3-3.2 cm long, white at base, darker towards tip and densely pubescent. In *Z. zerumbet*, calyx 1.5-2 cm long, truncate, white, pubescent towards tip, corolla tube 2.6-3.2 cm long, as long as bracts, creamy white with light yellow towards tip.

Fertile stamen

A single fertile stamen is present. Anther long, narrow, and connective prolonged into a slender-curved, beak-like appendage, as long as the pollen sacs, and with inflexed edges, enclosing the upper part of the style. Stigma is projecting just below the apex of the crest, with ciliate margins. In *Z. capitatum* var. *elatum, Z. montanum* and *Z. zerumbet*, anther is light yellow. It is dark yellow with red beak in *Z. cernuum* and *Z. nimmonii,* purple beak in *Z. neesanum,* and *Z. officinale,* dark purple red in *Z. wightianum* and red in *Z. roseum*.

Staminodes

The two lateral stamens are transformed into petal-like structures in *Zingiber* species which is fused with the labellum. Size of lateral staminodes varies from 0.8-2.7 x 0.5-0.9 cm. Smallest, 0.8-1 x 0.5 cm is present in *Z. montanum* and largest, 1.2 x 0.9 cm in *Z. capitatum* var. *elatum.* Colour varies from cream to yellow or pale yellow with purple spotted in *Z. cernuum*, light red with yellow spots in *Z. nimmonii*, yellowish with spots in *Z. wightianum,* dark red with yellow spots in *Z. officinale*.

Labellum

Labellum forms the most attractive part of the flower. It is deeply 3-lobed, staminodes fused with the mid lobe which is larger than the side lobes, apex emarginate, side lobes erect on either side of the stamen, colour is white in *Z. neesanum* with dark purple spots. It is yellow with dark yellow at the centre in *Z. zerumbet, Z. montanum* and *Z. capitatum* var. *elatum*. Yellow with purple spots in *Z. cernuum*, yellow with dark purple streaks in at centre and red colour with yellow spots at tip in *Z. nimmonii*, dark purple with yellow spots in *Z .officinale* and light violet with white spots in *Z. wightianum.*

Ovary

Ovary is inferior, trilocular with many ovules on axile placentae in each locule. Ovary is barrel-shaped, cylindrical or angular, glabrous or hairy. Size of the ovary ranges from 3 x 2 mm in *Z. officinale* to 5 x 6 mm in *Z. neesanum*.

Epigynous glands

On top of the ovary there are two stylodial nectariferous glands surrounding the base of the style. In most of the species it is yellow, equal or unequal in height. It is 4 mm long and light yellow in *Z. neesanum*; 5 mm long and yellow in *Z. capitatum* var. *elatum*; 7 mm long in *Z. cernuum*, 0.6 mm long in *Z. nimmonii* and *Z. officinale*. It is 9 mm long, creamy yellow and unequal in *Z. zerumbet*, *Z. montanum*, and *Z. wightianum.*

Style and stigma

The style is thin, linear, white and placed in a furrow in the filament and the anther, and protrudes above the anther. It passes through a groove in the corolla tube. The long curved anther appendage embraces style. Stigma projects just below the apex of the crest, with ciliate margins.

Fruits and seeds

Fruit is a fleshy loculicidal capsule that may dehisce by three longitudinal slits. Fruit wall is fleshy, slightly ridged, leathery when dry smooth and enclosed by persistent bract and bracteole. They are generally green when young but turns to dark red or dark purple on ripening. Seeds ellipsoid, black or dark brown covered by a thin, saccate, white aril with irregularly lacerate edges.

MORPHOLOGY OF THE RHIZOMES

The rhizome is present just below the surface of the soil. The subterranean stem of *Zingiber* is modified for vegetative propagation and storage of food materials and helps the plant to tide over difficult situations of the dry season. The rhizome consists of a main branch which gives rise to 2-6 primary branches. Branches arise from just above the node. It has nodes and internodes with scale leaves at nodes. Except for the first few nodes, all the nodes have axillary buds. The scale leaves later fall off, so that in mature rhizomes only the scars remain. Young scale leaves have pointed tips that help in penetration of soil. Primary branches in turn give rise to secondary, tertiary and quarternary branches. Shah and Raju (1975) reported branches up to fourth order in *Z. officinale.*

The main axis is developed from the apical bud, which later becomes an aerial shoot. The subsequent growth of the rhizome is due to the development of axillary buds. These axillary branches are plagiotropic at first and then become orthotropic carrying its apical meristem above the ground and produces photosynthetic leaves (Bell, 1980). The same pattern of growth is continued for successive branches to form a sympodial growth pattern.

***Z. capitatum* var. *elatum*:** Rhizome is light yellow, the main branch obconic, 2-2.6 x 2.7 cm and consists of 9 nodes with 0.4-0.6 cm long internodes (Fig. 2 A). 2-4 primary branches arise consists of 9 nodes with 0.4-0.6 cm long internodes. 2-4 primary branches arise from the main branch. Branches develop from abaxial side of the nodes, they grow upwards brought to the same level of the main branch. Primary branch is 1-1.5 x 1.6 cm with 8 nodes and 0.2-0.4 cm long internodes. It in turn give rise to 1-3 secondary branches, which are longer than primary branches, with about 4-5.5 x 2.6 cm long with about 7 nodes and 0.9-1 cm long internodes. Each secondary branch gives rise to 2-4 tertiary branches. They are shorter than secondary branches with an average length of 1.8-2.5 x 1.1 cm and with about 7 nodes, long internodes 0.3-0.4 cm. Numerous quarternary branches arise from each tertiary branch, average length is 0.8-1.5 x 0.5 cm with about 6 nodes and internodal length of 0.2-0.4 cm. Root tubers are formed from main branch and secondary branches.

***Z. cernuum*:** Rhizome is thick, fleshy, fibrous, yellow inside and purple-lilac at periphery and aromatic. Main branch elongated and thick consists of 2-3.4 x 2.2 cm with about 6 nodes and with an internodal length 0.2-1.7 cm (Fig. 2 B). Primary branches are 2-4 in number 2.5-5.4 x 1.8 cm long, 6-10 nodes develop just below the nodes, and internodal length 0.6-0.8 cm. Secondary branches are obconic, faces towards main branch 2-3.6 x 1.2 cm with about 6 nodes, internodal length 0.6 cm. Tertiary branches are smaller 1-1.3 x 0.7 cm long, with 4 nodes, internodal length 0.5 cm long. Quarternary branches are not seen. All branches brought to the same level of the main branch and produce axiliary branches and arranged both sides of the main branch, so they are seen in linear manner.

Z. montanum**:** Rhizome is dark yellow, aromatic; the main branch gives rise to primary, secondary, tertiary and quarternary branches (Fig. 2 C). Main branch is more or less spherical 2-3.3 x 3.1 cm long, more spherical at middle, with an average of 5 nodes; the length of internode is 0.4-0.6 cm. Main branch in turn gives rise to 2-6 primary branches. They are ovate, smaller than main branch with about 5 nodes, and 0.4 cm long internodes. It in turn gives rise to secondary branches; they grow upwards come to the same level of the main branch. Each secondary branch has a length of 2-3 x 1 cm, internodal length is 0.2-0.6 cm with average 6 nodes. Tertiary branches have an average length of 1.8-2.5 x 1.6 cm with 9 nodes and with an internodal length of 0.2 cm, quarternary branch with 7 nodes, internodal length 0.2 cm, length of the branch is 1-1.5 cm. The main branch and subsidiary branches are brought to more or less same level. Root tubers are formed from primary and secondary branches.

Z. neesanum**:** The rhizome is light yellow inside and aromatic, the main branch, primary branch, secondary branch, tertiary branch and quaternary branches are very closely arranged and they are brought together in almost at the same level below the soil (Fig. 3 A). The main branch is almost spherical, 1.8-2.5 x 1.5 cm, with average 3 nodes, internodal length 0.4-0.6 cm. It in turn gives rise to primary branches of 0.8-1.2 x 0.5 cm, at both sides, and internodal length 0.3 - 0.5 cm with about 3 nodes. The secondary branches 0.5-1.8 x 1 cm, are larger than primary branches with 4-6 nodes and internodal length 0.2-0.4 cm. Tertiary branches 1-2 x 0.6 cm long, with 5 nodes, internodal length 0.5-0.6 cm. Quarternary branches 0.5 x 0.5 cm, with average 4 nodes and internodal length 0.1 cm. The main and subsidiary branches are arranged in a row on both sides of main branch.

Z. nimmonii**:** Rhizome is thick, fleshy, fibrous, yellow inside and purple - lilac at periphery and aromatic (Fig. 3 B). Main branch elongated and thick consists of 3-3.5 x 2.5 cm with about 6 nodes and with an internodal length 0.4 - 0.8 cm. Primary branches are elongated, about 2-4 in number 3-4 x 2 cm long, 8 nodes develop just below the nodes, and internodal length 0.4 - 0.6 cm. Secondary branches are smaller than main branch and primary branch 1-2.1 x 1.8 cm with about 5 nodes, internodal length 0.3 cm. Tertiary branches are longer 4-5.6 x 3 cm long, with about 9 nodes, internodal length 1-1.5 cm. Quarternary branches are about 1-2.8 x 1.3 cm long, inter nodal length 0.3-0.5 cm, with about 5 nodes. Branches are arranged very closely with numerous roots, and root tubers.

Z. officinale**:** The rhizome is aromatic, fleshy and pungent, yellow at centre and grey at periphery (Fig. 3 C). The main branch is thick, more or less spherical, stout 3-3.5 x 2.5 cm with about 9 nodes, internodal length 0.3-0.6 cm. It gives rise to primary, secondary, tertiary and quarternary branches. Branching is very peculiar in *Z. officinale*, branches up to fourth order show well developed nodes and internodes which are negatively geotropic. Primary branch is smaller than main branch, 1.8-3.7 x 2.2 cm long, with 7-8 nodes, internodal length 0.4-0.5 cm. Secondary branches larger than primary branches, 5.3–7 x 1.3 cm long, with 4-9 nodes, internodal length 0.4-1 cm. Tertiary branches many, 1.5-2.4 x 1.5 cm, with 6 nodes, internodal length 0.6-0.8 cm. Quarternary branches very small, 0.4-0.6 x 1 cm, with about 2 nodes, internodal length 0.3 cm. Branches produced on both sides of the main branch are brought to the same level as that of the main branch and arranged in coral shaped manner.

Z. roseum**:** Rhizomes are thick, pale yellow to white, more fibrous and stoloniferous. Main branch, primary branch, secondary branch, tertiary branch and quaternary branches are present (Fig. 4 A). Main branch thick, almost rounded, 4.1-6.7 x 1.8 cm long, with 7-9 nodes, internodal length 0.6-0.7 cm. Primary branches are small, 2-4 in number with average length of 2.1-3.3 x 1.4 cm, and length of internode 0.2 cm long and with 6 nodes. Secondary branches are larger than primary branch, 1.6-2.8 x 1.8 cm long, with average 9 nodes and internodal length 0.4-6 cm. Tertiary branch is 3-4.5 x 1.9 cm long with 11 nodes and internodal length 0.9 cm. Quarternary branches are about 2-4.6 x 1.4 cm long, with 6 nodes and internodal length 0.7-0.9 cm. Main branch and other branches are thick, more fibrous than the rhizome of *Z. wightianum*.

Z. wightianum**:** Rhizome is yellow, more fibrous, thin and stolen like. Main branch is 9-12 x 1 cm long and number of nodes about 9, internodal length 1.1 cm (Fig. 4 B). Primary branches are also very long stoloniferous about 7-10.5 x 1 cm and with about 11 nodes and length of the internode, 1.5 cm.

Primary branches in turn give rise to secondary branches with about 4-6.5 x 0.8 cm long, with 5 nodes, internodal length is 1.4 cm. Tertiary branches are smaller, 1-1.5 x 0.5 cm with 4 nodes; internodal length 0.3 cm. Quarternary branches are not seen.

***Z. zerumbet*:** The rhizome is thick, yellow, fleshy and aromatic. Main branch is thick, almost spherical and stout with about 2.7-3.5 x 2.1 cm, nodes 7-10, internodal length 0.3-0.6 cm (Fig. 4 C). It in turn gives rise to 2-4 primary branches of 2.5-3.5 x 2.5 cm, with 5 nodes, internodal length 0.5-0.9 cm. Secondary branches are smaller than primary branches with 2.2-3.2 x 1.2 cm, with 6 nodes and internodal length 0.4-0.7 cm. Primary and Secondary branches run parallel to the soil surface. Tertiary branches1.3-6.5 x 2.7 cm long, about 4-7 nodes, internodal length 0.2-0.9 cm, suddenly turn upright and give rise to shoot. Quarternary branches are very small, 0.9-1.9 x 2.4 cm long, with 4 nodes and internodal length 0.3-0.4 cm. The main branch and tertiary branches brought to the same level under the soil.

Table No. 1. Number of branches in rhizome and its size.

Name of taxa	Branch	Size (cm)	Internodal length (cm)	No. of nodes
Z. capitatum* var. *elatum	Mb	2-2.6 x 2.7	0.4-0.6	9
	Pb	1-1.5 x 1.6	0.2-0.4	8
	Sb	4-5.5 x2.6	0.9-1	7
	Tb	1.8-2.5 x 1.1	0.3-4	7
	Qb	0.8-1.5 x 0.5	0.2 4	6

Name of taxa	Branch	Size (cm)	Internodal length (cm)	No. of nodes
Z. cernuum	Mb	2-3.4 x 2.2	0.2-1.7	6
	Pb	2.5-5.4 x 1.8	0.6-0.8	6-10
	Sb	2-3.6 x 1.2	0.6	6
	Tb	1-1.3 x 0.7	0.5	4
	Qb	ab	ab	ab
Z. montanum	Mb	2-3.3 x 3.1	0.4-0.6	5
	Pb	1.5-2.2 x 2.1	0.3-0.4	5
	Sb	2-3 x 1	0.2-0.6	6
	Tb	1.8-2.5 x 1.6	0.2	9
	Qb	1-1.5 x 1.2	0.2	7
Z. neesanum	Mb	1.8 - 2.5 x 1.5	0.4-0.6	3
	Pb	0.8-1.2 x 0.5	0.3-0.5	3
	Sb	0.5-1.8 x 1	0.2-0.4	4 - 6
	Tb	1-2 x 0.6	0.5-0.6	5
	Qb	0.5 x 0.5	0.1	4
Z. nimmonii	Mb	3-3.5 x 2.5	0.4-0.8	6
	Pb	3-4 x 2	0.4-0.6	8
	Sb	1-2.1 x 1.8	0.3	5
	Tb	4-5.6 x 3	1-1.5	9
	Qb	1-2.8 x 1.3	0.3-0.5	5
Z. officinale	Mb	3-3.5 x 2.5	0.3-0.6	9
	Pb	1.8-3.7 x 2.2	0.4-0.5	7-8
	Sb	5.3-7 x 1.3	0.4-1	4-9
	Tb	1.5-2.4 x 1.5	0.6-.8	6
	Qb	0.4-.6 x 1	0.3	2
Z. roseum	Mb	4.1-6.7 x 1.8	0.6-0.7	7-9
	Pb	2.1-3.3x 1.4	0.2	6
	Sb	1.6-2.8 x 1.8	0.4–0.6	9
	Tb	3-4.5 x 1.9	0.9	11
	Qb	2-4.6 x 1.4	0.7-0.9	6

Name of taxa	Branch	Size (cm)	Internodal length (cm)	No. of nodes
Z. wightianum	Mb	9-12.5 x 1	1.1	9
	Pb	7-10.5 x 1	1.5	11
	Sb	4-6.5 x 0.8	1. 4	5
	Tb	1-1.5 x 0.5	0.3	4
	Qb	ab	ab	ab
Z. zerumbet	Mb	2.7-3.5 x 2.1	0.3-0.6	7-10
	Pb	2.5-3.5 x 2.5	0.5-0.9	5
	Sb	2.2-3.2 x 1.2	0.4-0.7	6
	Tb	1.3-6.5 x 2.7	0.2–0.9	4-7
	Qb	0.9-1.9 x 2.4	0.3-0.4	4

Mb - Main branch, Pb - Primary branch, Sb - Secondary branch
Tb - tertiary branch, Qb - Quarternary branch, ab -absent.

Discussion

In *Zingiber* the rhizome is sympodial, thick, fleshy, often fibrous, aromatic, colour varies from white, purple, light yellow to dark yellow. The main branch with elongated internodes give rise to many primary, secondary, tertiary and quaternary branches. Nodes possess scale leaves and roots arise below the node. They are negatively geotropic.

Nodes: The number of nodes in the rhizome of each species varies. The main branch and the subsequent branches have 3-12 nodes. The internodal length of the rhizome branches ranges from 0.2-1.7 cm. The internodal length varies in a single branch. The longest internodal length is seen in

Z. wightianum. The secondary, tertiary and quaternary branches show the maximum length of internodes.

Scale leaves: The scale leaves are present only on the rhizome. They ensheath and protect the axillary buds in all the taxa studied. In mature rhizome only their scars remain. The young scale leaves have pointed tips, hence suited for soil penetration.

Roots: Roots develop from all parts of the underground main axis, and the axillary branches. During maturation of the rhizome the roots enlarge with stored food material and give rise to swelling near the tip region. Such root tubers are present in *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, and *Z. nimmonii*. They are abundant in starch.

Rhizome: In all South Indian species of *Zingiber*, a well developed rhizome is present. It is perennial and gives rise to shoot in the rainy season. In *Z. capitatum* var. *elatum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, and *Z. zerumbet* rhizome is thick, and with branches present up to fourth order. In *Z. cernuum*, the main and subsidiary branches appear as finger-shaped and subsidiary branches face towards main branch. The main and subsidiary branches are brought to the same level under the soil surface. In *Z. montanum* and *Z. zerumbet* the main and subsidiary branches are more or less spherical and arranged in a plane where as in *Z. officinale* they are more spread in the same plane, giving a coral like appearance. In *Z. roseum*, rhizome is thick, fibrous and stoloniferous and in *Z. wightianum,* it is thin, fibrous and stoloniferous. The negative geotropic growth can be correlated with the formation of sheath leaves and foliage leaves. The active axillary branches are on the abaxial side or on the lower side of a horizontally developing branch. It is due to the unequal concentration of auxins on the upper and lower side of a horizontally placed organ. (Bennet-Clark & Bali, 1951). The studies on the morphology of the rhizomes revealed that the architecture, size, shape, colour etc can be very well used as one of the important characters for the identification up to species level.

ANATOMY

The pioneer studies conducted about the vegetative anatomy of Zingiberaceae was by pharmacologists on the rhizomes of *Z. officinale* (Tomlinson, 1956). Schumann (1904) also studied the anatomy of Zingiberaceae, but it is mostly concerned with the rhizome. It was Tomlinson (1956), who studied Zingiberaceae from the point of systematic anatomy. According to him, the two subfamilies, Costoideae and Zingiberoideae differ markedly in the anatomy of the lamina, petiole, sheath, node in aerial stem, root, hairs, and distribution of silica inclusion. The anatomical evidence for the separation of the two subfamilies is supported by evidence from vegetative and floral morphology, geographical distribution, pollen, seedling structure and cytology.

According to Metcalfe (1959) the type of stomata, silica bodies, different pattern of sclerenchyma, leaf epidermis are of diagnostic value at the level of species rather than as indicators of broad taxonomic affinities. The structure and development of stomata in 70 species of Zingiberales were studied by Olatunji (1980) and found that paracytic, tricytic, tetracytic and polycytic stomata occur in Zingiberales, and tetracytic stomata is common in Zingiberaceae and its mode of development to tetraperigenous. Tomlinson (1961b) suggested that information on anatomy and floral morphology in the order Scitamineae makes possible very reasonable taxonomic sub-division and provides a logical explanation to the presumed phylogeny of the order. Stebbins and Khush (1961) studied the variation in the organization of the stomatal complex in the leaf epidermis of Monocotyledons and its bearing on their phylogeny. Hussin *et al*. (2000) studied the leaf anatomy of *Alpinia* from China and noticed that there is interspecific variation in the structure of the leaf midrib and petiole and can be used for species identification. Hussin *et al*. (2001) studied leaf anatomical variations between species of *Boesenbergia* and *Kaempferia*, and found that there are variations in the type of stomata, mid rib, petioles, and outlines of leaf margin, hypodermis, and trichomes in lamina.

The vascular pattern of stem of *Alpinia speciosa* L. was worked out by Bell (1980), which shows scattered vascular bundles in two distinct zones - an inner system and an outer system, separated by a cylinder of undifferentiated tissues called intermediate zone, retaining the features of a meristem. Dahlgren and Clifford (1982) stated that Zingiberaceae have vessel less leaves but roots have vessels with scalariform perforation plates.

Remashree *et al*. (1997) studied the vascular pattern of the under ground rhizome of ginger (*Zingiber officinale*). The internal structure showed an inner zone and an outer zone separated by intermediate layers, vascular bundles are collateral and scattered and more in inner zone and starch grains and oil cells present both sides of intermediate zone. Remashree *et al.* (1999) studied development, distribution and structure of oil cells, development of secretory ducts and diffusion of oil in rhizomes of *Z. officinale*. Oil cell differentiation initiate from a group of meristematic cells, and present in leaf, shoot apex, root apex, and contain stored volatile oil. Schizogenously developed secretory ducts found in primary tissues and lysigenously formed ducts are found throughout the developmental stages. Jayasree (2007) worked out the anatomy of South Indian Zingiberaceae, which includes the leaf anatomy of seven species of *Zingiber.*

Key to the species based on anatomical characters

1. Thickness of lamina 140-180 μm 2

1. Thickness of lamina 260-340 μm ……………………..……..……………3

2. Adaxial and abaxial midrib U-shaped, hypodermis single layered…...4

2. Adaxial midrib V-shaped and abaxial U-shaped, hypodermis two layered…………..…………………………………….……………*Z. roseum*

3. Palisade 2 or more layered ……………………………………..……..5

3. Palisade 1 layered ………………………………...………..……….....6

4. Adaxial epidermal cells higher than broad, 45-52 x 64-78 μm, fibrous band not complete in stem…………………....…………… *Z. montanum*

4. Adaxial epidermal cells longer than broad, 52-76 x 40-52 μm, fibrous band complete in stem…………………..……………………………... 7

5. Bundle arcs I, III, and IV are present in pulvinus……........……………..
……………………………….……………..…… *Z. capitatum var. elatum*

5. Bundle arcs l, ll, and lll are present in pulvinus…………..……………….... 8

6. Width of the leaf margin c. 170 μm, adaxial and abaxial midrib wide V-shaped ………………..…………………………..……..…..*Z. cernuum*

6. Width of the leaf margin c. 292 μm, adaxial side of midrib concave, and abaxial wide V-shaped ………………...……………..……*Z. nimmonii*

7. Arc lll bundle of Midrib present, leaf margin c. 82 μm broad…………………………………...……………..……...….*Z. officinale*

7. Arc lll bundle of Midrib absent, leaf margin c. 224 μm broad…………. …………………………………………….*Z. neesanum*

8. Adaxial and abaxial side of Leaf sheath U-shaped …......*Z. wightianum*

8. Adaxial side of Leaf sheath V-shaped and abaxial side flat …...……*Z. zerumbet*

Zingiber capitatum var*. elatum*

(Plate No. 2 & 3)

Leaf epidermis: Cells in the intercostal region of adaxial epidermis are rectangular, more or less hexagonal, transversely stretched with straight walls, and bear a thin cuticle. Size of the cells at the intercostal region is 80 x 32-64 μm. The cells in the costal region are smaller, iso-diametric, 45-50 × 48-52 μm with slightly thicker walls. The cells of the abaxial epidermis are irregular in shape and size. Cells are slightly smaller than those of adaxial surface, and size of epidermal cell in inter costal region is 35-66 × 32-64 μm. In the costal region isodiametric, 1-3 small cells of size 36-44 × 48-84 μm are present.

Trichome: Simple, unicellular hairs are abundant on the abaxial surface and are absent on adaxial epidermis. They are thin walled, pointed, length ranges between 551-896 μm.

Stomata: The stomata are amphistomatic and tetracytic, much more frequent on the abaxial surface than the adaxial surface and they are generally not seen in the costal region. Guard cells and the four subsidiary cells are quite distinct in size from the epidermal cells, and the long axis of the pore is parallel to the veins. The stomatal index of the adaxial epidermis is 2. 43 and that of abaxial epidermis is 8.06. Size of the stomata at the abaxial surface 48-53 μm long, and is slightly smaller than the adaxial surface, 50-63 μm long.

Lamina: Lamina is 340 μm thick, adaxial epidermal cells are broader than high and cells in the costal region are smaller than the rest. Abaxial epidermal cells are isodiametric, much smaller than upper ones. A single layer of hypodermis is present abaxially which is colourless and size ranges 45-56 x 42-52 μm. Large bundles are connected to adaxial and abaxial epidermis by 2-4 layers of sclerenchymatous bundle cap which is present only at upper and lower region and large parenchyma cells present both sides, which contain crystals. Mesophyll is 190 μm thick and consists of 3-5 layers, and transition from palisade to spongy is less differentiated.

Margin: Margin of the lamina is tapering, pointed and slightly bend downwards. Epidermal cells are high or slightly broader, 3-5 layers of palisade cells present and bundle is connected to abaxial epidermis only. Hairs are present on the abaxial epidermis. Hypodermis is seen only abaxially. Hyaline region is 2-4 seriate and 166 μm wide.

Midrib: Adaxial surface is concave and abaxial surface is wide V- shaped. Bundle arcs-I and III are present and arc-III is represented by a single bundle near adaxial surface. Hairs are absent on abaxial surface. Air canals present between the arc-I bundles at the medium region, are occupied by spongy parenchyma and it is subsequently followed by sub-stomatal cavity and stoma towards abaxial surface. The diameter of metaxylem of arc I bundle is 66-69 μm.

Pulvinus: Adaxial surface is concave and abaxial U-shaped. Bundle arc's-I, III and IV are present. Large, elongated parenchyma cells are seen around the median arc-I bundles. Collenchymatous thickening is seen in the bundle cap. Air canals are present in between the main arc bundles. The crystals and starch grains are present in the cells around the vascular bundle. The diameter of metaxylem of arc I bundle is 84-86.1 μm.

Leaf sheath: Both adaxial and abaxial surfaces are U-shaped. Bundle arcs-I, II and III are present. Air canals are present in between arc-I bundles. Chlorenchyma is seen around arc-I bundle and air canals, spongy parenchyma is present in air canal. The diameter of metaxylem of arc-I bundle is 62-65 μm. Hairs are present on adaxial surface.

Stem: Epidermal cells are thin walled, more or less rounded. Cortical bundles are arranged in two rows. Medium sized and small bundles alternate in the outer row. The second row consists of large bundles which alternate with outer row of bundles. The fibrous sheath around the central cylinder is thin and complete. Vascular bundles are scattered uniformly in the central cylinder. The fibrous thickening and bundle sheaths are poorly developed. Bundles with large xylem vessels are seen towards peripheral side.

Rhizome: Rhizome shows a cortex and a wide central cylinder. The outer most layers of the cortex are suberized and the cells are compactly arranged in radial rows. The cortex is separated from the central cylinder by endodermis. The central cylinder contains numerous scattered, vascular bundles and the structure resemble that of the bundles in the aerial stem. A well developed bundle sheath is present around the vascular bundle. Starch grains are seen in most of the cells of the cortex and inner layers of central cylinder. The bundle sheath of vascular bundles of central cylinder less developed. 1-3 metaxylem elements are seen. Oil cells are distributed uniformly in cortex and central cylinder.

Root: Root is fleshy and in cross section it is circular in outline. It consists of a wide cortex and a central cylinder. The piliferous layer is distinct, compact, arranged in radial rows and with suberized walls. Outer layers of cortex are suberized, middle layers of parenchyma cells are loosely arranged, where as inner layers are compactly arranged. Endodermal cells show thickenings which is followed by one layer of thin pericycle. Vascular bundles are radial and are polyarch. Xylem tissues include xylem vessels, tracheids, fibers and xylem parenchyma. The number of xylem vessels vary from 8-12, and posses scalariform thickening. End walls of vessels are oblique, with scalariform perforation plates and number of bars in the perforation plate varies from 16-22.

Zingiber cernuum

(Plate No. 4 & 5)

Epidermis: Cells of intercostal region of adaxial epidermis are rectangular with straight walls, with thin cuticle, and corners of the cells are slightly thickened. Size of the intercostal cell is 58-84 x 48-64 μm. Cells in the costal region are smaller, isodiametric, made up of single layer of five cells with slightly thickened walls. Size of the cell varies from 20-28 x 24 –32 μm. The cells of the abaxial epidermis are irregular in shape and size. The cells are slightly smaller than those of adaxial surface. The size of epidermal cell in the intercostal region is 36-44 x 40-56 μm. 3-5 small cells are seen in the row at the costal region of epidermis and its size varies from 24-28 x 24-28 μm.

Trichome: Hairs are simple, unicellular, and abundant on the abaxial surface. They are thin walled, pointed and length ranges from 750 μm – 1.2 mm.

Stomata: Stomata are tetracytic and amphistomatic, much more frequent on the abaxial surface than the adaxial surface, generally absent in the costal region. The long axis of the pore is parallel to the veins. The guard cells and the four subsidiary cells are different in size from the epidermis. Stomata is rare in adaxial epidermis, stomatal index of abaxial side is 6.63. The size of the stomata at the abaxial surface is slightly small 32-36.9 μm than the adaxial surface, 36-41μm.

Lamina: Lamina is 288 μm thick. Adaxial epidermal cells are broader than high in the intercostal region, and cells at costal region are smaller in size than rest. Epidermal cells at abaxial region are irregular in size and a single layer of hypodermis is present abaxially, it is colourless and size ranges from 44-52 x 42-51 μm. Main bundles does not extend up to lower epidermis and sclerenchymatous bundle sheath present on both sides. Crystals are cubical and more in lower layer of spongy parenchyma. Mesophyll is 150 μm thick and is made of single layer of palisade and three layers of spongy parenchyma. A single layer of spongy parenchyma is present in between vascular bundle and abaxial epidermis.

Margin: Tip is elongated, slightly bend downwards and beaked. Bundle is connected to the abaxial epidermis only. Hyaline region is 2-3 seriate and 170 μm wide.

Midrib: Adaxial as well as abaxial surfaces are wide V-shaped. Bundle arcs I and III are present, arc III is represented by a single bundle at the centre. Air canals are seen alternating with arc-I bundles. The air canals and vascular bundles are surrounded by chlorenchyma. Hairs long, pointed, present only on abaxial side. The diameter of metaxylem of arc-I bundle is 34-36.9 μm in diameter.

Pulvinus: Adaxial surface is concave and abaxial surface is wide U-shaped. Bundle arcs I, III, and IV are present, arc-I bundles are oval in shape with collenchymatous bundle cap. The diameter of metaxylem of arc I bundle is 72-75 μm. Air canals are present between main arc bundles and it is surrounded by chlorenchyma. Arc- III and IV bundles are round shaped with feeble thickening. Hairs are present.

Leaf Sheath: Adaxial and abaxial surfaces are wide U-shaped. Bundle arcs I, II and III are present. Bundle arcs I and II are alternating throughout the sheath. Arc-III bundles are represented by four bundles. The diameter of metaxylem of arc-I bundle is 50-53.3 μm wide. Air canals are seen in between arc I bundles and they are surrounded by chlorenchyma. Hairs are present on abaxial surface only. Length of hairs ranges from 752–973 μm. Cuboid crystals are present.

Stem: Epidermis consists of small, round, thin walled cells. Cortical bundles are in three rows. Outermost row consists of small bundles located in epidermal cells with fibrous sheath; middle row consists of elongated bundles which alternate with outer bundles, and third row consists of smaller bundles arranged along with fibrous thickening. Vascular bundles are scattered in central cylinder. More bundles are seen towards periphery. The bundle sheath around vascular bundle is not prominent.

Rhizome: Transverse section of rhizome shows cortex and central cylinder. The outermost layers of cortex are suberized. The cells are compactly arranged in radial rows. Vascular bundles are collateral and arranged in scattered manner. A well developed bundle sheath is present around the vascular bundle. Oil cells and starch grains are present in inner layers of cortical cells. The central cylinder contains numerous scattered vascular bundles in which bundle sheath less developed. The structure of the vascular bundles of cortex and central cylinder resemble that of the bundles in the aerial stem. 1-3 metaxylem elements are seen. Oil cells are distributed uniformly in the cortex and central cylinder.

Root: The section of the root shows a wide cortex and a central cylinder. Parenchyma cells are loosely arranged in outer layers of cortex where as in inner layers cells are compactly arranged. Vascular bundles are radial and polyarch. Protoxylem at the poles of the xylem, and phloem groups alternate. Xylem tissues show xylem vessels, tracheid, fibres and xylem parenchyma. Metaxylem vessels are 14-18 in number, possess scalariform thickening, end walls of the vessels are oblique, with scalariform perforation plates. Bars are widened, slightly bordered and number of bars ranges from 15-20.

Z. montanum

(Plate No. 6 & 7)

Leaf epidermis: Epidermal cells in the intercostal region of adaxial epidermis rectangular or hexagonal in shape with straight walls and size 45-52 $\times$ 64-78 μm. Slight thickening present at the angles. Cells in the costal region smaller, isodiametric, made up of single layers of 2-3 cells; with slightly thickened walls and size 20-32 $\times$ 16-20 μm. Cells of the abaxial epidermis are irregular in size and shape, and are slightly smaller than those of adaxial surface. Cells in the intercostal region are 62-40 x 38-45 μm, 3-5 small cells are seen at the costal region of epidermis and size is 20-44 x 12-36 μm.

Trichome: Simple, unicellular hairs are abundant on the abaxial surface. They are thin walled, pointed, length ranges from 790 μm -1.3 mm.

Stomata: Stomata are tetracytic, amphistomatic, much more frequent on the abaxial surface than the adaxial surface and generally absent in the costal region. The long axis of the pore is parallel to the veins. Guard cells and the four subsidiary cells are different in size from the epidermal cells. The stomatal index of the adaxial epidermis is 2.8 and that of abaxial epidermis is 8.69. The size of the stomata at the abaxial surface is slightly smaller than the adaxial surface. The guard cell is 48-53 μm long on adaxial surface and 45-49 μm on abaxial surface.

Lamina: Lamina is 160 μm thick, adaxial epidermal cells are broader than high and cells at the costal region are smaller than that of intercostal regions. Abaxial epidermal cells are irregular in size and shape. A single layer of hypodermis is present abaxially, and hypodermis is colourless and size range from 36-40 × 32-36 μm. All vascular bundles are extending to both epidermis. A single layer of sclerenchymatous bundle cap is seen abaxially and fibrous sclerenchyma is absent on both sides instead parenchyma cells are seen on the either side of vascular bundles. Crystals are sparse. Mesophyll is 92 μm thick; made up of 1 layer of palisade and 3 layers of spongy parenchyma.

Margin: Margin is tapering and slightly bend downwards. An epidermal hair is seen abaxially in the hyaline area. Bundle is connected to the abaxial epidermis only. Hyaline region is 2-3 seriate and 192 μm long.

Midrib: Adaxial as well as abaxial surfaces are wide U-shaped. Bundle arcs I and III are present, and arc-III is represented by a single bundle at the centre. The diameter of metaxylem of arc-I bundle is 42-45 μm. Air canals are seen alternating with arc-I bundles, air canals and vascular bundles are in turn surrounded by Chlorenchyma. Hairs long, pointed, present only on abaxial side, size ranges from 928-976 μm.

Pulvinus: Adaxial surface is wide V-shaped and abaxial wide U-shaped. Bundle arcs I, III and IV are present. Arc-I bundles are oval in shape with collenchymatous bundle cap. The metaxylem of arc-l bundle at the median region varies 68-74 μm in diameter. Air canals are present between main arc bundles, and chlorenchyma is seen around the air canals. Arc-III and IV bundles are circular in cross section with feeble fibrous thickening. Hairs are present on abaxial and adaxial surfaces; their length varies from 369-990 μm. Crystals present, they are rectangular or cuboid.

Leaf Sheath: Adaxial and abaxial surfaces are U-shaped. Bundle arcs I and II are present, and they are alternating throughout the sheath. The diameter of metaxylem of arc-l bundle at the median region ranges from 41-61.5 μm. Air canals are seen in between arc-I bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are present on abaxial surface only, and their length ranges from 496-544 μm. Rectangular crystals are present.

Stem: Epidermal cells are thin walled, more or less circular. Cortical bundles are arranged in three rows. Outer most rows consist of small bundles with thick sclerenchymatous bundle sheath; middle row shows large and small bundles. Bundles at the inner rows are medium sized and arranged irregularly. A fibrous sheath is present around the central cylinder and it is not complete. Vascular bundles are scattered in central cylinder and feeble thickening is seen around the vascular bundles and bundles with large xylem are seen towards the peripheral region. Crystals are present in the parenchyma cells of central cylinder.

Rhizome: Rhizome shows a cortex and a wide central cylinder. The outermost layers of the cortex are suberized, and cells are compactly arranged in radial rows. Vascular bundles are collateral, closed and arranged in scattered manner. A well developed bundle sheath is present around the vascular bundle of cortex. The fibrous thickening of the bundles of central region is less developed. 1-3 metaxylem elements are seen. Starch grains are seen in most of the cells of the cortex, and in the central region. Oil cells are distributed uniformly in the cortex and the centre.

Root: Root is fleshy; many root tubers present. The piliferous layer is distinct, tightly, arranged in radial rows and possess suberized walls. Cortex is divided into an outer cortex, where cells are loosely arranged and inner layers are compactly arranged. Vascular bundles are radial and are polyarch. Number of metaxylem vessels range 12–16, posses scalariform thickening and oblique perforation plate and number of bars range from 14-19.

Zingiber neesanum

(Plate No. 8 & 9)

Leaf epidermis: Epidermis bears a thin cuticle. Cells in the intercostal region of adaxial epidermis are rectangular, with straight, transversely stretched walls, and size varies from 56-76 $\times$ 40-52 μm. Epidermal cells in the costal region are smaller; size 20 $\times$ 24 μm and with thick and isodiametric walls**.** Abaxial epidermal cells are irregular in shape and size. Size of cells in the intercostal region varies from 34-64 $\times$ 20-52 μm. Two small isodiametric cells are seen at the costal region. Its size varies from 24-32 $\times$ 24-28 μm.

Trichome: Hairs are simple, unicellular, thin walled, pointed, length ranges between 672 μm -1.02 mm. Hairs are absent on adaxial epidermis and present only near the midrib of abaxial region.

Stomata: Stomata are amphistomatic and tetracytic, more frequent on the abaxial surface and absent in the costal region. The long axis of the stomatal pore is parallel to the veins. The guard cells and the four subsidiary cells are quiet distinct in size from the epidermal cells. Stomatal index of the adaxial epidermis is 2.70 and that of abaxial epidermis is 8.63. The guard cell is 38-40 μm long on adaxial surface and 36-40 μm long on abaxial surface.

Lamina: Lamina is 176 μm thick. Adaxial epidermal cells in the intercostal region are broader than high. Cells at the costal region are smaller and isodiametric in shape. Abaxial epidermal cells are irregular in size and shape. A single hypodermal layer is present abaxially and is colourless, size ranges 20-28 $\times$ 32-48 μm. Large bundles are connected to both epidermis. Bundle cap consists of a single layer of cells abaxially. All vascular bundles do not extend to both epidermis. Mesophyll is 42 μm thick and is made up of single layer of palisade and three layers of spongy parenchyma.

Margin: Leaf margin is elongated, beaked and bend downwards. Bundle is connected to the abaxial epidermis only. Hyaline region is 3-2 seriate and 224 μm wide.

Midrib: Adaxial surface is U-shaped and abaxial surface is wide U-shaped. Only arc-I bundle is present. Air canals are present alternate to the bundles. Air canals are surrounded by chlorenchyma. The arc-I bundles are oval in shape, a single metaxylem present and its diameter varies from 32-41μm.

Pulvinus: Adaxial surface is wide V-shaped and abaxial wide U-shaped. Bundle arcs I, II and III are present, arc-I bundles are oval in shape with collenchymatous bundle cap. Air canals are present in between the bundles. Chlorenchyma is seen around the air canals. Arc-II is represented by a single bundle. Arc-III bundles are circular in outline with feeble fibrous thickening. Size of metaxylem ranges from 38-45.1 μm. Hairs present on abaxial and adaxial surfaces. The length of hairs varies from 42-64 μm. Elongated large parenchyma cells are seen around the Arc-I bundles of the median region crystals with rectangular and cuboid shapes and starch grains also present.

Leaf Sheath: Adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Bundle arcs I and II are alternating throughout the sheath. The size of metaxylem ranges from 58-61.5 μm diameter. Air canals are seen in between arc-I bundles and air canals are in turn surrounded by chlorenchyma.

Stem: Cells in the epidermis are thin walled and cortical bundles are arranged in 2-3 rows. Bundles near the epidermis are small with single xylem vessels and well developed fibrous thickening. In the middle row medium sized bundles alternates with outer row. The inner row consists of larger bundles seen along with the fibrous band. Fibrous thickening is complete around central cylinder. Vascular bundles in the cylinder are uniformly arranged in a scattered manner with reduced bundle cap.

Rhizome: Transverse section of rhizome shows a cortex and a wide central cylinder. The outermost layers of the cortex are suberized, and are compactly arranged in radial rows. Starch grains are abundant in inner layers of cortical cells as well as central cylinder. Oil cells are present. The central cylinder contains numerous scattered vascular bundles which resemble the bundles of the aerial stem. The fibrous thickenings of the bundles are less developed, with 1-3 metaxylem elements.

Root: Root shows a wide cortex and a central cylinder and endodermis present in between. A piliferous layer is distinct, tightly arranged in radial rows and has suberized walls. Parenchyma cells are loosely arranged in outer layers and cells are compactly arranged in inner layers. Xylem vessels 17-20 in number and possess scalariform thickening. The end walls of the vessels are oblique, with scalariform perforation plates; number of bars varies from 13-18.

Zingiber nimmonii

(Plate No. 10 & 11)

Epidermis: Epidermal cells in intercostal region of adaxial epidermis are rectangular with straight walls. It bears thin cuticle, and corners of the cells are slightly thickened. Size of the intercostal cell is 75–95 x 42 μm. Cells in the costal region smaller, more or less isodiametric, made up of single layer of five cells with slightly thickened walls. Size of the cell varies from 24 x 32 μm. The cells of the abaxial epidermis are irregular in shape and size. The cells are slightly smaller than those of adaxial surface. The size of epidermal cell in the intercostal region is 60–66 x 36 μm. 3-5 small cells are seen in the row at the costal region of epidermis and its size varies from 36 x 44 μm.

Trichome: Hairs are simple, unicellular, abundant on the abaxial surface. They are thin walled, pointed and length ranges from 684 μm–1.4 mm.

Stomata: Tetracytic and amphistomatic stomata are much more frequent on the abaxial surface than on the adaxial surface. Stomata are generally absent in the costal region. The long axis of the pore is parallel to the veins. The guard cells and the four subsidiary cells are different in size from the epidermis. Stomata on adaxial epidermis are rare and index on abaxial side is 6.83. The size of the stomata at the abaxial surface is 38-40 μm long and the adaxial surface is 40-46 μm long.

Lamina: Lamina is 260 μm thick. Adaxial epidermal cells broader than high. Costal cells are smaller in size than rest. Abaxial epidermal cells are irregular in size. A single layer of hypodermis is present abaxially, it is colourless, size ranges from 44-48 x 32-36 μm. Main bundles does not extend up to lower epidermis. Fibrous sclerenchymatous bundle sheath present on both sides. Cuboidal crystals are more in lower layer of spongy parenchyma. Vascular bundles are 100 μm in thickness. Mesophyll is 90 μm thick and made of single layer of palisade and 2 layers of spongy parenchyma. A single layer of spongy parenchyma is present in between vascular bundles and abaxial epidermis.

Margin: Tip is elongated, slightly bend downwards and beaked. Bundle is connected to the abaxial epidermis only. Hyaline region is 2-3 seriate and 292 μm wide.

Midrib: Adaxial side of midrib is concave and abaxial surface wide U-shaped. Bundle arcs I, and lll are present, arc-III is represented by three bundles at the centre. Arc-I bundles are seen through out the length and air canals are seen alternating with arc-I bundles. The air canals and vascular bundles are surrounded by chlorenchyma. The diameter of metaxylem ranges 38-42 μm. Hairs long, pointed, present only on abaxial side.

Pulvinus: Adaxial surface is concave and abaxial surface is wide U-shaped. Bundle arcs I, III, and IV are present. Arc-I bundles are oval in shape with collenchymatous bundle cap. The diameter of metaxylem of arc-I bundle is 28-36 μm. Air canals are present between main arc bundles and it is surrounded by chlorenchyma. Arc-III and IV bundles are round shaped with feeble thickening. Hairs are present.

Leaf Sheath: Adaxial and abaxial surfaces are wide U-shaped. Epidermis is made up of small cells, slightly collenchymatous. Bundle arcs I, II and lll are present. Bundle arcs I and II are alternating throughout the sheath. The diameter of metaxylem of arc-I bundle ranges from 32-80 μm. Air canals are seen in between arc-I bundles and they are surrounded by chlorenchyma. Hairs are present on abaxial surface only. Length of hairs ranges from 650 μm–1.2 mm. Cuboid shape crystals are present.

Stem: Epidermis consists of small, round thin walled cells. Cortical bundles are in 2-3 rows. Outermost row consists of small bundles located near epidermal cells with fibrous sheath; it is alternate with large bundles inside. Inner most bundles are smaller and are arranged along with fibrous thickening. Vascular bundles are scattered in central cylinder. More bundles are seen towards periphery. The bundle sheath around vascular bundle is feeble.

Rhizome: Rhizome shows a cortex and a central cylinder. The outermost layers of cortex are suberized. The cells are compactly arranged in radial rows. Vascular bundles are collateral and arranged in scattered manner. A well developed fibrous thickening is present around the vascular bundles. Oil cells and starch grains are present in the inner layers of cortical cells. The central cylinder contains numerous scattered vascular bundles and bundle sheath is less developed. The structure of the vascular bundles of cortex and central cylinder resemble that of the bundles in the aerial stem. 1-3 metaxylem elements are seen. Oil cells are distributed uniformly in the cortex and central cylinder.

Root: The root shows a wide cortex and a central cylinder. The piliferous layer is distinct, arranged in radial rows and possess suberized walls. Parenchyma cells are loosely arranged in outer layers of cortex; the inner layers of cells are compactly arranged. Xylem vessels 20-23 in number and posses scalariform thickening, and with oblique end walls and the number of bars in the perforation plate varies from 11-20.

Zingiber officinale

(Plate No. 12 & 13)

Leaf epidermis: Epidermal cells in the intercostal region of adaxial epidermis rectangular, with straight walls; outer wall is thickened at the corners. Size of epidermal cells at intercostal vary from 52-72 x 44-52 μm and epidermis bears a thin cuticle. The costal cells are smaller, made up of single or two rows of cells with slightly thicker walls, isodiametric, and size varies from 16-22 x 24-28 μm. The cells of abaxial epidermis are irregular in size and shape, slightly smaller than those of adaxial surface. The size of the epidermal cells in the intercostal region is 28-40 x 20-28 μm and costal cells are 20 x 28-32 μm.

Trichome: Simple, unicellular hairs are abundant on the abaxial surface. They are thin walled, pointed, length ranges between 800 μm–1.3 mm. Hairs are absent on adaxial epidermis.

Stomata: The stomata are amphistomatic, tetracytic, much more frequent on the abaxial surface than adaxial surface and generally absent at the costal region. The long axis of the pore is parallel to the veins. The guard cells and the four subsidiary cells are quite distinct in size from the epidermal cells. The stomatal index of the adaxial epidermis is 2.54 and that of abaxial surface is 8.67. The size of the stomata at the abaxial surface is 28-32.8 μm long and that of adaxial surface is 30-36.9 μm.

Lamina: Lamina is 176 μm thick, adaxial epidermal cells are broader than high and costal epidermal cells are smaller and isodiametric. Mesophyll consists of 3-4 layers and 68 μm thick with a single layer of palisade parenchyma and three layers of spongy parenchyma. A single layer of hypodermis, 28-32 x 24-28 μm thick, present abaxially. Main bundle extend between upper and lower epidermis. Smaller bundles are connected to the abaxial epidermis only and xylem consists of a single large xylem element of about 20.5 μm in diameter and 2-3 small angular xylem fibres. Crystals are sparsely present.

Leaf Margin: Leaf margin is tapering, small beaked and slightly bends downwards. Epidermal cells high or slightly broader, hairs present on abaxial epidermis only. Marginal bundle is connected to the abaxial surface and 2-3 layers of palisade constitute the mesophyll. A single layer of hypodermis is present on abaxial side. Hyaline region is 2-seriate and tapering to a single cell at the tip, 82 μm wide.

Midrib: Adaxial as well as abaxial surface are wide U-shaped. Bundle arcs I and III are present, and arc-III is represented by a single bundle. Air canals are seen in between the arc-I bundles. The air canals are in turn surrounded by chlorenchyma tissue. Hairs present on abaxial surface. Shape of the crystals is peculiar, look like an opened book. The diameter of metaxylem of arc-I bundle ranges 32-36.9 μm.

Pulvinus: Adaxial surface is concave and abaxial surface is U-shaped. Bundle arcs I, II and III are present. Collenchymatous thickening is present in the bundle cap and also at the corners of the cells near epidermis. Air canals are present in between the main arc bundles, chlorenchymatous cells are seen around air canals. Cuboid crystals, and starch grains are present in the cells around the vascular bundle. Diameter of the metaxylem element of arc-I bundle ranges from 20-30.9 μm.

Leaf sheath: Both adaxial and abaxial surfaces are U-shaped. Hairs are present on abaxial surface. Bundle arcs I and II are present. Air canals are seen in between arc-I bundles and they are in turn surrounded by chlorenchyma. Diameter of metaxylem of arc-I vascular bundle varies from 12-28.7 μm. Arc-II bundle is represented by fibre sheaths only.

Stem: Epidermal cells are thin walled. Cortical bundles are arranged in 3 rows. Outer row of smaller bundles are arranged with epidermal cells with one or two xylem and with developed bundle cap. Middle row consists of large sized bundles and alternating with bundles of outer row. Bundle sheath is well developed, but lack thickening in lateral sides of these bundles. Inner row consists of medium sized and smaller bundles with well developed bundle sheath. Fibrous band is complete around the central cylinder. Vascular bundles are scattered in central cylinder and more numbers are seen towards central region.

Rhizome: Rhizome shows cortex and a wide central cylinder. The outer most layers of the cortex are compactly arranged in radial rows with suberized walls. Oil cells and starch grains are present in the inner layers of cortical cells. Vascular bundles are numerous and scattered in central cylinder and the structure resemble that of the bundles in the aerial stem. 1-3 metaxylem elements are seen in vascular bundles. Numerous oil cells are distributed uniformly in the cortex and central cylinder. Most of the cells in the central cylinder are filled with starch grains.

Root: Root is fleshy and consists of a wide cortex and a central cylinder. Cortex is wide, parenchyma cells are loosely arranged, outer layers are suberized and inner layers are compactly arranged. The piliferous layer is distinct, arranged in radial rows and possess suberized walls. Vascular bundles are radial and polyarch. Central cylinder is with 28–34 metaxylem vessels and posses scalariform thickening and with scalariform perforation plates, bars are widely arranged slightly borderd and number of bars range from 12-19.

Zingiber roseum

(Plate No. 14&15)

Epidermis: Epidermal cells of inter costal region of adaxial epidermis rectangular with straight walls and bears a thin cuticle, and size varies from 44-48 x 56 μm. At the costal region cells are smaller, isodiametric, a row of 4-5 cells, with slightly thickened walls and size 20-28 x 16-24 μm. Cells of the abaxial epidermis are highly irregular in size and shape, and smaller than those of adaxial surface, size varies from 30-346 x 26 μm. Size of cells at the costal region, 24-28 x 20-24 μm.

Trichome: Simple, unicellular, hairs are abundant on the abaxial surface. They are thin walled, pointed, length ranges between 848–1. 2 mm. Hairs are absent on adaxial epidermis.

Stomata: Tetracytic and amphistomatic, more frequent on the abaxial surface than adaxial and generally absent in the costal region. The long axis of the pore is parallel to the veins. Stomatal index of the adaxial epidermis is 1.63 and that of abaxial epidermis is 8.48. The size of the stomata at the abaxial surface is slightly smaller, 40-44 μm than the adaxial surface, 44–48 μm.

Lamina: Lamina is 140 μm thick. Adaxial epidermal cells are broader than high but at the costal region, cells are smaller than the rest. Abaxial epidermal cells are irregular in shape. Two layers of hypodermis are present abaxially, and it is colourless, size 24-28 x 26-32 μm. Main bundle extend up to lower epidermis and fibrous parenchymatous bundle sheath present on both sides. Crystals are cuboid, more in lower layer of spongy parenchyma. Mesophyll is 100 μm thick, made up of single layer of palisade and two layers of spongy parenchyma.

Margin: Margin of the leaf is elongated, beaked, slightly bend downwards and hyaline region is 2-3 seriate and 160 μm wide.

Midrib: Adaxial surface is V-shaped and abaxial U-shaped. Bundle arcs I and III are present. Arc-I bundle is oval in shape and arc-III is represented by four bundles at the centre. Air canals are seen alternating with arc-I bundles and they are in turn surrounded by chlorenchyma. Spongy parenchyma is present in the air canal. Diameter of metaxylem of arc-I bundle varies from 56–68 μm.

Pulvinus: Adaxial surface is wide V-shaped and abaxial surface U-shaped. Bundle arcs I and III are present, arc-I bundles are oval in shape with collenchymatous bundle cap and size of metaxylem varies from 40-48 μm in diameter. Air canals present between main arc bundles and they are surrounded by chlorenchyma. Arc-III bundles are round shaped with feeble fibrous thickening. Hairs are abundant on abaxial epidermis and length varies from 465-678 μm.

Leaf sheath: Both adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Bundle arcs I and II are alternate through out the sheath. A fully grown arc-II bundles are seen at the median region only, others are represented by fibrous thickening. Arc-III bundles are also seen at the median region. Air canals are alternating with arc-I bundles and are absent towards tips. Hairs are present on abaxial surface and length ranges from 288-352 μm. Diameter of metaxylem of arc-I bundles ranges from 28-60 μm.

Stem: Epidermal cells are thin walled. Cortical bundles are arranged in 2-3 rows; outer row of smaller bundles arranged near epidermis with one or two xylem vessels and with well developed bundle cap. The inner row consists of large sized bundles and smaller ones. Fibrous band is complete around the central cylinder. In the central cylinder vascular bundles are scattered, with poorly developed bundle cap.

Rhizome: Rhizome shows cortex and a wide central cylinder. The outer most layers of the cortex are suberized; cells are compactly arranged in radial rows. Vascular bundles are scattered, collateral, closed with well developed fibrous thickening. Oil cells and starch grains are present in the inner layers of cortical cells. Vascular bundles are numerous in central cylinder, and the structure resembles that of the bundles in the aerial stem and bundle sheath less developed. 1-3 metaxylem elements are seen. Numerous oil cells are distributed uniformly in the cortex and central cylinder. Most of the cells in the central cylinder are filled with starch grains.

Root: Root consists of a wide cortex and a central cylinder. Parenchyma cells are loosely arranged, outer layers of are suberized, inner layers are compactly arranged in outer cortex. The piliferous layer is distinct, arranged in radial rows and possessing suberized walls. Number of metaxylem vessels varies from 15–18, posses scalariform thickening. The end walls are oblique; with scalariform perforation plates and bars are widened and slightly bordered and bars range from 24-32.

Zingiber wightianum

(Plate No. 16 & 17)

Leaf epidermis: Epidermal cells in the intercostal region of adaxial epidermis are rectangular, transversely stretched, with straight walls and bears a thin cuticle. Size ranges from 68-80 x 22-56 μm. Cells in the costal region are smaller, isodiametric, made up of single layer of 4-5 cells, with slightly thickened walls, size 16-28 x 28-36 μm. Cells of the abaxial epidermis are irregular in shape and size, 40-48 x 36-48 μm, slightly smaller than those of adaxial surface. 3-5 small cells are seen in the costal region and size varies from 32-28 x 16-12 μm.

Trichome: Hairs are absent in adaxial surface. On abaxial side, hairs are simple, unicellular, thin walled, pointed, length ranges from 680 μm–1. 2 mm.

Stomata: Stomata are tetracytic and amphistomatic, frequent on the abaxial surface than the adaxial surface. Stomata are generally absent in the costal region. The long axis of the stomatal pore is parallel to the veins. The guard cells and the four subsidiary cells are different in size from the epidermal cells. The stomatal index of the adaxial epidermis is 1.85 and that of abaxial surface is 9.82. The guard cell is 43-45.1 μm long on abaxial surface and 47-49.2 μm on adaxial surface.

Lamina: Lamina is 280 μm thick, adaxial epidermal cells at the intercostal region are broader than high. Cells at costal region are smaller in size than the rest. Abaxial epidermal cells are irregular in size. A single layer of hypodermis is present abaxially which is colourless and size ranges from 32-48 x 36-44 μm. Large bundles are connected to both epidermis. A single layer of sclerenchymatous bundle cap is seen abaxially. Crystals are distributed in hypodermis and lower layer of spongy parenchyma. Mesophyll is 152-168 μm thick, made up of 2 layers of palisade and 3 layers of spongy parenchyma.

Margin: Leaf margin is elongated, curved and beaked. Bundle is connected to the abaxial epidermis only. Hyaline region is 2-3 seriate and 198 μm wide.

Midrib: Adaxial as well as abaxial surfaces are wide V-shaped. Bundle arc-I and III are present, arc-III is represented by two bundles. Air canals are seen alternating with arc-I bundles and they are in turn surrounded by chlorenchyma. Diameter of metaxylem of arc-I bundle varies from 40-48 μm. Hairs are 78-125 μm long, present only on abaxial side.

Pulvinus: Both abaxial and adaxial surfaces are U-shaped. Bundle arcs I, II and III are present and arc-I bundles are oval in shape with collenchymatous bundle cap. Metaxylem of arc-I bundle varies from 36-64 μm diameter. Air canals present between main arc bundles, and chlorenchyma is seen around air canals. Arc II and III bundles are very small with prominent fibrous thickening and rounded. Hairs are present on abaxial surfaces, length varies from 75-110 μm.

Leaf sheath: Adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present, and arc-II bundles alternating with arc-I bundles throughout the sheath. Air canals are seen in between arc-I bundles and they are in turn surrounded by chlorenchyma. Size of metaxylem of arc-I bundle varies from 32-64 μm in diameter.

Stem: Epidermal cells are thin walled, small, rounded; cortical bundles are arranged in three rows. Outer row consists of small sized bundles with one large xylem vessel with well developed bundle sheath. Bundles in the middle row are larger, and inner row consists of medium sized bundles with bundle sheath and alternates with middle row. Very small bundles are also seen in the inner row, which fuses with the fibrous thickening. Fibrous sheath is thick and complete. Vascular bundles scattered in the central cylinder and more bundles are arranged towards periphery. Bundle sheath in the vascular bundles of central cylinder is feeble. Crystals and starch grains are present in the central cylinder.

Rhizome: Rhizome shows a wide cortex and a central cylinder. The outermost layers of the cortex are suberized; cells are compactly arranged in radial rows. Oil cells and starch grains are seen in the inner layers of cortical cells. Vascular bundles in the central cylinder are numerous, scattered, structure resembles that of the bundles in the aerial stem, and bundle sheath is less developed than cortical bundles, and with 1-3 metaxylem elements. Oil cells are present both cortical region and central cylinder.

Root: Root is fleshy, consists of a wide cortex and a central cylinder. Cortex is wide, parenchyma cells are loosely arranged, outer layers are suberized, inner layers are compactly arranged. Number of metaxylem vessels vary from 10–14, possess scalariform thickening, end walls are oblique with scalariform perforation plates and number of bars on the perforation plate ranges from 16-22.

Zingiber zerumbet

(Plate No.18 & 19)

Leaf epidermis: Cells in the intercostal region of adaxial epidermis are rectangular, more or less hexagonal in shape, with straight transversely stretched walls, and bears a thin cuticle. Size ranges from 68-92 x 30-46 μm. The cells are smaller and isodiametric at costal region, size 24 x 32 μm, in a single row, with slightly thick walls. The cells of the abaxial epidermis are irregular in shape and size, slightly smaller than those of adaxial surface and size ranges from 28-64 μm.

Trichome: Simple, unicellular, hairs are abundant on the abaxial surface. They are thin walled, pointed, length ranges from 720-768 μm. Hairs are absent on adaxial epidermis.

Stomata: The stomata are amphistomatic, tetracytic and much more frequent on the abaxial surface than the adaxial surface and generally absent at the costal region. The long axis of the pore is parallel to the veins. The guard cells and the four subsidiary cells are quite distinct in size from the epidermal cells. The stomatal index of the adaxial epidermis is 2. 27 and that of abaxial surface is 9.66. The size of the stomata at the abaxial surface is 36-38 μm and slightly smaller than the adaxial surface, 39-43 μm.

Lamina: Lamina is 272 μm thick, adaxial epidermis cells are broader than high and cells above bundles are smaller than the rest. Abaxial epidermal cells are smaller than upper ones. A single layer of hypodermis 38-44 x 28-32 μm is present abaxially; crystals are more in the hypodermal layer and the lower layer of spongy parenchyma. Main bundles extend between upper and lower epidermis, and towards adaxial region 5-6 layers of sclerenchymatous bundle cap and abaxial region a 3-4 layers of sclerenchymatous cells are seen. Mesophyll consists of 5-6 layered, 114 μm thick two layered palisade parenchyma and 3 layers of spongy parenchyma. Xylem consists of single large xylem element of about 45.1 μm diameter and 2-3 small angular xylem fibres.

Leaf margin: Tip tapering and pointed and slightly bent downwards. Epidermal cells high or slightly broader. Hairs are present on the abaxial epidermis. Bundle is connected to the abaxial surface only. 3-4 layers of palisade constitute the mesophyll. Hypodermis is seen only abaxially. Hyaline region is 2-3 seriate and 290 μm wide.

Midrib: Adaxial surface is wide U-shaped and abaxial surface is U- shaped and ribbed at the region of arc-I median bundles. Bundle arcs I and III are present and arc-III is represented by a single bundle. Air canals are present in between the arc-I bundles, and air canals are in turn surrounded by chlorenchyma tissue. The diameter of metaxylem element ranges from 52-56 μm in diameter and protoxylem lacunae are seen. Crystals are cuboid in shape. Hairs are present on abaxial surface

Pulvinus: Adaxial surface is concave and abaxial U-shaped. Bundle arcs I, II, and III are present. Collenchymatous thickening is seen in the bundle cap and in the corners of the cells abaxial to arc-1 bundle. Air canals are present in between the arc-I bundles, and they are in turn surrounded by chlorenchyma. Crystals and starch grains are present in the cells around the vascular bundle. The diameter of the metaxylem of arc-I bundle is 40-49.2 μm.

Leaf sheath: Adaxial side is V-shaped and abaxial surface is flat. Hairs are present on abaxial surface. Bundle arcs I, II and III are present. Air canals are present in between arc-I bundle, and chlorenchyma is seen around the air canals. The diameter of metaxylem of arc-I vascular bundle varies from 22-38 μm.

Stem: Epidermal cells are thin walled. At cortical region 1-3 or 1-4 rows of vascular bundles are present. Vascular bundles in the outer row are smaller, highly reduced, arranged in the epidermal layer. It is rounded with a prominent bundle cap with 1 or 2 xylem vessels. Vascular bundles in the middle row are larger in size with one large xylem vessel and prominent bundle cap thickening. Third row consists of elongated and rounded bundles, alternate with other rows. Fibrous thickening around the central cylinder is not continuous. Vascular bundles are scattered but more towards periphery. Bundle sheath poorly developed in central cylinder. 1-4 vessels are seen per bundles. Starch granules present.

Rhizome: Rhizome shows a cortex and a wide central cylinder. The outermost layers of the cortex are suberized, compactly arranged in radial rows. Vascular bundles are collateral and arranged in scattered manner. A well developed bundle sheath is present around the vascular bundle. Oil cells and starch grains are seen in the inner layers of cortical cells. The cortex is separated from the central cylinder by an endodermis. 1-3 metaxylem elements are seen in bundle.

Root: Root is fleshy and consists of a wide cortex and a central cylinder. Piliferous layer is distinct, tightly arranged in radial rows and possess suberized walls. Cortex is wide, parenchyma cells are loosely arranged, outer layers are suberized, inner layers are compactly arranged. Number of xylem group varies from 13-16, posses scalariform thickening the end walls are oblique, with scalariform perforation plates and number of bars ranges from 11-17.

Stomatal development

(Fig. No. 4)

The stomata are amphistomatic, and more frequent on abaxial side than adaxial surface in *Zingiber* species. Tetracytic stomata are present in all species of genus *Zingiber* in South India. The stoma is surrounded by four cells; two of which are parallel and the other two at right angles to the long axis of the guard cells. Olatunji (1980) reported stomatal development as tetraperigenous in Zingiberaceae. In the present study all species of *Zingiber* of South India have been worked out for stomatal development. Tender unopened leaves were taken for the study. Initially the cells in the epidermis are very small, with dense cytoplasm and prominent nucleus. The initial cell 'meristemoid' is usually distinguishable from other differentiating protodermal cells by its rounded corners, dense cytoplasm, relatively large nucleus, and deep staining contents. Surrounding each meristemoid are four neighbouring cells, two lateral neighbouring cells and two terminal neighbouring cells. They are smaller than the guard cell mother cell (GCMC). Both lateral and terminal neighbouring cells divide to cut off small cells surrounding the GCMC. Later GCMC divides and gives rise to two guard cells. Guard cells are long, dumb-bell-shaped with a prominent nucleus. A pore is developed in between the guard cells. Thus two parallel and two terminal subsidiary cells are formed around guard cells. This gives rise to tetracytic stomata with two guard cells and four subsidiary cells; two laterals and two terminals.

Xylem

(Plate No. 20 & 21)

The structure and distribution of xylem elements were studied by maceration method. Xylem tissues from midrib, pulvinus, leaf sheath, stem and root were taken for the studies. In *Zingiber* vessels are confined to the roots only, in all other parts only tracheids were present.

Table No. 2. Details showing the nature of vessel in root

Name of taxa	Nature of end wall	Diameter of the vessel (μm)	Number of bars
Z. capitatum var. elatum	Oblique	28-36.5	16-22
Z. cernuum	Oblique	29-38	15-20
Z. montanum	Oblique	18-28	14-19
Z. neesanum	Oblique	20-29.5	13-18
Z. nimmonii	Oblique	25-42	11-20
Z. officinale	Oblique	14-20	12-19
z. roseum	Oblique	18-29	24-32
Z. wightianum	Oblique	28-36.5	16-22
Z. zerumbet	Oblique	19-32	11-17

Vessels are with wide lumen, and scalariform thickening. The end walls are oblique, and perforation plates are seen at end walls and it is not bordered. Perforation plates are convex and its corresponding part may concave with few to many bars. The perforation plates of two ends may vary. They often encroach into the lumen of the adjacent vessels. The perforation plate can be recognised because of the absence of primary membrane, and the bars are supported only at their ends and evenly placed. The first formed xylem elements are very long and narrow. The later formed xylem vessels are larger, with wide lumen seen towards centre. Perforation plates showed variation in length, nature of end wall and width. According to Cheadle and Tucker (1961) scalariform perforation with many bars are considered primitive and with few bars as advanced. Cheadle (1953) classified the monocot families based on the presence of vessels in different organs and the family Zingiberaceae is included in families having some species with vessels in roots only.

Discussion

Dermal morphology and plant parts from lamina, midrib, pulvinus, leaf sheath, stem, rhizome and root were taken for study. Though *Zingiber* species share some common anatomical characters, they show many differences at specific levels.

Leaf epidermis: The epidermal cells of intercostal region of adaxial surfaces are rectangular, more or less hexagonal in shape with straight walls, size range from 44-48 x 56 μm in *Z. roseum* and 80 x 32-64 μm in *Z. capitatum* var. *elatum*. Intermediate size is observed in others *viz.,* 75-95 x 42 μm in *Z. nimmonii;* 58-84 x 48-64 μm in *Z. cernuum;* 56-76 x 40-52 μm in *Z. neesanum;* 52-72 x 44-52 μm in *Z. officinale;* 68-80 x 22-56 μm in Z. *wightianum;* 68-92 x 30-46 μm in *Z. zerumbet* and 45-52 x 64-78 μm in *Z. montanum*. Cell files are regularly arranged in adaxial epidermis, but the cells are smaller on abaxial epidermis and stomata are more in this layer. Cell walls are with thickened corners. Cells at the costal region are smaller and slightly thick walled and bear a thin cuticle. Thickness of the leaf and hyaline area on leaf margin are different among different taxa. The mesophyll consists of palisade and spongy parenchyma. Two or more palisade layers are seen in *Z. capitatum* var. *elatum*, *Z. wightianum* and *Z. zerumbet.* In *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, and *Z. roseum* one layer of palisade is present. Oil cells are distributed in lower epidermal cells of all species but they are abundant in *Z. officinale*. This agrees with the observation of Tomlinson (1956).

Thickness of lamina: Leaf thickness varies from 140-340 μm. Among the species studied, the thickest lamina, 340 μm is observed in *Z. capitatum* var. *elatum* and thinnest 140 μm in *Z. roseum*. It is 288 μm in *Z. cernuum*, 160 μm in *Z. montanum*, 176 μm in *Z. neesanum*, 260 μm in *Z. nimmonii*, 176 μm in *Z. officinale*, 280 μm in *Z. wightianum*, and 272 μm in *Z. zerumbet*. The portion beyond last bundle in lamina consists of mesophyll or colourless parenchyma cells only **(Plate. 22).**

Hypodermis: In all South Indian *Zingiber* species adaxial hypodermis is generally absent. A single layer of hypodermis is present on abaxial region in all species execpt in *Z. roseum*, which possess two layers. Solereder & Meyer (1930) suggested the hypodermis as water storage in function. The cells are large, colourless and transversely stretched. Largest cells are are present in *Z. capitatum* var. *elatum* 45-56 x 42-52 μm, and in *Z. cernuum* 44-52 x 42-51 μm. Size of hypodermal cell is 38-44 x 28-32 μm in *Z. zerumbet*, 32-48 x 36-44 μm in *Z. wightianum*, 44-48 x 32-36 μm in *Z. nimmonii*, 36-40 x 32-36 μm in *Z. montanum,* 28-32 x 24-28 μm in *Z. officinale*, and smallest 20-28 x 32-48 μm in *Z. neesanum*, and 24-28 x 26-32 μm, in *Z. roseum.* In *Z. cernuum* and *Z. nimmonii*, Calcium oxalate crystals are more confined to the hypodermal layer. The abaxial hypodermis is interrupted by large sub-stomatal chamber at the region of stoma.

Mesophyll: The mesophyll comprises parenchymatous tissue internal to the epidermis. It usually undergoes differentiation to form the photosynthetic tissues and contains chloroplasts (Fahn, 1989). The mesophyll is found to be heterogenous with distinct adaxial palisade and abaxial spongy parenchyma. The layer of columnar chlorenchyma cells below the epidermis is called palisade parenchyma. The tissue is mostly responsible for photosynthesis and the structure is well suited for the same due to the presence of chloroplast. The number of palisade and spongy layers vary from species to species. A single layer of palisade is present in *Z. cernuum*, *Z. nimmonii*, *Z. neesanum*, *Z. montanum,* where as three layers of spongy parenchyma are present in *Z. officinale* and *Z. roseum*. In *Z. capitatum* var. *elatum*, *Z. wightianum* and *Z. zerumbet* two or more layers of palisade parenchyma are seen in the mesophyll. In these species transition from palisade to spongy is not very distinct. A centric leaf structure is recorded in *Z. capitatum* var. *elatum* (Solereder and Meyer, 1930) where as Tomlinson (1956) described as dorsiventral structure.

Stomata: Stomata observed in all species posses a similar fundamental structure. Tetracytic stomata are prevalent and much more frequent in abaxial surface than adaxial (Olatunji, 1970). Guard cells are dumb-bell shaped, two lateral and two terminal subsidiary cells associated with each pair of guard cells are distinct in size from other epidermal cells. They are generally absent in the costal region. The orientation of stomata is unidirectional; the guard cells lie more or less parallel to the long axis of the veins. Size of guard cell in abaxial epidermis is smaller than that of adaxial surface. The longest stomata are present in *Z. capitatum* var. *elatum* 50-63 μm, while the smallest in *Z. officinale* (30-36.9 μm). In *Z. cernuum* 36-41 μm, *Z. montanum* 48-53 μm, *Z. neesanum* 38-40 μm, *Z. nimmonii* 40-46 μm, *Z. officinale* 30-36.9 μm, the smallest, *Z. roseum* 44-48 μm, *Z. wightianum* 47-49.2 μm, and *Z. zerumbet* 39-43 μm. According to Dunn *et al*. (1965)

stomatal patterns and size of stomata in each species of monocotyledons are much more consistent than in dicotyledons and can be used as a reliable character. The study of stomatal development shows that tetraperigenous development is predominant in genus *Zingiber* of South India.

Stebbins and Khush (1961) suggested that the variation in the organization of the stomatal complex in the leaf epidermis has a role in phylogeny. Olatunji (1970) suggested a tetraperigenous development of stomata in the genus *Zingiber*.

Trichome: These are unicellular hairs with pointed tips. The base of the trichome is swollen. The lumen is narrow and the walls are thick due to cuticularisation. Hairs upto 1 mm long are seen on the midrib, petiole, sheath and leaf margins and the type of hair is 'Borte" bristle type. Delicate hairs 'Weichhaarre' type are seen on the abaxial surface of *Z. officinale* (Tomlinson, 1956), *Z. nimmonii*, *Z. zerumbet* and *Z. wightianum*. Length varies from 500 μm to 1.3 mm. Smallest trichome are seen in *Z. capitatum* var*. elatum* 551-896 μm and largest in *Z. montanum* 790 μm-1.3 mm and *Z. officinale* 800 μm-1.3 mm. Trichomes are present only on lower epidermis.

Leaf margin: In *Zingiber* leaf, margin consists of a hyaline region extends into a beak, which can be long or short, curved or hooked. Smallest beak is found in *Z. officinale* 82 μm, whereas longest, in *Z. nimmonii* 292 μm. It is 290 μm in *Z. zerumbet*, 224 μm in *Z. neesanum*, 198 μm in *Z. wightianum*, and 192 μm in *Z. montanum* **(Plate. 23)**.

Table No. 3. Anatomical features of leaf.

Name of taxa	Size of epidermal cell in μm (adaxial)	Thickness of lamina (μm)	Mesophyll		Trichome length	Leaf margin(length in μm)
			Palisade layer	Spongy Layer		
Z. capitatum var. *elatum*	80x 32-64	340	Only palisade	Absent	551μm - 896 μm	166
Z. cernuum	58-84 x 48-64	288	1	3	750 μm -1.2mm	170
Z. montanum	45-52 x 64-78	160	1	3	790 μm-1.3 mm	192
Z. neesanum	56-76 x 40-52	176	1	3	672 μm -1.02 mm	224
Z. nimmonii	75-95 x 42	260	1	2	684 μm -1.4 mm	292
Z. officinale	52-72 x 44-52	176	1	3	800 μm-1.3 mm	82
Z. roseum	44-48 x 56	140	1	2	848 μm -1.2 mm	160
Z. wightianum	68-80 x 22-56	280	2	2-3	680 μm -1.2 mm	198
Z. zerumbet	68-92 x 30-46	272	2	3	720 μm -768 μm	290

Medium sized beak is present in *Z. capitatum* var. *elatum* (166 μm), *Z. cernuum* (170 μm) and *Z. roseum* (160 μm). The hyaline area is 3-4 celled in thickness near the vascular bundle, but two celled thickness in the end region in all, but 3-celled in *Z. montanum.* The shape and length of the hyaline region differ in different species **(Plate. 37)**

Vascular system: On the basis of the size of the vascular strand, bundles can be grouped into large bundles or medium sized bundles and small bundles. A single large xylem element and small angular xylem elements are separated from phloem group by one or two rows of small celled conjunctive tissue. Protoxylem is found only in largest bundle. The bundles are sheathed laterally by one or some times two layers of elongated parenchyma cells. These are colourless cells and contain Calcium oxalate crystals, silica or starch. The bundle sheaths are made up of thick walled fibre cells above and below. The bundle sheath extension does not reach the abaxial epidermis but remain separated by a layer of hypodermal cells in *Z. cernuum* and *Z. nimmonii*. In other species of *Zingiber* the 1st order bundles sheath extension reach the abaxial epidermis. The sheath of smaller bundles may be entirely parenchymatous. In the medium sized bundle the fibres are generally confined to the abaxial part of the sheath. In *Z. montanum* and *Z. capitatum*, 1st order vascular bundles are very closely arranged and most of the bundle sheath reach both epidermis.

Mid rib: The mid rib is more or less semicircular in outline with a curve of V or U at the adaxial and abaxial region. Adaxial side is U-shaped in *Z. neesanum*, wide U-shaped in *Z. montanum*, *Z. officinale* and *Z. zerumbet*. It is V-shaped in *Z. roseum* and wide V-shaped in *Z. cernuum*, and

Z. wightianum. Adaxial side is concave in *Z. capitatum* var. *elatum* and *Z. nimmonii*. Abaxial side is U-shaped in *Z. roseum*, wide U-shaped in *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, wide V-shaped in *Z. capitatum* var. *elatum*, *Z. cernuum* and *Z. wightianum.* In *Z. zerumbet* the abaxial side in U-shaped and ribbed at the region of the arc-I bundles. The epidermal cells are smaller in size and thick walled. The epidermis is followed by ground parenchyma where the bundles are arranged towards abaxial epidermis.

The bundles of the midrib belong to several different systems which are longitudinally continuous through out the sheath, petiole and lamina. These systems are seen as distinct arcs. The main arc is arranged near to the abaxial epidermis. Bundles are pear-shaped in section and some what constricted across the centre. In the mid rib, bundles arcs I and III are present. In *Z. neesanum* only arc-l is present. Bundle arc-I is represented by 1-5 bundles. The individual bundles of the main arc are designated as Musa-type (Solereder & Meyer, 1930).

A large metaxylem is present in each bundle. A single layer of conjunctive parenchyma separates the xylem from the abaxial phloem group. They are arranged around the metaxylem in very regular and concentric manner. The phloem consists of sieve tube elements, companion cells and parenchyma.

Table No. 4. Anatomical features of the mid rib.

Name of taxa	Shape of Adaxial side	Shape of Abaxial side	Bundle arcs		Xylem (µm)
Z. capitatum var. *elatum*	concave	Wide V	I	III	66-69
Z. cernuum	Wide V	Wide V	I	III	34-36.9
Z. montanum	Wide U	Wide U	I	III	42-45
Z. neesanum	U	Wide U	I	absent	32-41
Z. nimmonii	concave	Wide U	I	III	38-42
Z. officinale	Wide U	Wide U	I	III	32-36.9
Z. roseum	V	U	I	III	56-68
Z. wightianum	Wide V	Wide V	I	III	40-48
Z. zerumbet	Wide U	U-shaped and ribbed	I	III	52-56

The bundle sheath is separated into an upper and lower fibre cap by the presence of parenchyma in the median part of the bundle. At the level of the metaxylem elements the lateral parenchyma cells are colourless and contain Calcium oxalate crystals, starch and silica. In *Z. officinale* the shape of the crystal is like an opened book. Various shapes of crystals such as cuboid, pentagonal and rectangular are present. Laterally, the bundles of the main arc of the midrib show a gradual transition in structure to those of the lamina. A single tracheal element is present in small bundles and protoxylem is generally absent. In between the main arc–I bundles air canals are seen. The air canals are in turn surrounded by chlorenchyma tissue. In *Z. capitatum* var. *elatum* the air spaces between the bundles are occupied by spongy parenchyma cells **(Plate. 24).**

Pulvinus: The lamina is separated from the sheath by a distinct petiole. It is an important distinguishing character of the genus *Zingiber*. The petiole is colourless, swollen and has the appearance of the pulvinus. This character makes the genus different from other genera of the family. The epidermal cells are smaller in size and the thickening of the wall is confined to the outer region. There is a gradual transition from smaller to the larger cells from the peripheral region to the centre. Air canals and chlorenchyma cells are alternating with the main arc bundles. Air canals are in turn surrounded by chlorenchyma cells. The chlorenchyma resembles mesophyll cells in their round shape and short prolongations are seen towards the intercellular spaces. The chlorenchyma band and air space system shows a maximum development in the petiole. Tomlinson (1956) stated that air canals are absent in pulvinus of *Zingiber*. But present studies revealed that it is well present in all South Indian taxa.

Adaxial side of pulvinus is concave in *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. nimmonii*, *Z. officinale*, and *Z. zerumbet*. It is U-shaped in *Z. wightianum*, and wide V-shaped in *Z. montanum*, *Z. neesanum*, and *Z. roseum.* Abaxial side is U-shaped in *Z. capitatum* var. *elatum*, *Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet* and it is wide U-shaped in *Z. cernuum*, *Z. montanum*, *Z. neesanum*, and *Z. nimmonii*. Bundle arcs I, ll, and III are present in *Z. neesanum*, *Z. officinale*, *Z. wightianum* and *Z. zerumbet*, where as in *Z. capitatum var. elatum*, *Z. cernuum*, *Z. nimmonii* and *Z. montanum* bundles arcs I, III, and IV are present. In *Z. roseum bundle* arcs I and III are present.

In *Z. neesanum* and *Z. capitatum* var. *elatum* the parenchyma tissue around the two or three bundles in the median region become radially elongated and gave a specific appearance to the bundles. In these species more growth is confined around the region of these bundles.

Table No. 5. Anatomical features of pulvinus.

Name of taxa	Shape of Adaxial side	Shape of Abaxial side	Bundle arcs				Size of xylem (m)
Z. capitatum var. *elatum*	Concave	U	1	ab	III	IV	84-86.1
Z. cernuum	Concave	Wide U	I	ab	III	IV	72-75
Z. montanum	Wide V	Wide U	I	ab	III	IV	68-74
Z. neesanum	Wide V	Wide U	I	II	III	ab	38-45.1
Z. nimmonii	Concave	Wide U	I	ab	III	IV	28-36
Z. officinale	Concave	U	1	II	III	ab	20-30.9
Z. roseum	Wide V	U	I	ab	III	ab	40-48
Z. wightianum	U	U	I	II	III	ab	36-64
Z. zerumbet	Concave	U	I	II	III	ab	40-49.2

ab- absent

Arc-I bundles are same size in the median region and gradually becoming smaller towards the margin. Arc-III and IV bundles are arranged irregularly in the adaxial side of the arc-I bundles. The arc-III bundles show maximum development in the petiole and the number decreases gradually towards the base of the leaf sheath. In the leaf sheath only a single row or arc-III bundles are present. The structure of the bundles of the pulvinus is similar to that of the midrib. Bundle sheath is well developed and collenchymatous (Tomlinson, 1956). A single large tracheal element and several smaller elements are present. Protoxylem lacunae are not seen in these bundles. The bundles of arc-IV are arranged near adaxial epidermis. The bundles are very much reduced and a well developed mechanical sheath is present around them **(Plate. 25)**

Leaf sheath: The epidermal cells in the adaxial side are larger, thin walled and transversely stretched. Hairs are absent. The epidermal cells of the abaxial surface are smaller in size and the wall is slightly thickened. There is a gradual transition to larger central cells, from the epidermis to centre and these central cells are associated with intercellular spaces. Hairs are present on abaxial surface.

Adaxial and abaxial sides are U-shaped except in *Z. zerumbet,* in which adaxial side is V-shaped and abaxial side is flat. Bundle arcs I, II, and III, are seen in the leaf sheath and the arc- I constitutes the main bundle arc. Arc-I bundles are arranged close to the abaxial surface and bundles are same size at the median region and the gradually decreases towards the margin.

Arc-ll bundles are much smaller in size and alternate with arc-l bundles. Adaxial to arc-I, intermediate sized bundles of arc-III are arranged irregularly. . Arc-I, II and III bundles are present in *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. neesanum*, *Z. nimmonii*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet.* In *Z. officinale* and *Z. montanum* only bundle arcs I and II are present.

Table No. 6. Anatomical features of leaf sheath.

Name of taxa	Shape of Adaxial side	Shape of Abaxial side	Bundle arcs			Xylem (µm)
Z. capitatum var. *elatum*	U	U	I	II	III	62-65
Z. cernuum	U	U	I	II	III	50-53.3
Z. montanum	U	U	I	II	ab	41-61.5
Z. neesanum	U	U	I	II	III	58-61.5
Z. nimmonii	Wide U	Wide U	I	II	III	32-80
Z. officinale	U	U	I	II	ab	12-28.7
Z. roseum	U	U	I	II	III	28-60
Z. wightianum	U	U	I	II	III	32-64
Z. zerumbet	V	flat	I	II	III	22-38

ab- absent

Arc-I bundles are similar in structure of the bundles in the mid rib. Each bundle of the arc-II shows a well developed fibrous sheath, but it is not well developed as the bundle sheath of arc-III. A simple large xylem tracheid and several smaller elements are present. Arc-I, II, III bundles become reduced towards the margin and the bundles are represented by a fibre strand only in *Z. nimmonii*, *Z. neesanum, Z. wightianum,* and *Z. capitatum.* Air canals are seen in between the main arc bundles and they are in turn surrounded by a band of chlorenchymatous tissue. Spongy parenchyma is present in air canals. According to Bell (1980), the bundles of the main arc-I of the sheath passes gradually into the central cylinder. The bundles of the outer arc-II do not enter into cortical system and no fusion takes place between the bundles of the two different systems **(Plate. 26).**

The stem: The epidermal cells are smaller in size and the outer wall is slightly thickened. A continuous cylinder of fibre strand separates cortex from central cylinder. The cortical bundles are arranged in 3 or 4 rows and specific number of rows are seen for a particular species. According to Tomlinson (1969), the tissue present between cortex and central cylinder is meristematic and this region eventually differentiates into thin walled fibres.

Petersen (1899) used the term intermediate zone to the undifferentiated region between these two. It separates vascular tissue into two regions. Bell (1980) described it as an inner system and an outer system for the cortex and central cylinder respectively.

Vascular bundles are collateral, and those of the cortex being wider with a well developed fibrous sheath but variable in diameter (Bell, 1980). The outermost row of bundles of the cortex is seen in the epidermis and it resembles those of the arc- II bundles of the bundle sheath. The xylem consists of a single large element and several smaller ones. The xylem is separated from the fibres of the bundle sheath and from the small group by parenchyma.

The fibrous thickening is complete around central cylinder in *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale Z. roseum* and *Z. wightianum.* In *Z. montanum* and *Z. zerumbet* fibre thickening is incomplete and parenchyma patches are seen at certain regions. Elongated bundles are seen in the cortex of *Z. zerumbet*, near the fibrous thickening. In these regions lower portions of elongated bundles extend to the central cylinder. Fibrous thickenings are absent in these regions. In *Z. cernuum* cortical bundles are in three rows but in *Z. nimmonii*, they are arranged in two rows. The central cylinder contains numerous bundles scattered irregularly in a uniform ground parenchyma **(Plate. No. 27)**.

Rhizome: According to Tomlinson (1956) rhizome is morphologically equivalent to the aerial stem, and there is a fundamental similarity in the anatomy of the two organs. The outer cortical cells of the rhizome are suberized, and a periderm is seen in older rhizomes and several successive layers are present. A distinct cortex and central cylinder are separated by an endodermis. Cortex contains scattered vascular bundles. The central cylinder also contains numerous scattered vascular bundles. Xylem and phloem are less developed in central cylinder. Starch grains are present in cortex and central cylinder, and generally absent in endodermis. Oil cells and crystals are also seen in cortex and central cylinder **(Plate. No. 28)**.

Starch grains: Starch is present in rhizome and root tubers. They are seen in various shapes such as oval, elliptical, circular, triangular, cylindrical and flattened. Each taxon show particular shape and size of starch grains. A single hilum is present and it is eccentric, situated in a projecting beak and striations around the hilum are clearly visible. Starch grains are present in cortex and central cylinder but they are abundant in central cylinder. Starch grains are generally absent in endodermis. The grains are almost spherical, with a beak at the region of hilum, in *Z. capitatum* var. *elatum*15-22 x 7-12 µm, oval shaped, *in Z. cernuum* 36-92 x 36-68 µm, spherical to oval, in Z*. montanum* 32-52 x 24-40 µm, spherical to oval, in *Z. neesanum* 36-64 x 28-44 µm. In *Z. nimmonii* grains are cylindical or oval, 20-35 x 12-18 µm; in *Z. officinale* spherical to oval (4-24 x 4-36 µm), in *Z. roseum* (18-35 x 12-24 µm) and in *Z. wightianum* grains are triangular, oval and outer margin irregular (20-24 x 10-16 µm). In *Z. zerumbet* the grains are triangular, oval or cylindrical, 30-64 x 20-24 µm. The shape of the starch grain appears to be constant in particular taxa, and can be taken as a characteristic feature for species delimitation **(Plate. No. 29)**.

Root: Roots are developed from the lower portion of the node of rhizome. Numerous roots are developed from the lower region of rhizome. The cortex is wide and outer layers are radially arranged and suberized. Inner layers are loosely arranged with intercellular spaces. Protoxylem vessels are present at the poles of the xylem, and phloem groups alternate with them. Metaxylem vessels are 10-32 in number with wider lumen and arranged towards centre. Pith is large in *Z. neesanum* and *Z. nimmonii*, *when* compared to other species.

Generally the roots show same anatomical characters but differ in the number of metaxylem vessels, among the South Indian taxa. The number of metaxylem varies from 8-12 in *Z. capitatum* var. *elatum*, 14-18 in *Z. cernuum*, 12-16 in *Z. montanum*, 17-20 in *Z. neesanum*, 20-23 in *Z. nimmonii*, 28-34 in *Z. officinale*, 15-18 in *Z. roseum*, 10-14 in *Z. wightianum* and 13-16 in *Z. zerumbet.*

Maceration studies showed that xylem vessels are confined only to the roots. Vessels in the Protoxylem elements are very long and narrow with very oblique imperforate end wall. The later formed xylem vessels are larger with wide lumen. The end wall of perforation plates showed variation in length, nature of end wall and in width. In metaxylem, vessels are seen with scalariform thickening, and the end walls with scalariform perforation plates **(Plate No. 30).**

According to Tomlinson (1956) the occurrence and distribution of tracheids and vessels are of considerable phylogenic interest. Dahlgren and Clifford (1982) stated that Zingiberaceae have vessel less leaves and roots have vessels with scalariform perforation vessel types. According to Wagner (1977) Zingiberaceae possess more advanced vessel types in roots than do the other families of monocotyledons.

Cheadle (1968) pointed out that vessels originated in roots and then upward in the plant and that specialisation of vessels followed the same sequence, and in a given organ the origin and specialization of vessels occurred in first in late-formed metaxylem and then successively in the earlier formed xylem. Based on vessel characters Cheadle and Tucker (1961) stated the possible origin of Zingiberales from Commelinaceae, because in Commelinaceae, the vessels are highly specialized than Zingiberaceae.

PHYTOCHEMISTRY

The rhizomes of genus *Zingiber* have been used in Ayurvedic and other natural systems of medicine from time immemorial. This is mainly due to the presence of phytochemicals or secondary **metabolic** compounds found in this group of plants. Many of these are known to provide protection against **insect** attacks and microbial infections. They also exhibit a number of protective functions for human consumers. In Ayurveda, ginger (*Z. officinale*) is used as a carminative and digestive. It is pungent, hot, anodyne, antirheumatic carminative, cooling, diuretic, and aphrodisiac and promotes digestive power. Rhizome of *Z. officinale* is used for treating cough, bronchitis, asthma, heart and abdominal troubles, piles, elephantiasis, scorpion sting, snake bite and also as appetizer, stomachic. Dry ginger is used in the treatment of asthma, cough, diarrhoea, flatulence, nausea and vomiting (Datta & Mukerji, 1950). It is an important spice extensively used in preparation of condiments, curries and syrups.

The rhizome of *Z. montanum* is given in diarrhoea, colic, also used as a stimulant, carminative, flavoring agent, and also an antidote to snake poison (Prakash & Mehrotra, 1996). Rhizome of *Z. roseum* is used in cold, cough and rheumatism. *Z. zerumbet* rhizome is given in cough, asthma, stomach ache, vermifuge, leprosy and other skin diseases and also used as substitute for true gingers, (Prakash & Mehrotra 1996). Therefore, it is important to apply the phytochemical methods to screen and analyze bioactive components, not only for the quality control of crude **drugs**, but also for the elucidation of their therapeutic mechanisms.

Mathai (1975) studied seasonal accumulation of chemical constituent in *Z. officinale* varieties and trends in oleoresin accumulation using Ethyl alcohol and acetone as solvents. Sreekumar *et al*. (1999) developed a new commercially viable technology for recovery of ginger oil with fresh flavour from fresh rhizomes of *Z. officinale*. Nishimura (2001) studied the fresh rhizomes of *Z. officinale* using multidimensional GC system in Japan and revealed that linalool, 4-terpineol, isoborneol and borneol are present.

Fakim *et al*. (2002), studied the chemical composition of the essential oils obtained from hydrodistillation of the rhizomes of *Z. officinale, Hedychium coccineum, H. flavescens and H. coronarium* by GC and GC/MS. Oil of *Z. officinale* was characterized by the presence of geranial, neral, zingiberene, β-sequiphellandrene and ar-curcumene. Pino *et al*. (2004) studied the chemical composition of the essential oil obtained from the rhizomes of *Z. officinale* by combined GC and GC-MS. The oil was characterized by the presence of ar-curcumene, zingiberene, β-bisabolene and cadina-1, 4 diene.

Oliveros (1996) worked out the main constituents of the volatile oil of *Z. purpureum* and found that chemical compounds such as zingisol and zingiment have the antibacterial and antifungal activities and can be used as alternative medication in cases where skin infections are caused by strains that have developed resistance to antibiotics available in the market. Volatile oil from rhizome contains terpinen-4-ol. The rhizome is used as folk medicine for the treatment of asthma, rheumatism, diarrhoea, cough and skin diseases.

Bordoloi *et al.* (1998) studied essential oils of the leaf and rhizome of *Z. officinale* by GC and found the major compounds such as zingiberene (16.05%) and geranial (12.50%), geranyl hydroxy-9-epis caryophyllene (35.74%), geranyl acetate (10.60%), geranil (0.2%), geranial (8.78%), caryophyllene oxide (8.60%) in leaf while sesquiphellandrene (6.11%), bisabolene (5.50%), camphene (5.46%) and (E, E)-a farnesene (5.00%) are found in rhizome oil only.

Sabulal *et al*. (2006), isolated oil from the rhizomes of *Z. nimmonii* and carried out GC and GC-MS analysis. Major oil constituents are β-caryophyllene and α-humulene (α-caryophyllene as of isocaryophyllene). Oil contained 71.2% sesquiterpenes, 14.2% oxygenated sesquiterpenes, 8.9% monoterpenes, and 1.9% oxygenated monoterpenes and 1.3% non-terpenoid constituents. The oil also showed inhibitory activity against certain fungi and bacteria

Prakash *et al*. (2006), studied phytochemical composition of essential oil from the seeds of *Z. roseum* and its antispasmodic activity in rat duodenum. The major compounds being α-pinene, β-pinene, limonene, P-cymene, α-terpineol and verticiole. The presence of mono-and sesquiterpene hydrocarbons which make about 82% of the oil, and the oil showed myorelaxant activity on isolated rat duodenal smooth muscle.

Sabulal *et a*l. (2007) worked out the oil constituents of *Z. neesanum* by GC and GC-MS. Phenylbutanoids (E)-1-(3', 4'-dimethoxy phenyl) butadiene an anti-inflammatory compound, (E)-1-(3'4'-dimethoxy phenyl) but-1-ene, trans-ocimene, β-pinene and linalool are major terpenoid constituents of rhizome oil.

Nazrul *et al.* (2008) worked out the chemical components of *Z. cassumunar* by GC-MS and identified 64 components in the rhizome oil. The main component of leaf oil is sabinene (14.99%), β-pinene(14.32%) and caryophyllene (9.47%). The rhizome oil contained triquinacene 1,4-bis (methoxy)(26.47%), z-ocimene (21.97%) and terpinene 4-ol (18.45%).

Observations

Rhizomes of *Z. capitatum* var. *elatum, Z. cernuum, Z. montanum*, *Z. neesanum*, *Z. nimmonii, Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet* (from two localities *viz.,* Kozhikode and Ponmudi) were subjected to hydrodistilation; essential oils were isolated and carried out GC-MS analysis to study the chemical components of the oil. Among South Indian zingibers, rhizome of *Z. capitatum* var. *elatum* is very small, and the oil yield is too low to detect and thus its chemical characterization was not possible. More over, the distribution of the species is scanty to repeat the experiment. The characters of the essentional oil from other South Indian *Zingiber* are given below.

***Z. cernuum*:** Rhizome is thick, fleshy, purple-lilac inside, oil is pale yellow with a pleasant aroma, and percentage of yield is 0.35. Major components are β-caryophyllene (18.6%), terpinene- 4-0l (13%) and other major compounds are caryophyllene oxide (5.6%), β- phyllandrene (5.4%), α-humulene (9.8%).

***Z. montanum*:** Rhizome is thick, fleshy, yellow inside, oil is dark yellow, pleasantly aromatic, and percentage yield is 0.24. The major components include terpinene-4-0l (17.4%), β-pinene (9.5%), α-pinene (3.8%) and γ-terpinene (3.4%).

***Z. neesanum*:** Rhizome is small, light yellow inside. Oil is yellow, with pleasant aroma, percentage yield is 2.33. Major components are (E)-1-(3`, 4`-dimethoxy phenyl) butadiene (31.1%), (E)-1-(3`, 4`-dimethoxy phenyl) but-1-ene (23.1%). Other major compounds are trans-ocimene (12.7%), β-pinene (7.4%), linalool (6.8%).

Z. nimmonii**:** Rhizome is thick, fleshy, purple lilac inside, oil is pale yellow, pleasantly aromatic, and percentage of yield 0.5. Caryophyllene oxide (49.7%) is the major compound, followed by β-caryophyllene (17%), and terpinene-4-0l (6.5%).

Z. officinale**:** Rhizome is thick, fleshy, grey inside, oil is yellow with characteristic pungent aroma and percentage of yield is 0.65. Major components are ar-curcumine (13.6%), zerumbone (5.3%), borneol (5.8%), β-sesquiphellandrene (5.6%), β-bisabolene (4.5%), and α-zingiberene (4.0%).

Z. roseum**:** Rhizome is stoloniferous, fibrous, thick, white inside. Oil is pale yellow with a feeble aroma and percentage of yield is 0.16. Major compounds are caryophyllene oxide (21.4%), humulene epoxide II (22.5%), and α-humulene (7.1%) and β-caryophyllene (4.5%).

Z. wightianum**:** Rhizome is thin, stoloniferous, pale yellow inside. Oil is pale yellow with no characteristic aroma and percentage of yield is 0.35. Major components are β-eudesmol (14.5%), germacrene D (12.1%), and **τ-**cadinol (7.4%).

Z. zerumbet (Kozhikode)**:** Rhizome is thick, fleshy, aromatic, deep yellow inside, oil is pale yellow with a pungent aroma and percentage of yield is 1.32. Major compound is zerumbone (62.1%), others include humulene epoxide I (7.4%), camphene (5.2%), α-humulene (3.3%).

Z. zerumbet (Ponmudi)**:** Rhizome is thick, fleshy, aromatic, deep yellow inside, oil is pale yellow, aromatic and percentage of yield is 2.06. Major compound is zerumbone (72.5%), others are humelene epoxide I (4.9 %), camphene (4.0%), α-humulene (4.6%).

Percentage of yield

The colour of the essential oils extracted is different shades of yellow. Percentage of oil was calculated on dry weight basis and given in the table **7.** Out of the eight species of *Zingiber* analysed, the maximum oil yield was for *Z. neesanum*, 2.33%, followed by *Z. zerumbet* and *Z. officinale*. The minimum oil yield was observed in *Z. roseum* (0.16%). Qualitative and quantitative characterization of the oils were carried out by GC-MS analysis. The major constituents in all the species were determined and given in the table 4. Phytochemical compositions of essential oils in *Z. nimmonii, Z. wightianum* are reported for the first time.

Table No. 7. Details of percentage of oil obtained from different taxa

Species	Colour of oil	Percentage of yield
Z. cernuum	Pale yellow	0.35
Z. montanum	Dark yellow	0.24
Z. neesanum	Yellow	2.33
Z. nimmonii	Pale yellow	0.5
Z. officinale	Yellow	0.65
Z. roseum	Pale yellow	0.16
Z. wightianum	Pale yellow	0.35
Z. zerumbet (Ponmudi)	Pale yellow	2.06
Z. zerumbet (Kozhikkode)	Pale yellow	1.32

Table No. 8
Major chemical compounds in *Zingiber* species in percentage

Major components	*Z. cernuum*	*Z. montanum*	*Z. neesanum*	*Z.nimmonii*	*Z. officinale*	*Z. roseum*	*Z. wightianum*	*Z. zerumbet* (Kozhikode)	*Z. zerumbet* (Ponmudi)
(E)-1-(3’,4’-dimethoxyphenyl)butadiene	-	-	31.1	-	-	-	-	-	-
E)-1-(3’,4’-dimethoxyphenyl)but-1-ene	-	-	23.1	-	-	-	-	-	-
trans-ocimene	-	-	12.7	-	-	-	-	-	-
β-pinene	-	9.5	7.4	-	-	-	-	-	-
linalool	-	-	6.8	-	-	-	-	-	-
β-caryophyllene	18.6	-	-	17.0	-	4.5	1.4	-	-
terpinene-4-ol	13.0	17.4	-	6.5	-	-	-	-	-
caryophyllene oxide	5.6	-	-	49.7	-	21.4	3.0	-	-
zerumbone	-	-	-	-	5.3	-	-	62.1	72.5
humulene epoxide I	-	-	-	-	-	-	-	7.4	4.9
camphene	-	-	-	-	-	-	-	5.2	4.0
humulene epoxide II	-	-	-	-	-	22.5	-	-	-
β-phyllandrene	5.4	-	-	-	-	-	-	-	-
α-humulene	9.8	-	-	-	-	7.1	-	3.3	4.6
α-pinene	-	3.8	-	-	-	-	-	-	-
□-terpinene	-	3.4	-	-	-	-	-	-	-
ar-curcumene	-	-	-	-	13.6	-	-	-	-
borneol	-	-	-	-	5.8	-	-	-	-
β-sesquiphellandrene	-	-	-	-	5.6	-	-	-	-
β-bisabolene	-	-	-	-	4.5	-	-	-	-
α-zingiberene	-	-	-	-	4.0	-	-	-	-
germacrene D	-	-	-	-	-	-	12.11	-	-
β–eudesmol	-	-	-	-	-	-	14.50	-	-
τ-cadinol	-	-	-	-	-	-	7.4	-	-

Discussion

The chemical profile of the oil is with respect to its major constituents is very specific to each species studied (table-8), indicating the chemical uniqueness of the species. Thus essential oil components can be considered as chemical markers of *Zingiber* species. A higher concentration of humulene epoxide II (22.5%) makes *Z. roseum* distinct from its counterparts in South India. The presence of β-caryophyllene, caryophyllene oxide and α-humulene indicates the chemical relationship between *Z. nimmonii*, *Z. roseum*, *Z. zerumbet*. Though β- caryophyllene and caryophyllene oxide is in lower concentrations in the oil of *Z. wightianum*, indicates its slight chemical affinity to these three species. By the presence of β-pinene, *Z. neesanum* shows its affinity to *Z. montanum*. Terpinene-4-ol is present in *Z. montanum*, *Z. cernuum* and *Z. nimmonii*. *Z. neesanum* stands unique due to the presence of its major compounds (E)-1-(3',4'-dimethoxyphenyl) butadiene (31.1%) and (E)-1-(3',4'-dimethoxyphenyl) but-1-ene (23.1%), which together constitutes more than 50% of the oil components. The oil of *Z. montanum* is specific with a characteristic pleasant aroma due to its major compounds terpinene-4-ol (17.4%) and β-pinene (9.5%). The chemical profile of the oil of *Z. zerumbet,* an accession collected from high altitude (Ponmudi) is distinct with the very high concentration of zerumbone (72.5%). Another accession collected from Kozhikode (from a lower altitude) also shows a very same chemical profile as that of an accession from Ponmudi indicates the altitude variation of the two sites does not make any prominent impact in its oil components (table-8).

Though in a very low percentage (5.3%), zerumbone is detected in the oil of *Z. officinale* indicates its slight chemical relation with *Z. zerumbet*. The presence of α- humulene in both these species also supports the affinity between them.

The green coloured, *Z. cernuum*, collected from Beypore showed β-caryophyllene as its major component of the essential oil (18.6%) followed by terpinine 4-ol (13%) and α-humulene (9.8%). In red coloured accession from Anamalai, *Z. nimmonii*, caryophyllene oxide (49.7%) followed by β-caryophyllene (17%) and terpinene-4-ol (6.5%). The absence of α-humulene and very high concentration of caryophyllene oxide in the latter makes it a chemical variant in support to its variation in colour of the pseudostem. Presence of β-eudesmol (14.5%), germacrene (12.11%), and τ-cadinol showed the uniqueness of *Z. wightianum* in its oil profile.

PALYNOLOGY

The term Palynology was first introduced by Hyde and Williams in 1941 and it is derived from the Greek words 'Paluno' (sprinkle) or 'Pale' (dust) which is cognate with Latin word for pollen. An early evident of above pollen is from the stone carvings of the Assyrian period in Egypt 717 BC depicting winged humans pollinating the date palm (Maheswari, 1950). Scientific studies of pollen and spore morphology was initiated with the discovery of compound microscope. In 1640, it was Nehemiah Grew, who first microscopically observed pollen in Britain (Erdtman, 1952). With the discovery of airborne pollen as a cause of allergy, several new lines of investigation have been emerged. Subsequently, many sub branches such as aeropalynology, paleopalynology, mellito palynology etc. were emerged (Erdtman, 1952).

Erdtman (1952) conducted many extensive studies of pollen grains of different taxa and with the discovery of Electron Microscopy, palynological studies assumed a new meaning, and has been recognized as an integral part of plant science research. According to Vishnu-Mittre (1964) palynology does not merely comprise a study of the morphology of spores and pollen; it has become a tool of great utility in the solution of several problems of academic and applied interests which depend upon the co-operation of diverse disciplines of science.

Erdtman (1952) introduced the acetolysis technique of pollen preparation which dissolves all but the exine. Woodhouse (1935) studied pollen without any chemical treatment, leaving the pollen protoplasm intact. Skavarla and Rowley (1970) studied pollen wall of *Canna* and its similarity to the germinal apertures of other pollen. Although the pollen wall of *Canna generalis* Bailey. is exceptionally thick only a minor part of it contains detectable amounts of sporopollenin. According to them the entire pollen wall of *C. generalis* is similar to the thick intine and thin exine typical for germinal apertures in many pollen grain types.

Pillai *et al* (1978) studied flowering behaviour, cytology of pollen germination in *Zingiber officinale*. They found irregular meiosis and only 37% of the pollen grains were stainable in acetocarmine and maximum germination observed in artificial medium was only 14.5%. Skavarla *et al.* (1978) reported vicin threads on the pollen wall of all taxa of Onagraceae except in certain populations of *Circaea* spp. Though smooth, compound, beaded, and segmented vicin threads occur within the family they suggest that segmented and compound vicin threads are adaptations that promote more efficient pollen transport by animal vectors.

Kress *et al*. (1978) studied the pollen of *Heliconia* and many of its relatives in the Zingiberales and it is virtually devoid of a conspicuous, protective exine. Stone *et al.* (1979) observed the pollen of *Heliconia* and most of its Zingiberaceous relatives are destroyed by the standard acetolysis preparation and the fragility of the grain is the result of the weak exine development and sporopollenin deposition. Pollen morphology of Zingiberaceae is poorly understood and several taxa remain palynologically unknown (Zavada, 1983). According to Dahlgren and Clifford (1982) inaperturate pollen grains occur in Zingiberiflorae and most of the members are devoid of a conspicuous protective exine. Zavada (1983), found pollen of *Zingiber* as inaperturate and exine sculpturing is spinulose or psilate. Recent EM studies by Kress *et al*. (1978), Skavarla and Rowley (1970), Pettitt and Jermy (1975), Hesse and Waha (1983) and Stone (1987) indicate that in a majority of Zingiberales there exists an exinous layer, through it is poorly developed in many taxa.

Evolutionary trends of pollen aperture and wall structure in the monocot is parallel to those proposed by Walker (1976) in dictos (Zavada, 1983) and pollen of Zingiberaceae is generally inaperturate except in *Zingiber* where it is monosulcate and exine sculpture is spinulose or psilate. Kress *et al*. (1978) reported the pollen grains of Zingiberaceae as exineless.

Kress and Stone (1983) studied pollen morphology of 27 species of *Heliconia.* Pollen of species with erect inflorescence has many character states in common with pollen of pendent species. Among the species with pendent inflorescences four groups can be distinguished by pollen features.

Sassafras and *Heliconia* have inaperturate pollen with a highly reduced exine and thick channeled intine. The ontogenetic basis for this wide spread convergence in pollen structures is simply a reduction or deletion of exine and a correlated elaboration of intine deposition (Stone, 1987). Mondal (1987) studied pollen morphology of some species of *Desmodium* Desv. from different phytogeographical regions of India with a view to estimate the variation in palynological characters with the variable ecological conditions of the plant. Palynological variations are not limited in a particular characters of the palynomorph, but over any of the major or infra characteristics of the pollen grains. Meerow and Deghan (1988) studied pollen morphology of Eucharideae of Amarillidaceae. The evolution of novel floral adaptations within the Eucharideae has been accompanied by reduction in pollen grain size and coarseness of exine recticulum.

Liang (1988) studied the pollen morphology of 89 species and 3 varieties under18 genera of Zingiberaceae in China, under both light microscope and scanning electron microscope and found that the pollen grains of Zingiberaceae were spherical, subspherical, ovoid and prolate, 36-225 µm in size, nonaperturate or aperturate (spiraperturate, porate). Pollen grains are not resistant to acetolysis. The wall is composed of a very thin exine and a thick intine. The exine is psilate, spinate, cerebelloid-areolate, striate, verrucate and foveolate.

According to the presence or the absence of aperture and differential ornamentations, two types and six subtypes are recognized: I. The type Nonaperturate: (85 species and 3 varieties in 18 genera). Four subtypes can be recognized within the type based on the characteristics of the exine sculpture. These are: (1) the subtype psilate, in which, the exine is nearly smooth (including: *Hedychium*, *Curcuma*, *Kaempferia*, *Caulokaempferia* *coenobialis* (Hance) K. Larsen., *Boesenbergia rotunda* (L.) Mansf., *Stahlianthus*, *Amomum compactum* Sol. ex. Maton., *Etingera*, *Hornstedtia*, and *Rhynchanthus*. (2) the subtype spinate, which comprises two groups: (A) the group short-spinate, pollen grains with smaller spines (Globba), (B) the group long-spinate, pollen grains with longer spines (*Alpinia*, *Amomum*, *Plagiostachys*, *Roscoea*, *Cautleya*, *Boesenbergia fallax* Loes., *Caulokaempferia yunnanensis* (Gagnep.) R. M. Sm., (3) the subtype cereblloid-areolate, pollen grains of which are spherical or subspherical, with cerebelloid sculpture (*Zingiber* Sect. *Zingiber*). (4) The subtype striate, pollen grains of which are prolate or olive shaped, and striate (*Zingiber* Sect. *Cryptanthium*). II. The type aperturate, in which pollen grains are acetilysis-resistant and possess distinct apertures (mixed colpate-porate or forate), including two subtypes: (1) the subtype mixed colpate and porate. Pollen grains are both 3-colpate and 1-3-porate, and usually with one long spiral, two short (straight or slightly curved) colpi and 1-3-pores. The exine is verrucate or not, nearly sinuolate (*Costus speciosus* (Koenig) Smith., *C. tonkinensis* Gagnep., *C. lacerus* Gagnep.). (2) The subtype porate, whose grains are 6-8-porate and exine is foveolate (*Costus megalobractea* K. Schum.). The taxonomic significance of the pollen types in the family Zingiberaceae is also discussed.

Kronestedt and Rowley (1989) studied the pollen grain development and tapetal changes in *Strelitzia reginae* (Strelitziaceae). The proexine that forms within the callosic envelope before the end of the microspore tetrad period is thick (1µm) and exceptionally complex. It has components equitable with tectum, columellae and a nexine that includes lamellar zones. All these components persists in the exine though late in development they become difficult to recognize because the exine is reduced in thickness, apparently by stretching to a maximum of 0.2 µm. *Strelitzia* is an example of an exine template with receptors for sporopollenin that is not maintained during development.

Mangaly and Nayar (1990) studied 21 species under 9 genera of Zingiberaceae of South India. It includes the genera *Alpinia*, *Amomum*, *Boesenbergia*, *Costus*, *Curcuma*, *Elettaria, Globba*, *Hedychium* and *Zingiber.* They observed that exine is absent only in *Kaempferia*. A discontinuous exine layer consisting of circular plates joined together at margins occurs in *Alpinia galanga* (L.) Sw. and *Amomum hypoleucum* Thw., while all other taxa possess an uninterrupted exine layer. Exine is spinulose in *Alpinia* but smooth in *A. sanderae* Sander., *Amomum,* and *Boesenbergia*, verrucose in *Elettaria*, tuberculate to areolate or striate in *Zingiber*, papillose in *Globba* and smooth or nearly so in *Curcuma*, *Costus* and *Hedychium*. Pollen grains are spheroidal in *Globba ophioglossa* Roxb. and inaperturate and foraminate in *Costus*. Shape of the grain is ovoid or ellipsoid in *Curcuma* and *Zingiber,* sulcate. A lamellated intine, much thicker than exine occurs in all, and it is thinner at the aperture region in *Curcuma*, *Costus* and *Zingiber*. Intine is thinner in one or few large scattered circular areas, and it is thinner on one side of the genus in *Boesenbergia* and *Alpinia zerumbet*

(Pers.) B. L. Burtt & R. M. Sm. Palynologically *Alpinia*, *Amomum*, *Boesenbergia*, *kaempferia* and *Zingibe*r constitute one group, while *Elettaria*, *Hedychium*, and *Costus* constitute another.

Mangaly and Nayar (1990) worked out three species of *Zingiber*, *viz.,* *Z. zerumbet*, *Z. officinale*, and *Z. roseum*, and reported a well defined sulcus, in all these species. In *Z. zerumbet* the pollen grain as sub-spheroid and sulcus as triangular suggesting a trichotomonosulcate condition and thickness of exine as 3.2 µm. Theilade *et al*. (1993) using SEM and TEM studies stated that these as depressions or furrows in the pollen wall. Mangaly and Nayar (1990) also reported *Z. officinale* as elliptical with tuberculate ornamentation and *Z. roseum* as elliptical and with striate ornamentation. This may be due to mis identification of plants. But the present SEM studies showed that the shape of pollen grain of *Z. officinale* as spheroid with cerebroid ornamentation and that of *Z. roseum* is ellipsoid with incipient ornamentation and the pollen grain of *Z. cernuum* is ellipsoid with spiro-striate ornamentation.

Yunus (1990), examined pollen surface configuration of 13 species under 4 genera of the family Malpighiaceae using SEM. Periporate pollen occurs in all the taxa except *Tristellateria australasiae* A. Rich., which has been considered as advanced than the primitive tricolporate condition.

Theilade *et al*. (1993) worked out the pollen morphology and structure of 18 species of *Zingiber* using LM, SEM and TEM. It includes 3 taxa of South India, *viz*., *Z. zerumbet*, *Z. officinale* and *Z. capitatum*. They found ellipsoidal pollen grains with striate ornamentation and spherical with cerebroid ornamentation. Pollen grains are inaperturate, exine 2-3 μm thick and outer intine 5 μm and inner layer 2-3 μm thick. They found Sect. *Zingiber* and *Dymczewiczia* with spherical pollen and cerebroid sculpturing, and Sect. *Cryptanthium* with ellipsoidal grains and striate sculpturing.

Poston and Nowicke (1993), studied pollen morphology, trichome types and relationships of the Gronovioideae (Loasaceae) with the help of LM, SEM, TEM and closely related species *Gronovia*, *Fuerteria* and *Cevallia* are distinguished by pollen characters as well as specialized trichome types.

Ambwani and Kumar (1993) studied pollen morphology of 3 species of *Pseudophoenix* (Arecaceae) using SEM and revealed that pollen of different species show distinguishing characters based on pollen morphology. Perez-Munoz *et al*. (1993), by LM and SEM observations characterized the pollen wall layers that comprise *Vigna vexillata* L. and identified the timing of their development.

In *Zingiber spectabile*, microspores develop a thick primexine where as the mature pollen exhibits an extremely thin and discontinuous exine. The development of a channeled intine was initiated after the disintegration of the callose wall, when the microspores had entered the free stage. It reached maximum thickness in the late microspore period after which it decreased in thickness. A thin inner intine was found and an electron dense material appeared in the channels of the outer intine. Thus the general pattern of sporoderm development is similar to that observed in other members of Zingiberales. (Theilade & Theilade, 1996).

Kirpes *et al.* (1996) studied the systematic significance of pollen arrangement in microsporangia of Poaceae and Cyperaceae. Rudall *et al.* (1997) studied microsporogenesis and pollen sulcus type in Asparagales (Lilianae) by cladistic analysis. They found three unordered character states. (1) Taxa with successive microsporogenesis, tetragonal tetrads, and sulcate apertures. (2) Taxa with simultaneous microsporogenesis, tetrahedral tetrads, and sulcate apertures. (3) Taxa with simultaneous microsporogenesis, tetrahedral tetrads, and trichotomosulcate apertures.

Kosenko (1999) studied pollen morphology and taxonomy of 34 species and 7 genera of Liliaceae. The genera *Tulipa* and *Lilium* are heterogenous in both aperture type and exine ornamentation. The other genera are homogenous in possessing a single longitudinal aperture. Pollen morphological data support the division of the family.

Ahmad *et al.* (2001), discussed difference in morphological characters and its taxonomic implications in pollen of 13 species of Guttiferae in which pollen grain characters like shape, aperture, exine ornamentation and puncta are considered. Starchy pollen was reported in Commelinoid monocots comprising the Arecales, Commelinales, Poales and Zingiberales (Zona, 2001). Two types of microsporogenesis are recognized, *viz*., successive and simultaneous, although intermediates occur and successive microsporogenesis is predominant in Monocotyledons (Furness & Rudall, 1999). Cooper *et al*. (2000) reported aperture like region in the pollen grain of some species of *Callitriche*. Harley and Baker (2001), studied pollen aperture morphology in Arecaceae and cladistic analysis of Arecaceae have worked out.

Dhamayanthi *et al*. (2003) studied the structure and development of male and female gametophytes of *Zingiber officinale* and found that stigmatic and stylar incompatibility was predominant in ginger cultivars and the failure of sexual reproduction may be due to the stigmatic and stylar incompatibility.

Wang *et al*. (2004) studied 37 species of family Zingiberaceae and found that 33 had starchy pollen, all species of tribe Zingibereae and Globbeae had pollen with no starch and Alpinieae, Hedychieae had pollen with or without starch but species of Costaceae had starchy pollen with abundant lipids. Friis *et al*. (2004), reported characters like inaperturate, striate pollen of *Mayor portugallica* from the early cretaceous of Torris Vedras in the Western Portuguese Basin. It forms strong evidence on the emergence of monocotyledons from the early cretaceous. Among monocots inaperturate pollen with predominant striae occur in both Arecaceae and Zingiberaceae. Wang *et al*. (2005), while studying self pollination by sliding pollen in *Caulokaempferia coenobialis* K. Larsen., noticed that pollen grain being held together by pollen connecting threads and this is the first report of such threads in the Zingiberaceae.

Acetolysis is a drastic process of treatment of pollen with strong acids, and is known to affect different pollen differently, altering their shape, size and some other features. It renders the exine most remarkably clear for study and for this reason it has been widely accepted by palynologists world over. But this method is unsuitable for study of some pollen, as the pollen wall in these taxa also gets dissolved off by the acid treatment (Mangaly & Nayar 1990). They found the common techniques of pollen preparation for morphological studies were found unsuitable for members of the Zingiberaceae, because acetolysis dissolve the pollen completely in the majority of taxa, while pollen of *Costus* becomes distorted on acetolysis. Among various techniques tested, they recommended direct mounting of pollen in glycerine jelly after killing and fixing fresh pollen in 70% Ethyl alcohol and washing it in distilled water. As pollen contents tended to take deep stain such as safranine were found unhelpful. Acetolysis resistant pollen has been reported in *Tapeinochilos* Miq. of Costaceae by Stone *et al*. (1981). The primexine which is build up solidly between apertures and become packed into layers to form a thick stratified exinous covering. No secondary exine development during the free spore period and the juvenile primexine persists as the protective coat on the mature pollen grain.

Pollen morphology is extremely stable and unaffected by external influences; it can be utilized for understanding the phylogeny and relationships among various groups of angiosperms. In the present study 9 taxa of *Zingiber* in South India have been worked out. Plants show variation in pollen morphology especially in ornamentation pattern, stratification, size and shape.

Key to the species based on Pollen Characters

1. Pollen grains ellipsoidal, striate..2

1. Pollen grains spherical, cerebroid, lumen irregular, ...5

2. Ornamentation incipient, diffuse striate ....*Z. roseum*

2. Ornamentation prominent, spiro-striate 3

3. Length of muri 71.42 – 116.07 μm; lumen 1.27-2.76 μm wide .... *Z. cernuum*

3. Length of muri 3.2 – 46.87 μm and lumen 0.42 μm or very small......4

4. Branching bracket-shaped, branches widely arranged, 7.44-12.76 μm ....*Z. nimmonii*

4. Branching normal, branches closely arranged, 0.42- 0.6 μm................ ....*Z. wightianum*

5. Puncta absent 6

5. Puncta sparse or numerous...7

6. Muri pebble - like, elongated ones at ridge.. ....…….. *Z. capitatum* var. *elatum*

6. Muri sinuous, dissected, triangular with a depression at centre............. ....……….....*Z. neesanum*

7. Muri irregular, puncta numerous .... *Z. zerumbet*

7. Muri regular, puncta sparse...8

8. Equatorial diameter 52–54 m, muri sinuous, pebble–like …………………………..…………...………………………… Z. *officinale*

8. Equatorial diameter 42 – 48 m, muri rectangular shaped...................

....*Z. montanum*

Observations

Pollen grains are mostly aggregated in loose clusters in (*Z. capitatum* var. *elatum*, *Z. neesanum*) or in irregular masses (*Z. zerumbet*). The pollen found in the genus *Zingiber* of South India are of two types; spheroidal and ellipsoidal. Spheroid grains present in *Z. capitatum* var. *elatum*, *Z. montanum*, *Z.* neesanum, *Z. officinale*, and *Z. zerumbet* which exhibit cerebroid ornamentation. Ellipsoidal pollen grains present in *Z. cernuum*, *Z. nimmonii*, *Z. roseum*, *Z. wightianum* in which the ornamentation is spiro-striate or diffuse striate.

Pollen grains are enveloped by a characteristic wall which gives its distinctive morphology. The wall consists of two layers, an outer exine and an inner intine which are morphologically, structurally and functionally distinct. The exine is a secretory product and is made up of sporopollenin, a non-living layer and resistant to acetolysis (Erdtman, 1952). Heslop-Harrison (1968) worked on the origin of sporopollenin and found that tapetum in anthers of flowers is responsible for producing and depositing sporopollenin in the exine of pollen. Thickness ranges from 1-3.2 μm, with characteristic ornamentation. Earlier Mangaly and Nayar (1990) reported the shape of the grains as ellipsoid with tubercled ornamentation in *Z. officinale*, ellipsoid grains with striate sculpturing in *Z. roseum* and sub spheroid grains with areoles in *Z. zerumbet*. Theilade et al. (1993) and Liang (1988) reported cerebroid sculpturing in spherical grains and spiro-striate in ellipsoidal grains.

Pollen size and shape

Pollen size and shape are important characters in the study of pollen morphology. In the case of spherical pollen grains the diameter of the grains is given as the size of the grain. In the case of ellipsoidal pollen grains, diameter of the grain along the longest equatorial axis is given, followed by diameter along the short equatorial axis (Theilade *et al*., 1993).

Exine: The study shows that the exine is thin, coherent and granular. Exine ornamentation is cerebroid in spherical grains and spiro-striate in ellipsoid ones (Liang, 1988). Theilade *et al*. (1993) reported such ornamentation in *Z. zerumbet*,

Z. capitatum, and *Z. officinale*. Exine consists of ridges and grooves. The ridges are known as muri and grooves as lumen. In cerebroid sculpturing, muri are compactly arranged and lumen is very narrow or absent. In SEM studies muri looks pebble- like, rectangular, elongated or sinuous. In ellipsoid grains the muri are elongated, parallely arranged, sometimes bifurcated, and extend one end to the other. Lumen is wide compared to spherical grains and parallely arranged.

Intine: Intine is a prominent layer; it is thick and consists of two layers ranges from 2-5 μm; a thick outer layer, which is radially channelled, and a thinner, finely granular band adjacent to protoplast. The channels are closely packed, stretching from the inner intine layer to the exine. The channels are subdivided by numerous tangentially oriented partition walls. A tangential section of the pollen wall shows that the channels have circular profiles. The thickness of the intine layers is uniform along the entire circumference of the grains (Theilade *et al*., 1993).

Plasma membrane: There is a distinct protoplasmic membrane between intine and protoplast. At the time of pollen germination, pollen tube breaks open the intine and exine. The pollen tube wall is in continuation of protoplasmic membrane (Mangaly & Nayar, 1990).

Aperture: Aperture is reported in *Z. zerumbet*, *Z. roseum* and Z*. officinale* by earlier workers like Mangaly and Nayar (1990). Recent studies of Theilade *et al.* (1993) recognized these as depressions or furrows in the pollen wall and vary considerably in shape and size. SEM studies have shown that pollen of South Indian zingibers are inaperturate but the aperture-like structures or furrows seen on the pollen wall. Cooper *et al*. (2000) reported aperture–like region, in the pollen grain of some species of *Callitriche* (Callitrichaceae).

Pollen germination: Studies of pollen germination in artificial media in sucrose-agar-gelatin showed about 15% germination in *Z. officinale*. Pillai *et al*. (1978) suggested that this may be due to failure of pollen germination on stigma or incompatibility. In *Z. neesanum*, *Z. nimmonii*, *Z. zerumbet* pollen germination is about 82%, In *Z. montanum*, and *Z. wightianum* about 79% and *Z. capitatum* var. *elatum* and *Z. roseum* it is 75%.

***Zingiber capitatum* var*. elatum*:** Pollen grains are cap-shaped, more or less triangular in distal view and sub-spherical in shape. Proximal half is less convex and a ridge is seen between distal and proximal half. Equatorial diameter is 42 - 44.69 μm. Aperture is absent. Exine is 2 μm thick, consists of an outer thin layer and ornamentation is cerebroid. Theilade *et al*. (1993), reported cerebroid ornamentation in *Z. capitatum*. It consists of muri and lumen. Muri are compactly arranged, pebble-like and elongated ones are seen at the ridge. Length of muri ranges from 8.33 – 10.92 μm. Puncta are absent on muri and lumen in between muri are very narrow and irregular **(Plate. 31 A & B)**.

***Zingiber cernuum*:** Pollen grains are ellipsoidal, with a cap at one end and rounded at the other end. Size the grain, 89.3-118 X 44.5 - 47.9 μm, exine 1.8 μm, nearly hyaline, and ornamentation spiro–striate, with prominent muri and lumen, muri slightly sinuous, noodle-shaped, parallely arranged, occasionally branched, obliquely oriented from one lateral end to the other, converging into a cap at one end, clear and flat . Muri 71.42–116.07 X 2.56 - 3.19 μm thick, and lumen parallel, 1.27-2.76 μm. Exine is sometimes shed in one piece and then maintains original shape. Intine nearly hyaline, 1.8 μm thick, consists of an outer layer and an inner layer. Aperture and puncta are absent **(Plate. 31 C & D)**.

***Zingiber montanum*:** Pollen grains are spherical and inaperturate. Equatorial diameter 42-48 μm. Exine is very thin, 1.5 μm thick, Intine consists of two layers, outer 5 μm thick and inner thin 2-3 μm inner layer adjacent to the protoplast. Ornamentation is cerebroid. Muri are compactly arranged and made up of rectangular-shaped and pebble-like structures, length varies from 3.75 – 6.6 X 2.5 - 3.19 μm and puncta sparse. Lumen very narrow and irregular. Exine and intine layers seem to be ruptured during germination. A protoplasmic layer forms the pollen tube wall **(Plate. 31 E & F)**.

***Zingiber neesanum*:** Pollen grains are spheroid in shape with less convex, proximal. Equatorial diameter 42-47 μm. Exine is 1.6 μm in thickness; consists of an outer thin layer and with cerebroid ornamentation. Circular depressions are present in the exine. Muri are compactly arranged, sinuous are highly dissected or triangular shaped with a depression at centre and length varies from 8.57–10 X 2.12–4.25 μm. Lumen very irregular and puncta are absent. Intine consists of an outer thick layer and a thin inner layer **(Plate. 32 A & B)**.

***Zingiber nimmonii*:** Pollen grains are ellipsoidal, with a cap at one end and rounded at the other end. Size of the pollen grains is 74.26 – 85 x 43.24 μm, exine 1.6 μm, hyaline, and ornamentation spiro-straite. Muri oriented from one lateral end to the other, converging into a cap at other end. Muri are very closely and compactly arranged, often overlapping, branching, bracket-shaped, branches widely arranged. Lumen in between muri is very small, irregular or in some regions absent. Intine hyaline, 1.8 μm thick, consists of an outer layer and an inner layer **(Plate. 32 C & D)**.

***Zingiber officinale*:** Pollen grains are spheroid, proximal half is less convex than the opposite side and equatorial diameter 52-54 μm. Exine is thin, light brown, 1.5 μm thick forming a continuous layer. It is coherent, semitectate, and ornamentation is cerebroid. Muri sinuous, some times pebble-like or elongated, bifurcated, and more or less fused or compact, length 6.57–23.68 X 3.19-4.26 μm and puncta sparse. Lumen in between muri is very narrow and irregular. Depressions are present on the grain. The entire exine is sometimes shed as a whole. Exine is 2 μm thick; Intine consists of an outer thick layer of 3 μm and an inner thin layer of 1.5 μm. There is a distinct thin protoplasmic membrane between intine and the protoplast. At germination pollen tube is produced at one end of the colpus and it breaks open the intine as well as the exine. Protoplasmic contents dense, prominently granular and dull brownish in colour. Mangaly and Nayar (1990) reported the grains of *Z. officinale* as ellipsoid with sulcus, size 72 x 62 μm, and ornamentation tubercular. The present study revealed the pollen as sub spheroid and ornamentation cerebroid. The SEM studies by Theilade *et al*. (1993), showed the grains as spheroid, size 95-105 μm, ornamentation cerebroid and nonaperturate **(Plate. 32 E & F)**.

Zingiber roseum**:** Pollen grains are ellipsoidal and inaperturate. Length varies from 82–101.1 μm along the longer axis and 37–38 μm along the shorter axis. The exine ornamentation is incipient and diffuse–striate by which it is different from other species. Muri look like heteromorphic islands of various sizes and contours. The muri and lumen found in other *Zingiber* species is not prominent in *Z. roseum*. It is connected by strands bridges over the low striate, which is formed by variously shaped elongated channels, or rounded depression. They are oriented along the long axis and directed towards the lateral ends. One end of the grain is beaked and the other round. Exine 3 μm thick and intine consists of two layers, outer 1.0 - 1.5 μm thick and inner 1 μm **(Plate. 33 A & B)**.

Zingiber wightianum**:** Pollen grains ellipsoidal with a beak at one lateral end, acute at the other end. Size of the pollen grain varies from 114.9 - 97.9 μm along the longer axis and 40-47.9 μm along the shorter axis. Exine is 1.2 μm thick, intine is nearly hyaline and 1.8 μm thick. Ornamentation is spiro-striate, muri are noodle-shaped, parallely arranged and obliquely oriented from one end to the other, converging into a cap at one end. They occasionally bifurcate and foldings are found at certain regions and converging at two lateral ends with narrow lumen. Average thickness of muri ranges from 2.12 - 2.98 μm and lumen 0.42 μm. Exine sometimes shed in one piece and then maintains the original shape **(Plate. 33 C & D)**.

Zingiber zerumbet**:** Pollen grains are spherical, cap like and the proximal half is less convex. A large triangular depression is present. Equatorial diameter 90-94 μm. Exine is a thin layer of 2 μm in thickness and intine is thick, yellowish brown to nearly hyaline in colour and uninterrupted. Ornamentation is cerebroid. Muri are compactly arranged, irregular, bifurcated, 0.37–5.83 X 2.91–5.20 μm thick, lumen is very irregular. Numerous puncta are seen in higher magnifications. Intine consists of two layers, outer 3.5 μm thick, inner 1 μm and hyaline, protoplasmic contents dense, yellowish brown and prominently granular. A solitary pollen tube emerges during germination. The protoplasmic membrane forms the pollen tube wall. Pollen grains are aggregated and starch present along with irregular masses of pollen grains. Theilade *et al*. (1993) reported pollen of *Z. zerumbet* as spheroid, inaperturate with cerebroid ornamentation, and exine as 2-3 μm thick **(Plate. 33 E & F)**. Palynological studies of *Z. capitatum var. elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanuum*, *Z. nimmonii* and *Z. wightianum* were done for the first time.

Discussion

The present study supports and expands the role of pollen as a useful character for identifying and classifying members of the genus in South India. Pollen grains of the nine South Indian taxa of *Zingiber* studied can be grouped into two categories viz. ellipsoidal type and spherical type, and each one has distinct morphological characters. Spherical grains are present in *Z. capitatum* var. *elatum*, *Z. montanum*, *Z. officinale*, *Z. neesanum* *Z. zerumbet* and ellipsoidal in *Z. cernuum*, *Z. nimmonii*, *Z. wightianum* and *Z. roseum*. Exine ornamentation is cerebroid, spiro-striate or incipient striate.

In *Z. roseum* pollen grain is ellipsoid and with incipient ornamentation. SEM studies have shown that character of pollen grains can be utilized for the delimitation of the species.

Baker (1892) recognized four sections of the genus *Zingiber.* Sect –I. *Cryptanthium* in which spikes are produced directly from the rhizome and are very short and dense and peduncle very short. Sect –ll. *Lampuzium* Horan. in which spikes produced from the root stock more or less elongated peduncles with sheathing scariose bracts leaves. Sect- lll. *Pleuranthesis* Benth. spike peduncled arising from the side of the leafy stem. And Sect-lV *Dymczewiczia* (Horan.) Benth.**-** Spikes terminal on the leafy stem.

Burtt and smith (1972) renamed Sect. *Lampuzium* Horan. as Sect. *Zingiber*, since it includes the type species *Zingiber officinale.* Theilade *et al.* (1993) suggested that the division into Sections *Zingiber* and *Dymczewiczia* based on inflorescence habit alone was not satisfactory. They observed that the two Sections *Zingiber* and *Dymczewiczia* were alike in having spherical pollen with cerebroid sculpturing.

Liang (1988) while working in Chinese *Zingiber,* included pollen grains with spherical or sub-spherical shape and cerebroid ornamentation in Section *Zingiber* and striate grains in Section *Cryptanthium*.

In *Z. cernuum*, *Z. nimmonii*, *Z. roseum* and *Z. wightianum*, the spike is short and dense is produced directly from rhizome. The pollen grains are ellipsoidal with spiro-striate ornamentation. In *Z. roseum*, pollen grain is ellipsoidal and surface diffuse striate or with incipient ornamentation. These taxa included under Sect. *Cryptanthium*. In *Z. capitatum* var. *elatum*, *Z. montanum*, *Z. officinale*, *Z. neesanum*, and *Z. zerumbet*, the pollen grains are spherical with cerebroid sculpturing. *Z. capitatum* var. *elatum* belongs to the Sect. *Dymczewiczia*, in which the spike is terminal also show cerebroid ornamentation. *Z. montanum*, *Z. officinale*, *Z. neesanum*, and *Z. zerumbet*, comes under the Sec. *Zingiber* in which spikes produced from the root stock and with more or less elongated peduncles, show pollen grains with cerebroid sculpturing.

Among ellipsoidal grains the pattern of arrangement of muri and lumen are different. In *Z. cernuum* muri sinuous, noodle-shaped, obliquely oriented from one end to the other, and lumen is wide and parallely arranged. Muri are almost parallel, with dichotomous branching. In *Z. nimmonii* muri are closely arranged, branching is prominent, bracket shaped, and branches are widely arranged. Lumen is very small or absent. In *Z. wightianum* muri are occasionally branched, closely arranged and folding of branches projects out side. Walker (1976) regarded the large boat-shaped pollen grains as primitive and smaller globose forms as derived.

A well distinct depression is present in *Z. neesanum, Z. montanum, Z. officinale* and *Z. zerumbet*. Exine is coherent, inaperturate, sculpturing cerebroid, puncta sparse, common or absent. Muri may be variously arranged. In *Z. montanum* muri pebblate, rectangular or finger-shaped, loosely arranged and puncta sparse. In *Z. neesanum* muri more compact, sinuous, often triangular, with a depression at centre, and puncta absent. Muri are finger-shaped, bifurcated, sometimes pebble-like in *Z. officinale* and muri, more compact, irregular, puncta numerous in *Z. zerumbet.* Species where spikes from the root stock with more or less elongated peduncles with sheathy scariose bract leaves are included under section II *Lampuzium* .

Spike is terminal on the leafy stem in *Z. capitatum* var. *elatum*. It comes under section IV. *Dymczewiczia* (Horan). Benth. and pollen is spheroidal, cap-shaped and more or less triangular in distal view. A ridge is present between distal and prominent half. Ornamentation is coherent, cerebroid and inaperturate.

Though the plants of Sect. *Zingiber* show spheroid pollen grains and cerebroid ornamentation, each one has characteristic arrangement of muri and lumen. *Z. capitatum* var. *elatum* which includes under Sect. *Dymczewiczia* exhibit the same ornamentation and shape that of the pollen grains of Sect. *Zingiber*. So the division based on the position of inflorescence is not entirely satisfactory. *Z. capitatum* var. *elatum* can be included under Sect. *Zingiber.*

MOLECULAR STUDIES

The use of molecular characters in cladeistic analyses has been highly successful in plants, particularly in taxonomically difficult groups in which it is hard to interpret morphological homology. Sequence data derived from the chloroplast gene *rbcL,* which encodes the large subunit of ribulose biphosphate carboxylase, has provided resolution at higher taxonomic levels in plants. According to Bentham and Hooker (1883), Schumann (1904), Nakai (1941), Tomlinson (1962), Dahlgren *et al.* (1985) and Kress (1990) Zingiberales form a distinct order of monocots. Phylogenetic analysis of the Zingiberales based on *rbcL* sequences supported the evidence that the closest clade comprised of Commelinaceae / Haemodoraceae / Pontederiaceae (Smith *et al.* 1993). Dahlgren and Rasmussen (1983) performed the first cladeistic analysis of the Zingiberales using eight families: Musaceae, Lowiaceae, Heliconiaceae, Strelitziaceae, Zingiberaceae, Costaceae, Marantaceae, and Cannaceae. and polarized characters using Commeliniflorae. This analysis resulted in a single tree composed of three main cladees that included Zingiberaceae-Costaceae, Marantaceae-Cannaceae and Musaceae-Heliconiaceae.

Table No. 9. Plant materials used along with the accession numbers and place of collection

Sl. No.	Sample Code	Sample Name	Place of collection	Accession No.
1	1.2	*Zingiber zerumbet*	Punalur, Kollam	2010 - 9
2	1.3	*Zingiber zerumbet*	Kulathupuzha, Kollam	2010 - 107
3	2.1	*Zingiber neesanum*	Ezhumalai, Idukki	2007 - 6
4	2.2	*Zingiber neesanum*	Ponmudi	2007 - 7
5	3.1	*Zingiber nimmonii*	Poovathode, Kottayam	2011 - 74
6	3.2	*Zingiber cernuum*	Calicut Uty campus	2011 - 45
7	5.1	*Zingiber wightianum*	Anamalai	95656
8	35.1	*Zingiber officinale*	Valparai, Tamil Nadu	86179
9	35.2	*Zingiber officinale*	Valparai, Tamil Nadu	86180
10	16.1	*Zingiber montanum*	Jharkand	73429
11	15.1	*Zingiber capitatum*	Barapani, Meghalaya	95627
12	15.2	*Zingiber capitatum*	Barapani, Meghalaya	95628
13	21.1	*Zingiber roseum*	Maruthamalai, AP	106008
14	21.2	*Zingiber roseum*	Cheruvapalam	106001
15	7.2	*Amomum pterocarpum*	Minkong forest, Nagaland	103616
16	25.1	*Alpinia blepharocalyx*	Barapani, Shillong	86265

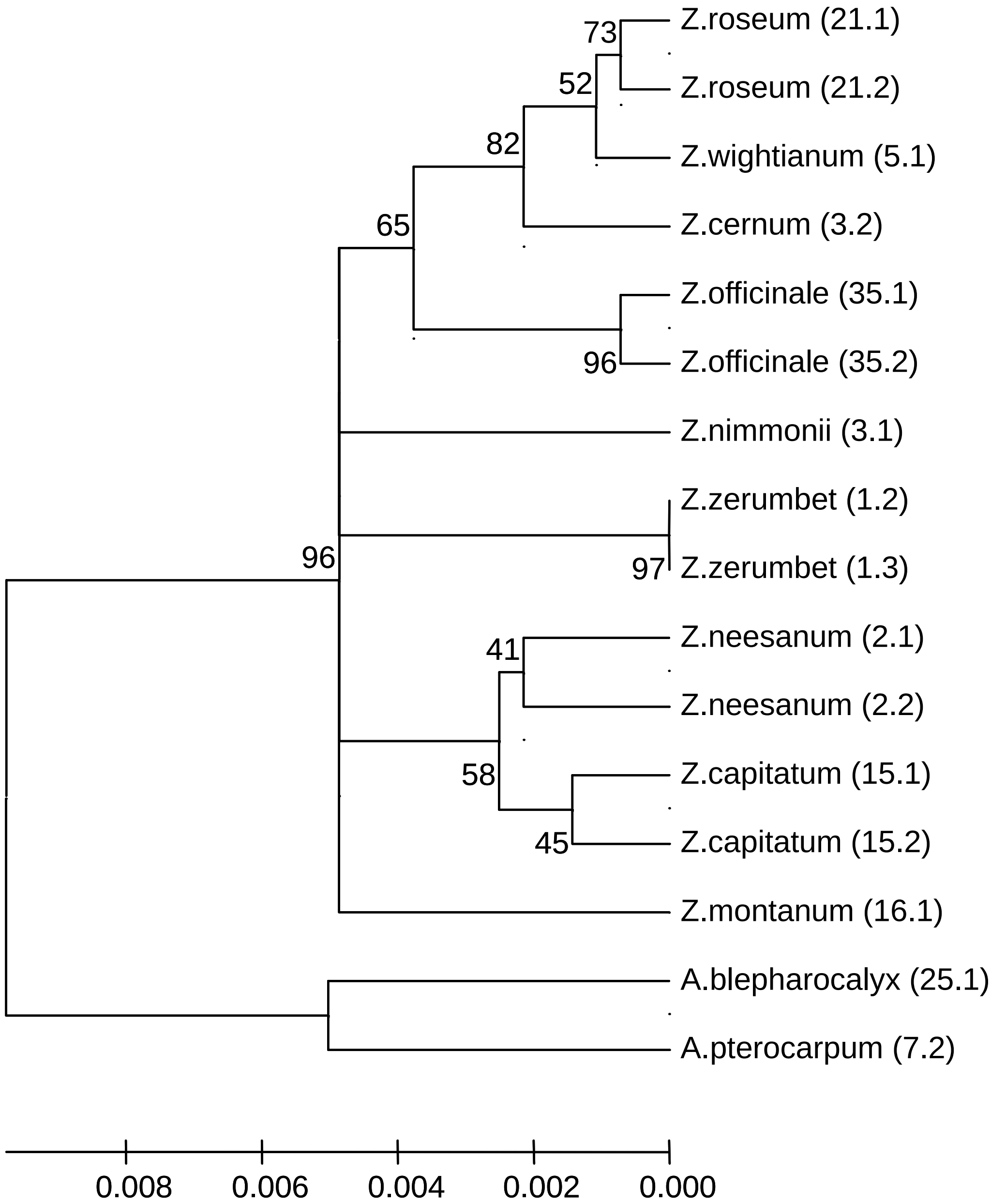

Fig. No. 18: Minimum evolution 50% majority rule bootstrap consensus tree resulting from analysis of *rbcl* sequences for a selection of Zingibereae tribe and Alpinieae outgroups. Bootstrap support is indicated above the nodes

Discussion

Sequences obtained for 14 plants of genus *Zingiber* from India from different localities were employed for study. The strict consensus topology shows that *Alpinia* and *Amomum* form a sister group to the rest of *Zingiber*, and species of South Indian Zingiberaceae plants i.e., *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum*, and *Z. zerumbet* which receives 95% bootstrap support were grouped together.

The clade comprise *Z. roseum*, *Z.wightianum*, *Z. cernuum*, (3.2) and *Z. officinale* receives 65% boot strap support. Two accessions of *Z. roseum* (21.1 & 21.2) were grouped together with 73% boot strap support shows these were had a single origin. *Z. wightianum* (5.1) shows 52% boot strap support to *Z. roseum*. *Z. nimmonii* (3.2) shows 82% boot strap support. This clade shows similar character in inflorescence. Two accessions of wild *Z. officinale* (35.1 & 35.2) received 96% boot strap support showing that South Indian *Z. officinale* had a single origin.

Z. nimmonii and *Z. cernuum* of South India show some morphological similarity but found to be polyphyletic, as the two accessions (3.2 & 3.1) clustered differently. *Z. cernuum* (3.2) is grouped along with *Z. wightianum* (5.1). Accession of *Z. nimmonii* (3.1) clustered differently.

The accessions of clade *Z. neesanum* (2.1& 2.2) were received 41% boot strap support and clade of *Z. capitatum* var. *elatum* (15.1 & 15.2) received 45% boot strap support, which was very low and not well supported. Both clades were shown 58% boot strap support.

The clade of *Z. zerumbet* (1.2 &1.3) shows a good boot strap support (97%) showing a single origin. The accession of *Z. montanum* appeared in the tree separately.

CYTOLOGY

Cytological informations like chromosome number structure and behaviour during mitotic division have been of considerable value while interpreting interrelationships and delimitation of taxa. Raghavan and Venkatasubbam (1943) studied the cytology in relation to taxonomy, which includes two species of *Costus*, *Zingiber officinale*, *Z. cassumunar*, and *Z. zerumbet.* They grouped the chromosomes of *Z. officinale* into 5 long, 4 medium, and 2 short pairs, and found 6 pairs of rod-shaped, 3 pairs of 'V'-shaped, and 2 pairs of crescent-shaped chromosomes. In *Z. cassumunar* and *Z. zerumbet* chromosomes are fairly short, 7 rod-shaped, 2 'V'-shaped, and 2 crescent type. In *Z. zerumbet*, one pair showed the presence of satellite at its proximal end. Later workers like Beltran & Kam (1984), Chakravorti (1948, 1952), Larsen (1972), Mahanty (1968), Mukherjee (1970), Omanakumari and Mathew (1984), Ramachandran (1968), Sato (1948), Sharma and Bhattacharyya (1959), Spearing and Mahanty (1970) carried out cytological studies considering the phylogeny and evolutionary tendency of the family.

The cytology of South Indian Zingiberaceae have been worked out by Ramachandran (1968), Omanakumari and Mathew (1984, 1985), and Sharma and Bhattacharyya (1959).

Sharma and Bhattacharyya (1959) investigated the chromosome number, structure and behaviour of chromosomes, and cytology of 26 taxa of Zingiberaceae, which includes *Z. officinale* and found 2n= 22.

Ramachandran (1968) determined the cytology of 26 species of Zingiberaceae under 11 genera and it includes 5 species of *Zingiber*, namely *Z. roseum*, *Z. wightianum*, *Z. zerumbet*, *Z. macrostachyum*, and *Z. officinale* and found 22 chromosomes in root tip cells and meiosis in *Z. roseum*, *Z. wightianum* and *Z. zerumbet* were regular with good pollen and seed fertility. *Z. macrostachyum* shown 1or 2 bridges with fragments at anaphase-1, and in cultivars of *Z. officinale* showed structural hybridity involving interchanges and inversions.

Mahanty (1970) studied the cytology of 44 taxa, which include *Z. meioga* and *Z. officinale*. According to him most of the species in the tribe Zingiberaceae show 48 chromosomes in their somatic complements except in genus *Zingiber*, and in all other species chromosomes are small to minute. On the basis of the number, size and morphology of chromosomes he suggested that *Zingiber* should be placed in Hedychieae than in Zingibereae. He also suggested that haploid number 11 is the original basic number for the whole of Scitamineae and other numbers such as 9, 10, 12, 13, 14, 16 and 17 are secondary in origin. However, this was not accepted by Burtt & Olatunji (1972). They separated *Zingiber* from Hedychieae and placed it in monogeneric tribe Zingibereae. According to Beltran & Kam

(1984) chromosome number gives no evidence to support the treatment of *Zingiber* in a separate tribe.

Pillai *et al.* (1978) reported meiosis as highly irregular in *Z. officinale* and 12.2% PMC showed univalents, 12.2% trivalents, 9.4% quadrivalents, and clumping 8.1%, extra fragments 12.2%, and opined that the high percentage of meiotic irregularities naturally could lead to high percentage of pollen sterility.

Omanakumari and Mathew (1984) studied karyomophology of *Z. officinale, Z. zerumbet, Z. wightianum and Z. macrostachyum* and found *Zingiber* as a monobasic genus with x=11. A detailed study of karyotypes of the four species showed general uniformity, but in final details recognizable differences were found with regard to distribution of secondary constrictions and centromeric positions of a few individual chromosomes and they stated that numerical and gross structural changes in chromosomes have not played any major role in speciation and evolution of the genus.

Das *et al*. (1998) while doing the estimation of 4c DNA and karyotype analysis in *Zingiber officinale* found that the 4c DNA content and genome volume were positively co-related and the structural alterations in the chromosomes without changes in the numeric chromosome number (2n = 22) caused variations in the DNA amount at cultivar level. Marginal variations in the genome size indicated a close relationship between the cultivars. Chromosome numbers reported by previous workers show 2n=22, except in *Z. mioga*, 2n=55.

Table No. 10

Chromosome number reported in the genus *Zingiber*.

Species	n	2n	Authors
Z. montanum (*Z. cassumunnar*)	11	22	Raghavan and Venkattasubban, 1943. Chakravorti,1948.
Z. neesanum (*Z. macrostachyum*)	11	22	Ramachandran,1968. Omanakumari and Mathew, 1984.
Z. officinale	11	22	Sugiura,1928. Raghavan and Venkattasubban,1943. Chakravorti,1948. Ramachandran, 1968. Omanakumari and Mathew, 1984.
Z. rubens	11	22	Chakravorti,1948.
Z. wightianum	11	22	Chakravorti, 1948. Ramachandran,1968. Omanakumari and Mathew, 1984.
Z. zerumbet	11	22	Chakravorti, 1948. Ramachandran,1968. Omanakumari and Mathew 1984.
Z. mioga		55	Morinaga *et al*.1929.

The chromosome number of nine South Indian species was determined in the present study. Mitotic preparations of root tips at metaphase of *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet* were studied. Roots were obtained from different species between 10.30 - 12.30 a.m. and were pre-treated in a saturated aqueous solution of para-dichloro benzene (Sharma & Mookerjee, 1955) for two hours at 6-8^{o} C. Roots were fixed in (3:1) acetic acid-alcohol for 45 minutes. Roots were thoroughly washed and hydrolyzed in 1% Hcl. and stained in a mixture of 2% acetocarmine - Haematoxylin (9:1) by heating over a flame for a few seconds. Smearing was done in 1% Acetocarmine solution and slides were sealed with paraffin. They were observed under trinocular compound microscope. Photographs were taken with Nokia camera (model Nikon COOLPIX 5000) attached to compound microscope (Olympus CX21FS 1 model).

Discussion

The chromosome data in the genus *Zingiber* showed that all South Indian species are diploids with 2n = 22; which indicate that, n = 11 is the basic chromosome number of the genus **(Plate. 34)**. Chromosome number is reported for the first time in *Z. capitatum* var. *elatum*, *Z. cernuum* and *Z. nimmonii*. There is no interspecific differences in the chromosome numbers of all the species studied. The uniformity in the chromosome number in all species indicate the absence of a species boundaries within them.

POLLINATION BIOLOGY

Pollination is an important mutualism and ecosystem service that links the dominant flora with the dominant fauna, the insects of the world, from the tropics to the artic. Self-pollination does not allow much modification in the genetic makeup of the plant since the seeds produced by self-pollination create plants essentially identical to the individual producing the seed. A plant population that has all individuals identical in form, size, and growth requirements has little possibility of modifications to allow for change in its environment.

Most plant species have evolved ways to ensure an appropriate degree of interchange of genetic material between individuals in the population, and cross-pollination is the normal type of pollination. In this case flowers are only pollinated effectively if the pollen comes from another plant. Plants benefit most by being pollinated by other individuals because this broadens the genetic characteristics of individual plants. As a result, they are more adaptable to necessary changes.

Perhaps, the simplest form of pollination is that of wind pollination, which is common in many of the early spring-flowering trees in temperate areas. Plants have co-evolved with insects, and each insect pollinator group is closely associated with a particular type of plant. This is called a pollination syndrome. Without even knowing the exact insect that pollinates a plant, the type of insect that will visit the plant can be predicted because of the shape, color, size, and scent of the flower involved (Croat, 2001).

Two types of floral morphs were reported in *Alpinia blepherocalyx* (Zingiberaceae) by Zhang *et al.* (2003). Cataflexistylous morph in which the stigma is held erect above the dehiscent anther when anthesis begin in the morning and become curved under the anther at after noon and anaflexistylous morph in which receptive stigma is curved under the indehisecent anther first and moves into a reflexed superior position above the anther as it begins to shed pollen in the afternoon.

A new protandrous mechanism is reported in *Curcumorpha longiflora* (Zingiberaceae) by Gao *et al.* (2004), while studying pollination ecology and found with a two day flowering to avoid autogamy and the taxa produce only one flower to keep geitonogamy to a minimum. Deng *et al*. (2004) reported that the striped squirrel (*Tamiops swinhoei*) as the necter robber from *Alpinia kwangsiensis* in tropical forests of China.

Floral phenology

Plants are perennial herbs that inhabit hilly, low land forests, and plains. Inflorescence is a lateral spike with peduncle of 20-50 cm in *Z. zerumbet* and the peduncle is very short and base of the spike immersed in soil in the case of *Z. cernuum*. Spike is composed of congruent bract and bracteoles and each bract subtends a single flower. The flower has a tubular calyx, cylindrical corolla tube, with three corolla lobes. Dorsal lobe is broader than two laterals, present below the labellum. Labellum forms the most attractive part of the flower. Staminodes are fused with the midlobe and the middle lobe is yellow with dark yellow at the centre, in *Z. zerumbet* and yellow with purple spots in *Z. cernuum*, makes them very attractive, fused with the base of the single stamen forms a landing platform for pollinators. During blooming, each inflorescence produces 1-2 flowers that last only for 9-12 hours. The flowering season extends for about two to three months from June to August.

Flower visitors

Two main insects**,** *Apis dorsata* and *Amegilla* species bees were observed visiting flowers of *Z. cernuum* and *Z. zerumbet* and found to be primary pollinators. Secondary nectar robbers consist of ants **(Plate. 35)**.

Frequency and behaviour of visitors

Flowers fully open in the morning at 5-6 am, soon after opening, anther dehisces and begins to release the pollen grains. The bees visited the flower between 6.30 am-12.30 pm. They preferentially collect the pollen in the early morning to noon. Pollen grains were observed both the bodies of insects. Nectar production is difficult to measure because of the long and fragile corolla tube with a very thin inner space.

Pollen / ovule ratio

It has been observed that a good number of pollen is produced per flower in these plants. It is about 7000/ flower in *Z. zerumbet* and 6400/

flower in the case of *Z. cernuum*. Ovules produced per flower are 5-8 in *Z. zerumbet* and 35-45 in the case of *Z. cernuum.* Pollen grains are sub-spheroidal in *Z. zerumbet* and ellipsoidal in *Z. cernuum.*

Pollen viability

Among South Indian species of *Zingiber*; *Z. montanum*, *Z. cernuum*, *Z. neesanum*, *Z. officinale* and *Z. zerumbet* were examined for pollen viability. In *Z. nimmonii*, *Z. montanum*, and *Z. zerumbet* flower opens in the early morning. Anther dehiscence takes place soon after opening of the flower. Pollen samples were taken from every plant at an interval of two hours after 6 am. Pollen samples were placed in a drop MTT and set to dry on a slide. Slides were examined under a compound microscope (Olympus CX21FS 1 model). Pollen grains were stained as purple brown colour indicates the presence of dehydrogenase, and it is a sign of pollen viability. In *Z. cernuum*, pollen is viable up to 4.30 pm. After one hour it diminishes to 40%, then after two hours it is reduced to 5%. In *Z. montanum* 95% of the pollen is viable up to 2-3 pm. Pollen viability become reduced to 60%, after two hours and pollen grains can be observed as dark in colour and it is further reduced to 5% after 6 pm. *Z. neesanum* flowers in the evening between 4-5 pm. 98% of the pollen is viable in the evening. Viability will be lost after 12 hrs. up to 36%. After that the flower withers away. In *Z. officinale*, the pollen is viable up to 7-8 am. Later the flower withers away.

Discussion

Zingiber flowers are large and labellum with attractive colours like light yellow, dark yellow, white with spots, yellow with red spots and light violet with white spots. *Apis dorsata* and *Amegilla* species bees and ants were found as pollinators. The bees visited the flower between early morning to noon. *Z. zerumbet* and *Z. cernuum* develops fruits after flowering in natural habitat. Among South Indian Zingibers, pollen is viable for 9-12 hrs. *Z. cernuum* and *Z. zerumbet* flowers in the morning and pollen is viable upto 4.30 pm. *Z. neesanum*, *Z. montanum* and *Z. officinale* flowers in the evening between 4-5 pm. 98% of the pollen grains are viable in the evening and lasts for about 9-12 hrs.

CLASSIFICATION

Members of the family Zingiberaceae was first appeared in '*Species Plantarum*' of Linnaeus (1753). He described *Amomum Zingiber* L., *A. zerumbet* L., *A. cardamomum* L., *Alpinia racemosa* L., *A. grana paradisi* L., *Costus arabius* L., *Curcuma rotunda* L., *C. longa* L., *Kaempferia rotunda* L. and *K. galanga* L. under five genera in his *Monandria Monogynia*. Later, some of these species have been transferred to other genera, *viz*., *Amomum zingiber* to *Zingiber officinale* Roscoe, *A. zerumbet* to *Zingiber zerumbet* (L.) Smith, *Amomum cardamomum* to *Elettaria cardamomum* (L.) Maton and *Curcuma rotunda* to *Boesenbergia rotunda* (L.) Mansf.

Lestibodois (1841) circumscribed the present day Zingiberaceous taxa under six tribes *viz*.: *Kaempferiees*, *Hedychiees, Curcumees*, *Alpinees*, *Costoidees* and *Mantisiees* and included *Zingiber* under tribe *Hedychiees*, Duchartre (1849) followed the same classification.

Bentham and Hooker (1862-1883) in their '*Genera Plantarum*' proposed a natural classification and included four tribes under the order Scitamineae. They grouped 36 genera of the order Scitamineae under four tribes; Canneae (1), Maranteae (10), Museae (4) and Zingibereae (21).

Engler and Prantl (1887-1899) raised Scitamineae to the ordinal status with four families: Zingiberaceae, Marantaceae, Cannaceae, and Musaceae.

Baker (1892) in *Flora of British India* classified the order Scitamineae into 4 tribes, Zingibereae, Maranteae, Canneae and Museae. Petersen (1899) in Engler and Prantl's *Die Naturlichen Pflanzenfamilien* recognized four families *viz*., Zingiberaceae, Marantaceae, Cannaceae and Musaceae under the order Scitamineae. He further divided Zingiberaceae into three tribes, *viz*., Hedychieae, Zingibereae and Globbeae. Zingibereae is characterized by the absence of lateral staminodes, which is fused with the labellum, in comparison with tribe Hedychieae, in which lateral staminodes are free and well developed.

Schumann (1904) in Engler's *Das Pflanzenreich* divided Zingiberaceae into two subfamilies: Zingiberoideae K. Schum. and Costoideae K. Schum. and retained three tribes circumscribed by Petersen (1889) Hedychieae, Zingibereae and Globbeae under Zingiberoideae.

Loesener (1930) in Engler and Prantl's *Die Naturilichen Pflanzenfamilien* followed the same classification as Schumann and he included *Zingiber* under the tribe Zingibereae. Nakai (1941) raised subfamily Costoideae to the rank of family Costaceae.

Holttum (1950) made rearrangements in Schumann’s subdivision of the subfamily Zingiberoideae and separated the genus *Zingiber* from the tribe Zingibereae and renamed it as Alpineae and placed the genus *Zingiber* under the tribe Hedychieae. He classified Zingiberaceae into two subfamilies Zingiberoideae and Costoideae and Zingiberoideae further classified into four tribes Alpineae, Hedychieae, Globbeae and Zingibereae.

Burtt and Olatunji (1972) separated the genus *Zingiber* from Hedychieae and placed it in monogeneric tribe Zingibereae.

Burtt and Smith (1972a) modified Schumann's (1904) classification and proposed a new infra-familial classification of the family Zingiberaceae and tentative key to the genera. They divided family Zingiberaceae into two subfamilies. Subfamily Costoideae is distinguished by spirally arranged leaves, tubular closed sheaths, absence of lateral staminodes and epigynous glands and absence of aromatic oil cells. Subfamily Zingiberoideae is distinguished by distichous leaves, open sheaths, presence of lateral staminodes, and epigynous glands. Subfamily Zingiberoideae is further divided into four tribes; Globbeae (4 genera), Zingibereae (1 genus), Hedychieae (16 genera), Alpinieae (24 genera).

In globbeae, ovules are arranged on a parietal placenta and anther usually long, exerted on an arched ascending filament. Zingibereae is characterized by distichy of leaves parallel to rhizome, style exserted beyond the anther, anther crest wrapped around the style, and trilocular ovary, with axile placentation. In Hedychieae, distichy of leaves parallel to rhizome, style is not exserted beyond the anther, anther crest not wrapped around the style, lateral staminodes petaloid, and free from labellum and pseudostem short. In Alpinieae, pseudostem is well developed, distichy of leaves transverse to rhizome, style not exserted beyond the anther, lateral staminodes small, teeth like or absent.

Vegetative and floral characteristics were considered in all these classifications of Zingiberaceae. The classification of Bentham and Hooker stands unchanged even though the number and constitution of families changed with authors and the taxonomic status of Scitamineae was raised to that of an order (Zingiberales) or Super order (Zingiberanae). It forms a very closely interrelated assemblage of monocotyledonous taxa, probably very distinct from other groups

Larsen *et al*. (1998) divided Zingiberacae into 4 tribes *viz.* Hedychieae Petersen. (19 genera), Globbeae Petersen. (4 genera), Zingibereae Petersen. (1 genus) and Alpinieae Meisn. (21 genera).

Kress *et al*. (2002) proposed a new classification of the family Zingiberaceae based on the molecular data, which is followed in the present treatment. They recognized four subfamilies. The subfamily Siphonochiloideae, includes only one tribe Siphonochileae, which includes a single genus *Siphonochilus*. Subfamily Tamijioideae includes one tribe Tamijieae, and *Tamijia* is the single genus. Subfamily Alpinioideae consists of 21 genera divided into two tribes; Alpinieae and Riedelieae. Alpinieae with 16 genera (*Aframomum*, *Alpinia*, *Amomum*, *Aulotandra*, *Cyphostigma*, *Elettaria*, *Elettariopsis*, *Etlingera*, *Geocharis*, *Geostachis*, *Hornsteditia*, *Leptosolena*, *Paramomum*, *Plagiostachys*, *Renealmia*, and *Vanoverberghia*). Riedelieae with 5 genera (*Burbidgea*, *Pleuranthodium*, *Riedelia*, *Simanthus*, and *Siliquamomum*). And subfamily Zingiberoideae is divided into two tribes; Zingibereae and Globbeae The tribe Zingibereae includes 25 genera

(*Boesenbergia*, *Camptandra*, *Cautleya*, *Cornukaempferia*, *Curcuma*, *Curcumorpha*, *Distichochlamys*, *Haniffia*, *Haplochorema*, *Hedychium*, *Hitchenia*, *Kaempferia*, *Laosanthus*, *Nanochilus*, *Parakaempferia*, *Pommoreschea*, *Pyrgophyllum*, *Rhynchanthus*, *Roscoea*, *Scaphochlamys*, *Smithatris*, *Stahdiochilus*, *Stahlianthus* and *Zingiber*). The tribe Globbeae with 5 genera (*Gagnepainia*, *Globba*, *Hemiorchis*, *Mantisia* and *Caulokaempferia)*.

Classification of Kress *et al*. (2002) represent natural groups and more convinced and this classification is accepted in the present study. Genus *Zingiber* comes under subfamily Zingiberoideae, and tribe Zingibereae.

Genus history

Linnaeus (1753) in his '*Species Plantarum*' listed the Zingiberaceae under class 1. Monandria Monogyna. He enumerated *Amomum zingiber, A. zerumbet, A. cardamomum, A. granaparadisi, Costus arabicus, Alpinia racemosa, Curcuma rotunda, C. longa, Kaempferia rotunda* and *K. galanga*. Later *Amomum zingiber* and *A. zerumbet* were transferred to *Zingiber* Boehm. as *Zingiber officinale* Roscoe and *Zingiber zerumbet* respectively.

Schumann (1904) included *Zingiber* Adans. Under tribe Zingiberaceae Petersen. Holttum (1950) removed *Zingiber* from the *Alpinia* group and re-named that tribe Alpinieae. He placed *Zingiber* in Hedychieae, without changing the name of tribe, fearing the confusion that would arise. Several authors like Weisse (1932), Mahanty (1970) *etc*. adopted it.

Tomlinson (1956) suggested that *Zingiber* agrees with Hedychieae in having the plane of distichy of the leaves parallel to the axis of the rhizome, whereas in Alpinieae it is transverse and *Zingiber* has the fleshy rhizome which tends to differentiate Hedychieae from the Alpinieae, in which rhizome is more fibrous.

Burtt and Smith (1964) proposed that *Zingiber* should be recognized as an independent tribe. This was done mainly because of the lateral staminodes fused with labellum in *Zingiber* whereas in Hedychieae they are free from labellum. Burtt and Olatunji (1972) separated the genus *Zingiber* from Hedychieae and placed it in monogeneric tribe Zingibereae.

The genus in India was studied by Roxburgh (1810) and reported 11 species. He placed them under two sections based on the nature of the spike; Section -1. Spike radical, includes *Zingiber officinale* Roscoe, *Zingiber zerumbet* (L.) Smith., *Zingiber cassumunar* Roxb., *Zingiber roseum* (Roxb.) Roscoe, *Zingiber ligulatum* Roxb., *Zingiber rubens* Roxb., *Zingiber squarrosum* Roxb. and Section-2. Spikes terminal, includes *Zingiber capitatum* Roxb., *Zingiber marginatum* Roxb.

Baker (1892) described 24 species from British India and placed them under 4 sections. Section I. *Cryptanthium* Horan. – Spikes are produced directly from the rhizome and are very short and dense; peduncle very short (11 species.). Section. II. *Lampuzium* Horan. – Spikes produced from the root stock more or less elongated peduncles with sheathing scariose bracts (10 species). Section III. *Pleuranthesis* Benth. – Spike peduncled, arising from the side of the leafy stem (1 species). Section IV. *Dymczewiczia* (Horan.) Benth. **-** Spikes terminal on the leafy stem (2 species).

Burtt and smith (1972) renamed Sect. *Lampuzium* Horan. as Sect. *Zingiber* without any change in constituent taxa, since it includes the type species *Zingiber officinale.* Theilade *et al.* (1993) suggested that the division into Sections *Zingiber* and *Dymczewiczia* based on inflorescence habit alone was not satisfactory. They observed that the two Sections were alike in having spherical pollen with cerebroid sculpturing and it appeared that pollen morphology offers a more useful criterion than inflorescence habit for the classification into Sections. Hence the Sect. *Dymczewiczia* was merged with Sect. *Zingiber*.

SYSTEMATIC TREATMENT

Zingiberaceae Adans. (*nom. cons*.)

Zingiberaceae Adans., Tan. Pl. 2: 61. 1763; Nakai, J. Jap. Bot. 17: 189. 1941.

Type genus: *Zingiber* Boehm.

Plants annual or perennial rhizomatous herbs, terrestrial or epiphytic (*Hedychium* spp.). Rhizome small, medium or large, conical or obovate variously coloured, branched, condensed or elongated, tips ending in an erect leaf bearing shoot or in a flowering shoot only, sessile tubers may be present or absent; root tubers small, ovoid or elliptic, rarely long, cylindrical; roots many, fleshy or fibrous. Leafy shoots single or in tufts, unbrached, 1-5 m long, formed by the overlapping leaf sheaths, sheaths open or closed (*Roscoea* spp.). Leaves distichous, sessile or petiolate, petiole short or long; lamina elliptic to oblong, lanceolate, or circular, green, some times variegated, glabrous or pubescent, ligulate; ligule short or long. Inflorescence terminal or on a separate shoot, subterranean or prostrate, erect or pendulous; peduncle short or long, covered by sheaths; spike condensed, or very long, sometimes coloured. Fertile bracts spirally or distichously arranged (*Boesenbergia* spp.), free to the base or sometimes adnate each other laterally, forming basal pouches (*Curcuma* spp.) green or coloured, persistent to deciduous, sometimes absent, turns to red at fruiting stage (*Zingiber* spp.) Bracts subtend 1 to many flowered cincinni, rarely flowers are replaced by bulbils (*Globba* spp). Bracteoles very small (*Curcuma* spp.) or large (*Alpinia* spp.); sometimes longer than bracts (*Scaphochlamys* spp.), tubular or open to the base, rarely in upper part of inflorescence (*Alpinia* spp.), flowers trimerous, zygomorphic, large and showy or small. Calyx tubular or truncate, 3-toothed, often split rather deeply down on one side, persistent or deciduous. Corolla tube short or long, tubular or funnel-shaped. Corolla lobes 3, equal or sub equal, variously coloured; dorsal lobe often longer and broader than the laterals, always overlapping the others in bud, tip hooded; lateral lobes usually narrower, tip rounded, without a hood. Labellum large, conspicuous, form the attractive part of the flower, coloured white, pale yellow to deep yellow, purple or violet, with stripes or spots, adnate at the base to the corolla tube, shortly 3-lobed or entire, tip emarginate or deeply split, margins wavy or crisped. Lateral staminodes on either side of the dorsal corolla lobe, conspicuous petaloid structure adnate with labellum at base (*Zingiber* spp.) or free, sometimes reduced to small subulate teeth joined to the labellum at base. Stamen single, sessile or with a distinct filament; filament broad or narrow, joined to the corolla tube at the base, sometimes joined to the labellum or to the staminodes above the insertion of the corolla lobes, short, equal to or longer than the labellum; anther connective sometimes extended laterally into 2 or 4 appendages (*Globba* spp.), or small or large crest or wrapped around the style (*Zingiber* spp.); thecae parallel, divergent or convergent, usually dehiscing longitudinally, rarely by apical pores (*Boesenbergia* spp.), in some taxa basal portion is extended into two small spurs (*Curcuma* spp.), rarely the spur also may be fertile (*Curcuma vamana* Sabu & Mangaly). Epigyous glands usually two, free or united on the top of the ovary or rarely absent (*Curcuma vamana*, *C. sparganifolia* Gagnep.). Style long, slender, pass through a groove in the corolla tube, sometimes becomes separated from the long, slender filament and form a bow-string across the curvature; stigma often swollen, bilipped, rarely not swollen, fringed with hairs. Ovary inferior, unilocular with parietal placentation (tribe Globbeae) or apparently trilocular with axile placentation. Fruit is a capsule or berry, wall thick, fleshy or dry with ridges or spinous outgrowths, ovate, spherical or trigonous, sometimes much elongated, dehiscent, breaking irregularly or loculicidal. Seeds small, arillate, aril lacerate or covering the seed completely or a basal cushion only.

Distribution: There are 53 genera and about 1200 species distributed mainly in tropics and sub tropical Asia. About 21 genera and about 200 species are represented in the whole of India (Sabu, 2006). There are 65 species and 2 varieties under 10 genera are reported from South India.

Flowering & Fruiting: Seasonal, mostly during the rainy season. Some in summer and rarely throughout the year.

Notes: The family Zingiberaceae is related to Musaceae, Cannaceae and Marantaceae of order Scitamineae of Bentham and Hooker and form a natural group. The herbaceous habit, rhizome, sheathing petiole, calyx and corolla in separate whorls, inferior ovary are common for this group. The order is a very advanced group and representing the climax of one line of development of the division in which the calyx and corolla remained in separate whorls (Hutchinson,1934). He also considered this as a parallel group to Orchidales, a climax group of petaloid monocotyledons, with regard to a reduction in one stamen in both. Musaceae share a common arrangement of floral characters with that of common monocotyledons. In Zingiberaceae and Costaceae a single stamen is fertile and only half anther is functional in Cannaceae and Marantaceae and rest of the stamens being petaloid. In Marantaceae the number of ovule is reduced to one in each chamber or sometimes two of the three chambers abort, while other families have trilocular ovary.

Bentham and Hooker placed the family in Scitaminaeae under the series Epigynae as they have common features such as rhizomatous herbaceous habit, imbricate bases of sheathing petioles, calyx and corolla in separate whorls and inferior ovary. Cronquist (1981) included 8 families under Zingiberales *viz.,* Costaceae, Cannaceae, Heliconiaceae, lowiaceae, Marantaceae, Musaceae, Strelitziaceae and Zingiberaceae. The families of the order show a reduction of stamens and number of ovules. Musaceae shows common features of the monocotyledons, in Zingiberaceae and Costaceae a single stamen is fertile, in Cannaceae and Marantaceae only one half-anther is fertile. In Heliconiaceae and Strelitziaceae, five stamens fertile and ovary three celled. One petal of Lowiaceae is modified into a large labellum like orchids. Hutchinson (1934) considerd Zingiberaceae as very advanced group and a parellel group to orchidales in the presence of a single stamen in both.

Key to the Subfamilies

Recently Kress (2002) divided the family into four sub families based on molecular data.

1. Plane of distichy of leaves perpendicular to rhizome ………………..2

1. Plane of distichy of leaves parallel to rhizome ………… Zingiberoideae

2. Lateral staminodes reduced or absent.............................. Alpinioideae

2. Lateral staminodes well developed and fused to the labellum ………..3

3. Plants evergreen with fibrous rhizomes; ovary unilocular with parietal placentation .... Tamijioideae

3. Plants with seasonal dormancy period and fleshy rhizomes; ovary trilocular with axile placentation …………………… Siphonochiloideae

Subfamily: Zingiberoideae Hassk.

Zingiberoideae Hassk., Cat. Hort. Bot. Bogor, 1844.

The subfamily Zingiberoideae contains the genera formerly placed within the three tribes Zingibereae, Hedychieae and Globbeae. The most recognizable floral features of this subfamily are the conspicuous and often well-developed lateral staminodes that are generally absent in Alpinioideae. These lateral staminodes are fused to the corolla tube and free from the labellum in most of the former Hedychieae, whereas they are fused to the labellum in the genus *Zingiber* (former Zingibereae) and connate to the filament in *Globba* (part of the former Globbeae). In a few genera lateral staminodes or the labellum are reduced or absent. In a recent classification proposed by Kress *et al*. (2002) divided the Zingiberoideae into two tribes Zingibereae and Globbeae.

Key to the tribes

1. Ovary trilocular with axile, basal or free columnar placentation; labellum usually not connate to filament ………………. **Zingibereae**

1. Ovary unilocular with parietal placentation; labellum often connate to filament in a slender tube ……………………………………. **Globbeae**

Tribe: Zingibereae Meisn.

Zingibereae Meisn**.** Pl. Vasc. Gen. Tab. Diagr. 388. Comm. 290. 1842.

Leaves distichous, plane of distichy parallel to rhizome. Labellum and lateral staminodes well developed, lateral staminodes free or fused to the labellum, labellum usually not connate to the filament. Ovary trilocular with axile, basal or free columnar placentation.

Type genus: *Zingiber* Boehm.

Taxonomic notes: Three tribes were recognized in the subfamily Zingiberoideae viz., Globbeae, Hedychieae and Zingibereae by Peterson (1889), Schumann (1904) and Loesner (1930) based on the petaloid development of the staminodes and ovary. The genus *Zingibe*r was included in the tribe Zingibereae along with *Alpinia*, *Amomum* and it is characterized by the absence of lateral staminodes or which are limited to the labellum, whereas in the tribe Hedychieae the lateral staminodes are well developed.

According to Holttum (1950), *Zingiber* is closer to genera under Hedychieae as their lateral staminodes appear as lobes at the base of the labellum, than to *Alpinia*, *Amomum etc.* in which the lateral staminodes are much reduced. So he removed *Zingiber* from Zingibereae and renamed it as Alpinieae. He placed *Zingiber* in Hedychieae, without changing the name of tribe, fearing the confusion that would arise. This was adopted by several authors (Weisse, 1932; Mahanty, 1970) but as this is nomenclaturally in correct, Burtt & Smith (1964) proposed that *Zingiber* be recognized in an independent tribe. This was supported by Tomlinson (1956) based on anatomical and morphological peculiarities.

Panchaksharappa (1962) suggested that tribe Hedychieae should be renamed as Zingibereae since it includes the type genus *Zingiber*. Burtt and Smith (1964) tentatively suggested that *Zingiber* should be kept as an independent tribe which would be botanically and nomenclaturally correct. Subsequently, Burtt and Olatunji (1972) revised the tribe Zingibereae, with *Zingiber* as its sole genus. The present treatment includes the genus *Zingiber* and the members of Hedychieae under the tribe Zingibereae.

Key to the genera of South India

1. Lateral staminodes adnate to the labellum; anther erect, elongated, embracing the style.....….….……………………………………... ....**Zingiber**

1. Lateral staminodes free from the labellum; anther with or without a crest; not embracing the style ……………………………………….......2

2. Primary bracts adnate to each other laterally for about half their length, forming basal pouches ....**Curcuma**

2. Primary bracts not adnate laterally …………………………………......3

3. Stem well developed; corolla tube long, exserted from bracts..……….. ………………………………………………………................**Hedychium**

3. Stem short, poorly developed or absent; corolla tube short or long, sometimes exceeding the bracts ……………………………………...4

4. Bracts distichously arranged; bract matures from tip to base; anther crest short or absent …………………………………….. **Boesenbergia**

4. Bracts spirally arranged; bract matures from base to top; anther crest petalloid …………………………………………….............**Kaempferia**

Zingiber Boehm**.** (*nom. cons*.)

Boehm. in Ludwig, Defin. Gen. Pl. 89. 1760; Roxb., Asiat. Res. 11: 345. 1810, Fl. Indica 1: 46. 1820; Dalzell & Gibson, Bombay Fl. 272. 1861; Benth. & Hook. f., Gen. Pl. 3: 646, 1883; Baker in Hook. f., Fl. Brit. India 6:

243. 1892; Trimen, Handb. Fl. Ceylon 4: 256. 1898; K. Schum. in Engler, Pflanzenr. 4 (46): 165. 1904; T. Cooke, Fl. Pres. Bombay 2: 733. 1907; C.E.C. Fisch., Rec. Bot. Surv. India 9: 178. 1921, in Gamble, Fl. Pres. Madras 8: 1487. 1928; Holttum, Gard. Bull. Singapore 13: 48. 1950; A.S. Rao & D.M. Verma, Bull. Bot. Surv. India 14: 136, 1972; Ramamoorthy in Saldanha & Nicolson, Fl. Hassan Dist. 768. 1976; B.L. Burtt & R. M. Sm. in Dassan., Rev. Handb. Fl. Ceylon 4: 492. 1983; Manilal, Fl. Silent Valley 314. 1988; R. M. Sm., Notes Roy. Bot. Gard. Edinburgh 45: 409. 1989; S. Kumar, Zingiberaceae of Sikkim 66. 2001. M. Sabu, Folia Malaysiana 4(1): 25-52. 2003; M. Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Type species: *Zingiber officinale* Roscoe

Plants perennial rhizomatous herbs. Rhizome, thick, fleshy, subterranean, aromatic, coloured. Leaves shortly petiolate or sessile; ligule short or long, entire or deeply bilobed; lamina lanceolate, broad or narrow. Inflorescence terminal or on a separate shoot. Peduncle short or long, clothed with leafless sheaths. Spikes short or long, ovoid or cylindrical, growth racemose type. Bracts persistent, large, fleshy, closely imbricating, with a membranous hyaline margin, subtending a single flower. Bracteoles persistent, facing the bract, split to the base. Calyx tubular, tip 3-toothed, shorter than the bracteole. Corolla tube cylindrical, tubular, as long as the bract; dorsal lobe broader than the laterals, erect, narrowed to the tip and edges inflexed; lateral lobes linear-lanceolate, situated just below the labellum, joined together partly by their adjacent sides and to the labellum, white or cream coloured. Labellum 3-lobed, lateral staminodes fused with the midlobe, erect on either side of the stamen, midlobe equal or shorter than the lateral corolla lobes, apex emarginate, white, purple, yellow, cream or sometimes deeply purple spotted. Filament short, broad, anther long, connective prolonged into a slender, curved crest, enclosing the upper part of the style. Stigma ciliate, project below the apex of the crest. Epigynous glands two, linear. Ovary barrel-shaped, hairy or glabrous, 3-locular with many ovules on axile placenta. Fruit a capsule, fleshy when fresh, leathery when dry, enclosed within persistent bract and bracteole, dehiscing loculicidally. Fruit turns to dark red at maturity. Seeds many, ellipsoid, arillate, aril black or dark brown.

Distribution: The genus is represented by 141 species (Theilade, 1999; Theilade & Mood, 1999a), distributed mainly in tropical areas in dense forests, open grass lands at high altitudes and in plains at lower elevations in regions like, Malaysia, Queensland, Japan, East Indies, Java, New Guinea, Thailand, Kampuchea, Cambodia, Laos, Philippines, China. Sri Lanka, India etc.

In India *Zingiber capitatum* var. *elatum* is distributed in Karnataka, Bihar, West Bengal and Sikkim. *Z. montanum* considered to be a native of India, cultivated widely in tropical Asia, Malay Peninsula and Sikkim, Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu. *Z. cernuum*, *Z. nimmonii* and *Z. neesanum* are endemic to Peninsular India and are reported from

Maharashtra, Karnataka and Kerala and Tamil Nadu. *Z. officinale*, is wildely cultivated in all districts of South India. Some wild forms occur in the evergreen forests of Kerala. *Z. roseum* is considered as a native of India. In South India it is reported from Northern Circars and Western Ghats. *Z. wightianum* occur in Peninsular India and Sri Lanka, seen mainly in dense ever green forests at high altitude upto 1500 m. *Z. zerumbet*, distributed throughout India, is supposed to be a native of India (Holttum, 1950).

Ecology: South India consists of a wide variety of habitat with main mountain systems, laterite hills, valleys, swamps, marshy low lands, sandy sea coasts, fresh water rivers, ponds, back waters and harbours diverse types of vegetation. Kerala and western parts of Karnataka have a warm humid climate with heavy rainfall and support dense vegetation. This region forms one of the richest floristic regions in the country. Species like *Z. wightianum* and *Z. neesanum, Z. nimmonii are* restricted to tropical forests of high altitudes. *Z. roseum* is confined only to Northern Circars. *Z. montanum* is mainly distributed in hilly areas of Andhra Pradesh, Karnataka and Goa. *Z. capitatum* var. *elatum* is seen in hill slopes and open grass lands of Karnataka. *Z. officinale* is widely cultivated in all districts of South India whereas *Z. zerumbet* and *Z. cernuum* are well distributed throughout South India.

Flowering and fruiting: In genus *Zingiber* flowering period is very short and usually associated with rainy season. In *Z. cernuum*, *Z. zerumbet*, *Z. nimmonii*, *Z. neesanum, Z. montanum* and *Z. roseum,* flowering takes place along the onset of south west monsoon and in *Z. officinale* in between September- November. *Z. capitatum* var. *elatum* and *Z. wightianium* flowers during the south east monsoon and subsequently fruiting also occur.

Taxonomic Notes: Amomum and Z*ingiber* look alike in vegetative stage but A*momum* has hard and woody leafy shoots and the latter has a fleshy leafy shoot. *Zingiber* is characterized by a swollen pulvinus at the base of the petiole; anatomically it is due to the thickening of collenchyma cells of vascular bundle sheath (Tomlinson, 1956; Jayasree, 2007). In other genera of Zingiberaceae, the bundle sheaths are sclerenchymatous.

Key to the species

1. Spike terminal, on the leafy stem.............**1. *Z. capitatum* var. *elatum***

1. Spike lateral, from the base of the leafy stem.......................................2

2. Peduncle immersed in soil, not erect 2-9.5 cm long or absent.............3

2. Peduncle erect, 10 - 50 cm long.. 6

3. Labellum white with spots, c. 3.2 cm long, oblong, cuneate, margin recurved, rhizome white inside ....**6. *Z. roseum***

3. Labellum yellow or purple with spots, 2.4-2.7 cm long, obovate or subovate, rhizome purple-lilac or yellow inside....................................4

4. Rhizome purple-lilac inside, sympodial, ligule 5 mm -1 cm long, bilobed; labellum yellow with purple spots or streaks.........................5

4. Rhizome yellow inside, stoloniferous, ligule 3-3.5 cm long, deeply notched, labellum light violet with white spots......... **8. *Z. wightianum***

5. Leafy shoot 65-90 cm tall, peduncle 0.8 cm long, flower 5.8 cm long ....……... **2. *Z. cernuum***

5. Leafy shoot 1.2- 1.5 m tall peduncle 9.5 cm long, flower 7.7 cm long ....…......................**5. *Z. nimmonii***

6. Labellum pale yellow, unspotted……………………………………....7

6. Labellum dark purple or purple spotted………………………………....8

7. Bracts greenish brown, spike ovate with acute tip......**3. *Z. montanum***

7. Bracts green, turn to red at maturity, spike globose with round tip………………………………..…………….......…....**9. *Z. zerumbet***

8. Leaves lanceolate, stem dark red, spike cylindrical, dark red, labellum white with purple spots...**4. *Z. neesanum***

8. Leaves linear, narrowly lanceolate, stem green, labellum dark purple with creamy yellow blotches……....……………………..**7. *Z. officinale***

1. ***Zingiber capitatum*** Roxb. var. ***elatum*** (Roxb.) Baker in Hook. f., Fl. Brit. India 6: 249. 1892. Prain, Bengal Pl. 2: 785. 1963; Jha & Varma in A.K. Pandey, Taxonomy and Biodiversity 110. 1995; S. Kumar, Zingib. Sikkim 69. 2001. M. Sabu, Folia Malaysiana 4(1): 25-52. 2003; M. Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Zingiber elatum Roxb., Fl. Indica 1: 57. 1820.

Type : Zingiber capitatum Roxb. var. *elatum* Roxb. Iconotype-Icones Roxburghianae *t. 1509* (CAL).

Dymczewiczia elata Horan., Monogr. 27. 1862.

(Fig.No. 19 Plate No.36)

Plant a herb with perennial rhizome. Rhizome thick, yellow, sympodial, tuberous inside, aromatic, root tubers many, oblong. Plants 1-1.5 m high, internodes 2.2 cm long. Leaves many, lower smaller in size, upper 32-45 x 2-3.3 cm, narrow lanceolate, margin recurved, base round, glabrous above and minutely hairy on the lower side; tip acuminate, ligule very small, 0.1 mm long; sheath hairy. Spike terminal, sessile, linear; deep green, oblong, many flowered, tip obtuse, 12-14 x 2-3.5 cm. Bracts 3.3-3.8 x 1-1.5 cm, lanceolate, green with red margins and white below, pubescent, turn bright red at maturity. Bracteoles 2.5-3 x 1.8-2.2 cm, linear, lanceolate, margin smooth light green, outer sparsely hairy. Flowers 4.8-5.2 cm long, pale yellow, 4-6 opens at a time, longer than bracts. Open after 3 pm. Calyx 1.2-1.4 x 1-1.2 cm, unequally 3-toothed, apex truncate, membranous, white, hairs present on the margin. Corolla tube 1.5 cm long, cylindric, light yellow, glabrous, lobes unequal. Dorsal lobe, 2.4-2.8 x 1.3-1.5 cm, lanceolate, boat-shaped, hooded, yellow; lateral lobes 2-2.3 x 0.4-0.5 cm, yellow, narrow, lanceolate. Labellum 2.5-2.9 x 2-2.4 cm, emarginate, margin wavy, yellow, deep yellow at centre; lateral lobes 2.5-2.7 cm long, margin wavy, yellow. Anther 1.2 cm long, beak equal to anther lobes, yellow. Ovary 4 mm long, pubescent, style shorter, stigma funnel-shaped, emerges through the anther lobe, white, margin ciliate. Epigynous glands two, c. 0.5 cm long, elongate, equal, linear, free from each other and yellow. Seeds many, black, surface with longitudinal grooves, arillate, aril white.

Distribution: It is reported from Bihar, West Bengal (Jha & Varma, 1995) and Sikkim (Kumar, 2001). Sharma *et al.* (1984) reported *Z. capitatum* in Karnataka. This forms a new record for South India.

Flowering: It flowers in July - October, 4-6 opens at a time and flowers open during 3-5 pm. and wither in the next day after noon.

Notes: First reported by Roxburgh (1820) and he treated this as an independent species *Z. elatum* Roxb. Later Baker (1892) considered it only as a variety of *Z. capitatum* Roxb. While Horaninow (1862) placed this under a new genus *Dymczewiczia.* Varma *et al*. (1991) confirmed Baker's view and treated as a variety of *Z. capitatum* based on flavanoid spot pattern characters.

Specimens examined: ANDRA PRADESH. Visakapatanam Dt.: way to Gudam Chittapalli, *Ellis 3729* (MH). Warangal Dist.: Pakhal, near rest house, *Sebastine 11704* (MH). MEGHALAYA: Shillog Dt.: *Barapani lake side, Sanoj 95627* (CALI).

2. *Zingiber cernuum* Dalzell in Hook. Kew J. Bot. 4: 342, 1852. Dalzell & Gibson, Bombay Fl. 273. 1861. Baker in Hook. f., Fl. Brit. India 6: 245. 1892; K. Schum. in Engler, Pflanzenr. 4(46): 182. 1904; T. Cooke, Fl. Pres. Bombay 2: 734. 1907. Santapau, Fl. Khandala ed. 3. 274. 1967.

Type: To be typified. All efforts to locate the types at CAL, K, BM, and BLAT were in vain.

(Fig No. 20, Plate. 38)

Plant a herb with perennial rhizome, fleshy, subterranean, main branch 3-3.5 cm, purplish-lilac inside, aromatic, roots many, bearing ovoid tubers. Leafy shoot 65-90 cm tall, slightly bending, pseudostem 50-66 cm tall, ensheathed by green bracts. Leaves shortly petiolate, 11-15 in number, distance between leaves 6-6.8 cm long, pulvinate; ligule 5 mm long, bilobed, lobes rounded, membranous; lamina 20-28 x 7-10 cm, oblong-lanceolate, tip acuminate, base oblique, veins closely arranged, prominent, glabrous above, densely pubescent beneath. Inflorescence directly from the rhizome, peduncle short, c. 0.8 - 3 x 1cm, green; ensheathed by 2.5-5 x 1.3-2.3 cm, reddish green sheaths, outer surface pubescent. Spike subglobose, 5-6.8 x 2-2.7 cm, reddish green, base submerged in soil. Bracts numerous, c. 3-4 x

1 cm, linear oblong, tip hooded, acuminate greenish or with red streaks, outer densely pubescent, inner surface glabrous. Bracteoles 2.7-3 x 1-1.2 cm, lanceolate, pale yellow, trilobed at the tip, outer pubescent, inner glabrous. Flowers 5.5-5.8 cm long, fragile, dark yellow with red spotted labellum, one or two opens at a time. Calyx tubular, 1-1.3 x 0.6 cm, pale yellow, 3-toothed, outer sparsely pubescent, unilaterally split. Corolla tube tubular, 3-3.5 cm long, yellow, slender, as long as bracts. Dorsal lobes larger, lanceolate, 2.3-2.7 x 0.8-1 cm, yellowish orange, hairs absent. Lateral lobes 2-2.3 x 0.5 - 0.7 cm, yellow, lanceolate. Labellum c. 2.6 x 1.2 cm, shorter than corolla lobes, ovate, emarginate c. 1.1 cm deep, dark yellow with purple red spots and streaks towards margin. Lateral staminodes c.1-1.3 cm long, yellow with red spots, small, rounded. Stamens yellow; filament very short, yellow; thecae 1.4 x 0.3 cm; anther crest 0.9-1.1 cm long. Style long, filiform; stigma slightly projecting from the anther crest, white, with ciliated margin. Epigynous glands two, 0.5 cm long, linear, yellow, tip tapering. Ovary 5x3 mm, pubescent, trilocular, with many ovules on axile placenta. Capsule ellipsoid, fleshy, green when young and turns to red at maturity. Seeds 6-8 x 2-4 mm, dark brown, striate, arillate.

Distribution: Endemic to India especially Kerala, Karnataka, Tamil Nadu and Maharashtra.

Flowering & fruiting: Flowering takes place during rainy season, i.e., June to October. Flower opens early in the morning; 1-2 opens at a time .Fruiting occurs during August to December.

Notes: *Zingiber cernuum* was first described by Dalzell in Hookers Kew Journel of Botany in 1852 along with *Z. nimmonii*. Subsequently, Dalzell and Gibson (1861), Baker (1892), Schumann (1904) and Cooke (1907) followed the same treatment.

Santapau (1967) treated both of them as conspecific and placed it under *Z. cernuum*. While Ramamoorthy (1976) officially transferd *Z. nimmonii* to *Z. cernuum.* Sabu (2003, 2006) based on the rule of priority (article 11. 4- ICBN. Mc Neill *et al*. 2006) treated *Z. nimmonii* as valid name and the *Z. cernuum* as synonym.

During the present study we have studied in detail a large number of specimens throughout South India and found that both specimens are distinct.

Z. cernuum shows different chemical profile in phytochemical studies. The major compounds are β-caryophyllene (18.6%), terpinene-4-ol (13%), others caryophyllene (5.6%), β-phyllandrene (5.4%), and α-humulene (9.8%). But caryophyllene oxide (49.7%) is the major compound in *Z. nimmonii*, and others are β-caryophyllene (17%), terppinene-4-ol (6.5%), β-phyllandrene (5.4%) and α-humulene (9.8%). In *Z. nimmonii* caryophyllene oxide (49.7%) predominates and it is followed by β-caryophyllene (17%) and terpinene-4-ol (6.5%).

In palynological studies these species showed distinct characters. Though pollen grains are ellipsoidal with spiro-striate ornamentation in both, size of pollen grain and arrangement of muri and lumen are different. The size of the grain is 89.3-110 x 44.5-47.9 µm, muri oriented obliquely, parallel and sinuous in *Z. cernuum*. But in *Z. nimmonii* pollen grain is 74.26-85 x 43.24 µm, muri compactly arranged, overlapping and anastomozing.

Anatomical studies showed that in *Z. cernuum*, intercostal cells of epidermis, 58-84 X 48-64 µm is smaller than *Z. nimmonii*, 75-95 x 42 µm and leaf margin is 170 µm wide in *Z. cernuum* and that of *Z. nimmonii* is 292 µm. Shape of the midrib at adaxial side is V-shaped in *Z. cernuum*, while that of *Z. nimmonii* is concave.

As per molecular studies *Z. cernuum* is grouped along with *Z. roseum* and *Z. wightianum* with 82% boot strap support but *Z. nimmonii* clustered differently.

Specimens examined: KARNATAKA: Chikmangalour Dt.: Kigga, *Bhat 1910* (PPCH). Lakvalla state forest, *Saniham 1958* (RRCBI). Coorg Dt.: Sampaje ghat, *Bhat 1949* (PPCH); Irpu, Kutta, *Simhan, Murthy & Nair 4321* (RRCBI). North Kanara Dt.: Castle rock, *Sedgwick 2861* (BLAT); Castle rock, *Ganamie 15542* (BSI); Joida Road, *Irani 1560* (BCAT). Shimoga Dt.: between 4th and 5th HP bend, Agumbe ghat, *Sabu 39122* (CALI); 60 km from Kunthapur towards jog falls, *Sabu 39126* (CALI). KERALA: Calicut Dt.: Olavanna, Kozhikodan Kunnu, *Sabu 37340* (CALI). Idukki Dt.: 11 km from Idukki towards Thodupuzha, *Mangaly 6731* (CALI). Kannur Dt.: Chengalayi, *Ansari 69982* (MH & CAL); Kannoth R.F., *Ramachandran 66969* (MH). Kasarkode Dt.: Near Government College, Kasarkode, *Sabu 39166* (CALI).

Kollam Dt.: Chalakayam, *Mohanan 59629* (MH); Olapara, *Nair 50946* (MH & CAL). Malappuram Dt.: Manimooly, Nilambur, *Sabu 37359* (CALI); Calicut University Campus, *Mangaly 6690* (CALI). Palakkad Dt.: Kanjirapuzha, near dam, *Sabu 37341* (CALI). Dhony R.F., 75 m, *Joseph 17211* (MH); Pothundy to Kainatty, 500 m, *Vajravelu 44720* (MH); Karappara estate boundary, *Nair 69726* (MH); Dhony hills, *Sabu 39111* (CALI); Silent Valley, *Sathish Kumar 11272* (CALI). Pezha, Parambikulam wilde life sanctuary *Thomas & Prasanth 103068* (CALI). Pathanamthitta Dt.: Konni, Kallely forest, *Thomas 103001* (CALI). Thiruvananthapuram Dt.: Sreekaryom, Chempazhanthy, *Mangaly 10254* (CALI). Wayanad Dt.: Thirunelly, near temple, *Sabu 37348* (CALI); Tholpetty, Begur range, *Ramachandran 52249* (MH). TAMIL NADU, Nilgiri Dt.: Kotamalai R.F., 900 m, *Vajravelu 43490* (MH); Grassland estate area, *Vajravelu 41887* (MH).

3. *Zingiber montanum* (K. D. Koenig) Link ex Dietr., Sp. Pl. 1: 52. 1831; B.L. Burtt & R.M. Sm., Notes Roy. Bot. Gard. Edinburgh 31: 194. 1972; Ramamoorthy in C.J. Saldanha & Nicolson, Fl. Hassan Dist. 769. 1976; Theilade, Nord. J. Bot. 19(4): 396. 1999. M. Sabu, Folia Malaysiana 4(1): 25-52. 2003; M. Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Type: Thailand, Phuket, Koenig s.n. (holo C)

Amomum montanum K.D. Koenig in Retz. Observ. 3: 51. 1783.

Zingiber purpureum Roscoe, Trans. Linn. Soc. London 8: 348. 1807; Alston in Trimen, Handb. Fl. Ceylon 6: 283. 1931; B.L. Burtt & R.M. Sm., in Dassan., Rev. Handb. Fl. Ceylon 4: 494. 1983; R.M. Sm., Notes Roy. Bot. Gard. Edinburgh 45: 418. 1989; M. Sabu & Mangaly. Prod. 2nd Symp. Fam. Zingiberaceae 21. 1996. S. Kumar, Zing. Sikkim 72. 2001.

Zingiber cassumunar Roxb., Asiat. Res. 11: 347 t. 5. 1810, Fl. Indica 1: 48. 1820; Dalzell & Gibson, Bombay Fl. 272. 1861; Baker in Hook. f., Fl. Brit. India 6: 248. 1892; K. Schum. in Engler, Pflanzen. 4(46): 179. 1904; T. Cooke, Fl. Pres. Bombay 2: 735. 1907; C.E.C. Fisch. in Gamble, Fl. Pres. Madras 8: 1490. 1928; Holttum, Gard. Bull. Singapore 13: 58. 1950; A.S. Rao & D.M. Verma, Bull. Bot. Surv. India 14: 137. 1972

Zingiber cassumunar var. *subglabrum* Thwaites, Enum. Pl. Zeyl. 315. 1861.

(Fig. 21; Plate. 39)

Herbs with a perennial rhizome. Rhizome 1.5-2 cm thick, perennial, aromatic, fleshy, sympodial and bright yellow. Leafy stem 1-1.16 m high, pseudostem c. 9.5 m high. Leaves 34, at a distance of 6.3-10.3 cm, sub sessile, lamina 23 - 41.5 x 3-3.5 cm ; linear, tip acute, base slightly rounded, upper glabrous, lower pubescent; ligule very short, c. 2 mm long; bilobed, pubescent, light green. Inflorescence separate, lateral spike from rhizome. Peduncle 10-25 cm long, sheathed by pubescent, brownish green sheaths, 3.8-4.1 x 1.9 cm; about 6 nos. spike ovate, tip acute, compact, greenish-brown, 8.6-10 x 3-3.4 cm, pubescent, base ovate; tip sub acute. Flowers pale yellow, 7.3 - 7.5 cm long, 1-2 open at a time. Bracts 3.6 x 3-3.8 cm; broadly ovate; subacute, greenish brown, inner glabrous, outer densely pubescent with narrow membranous margins, turn to red at maturity. Bracteoles 2.2-2.7 x 1.9-2.5 cm, 3-toothed; ovate, yellow with purple tinge at two regions; inner glabrous; outer pubescent. Calyx 1.5-1.8 x 0.7-7-1.2 cm; white, membranous, unilaterally split, glabrous; hairs more towards lower region. Corolla tube 2.3-2.5 cm long, light yellow; dorsal lobe 2.9 x 1.4 cm; lanceolate, cymbiform, lateral lobes c. 2.4 x 0.7 cm, linear, reflexed. Labellum 3-lobed, 3.1 x 2.4 cm, pale yellow; centre yellow, sub-orbicular, apex emarginate with crisped margin. Lateral staminodes 0.9 x 0.7 cm, oblong, yellow, fused with the labellum, oblong. Stamen yellowish white, filament short 0.2 cm long, white; anther thecae 1.2 cm long, light yellow with longitudinal furrow; anther crest c.1 cm long, curved, light yellow. Style long, filiform, glabrous; stigma white, margin ciliate, obconic. Epigynous glands two, linear, yellow, sub acute, 0.7 cm long, unequal, linear, yellow, ovary c. 0.5 cm long, pubescent, trilocular, numerous ovules on axile placenta.

Distribution: Distributed throughout India, Sri Lanka and Malay Peninsula. Widely cultivated in tropical Asia. Said to be native of India and Bengal Coromandal. In South India it is reported from Andhra Pradesh, Karnataka, Goa, Kerala and Tamil Nadu.

Flowering and Fruiting: June–August. Flower opens early in the morning, two at a time, withers away in the evening.

*Notes***:** Burtt & Smith (1972b) treated this under *Z. purpureum* Roscoe. Later Theilade (1999) again proposed the same combination which becomes superfluous. After the discovery of Koenig's specimen from Phuket in the Herbarium of Copenhagen, Theilade (1999, Theilade & Mood 1999a) accepted the combination of Dietrich.

Z. montanum closely resemble *Z. zerumbet* in yellow flowers with crisped margins but can be distinguished from the latter by the narrow leaves, shout bifid ligule. It also resembles the vegetative stage of *Z. officinale* but differs from it in the presence of yellow with purple spotted labellum.

*Uses***:** Rhizome is aromatic, yellow in colour, tribals use it as a substitute for *Curcuma longa*. It is also used in diabetics.

*Specimen examined***:** ANDHRA PRADESH: East Godavari Dt.: Rampa hills, *Narayana Swami 87* (CAL); Kutravada, *Subba Rao 68536* (MH); GOA: near shanthi durga temple, *Vasantha 103210* (CALI). KARNATAKA: North Kanara Dt.: Karwar, *Sedgwick & Bell 4092* (CAL); Forests of Nagagali, *Sedgwick 2390* (BLAT). KERALA: Palakkad Dt.: Silendri, *Thomas & Prabhu 115527* (CALI). Kannur Dt.: Karimbam, *Ansari 6748* (MH). MEGHALAYA: Shang pung, *Sanoj & Rajesh kumar 95185* (CALI). TAMIL NADU: Nilgiri Dt.: Nilgiri hills, *Wight 2810* (CAL); Kottamala R.F., *Vajra Velu 46446* (MH), Coimbatore Dt.: Arepalayam, Kollegal, 1000 m, *Narayana Swami 3504* (MH).

4. *Zingiber neesanum* (J. Graham.) Ramamoorthy in C.J. Saldanha & Nicolson, Fl. Hassan Dist. 769. 1976; Manilal, Fl. Silent Valley 314. 1988. Sabu & Mangaly, Proc. 2nd Symp. Fam. Zingiberaceae 21. 1996; Sabu, Folia Malaysiana 4(1): 25-52. 2003; Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Alpinia neesana J. Graham, Cat. Pl. Bombay 207. 1839.

Zingiber macrostachyum Dalzell in Hook., Kew J. Bot. 4: 342. 1852, & A. Gibson, Bombay Fl. 273. 1861; Baker in Hook. f., Fl. Brit. India 6: 247. 1892; K. Schum. in Engler, Pflanzenr. 4(46): 179. 1904; T. Cooke, Fl. Pres. Bombay 2: 735. 1907; C.E.C. Fisch. in Gamble, Fl. Pres. Madras 8: 1490. 1928.

(Fig. 22; Plate. 40)

Plant is a herb with perennial rhizome. Rhizome small, yellow inside with many fusiform root tubers. Leafy shoot 80-120 cm tall, pseudostem 62-90 cm tall, dark red with about 18 leaves. Leaves at a distance of 3.8 - 4.2 cm, shortly petiolate; lamina 20-31 x 2-3.5 cm, linear, oblong, lanceolate, tip acuminate, base slightly round, dark green, dorsal side glabrous, ventral side hairs confined mostly to midrib and petiole; ligule short, 2-3 mm long, membranous, bilobed, lobes rounded, reddish white. Inflorescence from the base of the leafy shoot, peduncle 18-30 cm, ensheathed by large oblong bract-like scarious sheaths, 5.5-6.5 x 1-1.9 cm with red streaks, 10 numbers, hairy outside, inner glabrous, membranous. Spike 5-25 x 1-1.7 cm, cylindrical, dark red, tapering to a narrow apex. Bracts 3.2-3.6 x 2-2.8 cm, ovate, tip rounded, slightly acute, reddish-green, pale green towards base, outer pubescent, inner glabrous, closely imbricating. Bracteoles 2-3 x 1-1.6 cm, pale yellow with red streaks, inner glabrous, outer pubescent, almost equal to bracts. Flowers 4.3 - 5 cm long, 1 or 2 at a time, white. Calyx, 1.6 cm long, hairs absent, hyaline, 3-toothed, deeply notched, membranous and glabrous. Corolla tube slender, cylindrical, white, 2.2-2.9 cm long, longer than bracts. Corolla lobes unequal, white; dorsal lobe 2.6 x 1.1 cm, white, hooded at apex. Lateral lobes 2.5 x 1.2 cm long, linear, white. Labellum shorter than corolla lobes, 2.2 x 1.4-1.6 cm, 3-lobed, obovate, emarginate, 0.8 cm long, white to pale yellow with diverging dark purple spots from the centre to periphery, margin wavy. Lateral lobes fused with middle lobe, 1.1 x 8 cm, white, glabrous, without spots. Filament very short, 0.3 mm broad, white. Anther thecae 1.1 x 0.5 cm, white, long, cylindrical. Anther crest 1.1-1.3 cm long, slightly notched at tip, white. Ovary creamy white, c. 0.5 x 0.3 cm, trilocular, barrel-shaped, many ovules on axile placentae. Style long, filiform, stigma, white, ciliate. Epigynous glands 2, 0.4 mm long, light yellow. Fruit, capsule, trilobed, 2 x 1.2 cm, sub-globose, light red towards base and dark red towards apex. Seeds black, 0.5 x 0.3 cm.

Distribution: Endemic to India, especially to forests of Kerala, Karnataka and Maharashtra.

Flowering & Fruiting: Flowering occurs between July to September. Flower opens in the evening after 4 pm and withers in the next after noon. Fruiting occurs between August to December.

Notes: *Alpinia neesana* was first described by Graham (1839) in "*Catologue of plants growing in Bombay and vicinity*". Later it was transferred to the genus *Zingiber* by Dalzell (1852) and he cited the epithet as "Mesana" from "Meesum", instead of "neesana from "Neesum" as done by Graham. Later Ramamoorthy (1976) published in *Flora of Hassan District* as *Z. neesanum*. *Z. neesanum* closely resembles *Z. montanum* but distinct by cylindrical spike, white with purple spotted labellum. Variation in shape of leaf, size and pubescence also seen among plants of different locations.

Specimens examined: KARNATAKA: Chikmangalur Dt.: Babuduon hills, *Saldanha & Ramesh 1721* (CAL). Coorg Dt.: Sampaje ghat, *Bhat 1948* (PPCH). Shimoga Dist.: Jog falls, *Sabu 39128* (CALI); Agumbe ghat, 1000 m, *Sabu 39125* (CALI); Hulical Ghat, *Sundara Raghavan 83103* (BSI); Near barakana, Agumbe, *Sundara Raghavan 83269* (BSI). KERALA: Calicut Dt.: Pannoth forest, *Sabu 39165* (CALI). Idukki Dt.: Peerumedu, Pulliparai, *Vivekanandan 21368* (MH); near Painavu, *Sabu 37328* (CALI). Munnar, *Vasantha 103202* (CALI). Kannur Dt.: Kottiyur, Talassery, *Sabu 37385* (CALI); on the way to Kannoth *R.F., Ramachandran 58713* (MH); Nedumpoyil, *Ramachandran 63940* (MH). Kollam Dt.: Thenmalai, near forest range office, *Sabu 33372* (CALI). Kottayam Dt.: Vagamon, Palai, *Mangaly 6743* (CALI). Palakkad Dt.: Kainatty to Pothundy, *Vajravelu 48786*

(MH); Thadikundu, *Vajravelu 48897* (MH);. Silendri, *Thomas & Prabhu kumar 115517*; Pulippara, Silent Valley, *Satheesh Kumar 10701* (MH). Thoothampara, Parambikulam WLS, *Prabhukumar 94880* (CALI). Pathanamthitta Dt.: On the way to Sabarimalai, *Mangaly 10305* (CALI); Sabarimalai, *Nair 50816* (MH). Thrissur Dt.: near Athirapalli water falls, *Thomas, Rajesh & Prabhu 94840* (CALI). Thiruvananthapuram Dt.: Ponmudi, *Sabu 37382* (CALI); Ponmudi, *Vasantha 103203* (CALI). Karimpanathode, *Rama Rao 1512* (CAL); Mundomurolin, Calder & *Ramaswami 183* (CAL). Thrissur Dt.: Sholayar, *Sabu 37336* (CALI). Wayanad Dt.: Thirunelly, behind temple forest, *Sabu 37351* (CALI); Thirunelly, *Ramachandran 62778* (MH); Pakshipathalam, *Sabu 39170* (CALI).

5. ***Zingiber nimmonii*** (Graham) Dalzell in Hooker, Kew J. Bot. 4: 341. 1852, ('nimmoi') & Gibson, Bombay Fl. 273. 1861. Baker in Hooker f., Fl. Brit. India 6: 244. 1892; K. Schum. In Engler, Pflanzenr. 4 (46): 184. 1904; Cooke, Fl. Pres. Bombay 2: 734. 1907; Gamble, Fl. Pres. Madras. 8: 1489. 1928.

Type: *Zingiber nimmonii* (J. Graham) Dalzell. Lectotype- Malabar, Concan, Law sn. (K).

Alpinia nimmonii Graham, Cat. Pl. Bombay 206. 1839.

(Fig. 23; Plate. 41)

Plant is a herb, rhizome thick, fleshy, sympodial, purple lilac inside, aromatic; roots many, fleshy with root tubers. Leafy shoot 1.2-1.5 m tall, leaves petiolate, petiole c. 6 mm long, number of leaves 21, distance between leaves 7 -9 cm; ligule 1 cm long, bifid, lobes rounded, coriaceous, green to hyaline, lamina 26–38 x 9.5–10 cm, oblong lanceolate, tip acuminate, base oblique, closely pinnately veined, upper surface glabrous, lower densely pubescent. Inflorescence arise from rhizome, peduncle 9.5 x1 cm, enclosed by 2-3.5 x 2.2-2.4 cm sheaths, obovate, light pink, with green streaks, coriaceous; spike ovate or sub-globose, dark purple, Bracts 4.2-4.4 x 1.2-1.1 cm, many dark purple, lanceolate, tip hooded, acuminate, outer pubescent, inner glabrous. Bracteoles smaller than bracts, 3.6 x 1.2-1.5 cm, lanceolate, tip 3-lobed, light purple towards tip and light towards base, outer pubescent, inner glabrous. Flower 7.5-7.7 cm long, one at a time. Calyx tubular 1.8 x 0.5 cm, tip shortly 3-lobed, unilaterally split, 9 mm long, white, densely pubescent. Corolla tube slender, 4.3 cm long, cream, hairy towards base; dorsal lobe 3.4 x 1.2 cm, lanceolate, tip acuminate, yellow, pubescent; Lateral lobe 2.8 x 0.8 cm, Labellum shorter than corolla lobes c. 3.2 x 1.8 cm, 3-lobed, middle lobe ovate, emarginate, 3 mm long, yellow, dark purple streaks at the centre, light red colour with yellow spots at tip, slightly pubescent. Lateral staminodes fused 0.2-0.3 cm long, yellow with red streaks. Anther sessile, deep yellow; thecae 1.5 cm long, elongate, slightly pubescent; anther crest 1.2 cm long, curved, dark red near tip, slightly pubescent, beak-like appendage. Stigma funnel–shaped, white, ciliate. Epigynous glands c. 0.6 x 3 mm, densely pubescent, trilocular with many ovules on axile placentae. Fruit a capsule, c. 5 x 2 cm, turning to red at maturity. Seeds 6 – 7 x 3 – 4 mm, black, striate, aril white.

Distribution: Endemic to India, especially Kerala, Karnataka, Tamil Nadu and Maharastra. In Karnataka and Maharashtra they are found along costal regions and high altitude. But in Kerala, they are mostly confined to high altitude mountain slopes.

Etymology: The specific epithet is in the honour of 'Nimmo'. Graham (1839) used the latin specific epithet as 'nimmonous' (sig. nimmonii). However, Dalzell (1852) Latinized the term as nimmonous (sig. nimmoi). Subsequently he corrected the specific epithet as 'nimmonii' (Dalzell & Gibson, 1861).

Notes: *Alpinia nimmonii* was described for the first time by Graham (1839) in his *'Catalogue of plants growing in Bombay and vicinity'*. Subsequently, it was transferred to the genus *Zingiber* by Dalzell (1852) along with another species *Z. cernuum* from the same locality. For long, these two species were treated as distinct by many workers such as Dalzell and Gibson (1861), Baker (1892) and Schumann (1904).

Santapau (1967) while working on the *flora of Khandala,* studied these plants in detail and treated them as conspecific and placed it under *Z. cernuum.* He noticed that both the species show many overlapping characters; hence they cannot be treated as distinct species. However, he concluded that only more field work could settle the problem.

According to Ramamoorthy (1976) leaf pubescence in *Z. nimmonii* and the absence of it in *Z. cernuum* is unreliable, and the description of flowers yellow in *Z. nimmonii* is probably an error and he combined *Z. nimmonii* with *Z. cernuum*.

While applying article 11. 4 (ICBN, Mc Neill *et al.* 2006), Sabu (2003) treated *Z. nimmonii* has priority over *Z. cernuum* and treated the latter as synonym.

During the present study we have collected a large number of specimens throughout South India and were cultivated in the Calicut University Botanical garden for detailed study. Morphology, Anatomy, Phytochemistry, Palynology, Cytology, and Molecular studies of these specimens were conducted in detail. These studies revealed that they differs in many aspects and hence treated here as distinct species.

Morphological studies showed that the shoot of *Z. cernuum* is 65-90 cm tall, slightly bending, leaves 20-28 x 7-10 cm, ligule 5 mm long, and bilobed. The leafy shoot of *Z. nimmonii* is 1.2-1.5 mts high, leaves 26-38 x 9.5-10 cm, and ligule 1 cm long.

Anatomical studies also showed that they differ in many aspects. Intercostal cells in adaxial epidermis is 58-84 x 48-64 μm in *Z. cernuum* and that of *Z. nimmonii* is 75-95 x 42 μm. The margin of lamina is wider, 292 μm in *Z. nimmonii* than *Z. cernuum*, which is 170 μm. In the mid rib both have bundle arc's I & III, but the adaxial side is concave in *Z. nimmonii* and the corresponding in *Z. cernuum* is wide V- shaped. Abaxial surface is wide V in *Z. cernuum* and wide U in *Z. nimmonii*. In cortical region of stem two rows of bundles are present in *Z. nimmonii*, but in *Z. cernuum* three rows present. Metaxylem vessels are 20-23 in number in root of *Z. nimmonii*, while that of *Z. cernuum* is 14-18.

Pollen grains of *Z. cernuum* and *Z. nimmonii* are different in size, and in arrangement of muri, though pollen grains in both are ellipsoidal and with spiro-striate ornamentation. Pollen grain of *Z. cernuum* is 89.3-110 x 44.5-47.9 µm, muri slightly sinuous, noodle-shaped, occasionally branched, obliquely oriented from one lateral end to the other, 71.42-106.07 x 2.56-3.19 µm, thick and lumen 1.27-2.76 µm. In *Z. nimmonii*, the size of the pollen grain is 74.26-85 x 43.24 µm, lumen between muri are very small or in some region it is absent, average length of muri is 3.2 µm, very closely and compactly arranged, often overlapping and anastomising.

Molecular studies showed that *Z. cernuum* belongs to the clad of *Z. roseum*, *Z. wightianum* and *Z. officinale* with 65% boot strap support, but *Z. nimmonii*, clustered differently.

Phytochemical studies showed different chemical profile in two plants. Major components in *Z. cernuum* are β-caryophyllene (18.6%), terpinene-4-ol (13%), caryophyllene oxide (5.6%), β-phyllandrene (5.4%) and α-humulene (9.8%). In *Z. nimmonii* the major compound is caryophyllene oxide (49.7%), and followed by β-caryophyllene (17%), terpinene-4ol (6.5%). The compounds β-phyllandrene and α-humulene of *Z. cernuum* is absent in

Z. nimmonii. The absence of α-humulene and very high concentration of caryophyllene may be the reason for its variation in colour of pseudostem.

Specimens examined: KERALA. Kollam Dt.: Ponmudi. *Vasantha 103208* (CALI). Palakkad Dt.: Silendri, *Thomas & Prabhu kumar 115521* (CALI). Mannarkad, *Shameer 94860* (CALI). Pathanamthitta Dt.: Konni, Kollery forest, *Thomas 103001* (CALI). Trissur Dt.: Vazhachal, *Thomas, Rajesh kumar & Prabhu 94843* (CALI).

6. *Zingiber officinale* Roscoe, Trans. Linn. Soc. London. 8: 348. 1807; Roxb., Asiat. Res. 11: 345. 1810, Fl. Indica 1: 46. 1820; Dalzell & Gibson, Bombay Fl. Suppl. 87. 1861; Baker in Hook. f., Fl. Brit. India 6: 246. 1892; K. Schum. in Engler, Pflanzenr. 4(46): 170. 1904; Fl. Pres. Bombay 2: 736. 1907; C.E.C. Fisch., Rec. Bot. Surv. India 9: 178. 1921 in Gamble, Fl. Pres. Madras 8: 1489. 1928; Holttum, Gard. Bull. Singapore 13: 54. 1950; A.S. Rao & D.M. Verma, Bull. Bot. Surv. India 14: 137. 1972; B.L. Burtt & R.M. Sm., Notes Roy. Bot. Gard. Edinburgh 31: 180. 1972, in Dassan., Rev. Handb. Fl. Ceylon 4: 498. 1983; B.L. Burtt in Manilal, Bot. Hist. Hort. Malab. 144. 1980; Nicolson *et al*., Interpret. Rheede Hort. Malab. 318. 1988; R.M. Sm., Notes Roy. Bot. Gard. Edinburgh 45: 412. 1989; S. Kumar, Zingib. Sikkim 7I. 2001. Sabu, Folia Malaysiana 4(1): 25-52. 2003; Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Amomum zingiber L., Sp. Pl. 1: 1. 1753.

'Inschi' Rheede Hort. Malab. 11: 23-25, t. 12. 1692.

Type: Herb. Hermann *4:7. No. 3* (BM) designated by Burtt (1993).

Vernacular names: Mal. inji; Tam. sukku; Tel. allamu.

(Fig. No. 24; Plate No. 43)

Plant a herb with perennial rhizome. Rhizome thick, fleshy, subterranean, branching sympodial, pungent, greyish yellow inside, strongly aromatic. Leafy shoot 80-115 cm long, leaves about 26 in number, at a distance of 2.5-3.4 cm, pseudostem 60-95 cm, shortly petioled; petiole 0.9-1.1 cm, pale green, pulvinate; ligule 2-4 mm long, slightly bilobed, membranous; lamina 25-30 x 1.5-2 cm, narrowly lanceolate, linear, tip acuminate, base attenuate. Lower surface pubescent, upper glabrous. Inflorescence a separate spike arising from rhizomes, ovoid. Peduncle 15-26 cm, enclosed by 3-5.3 cm long pubescent sheaths. Spike 4-6.6 x 2-3 cm, green, sometimes yellowish red at margin, ovate, bracts closely imbricating, turn to red when mature. Bracts 2.3-2.5 x 1.3- 2 cm, green, sometimes yellowish at margin, ovate, apex mucronate, inner glabrous, outer hairy. Bracteoles 2.4 x 1.1 cm, ovate-oblong, creamy white, tip minutely three-lobed, inner glabrous, outer pubescent. Flowers 4.2 - 4.5 cm long, dark yellow, 1 opens at a time, fragile, open in the evening. Calyx 1-1.2 x 0.8 cm, tubular, hyaline, teeth not prominent, unilaterally spit, white, hairs absent. Corolla tube c. 2.5 cm long, pale yellow; dorsal lobe, 2.1 x 0.7 cm, lanceolate, narrowed towards apex, yellow tinge; lateral lobes narrow, 0.2 x 0.4 cm, yellow, fused with labellum. Labellum, orbicular, round c. 1.5 x 1.2 cm, shorter than corolla lobes, margin wavy, deep purple with yellow blotches. Lateral staminodes c. 0.8 x 0.6 cm, ovate, free nearly to base, wavy, purple with yellow spots. Stamen dark purple, filament 0.2 cm long, colour white; thecae pale yellow, 0.9 cm long, erect; anther crest 0.9 cm long, curved, dark purple, ovary 0.4 x 0.3 cm, glabrous, 3-locular, 2-4 ovules on axile placentae. Style long, filiform; stigma pale white, ciliate at margin, epigynous glands two, 0.7 cm long, equal, tip tapering, light yellow, free from each other.

Distribution: Cultivated throughout the tropics since ancient times. It is widely cultivated in all districts of South India. Some wild forms occur in the evergreen forests of Kerala.

Flowering and Fruiting: Flowering takes place at the end of South west monsoon, during August to October. Flower opens in the evening after 3 pm.

Notes: Z. officinale closely resembles *Z. montanum* in the narrow leaves but differs from it in dark purple labellum with yellow spots.

Uses: Rhizome of ginger is an important ingredient in the preparation of condiments, curries, pickles and syrups. Rhizome is pungent and aromatic, widely used in indigenous systems of medicine, especially in rheumatism. It promotes digestive power and used for cough, fever, anemia, constipation and elephantiasis.

Specimens examined: ANDRA PRADESH: East Godavari Dt.: Maradumilli Cocoa Plantation, *Subba Rao 68528* (MH). ARUNACHAL PRADESH: East Siam Dt.: *Sanoj 92171* (CALI). KARNATAKA: Bangalore Dt.: Experimental garden, Indian Horticultural Research Institute, Hassarghat, *Subramaniayam*

4392 (FRC). KERALA: Calicut Dt.: Peruvannamuzhi, *Sabu 39155* (CALI). Idukki Dt.: Thenkachi, *Sharma 40876* (MH). Malappuram Dt.: Mangaly's garden, Thenhipalam, *Sabu 37332* (CALI). Palakkad Dt.: Thunakadavu, Parambikulam, *Sebastine 20914* (MH). Thellikkal, Parambikulam, *Prabhukumar 94878* (CALI). Silendri, *Thomas & Prabhu kumar 115518* (CALI). Thrissur Dt.: Thalikulam, *Sabu 37334* (CALI). NAGALAND: Okha, *Sanoj & Thomas 105561*(CALI). SIKKIM: Gangtok market, *Thomas & Nissar 95540* (CALI). TAMIL NADU: Coimbatore Dt.: Between Ollar and Thorakadavu, Anamalais, *Barbar 3678* (MH). Kanyakumari Dt.: Upper Kodayar 400 m, *Henry 48339* (MH). Nilgiri Dt.: Ayyankolli Forest, 900 m, *Vajravelu 42887* (MH).

7. *Zingiber roseum* (Roxb.) Roscoe, Trans. Linn. Soc. London 8: 348. 1807; Roxb., Asiat. Res. 11: 347. 1810, Fl. Indica 1: 49. 1820; Baker in Hook. f., Fl. Brit. India 6: 244. 1892; K. Schum. in Engler, Pflanzenr. 4(46): 184. 1904; C.E.C. Fisch. in Gamble, Fl. Pres. Madras 8: 1489. 1928; Manilal, Fl. Silent Valley 314. 1988. Sabu, Folia Malaysiana 4(1): 25-52. 2003; Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Amomum roseum Roxb. Pl. Coast Coromandel 2: t. 126. 1800.

Type: Zingiber roseum (Roxb.) Roscoe. Iconotype-Icones Roxburghianae. *t. 502.* (CAL).

(Fig. No. 25; Plate No.44)

Plant a herb with subterranean rhizome. Rhizome branched, white, tuberous, thick, stoloniferous, fibrous. Leafy shoot 90-110 cm long, pseudostem 60-70 cm high, dark green. Leaves 13-18 in number at a distance of 2.7-4.7 cm, sub-sessile; lamina 30-35 x 6.5-7.6 cm, lanceolate, tip acuminate, base acute, upper glabrous, lower densely pubescent; petiole very small, pubescent beneath, green, pulvinate; ligule 1.7-2.3 cm long, hyaline, bilobed, pubescent, membranous. Inflorescence very dense, arising from rhizomes, green with red streaks towards tip, base immersed in soil; spike globose, round at base, condensed, 4-6 x 25-30 cm. Bracts 3.3-3.8 x 0.9 - 1.2 cm lanceolate, outer pubescent and inner glabrous, base light green with red streaks towards tip, outer ones broadly ovate, inner ones ovate lanceolate. Bracteole 2.6-3 x 1.2-1.3 cm large linear-lanceolate, bilobed, white, and red spotted towards tip, inner glabrous. Flowers 6.2- 6.8 cm long, 1-2 opens at a time. Calyx tubular, membranous, 3-toothed, 1.7-0.9 cm long, white, hyaline, hairy towards base with a unilateral spitting, corolla tube slender, white, 3.5 cm, sparsely pubescent. Dorsal lobe 3.2-3.4 x 0.5 cm, linear with pointed apex, outer pubescent, inner glabrous; slightly bend outward when the flower opens, red colour is prominent along the veins; lateral lobes 2.4-2.7 x 0.3 cm, linear, outer pubescent, inner glabrous. Labellum 3.2 x 1.1 cm, orbicular, 3- lobed, margin recurved, crisped, oblong-cuneate, shorter than corolla lobes, white at the centre, yellow with red spots towards margin, lateral staminodes 0.2 cm long, yellow, orbicular, very small. Stamen arching over and equaling labellum, yellow; filament c.1 mm long, white. Anther thecae c. 1.6 cm long, yellow, connective deep yellow, open by longitudinal slits; crest c. 1.2 cm long, curved, deep yellow, ovary

0.4 cm long, pubescent, trilocular, numerous ovules on axile placentae. Style long, filiform, white, ciliate. Epigynous glands two, 0.5-0.6 cm long, linear, light yellow, tip oblong, free from each other. Fruit dehiscent capsule 3.5 x 2.6 cm, ovoid.

Distribution: It is reported from Central India and Eastern Ghats.

Flowering and Fruiting: Flowering takes place during South west monsoon i.e., June-August.

Notes: *Z. roseum* closely resembles *Z. cernuum*, *Z. nimmonii* and *Z. wightianum* but differ in long bifid ligule, small white labellum with yellow markings. Haines (1961) suggested that *Z. roseum* may be a form of *Z. rubens* with a more robust inflorescence but treated them as distinct species. Later Basbu (1977) suggested that they were closely related and differ only in the colour of the bracts and purple streaked tip. Jha and Varma (1995) studied these species and concluded that these two are distinct species. In the present study it is revealed that *Z. roseum* is with distinct characters such as oblong, cuneate, recurved, labellum white at centre and yellow with red spots towards margin. Anatomically it is very distinct from *Z. nimmonii* and *Z. wightianum* being thick and fibrous rhizome, which is white inside and abaxial side of midrib V-shaped.

Specimens examined: ANDRA PRADESH: East Godavari Dt.: Maradumalli to Kakure, *Subba Rao 67589* (MH). Ctevupalem forest, Maradumalli, *Prasanth & Prabhu 106001* (CALI). Maradumalli, *Prasanth & Prabhu 106005, 106023* (CALI); Visakapatnam Dt.: Forest near

Sankarimetta, *Balakrishnan 10944* (MH); Barmakonda R.F., *Jacob 17165* (MH); Cherukonda, *Subba Rao 28162* (MH).

8. *Zingiber wightianum* Thwaites, Enum. Pl. Zeyl. 315. 1861; Baker in Hook. f., Fl. Brit. India 6: 244. 1892; Trimen, Handb. Fl. Ceylon 4: 257. 1898; K. Schum. in Engler. Pflanzenr 4 (46): 186. 1904; C.E.C. Fisch., Rec. Bot. Surv. India 9: 178. 1921, in Gamble, Fl. Pres. Madras 8: 1489. 1928; B.L Burtt & R. M. Sm. in Dassan., Rev. Handb. Fl. Ceylon 4: 496. 1983. Sabu, Folia Malaysiana 4(1): 25-52. 2003; Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Zingiber squarrosum auct. non. Roxb., Wight, Icon. Pl. Indiae Orient. 6: 16, t. 2004, 1853.

Vernacular name: Mal. Malai-inchi.

Type: *Zingiber wightianum* Thwaites. Lectotype-*C. P. 2286* (PDA).

(Fig. No. 26; Plate No. 46)

Plants herbs with subterranean rhizome. Rhizome, 1.5-1.8 cm thick, fleshy, soporiferous; main branch 9-12.5 cm thick, yellow inside with many roots. Leafy shoot 85-90 cm high. Pseudostem 60-70 cm. Leaves 15-17 in number at a distance of 5-6 cm, reddish colour, ligule 3-3.5 x 1.1-1.2 cm, 6-7 mm long, deeply notched, lobes rather rounded, glabrous, membranous. Leaves oblong-lanceolate, tip acuminate, pulvinate, 2-3 mm thick, pale green, pubescent below; lamina 28-33 x 6.2-7.8 cm, upper surface glabrous, lower pubescent, base obovate. Inflorescence ovate or oblong on separate leafless peduncle; peduncle 2.5-6 cm long, ensheathed by sterile bracts, 5-5.5 x 1-1.2 cm, lanceolate with pointed tip, green with red sheaths, margin hyaline, pubescent externally, inner glabrous. Spike 8-8.5 cm long, oblong, greenish red, partly immersed in soil. Flower 6.1-6.4 cm long, 1-2 opens at a time, opens early in the morning. Bracts 4.1-4.3 x 0.8 cm, narrow, lanceolate, acuminate, greenish-red, tip curved, slightly pubescent. Bracteoles 3.2-3.4 x 0.9-1 cm, linear lanceolate, a little shorter than bracts, obtuse, tip two lobed, greenish-red, margin smooth, outer surface pubescent. Calyx 2-2.1 cm long, slightly 3-toothed, unilaterally split, 1-1.1 cm deep, light yellow, hairs more at lower side. Corolla tube c. 2.5 cm long, white at base, darker towards tip and densely pubescent. Dorsal lobe 2.8-3 x 0.5-0.8 cm, boat-shaped, tip beaked, pubescent, pale yellow with pale pink towards tip. Lateral lobes 2.6-2.8 x 0.5 cm, sparsely pubescent, tip beaked, pale yellow with pink towards tip. Labellum 2.4-2.7 x 1.5-1.6 cm long, cuneate, obovate, emarginate, white at centre, violet with white spots at periphery, light violet at tip, tip truncate, slightly notched, margin folded back. Lateral staminodes 1 x 0.5 cm, attached to labellum, purple at base, orange yellow and red streaks towards tip. Stamen shorter than labellum; filament 1.5-2 mm long, bright orange yellow; anther thecae 1.7 x 0.3 cm, beak curved, 1.1-1.3 cm long, deep yellow. Ovary 4.5-5 mm long, creamy white, densely pubescent, trilocular, numerous ovule on axile placentae; style long, white, filiform; stigma curved and ciliate. Epigynous glands two, tip yellow, obtuse, base bulged, 5.5-6.5 mm long, linear, free from each other.

Distribution: Distributed in India and Sri Lanka. In India, it is endemic to high altitudes of Western and Eastern Ghats.

Flowering & Fruiting: Flowering and fruiting occurs during the South-east monsoon in January to August. Flowers open at early morning.

Notes: Both terminal and lateral inflorescences are reported from Sri Lanka. It resemble *Z. nimmonii* in shortly peduncled spikes but differ in the colour of labellum which is yellow with purple spotted in *Z. nimmonii*, and violet yellow with light purple streaks and white spots in *Z .wightianum* .

Specimens examined: ANDRA PRADESH: East Godavari Dt.: Path Baison hill, *Barba 5030* (MH). Visakapatnam Dt.: Towards Borra, *Subba Rao 44265* (MH). KARNATAKA: Coorg Dt.: *Hole* Sl.No. 467917 (CAL). KERALA: Calicut Dt.: Chedaleth; 900 m *Ellis 19969* (MH). Ernakulam Dt.: Kavalary, *Meebold 12306* (CAL). Idukki Dt.: Thekkady leased forests, *Fischer 3758* (CAL). Anamalai, Top slip, Near Kerala check post, *Sabu & Sanoj 86178* (CALI). Palakkad Dt.: Karimalagopuram, Parambikulam, *Mangaly 17457* (CALI). Mukkali, *Thomas 115533* (CALI). Wayanad Dt.: Begur R.F., *Ramachandran 68266* (MH). TAMIL NADU: Coimbatore Dt.: Mt. Steuart, Anamalais, *Fischer 3639* (FRC); Water Falls Estate, 1000m, *Joseph 12803* (MH).

9. *Zingiber zerumbet* (L.) Smith, Exot. Bot. 2: 105, t. 112. 1806; Roxb. Asiat. Res. 11: 346. 1810, Fl. Indica 1: 47. 1820; Dalzell & Gibson, Bombay Fl. 272. 1861; Thwaites, Enum. Pl. Zeyl. 315. 1861; Baker in Hook. f., Fl. Brit. India 6: 267. 1892; Trimen, Handb. Fl. Ceylon 4: 259. 1898; K. Schum.

in Engler, Pflanzenr. 4(46): 172. 1904; T. Cooke, Fl. Pres. Bombay 2: 734. 1907; C.E.C. Fisch., Rec. Bot. Surv. India 9: 178. 1921, in Gamble, Fl. Pres. Madras 8: 1490. 1928; Holttum, Gard. Bull. Singapore 13: 59. 1950; A.S. Rao & D.M. Verma, Bull. Bot. Surv. India 14: 137. 1972; B.L. Burtt & R.M. Sm. Notes Roy. Bot. Gard. Edinburgh 31: 182. 1972, in Dassan., Rev. Handb. Fl. Ceylon 4: 495. 1983; Nicolson *et al*., Interpret. Rheede Hort. Malab. 319. 1988; R.M. Sm. Notes Roy. Bot. Gard. Edinburgh 45: 418. 1989. Fl. Udupi, 635. 2003, 1989; Sabu, Folia Malaysiana 4(1): 25-52. 2003; Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006.

Katon-inschi-kua Rheede, Hort. Malab. 11: 27. t. 13. 1692.

Type: This species remain to be typified “Linnaeus”. *Amomum* No. 3 may be identified as Z*. zerumbet*, but it has only been seen as microfische (Theilade, 1999).

Amomum zerumbet L., Sp. Pl. 1: 1. 1753.

Vernacular name: Mal: Malan Kua.

(Fig. No. 27; Plate No. 48)

Rhizome thick, 10-15 x 4 cm, fleshy, branching sympodial, yellowish inside, tuberous. Leafy shoot 1.5-2 m. Leaves shortly petiolate; petiole 4-5 mm long, pulvinate, ligule 2.5-3.5 cm long, membranous, entire, sparsely pubescent. Lamina 12-36 x 4-12 cm, lanceolate, base narrowed, apex acuminate, upper surface glabrous, lower pubescent. Inflorescence lateral spike, arising from rhizome, peduncle 20-50 cm long, spike globose, green, rounded at tip, turns to red at maturity. Bracts closely imbricating 3-3.7 x 2-

2.9 cm, ovate-obovate, green, white towards base, turn to red at maturity, outer densely pubescent, shiny adaxially, margin membranous. Bracteoles 2.6-3 x 1.2-1.5 cm, ovate-oblong, 3-toothed, membranous white, outer pubescent, inner glabrous. Flowers 5.5- 5.8 cm long, yellow, two or three opens at a time, fragile. Calyx 1.5-1.8 x 1.3-2 cm, membranous, outer sparsely pubescent towards tip, 3-toothed, splitting 1.2 cm deep, white. Corolla tube 2.6-3.2 cm long, slender, creamy white with light yellow towards tip; dorsal lobe 2.3-2.5 x 1-1.1 cm, lanceolate, pale yellow, tip acuminate with 7-9 parallel veins; lateral lobes 1.9 x 6 cm, tip acuminate, lanceolate, pale yellow, with 3 parallel veins, glabrous. Labellum 3- lobed, margin wavy, pale yellow, dark yellow towards centre, middle lobe 2.9 x 2.4 cm, sub-orbicular, emarginate, staminode fused with labellum, 8-1.8 x 6 mm, obovate, pale yellow, tip acuminate, free nearly to base, crumbled. Stamen creamy white; filament 0.3 cm broad, anther thecae 1.5-2 x 0.3 cm, anther crest 1.1 cm long, light yellow, curved. Ovary 0.5 x 0.3 cm, pubescent, 3-locular, 1 or 2 ovules per locule on axile placenta. Style long, filiform, stigma white, ciliate. Epigynous glands 2, 0.9-1 cm long, unequal, creamy white. Fruit dehiscent capsule, 1.7 x 1.3 cm, ellipsoid, angled, white with rose tinge at tip, surface smooth, trilocular. Seeds 9-12 nos., oval, surface striate, black, 0.5 x 0.2 cm, arillate, base slightly constricted.

Distribution: Distributed in India, Sri Lanka and Malay Peninsula. It is widely distributed all over India.

Flowering and Fruiting: June to October.

Taxonomic notes: It closely resembles *Z. montanum* and *Z. capitatum* var. *elatum*, both are unspotted with yellow or light yellow labellum. *Z. zerumbet* can be distinguished from *Z. montanum* in having a greenish spike and lanceolate leaves. It can also be easily distinguished from *Z. capitatum* in having lateral, globose spike.

Uses: Rhizome is given in cough, asthma, stomach ache, vermifuge, leprosy and other skin diseases and also used as substitute for true gingers (Prakash and Mehrotra 1996). The mucilage present in the inflorescence of *Z. zerumbet* is used as shampoo hence known as shampoo ginger. Ornamental plants are also reported (Sabu and Skinner 2005).

Specimens examined: ANDAMANS: Nayashir Reserve Forest, *Thomas & Shameer 113508* (CALI). KARNATAKA: South Kanara, Dt.: Mangalore, *Bhat 1912* (PPCH); Udupi, *Bhat 1939* (PPCH); KERALA: Kannur Dt.: Kannoth R.F., *Ramachandran 66967* (MH). Iritty, Kunnampally, *Vasantha 94870* (CALI). Kasarkode Dt.: Cheruvathur, *Ansari 67927* (MH). Kollam Dt.: Sangilapalam, Kulathupuzha, *Venketasubramaniyam* & *Sasidharan 11159* (FRC). Kallar, *Sabu 86159* (CALI). Ponmudi, *Sabu 103203* (CALI). Kottayam Dt.: Illikal, Palai, *Mangaly 6726* (CALI), Valara, *Sebastine 25352* (MH). Malappuram Dist.: Manjeri, *Ellis 35375* (MH); Aryavaidyasala Herbal Garden, Kottakkal, *Sabu 37338* (CALI); Calicut University Botanical Garden, *Mangaly 6686* (CALI). Palakkad Dt.: Parambikulam Submergible area, *Sebastine 14700* (MH). Pathanamthitta Dist.: Nilakkal, Chalakkayam, *Nair 50829* (MH). Thiruvananthapuram Dist.: Thanimoodu Road, *Mangaly 10277* (CALI); Forest patch beneath Agastya kudam, *Thomas* & *Prasanth 103032*

(CALI). Athirimala, near Ponmudi, *Sanoj 86194* (CALI). Near lower Sanatorium, *Mangaly 10279* (CALI), Varkala, near Sivagiri Mutt, *Sabu 37377* (CALI); Ponmudi near Golden Valley, *Sabu 37380* (CALI); Thrissur Dt.: Kodassery, *Ramamoorthy 48523* (MH). Wayanad Dt.: Pookode lake, Vythiri, *Sabu 39167* (CALI). NAGALAND: Nu garden, *22.5.07, Thomas & Nissar 95414* (CALI). NICOBAR: N.S.road, *Prasanth Kumar 92608* (CALI). TAMIL NADU: Coimbatore Dt.: Mt. Stewart, Anamalai, *Fishcer 38320*, *3460* (CAL). Kanyakumari Dt.: Balamore, *Henry 47520* (MH).

PHENETICS

The nine taxa of genus *Zingiber* of South India were subjected to numerical analysis (Table no. 11). The characters used in the study includes morphology, taxonomy, anatomy, phytochemistry and palynology. Taxa are grouped according to the character states. A guide line suggested by Sneath and Sokal (1973) was adopted for the selection of chrecters. The methodology adopted by Sahu (1991) and Gajurel *et al.* (2002) were used for cluster analysis except that Unweighted Pair Group Method with Arithmetic mean (UPGMA) was used as algorithm here instead of Weighted Pair Group Method with Arithmetic mean (WPGMA).

Table No. 11. *Zingiber* species (OTUs) Selected for the Study

Code Number	Name of Taxa (OTU)
1.	*Z. capitatum var. elatum*
2.	*Z. cernuum*
3.	*Z. montanum*
4.	*Z. neesanum*
5.	*Z. nimmonii*
6.	*Z. officinale*
7.	*Z. roseum*
8.	*Z. wightianum*
9.	*Z. zerumbet*

The qualitative characters were directly converted to numerical code using different codes for different character states. This tabulated data were used to generate dendrogram using the statistical package STATISTICA version 5.0 loaded in a personal computer (Table no. 13 & 14).

Table No. 12. Characters used in the Cluster Analysis

Sl. No.	Code	Character	Character States
1.	Hat	Habitat	Hilly, plain, plains and hilly.
2.	Ht	Height	60cm to 1m, above 1 m.
3.	ShRh	Shape of rhizome	Stoloniferous, disc-shaped, finger-shaped, coral-shaped.
4.	CRh	Colour inside the rhizome	Light yellow, dark yellow, purple- lilac, greyish yellow, white.
5.	CSte	Colour of stem	Green, dark purple.
6.	ShLf	Shape of leaf	Narrow linear, narrow lanceolate, oblong lanceolate.
7.	BaLf	Base of leaf	Cuneate, round.
8.	LfM	Leaf margin	Recurved, not recurved.
9.	NLi	Nature of ligule	Small, bilobed, notched, long entire.
10.	Sp	Spike	Terminal, lateral.
11.	Np	Nature of Peduncle	Sessile, long stalked, short staked, medium length.
12.	CSp	Colour of spike	Green, greenish brown, green with red streaks, dark purple, light rose to dark purple.
13.	ShSp	Shape of spike	Ovate, cylindrical, sub-globose.

Sl. No.	Code	Character	Character States
14.	TSp	Tip of spike	Acute, round, opened.
15.	ShB	Shape of bract	Lanceolate, ovate, ovate-obovate, broadly ovate, linear-oblong.
16.	L.Fr	Length of flower	4.2-5 cm, 5.2-6 cm, 6.2-7cm, 7.2-8 cm.
17.	CLa	Colour of labellum	Yellow unspotted, yellow spotted, white spotted, deep purple with yellow blotches, light purple with white spots.
18.	ShLa	Shape of labellum	Sub-orbicular, obovate, ovate, round, orbicular.
19.	NLa	Nature of labellum	Rounded, notched, emarginate.
20.	CStd	Colour of staminode	Yellow, yellow with red spots, purple with yellow spots, white, white with red spots.
21.	CSt	Colour of stamen	Yellow, deep yellow, white, yellow with purple tip, orange yellow.
22.	NMe	Nature of mesophyll	Palisade 1 layer, Palisade 2 layers, Palisade and spongy cannot differentiate.
23.	TLa	Thickness of lamina	140 to 200 μm, 201 to 280 μm, 281 to 340 μm.
24.	LfM	Leaf margin	80 to 120 μm, 121 to 180μm, 181 to 300 μm.
25.	AdMi	Adaxial Midrib	Slightly concave, wide V-shape, V-shaped, U-shaped, wide U-shaped.
26.	BMi	Bundle arcs of midrib	Arc I, Arc I, III.
27.	BPu	Bundle arc of Pulvinus	Arc I, III, IV; Arc I, II, III; Arc I, III
28.	BlSh	Bundle arc of Leaf	Arc I, II, III; Arc I, II

Sl. No.	Code	Character	Character States
		Sheath	
29.	ShPg	Shape of Pollen grain	Sub spheroidal, Ellipsoidal
30.	OrPg	Ornamentation of Pollen grain	Incipient, Striate parallel, striate overlapped, cerebroid
31.	NMu	Nature of muri	Round or elongated, parallel, overlapped, triangular, incipient
32.	LuP	Lumen of Pollen	Parallel, narrow, absent, lumen irregular
33.	Pt	Puncta	Present, absent, sparse
34.	β-Ph	β-phyllandrene	Present, absent
35.	β-Pi	β-pinene	Present, absent
36.	β-Ca	β-caryophyllene	Present, absent
37.	Te-4	Terpenene-4-ol	Present, absent
38.	CaOx	Caryophyllene oxide	Present, absent
39.	Ze	Zerumbone	Present, absent
40.	α-Hu	α-humulene	Present, absent
41.	COi	Colour of oil	Pale yellow, dark yellow, yellow

Table No. 13. Data of Multiple Range Test of Characters

Code for character	Characters	Grouping of taxa (represented by code number) according to their character states				
		1	2	3	4	5
Hat	Habitat	Hilly 3, 4, 5, 7, 8	Plain 1	Plains and hilly 2, 6, 9		
Ht	Height	60cm to 1m, 2, 6, 8	above 1m 1, 3, 4, 5, 9, 7			
CSte	Colour of	Green	Dark			

Code for charact er	Characters	Grouping of taxa (represented by code number) according to their character states				
		1	2	3	4	5
	stem	1, 2, 3, 6, 7, 8, 9	purple 4, 5			
ShRh	Shape of rhizome	Stolonifero us 7, 8	Disc shaped 1, 3, 4, 5, 9	Finger shaped 2	Coral shaped 6	
CRh	Colour inside the rhizome	Light yellow 1, 4, 8	Dark yellow 3, 9	Purple lilac 2,5	Greyish yellow 6	White 7
ShLf	Shape of leaf	Narrow linear 1,3	Narrowl y lanceola te 6	Oblong lanceolate 2, 4, 5, 7, 8, 9		
BaLf	Base of leaf	Cuneate 1,7, 8, 9	Round 2, 5, 6, 3, 4			
LfM	Leaf margin	Recurved 1	Not recurved 2, 3, 4, 5, 6, 7, 8, 9			
NLi	Nature of ligule	Small 1	Bilobed 2, 3, 4, 5, 7, 8	Notched 6	Long entire 9	
Sp	Spike	Terminal 1	Lateral 2, 3, 4, 5, 6, 7, 8, 9			
Np	Nature of Peduncle	Sessile 1	Long stalked 3, 4, 6, 9	Short stalked 2, 8, 7	Medium 5	
CSp	Colour of spike	Green 1, 6, 9	Greenis h brown 3	Green with red streaks 2, 8	Dark purple 4, 7	Light rose to dark purple 5
ShSp	Shape nof spike	Ovate 3,6,9	Cylindric al 1,4	Sub-globose 2,5,7,8		
TSp	Tip of spike	Acute	Round	Opened		

Code for charact er	Characters	Grouping of taxa (represented by code number) according to their character states				
		1	2	3	4	5
		3, 6, 4	1,9	2,5,7,8		
ShB	Shape of bract	Lanceolate 1, 7, 8	Ovate 4, 6	Ovate-obovate 9	Broadly ovate 3	Linear oblong 2,5
LFr.	Length of flower	4-5 cm 4, 6	5-6 cm 1,2,9	6-7 cm 7, 8	7-8 cm 3,5	
CLa	Colour of labellum	Yellow unspotted 1, 3, 9	Yellow spotted 2, 5	White spotted 7, 4	Deep purple with yellow bloches 6	Light purple with white spots 8
ShLa	Shape of labellum	Sub-orbicular 3,9	Obovate 4,8	Ovate 1,2,5	Round 6	Orbicul ar 7
NLa	Nature of labellum	Marginate 6, 7	Notched 8	emarginat e 1, 2, 3, 4, 5, 9		
CStd	Colour of staminode	Yellow 1,3,8,9	Yellow with red spots 2, 5	Purple with yellow spots 6	White 4	White with red spots 7
CSt	Colour of stamen	Yellow 1,3,9	Deep yellow with red spots red at tip 7	White 4	Yellow purple tip 6,5,2	Orange yellow 8
NMe	Nature of mesophyll	Palisade 1 layer 2, 3, 4, 6, 5, 7	Palisade 2 layers 8, 9	Palisade and spongy cannot differentiat e. 1		
TLa	Thickness of lamina	140 to 200 µm 3, 4, 6, 7	201 to 280 µm 5, 8, 9	281 to 340 µm 1, 2		
LfM	Leaf margin	80 to 120 µm	121 to 180 µm	181 to 300 µm		

Code for charact er	Characters	Grouping of taxa (represented by code number) according to their character states				
		1	2	3	4	5
		6	1, 2, 7	3, 4, 5, 8, 9		
AdMi	Adaxial Midrib	Slightly concave 1, 5	Wide 'V' shaped 2, 8, 9	'V' shaped 7	'U' shaped 3,4	Wide 'U' shaped 6
BMi	Bundle arc's of midrib	Arc I 4	Arc I, III 1, 2, 3, 5, 6, 7, 8, 9			
BPu	Bundle arc of Pulvinus	Arc I, III, IV 1, 2, 3, 5	Arc I, II, III 4, 6, 8, 9	Arc I, III 7		
BlSh	Bundel Arc of Leaf Sheath	Arc I, II, III 1,2, 5, 7, 8, 9	Arc I, II 3, 4, 6			
ShPg	Shape of Pollengrain	Sub spheroidal 1, 3, 4, 6, 9	Ellipsoid al 2, 5, 7, 8			
OrPg	Ornamentati on of Pollen grain	Incipient 7	Striate parallel 2,8	Striate overlaped 5	Cerebro id 1, 3, 4, 6, 9	
NMu	Nature of muri	Round or elongate 1, 3, 6	Parallel 2, 8	Overlappe d 5	Triangul ar 4, 9	Incipien t 7
Pt	Puncta	Present 9	Absent 1, 2, 4, 5, 7, 8	Sparse 3, 6		
LuP	Lumen of Pollen	Parellel 2	Narrow 8	Absent 7	Lumen irregular 1, 3, 5, 6, 9, 4	
β-Ph	β-Phyllandren e	Present 2	Absent 1, 3, 4, 5, 6, 7, 8, 9			
β-Pi	β-pinene	Present 3, 4	Absent 1, 2, 5, 6, 7, 8, 9			
β-Ca	β-	Present	Absent			

Code for character	Characters	Grouping of taxa (represented by code number) according to their character states				
		1	2	3	4	5
	caryophyllene	2, 5, 7	1, 3, 4, 6, 8, 9			
Te-4	Terpenene-4-ol	Present 2,3,5	Absent 1, 4, 6, 7, 8, 9			
CaOx	Caryophyllene oxide	Present 2, 5, 7	Absent 1, 3, 4, 6, 8, 9			
Ze	Zerumbone	Present 6, 9	Absent 1, 2, 4, 5, 7, 8, 3			
α-Hu	α-humulene	Present 2, 7, 9	Absent 1, 3, 4, 5, 6, 8			
COi	Colour of oil	Pale yellow 1,2,5,7,8,9	Dark yellow 3	Yellow 4, 6		

Table No. 14. Character States of OTU's

Character Code	Code for OTUs								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Hat	2	3	1	1	1	3	1	1	3
Ht	2	1	2	2	2	1	2	1	2
CSte	1	1	1	2	2	1	1	1	1
ShRh	2	3	2	2	2	4	1	1	2
CRh	1	3	2	1	3	4	5	1	2
ShLf	1	3	1	3	3	2	3	3	3
BaLf	2	2	2	2	2	2	1	1	1
LfM	1	2	2	2	2	2	2	2	2
NLi	1	2	2	2	2	3	2	2	4
Sp	1	2	2	2	2	2	2	2	2
Np	1	3	2	2	4	2	3	3	2
CSp	1	3	2	4	5	1	4	3	1
ShSp	2	3	1	2	3	1	3	3	1
TSp	2	3	1	1	3	1	3	3	2
ShB	1	5	4	2	5	2	1	1	3
LFr	2	2	4	1	4	1	3	3	2
CLa	1	2	1	3	2	4	3	5	1
ShLa	3	3	1	2	3	4	5	2	1
NLa	3	3	3	3	3	1	1	2	3
CStd	1	2	1	4	2	3	5	1	1

CSt	1	4	1	3	4	4	2	5	1
TLa	3	3	1	1	2	1	1	2	2
LfM	2	2	3	3	3	1	2	3	3
NMe	3	1	1	1	1	1	1	2	2
AdMi	1	2	4	4	1	5	3	2	2
BMi	2	2	2	1	2	2	2	2	2
BPu	1	1	1	2	1	2	3	2	2
BLsh	1	1	2	2	1	2	1	1	1
ShPg	1	2	1	1	2	1	2	2	1
OrPg	4	2	4	4	3	4	1	2	4
NMu	1	2	1	4	5	1	5	2	4
Pt	2	2	3	2	2	3	2	2	1
LuP	4	1	4	4	4	4	3	2	4
β-Ph	2	1	2	2	2	2	2	2	2
β-Pi	2	2	1	1	2	2	2	2	2
β-Ca	2	1	2	2	1	2	1	2	2
Te-4	2	1	1	2	1	2	2	2	2
CaOx	2	1	2	2	1	2	1	2	2
Ze	2	2	2	2	2	1	2	2	1
α-Hu	2	1	2	2	2	2	1	2	1
COi	1	1	2	3	1	3	1	1	1

Table No.15. Percent disagreement (new. Sta)

OTU	1	2	3	4	5	6	7	8	9
1	.00	.66	.51	.61	.59	.66	.71	.63	.49
2	.66	.00	.73	.78	.39	.76	.51	.51	.68
3	.51	.73	.00	.41	.56	.51	.73	.68	.49
4	.61	.78	.41	.00	.56	.51	.66	.61	.59
5	.59	.39	.56	.56	.00	.76	.51	.54	.66
6	.66	.76	.51	.51	.76	.00	.76	.71	.56
7	.71	.51	.73	.66	.51	.76	.00	.46	.68
8	.63	.51	.68	.61	.54	.71	.46	.00	.54
9	.49	.68	.49	.59	.66	.56	.68	.54	.00

Tree Diagram for 9 Cases Un weighted pair-group average

Percent disagreement

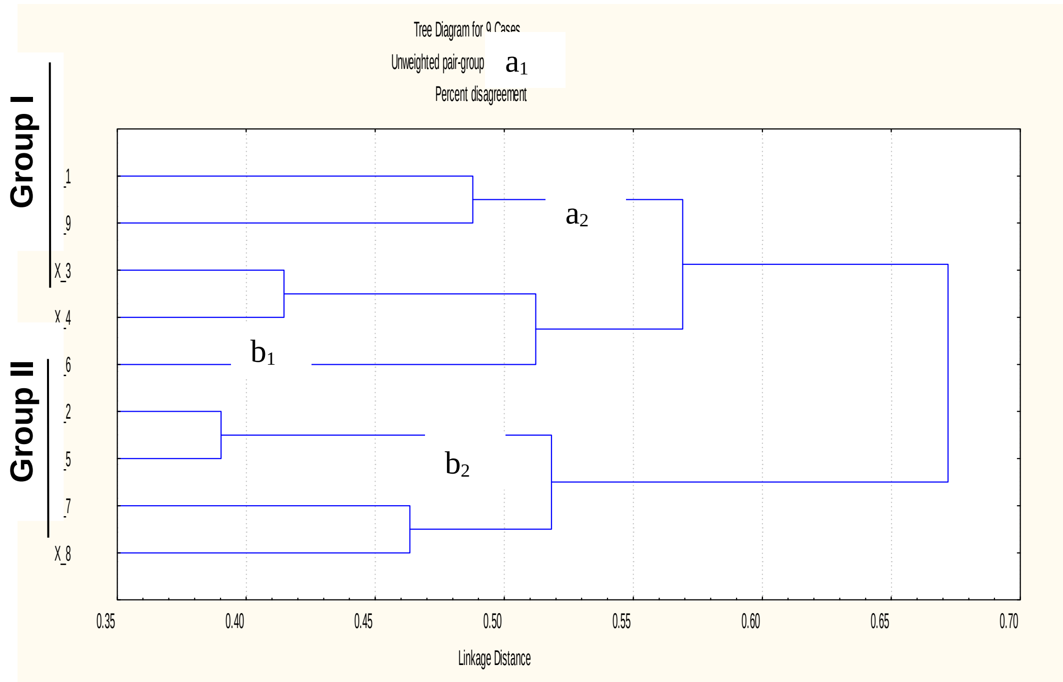

Fig. 21: **1**. *Z. capitatum* var. *elatum;* **2**. *Z. cernuum;* **3**. *Z.montanum;* **4.** *Z. neesanum;* **5**. *Z. nimmonii;* **6**. *Z. officinale;* **7**. *Z. roseum;* **8.** *Z. wightianum;* **9**. *Z. zerumbet.*

The nine taxa studied fall under two distinct groups. The 5 taxa of the first group are *viz., Z. capitatum* var. *elatum*, *Z. zerumbet*, *Z. montanum*, *Z. neesanum* and *Z. officinale.* Group I diversifies at 0.57 linkage distance into two clusters, group I a_1, group I a_2. Group I a_1, consists of *Z. capitatum* var. *elatum* and *Z. zerumbet*. They are dissimilar in colour of rhizome, shape of leaf and leaf mrgin, nature of spike and ligule, shape of bract, mesophyll, thickeness of lamina, shape of adaxial midrib, bundle arc of pulvinus, nature of muri and lumen in pollen grain. Group I a_1 and group I a_2 disagree at 0.57 linkage distance. Group I a_2 consists of *Z. montanum*, *Z. neesanum* and *Z. officinale.* In this *Z. montanum* and *Z. neesanum* cluster together and it shows 0.51 dissimilarity with *Z. officinale* and in this *Z. montanum* and *Z. neesanum* show highest affinity with each other, with 0.41 linkage distance thus having about 59% similarity in morphological characters. They differ in colour of stem, and rhizome, shape of leaf, colour of spike, shape of bract, colour of labellum, shape of labellum, colour of staminode, colour of stamen, bundle arc of midrib, bundle arc of pulvinus, nature of muri and lumen of pollen grain.

Group ll consists of 4 species and two subgroups. It diversifies at 0.52 linkage distance (Fig. 30) into two subgroups group ll b_1 and group ll b_2. Group ll b_1 consists of two taxa *Z. cernuum* and *Z. nimmonii*. This cluster shows 61% similarity show 0.39 linkage distance. They differ in height, colour of stem, nature of peduncle, colour of spike, thickness of lamina, leaf margin, shape of adaxial midrib, ornamentation of pollen grain, length of flower, nature of muri and lumen and presence of phytochemical compound β-phyllandrene. The group ll b_2 consists of *Z. roseum* and *Z. wightianum*. This cluster share 54% similarity. They were dissimilar in characters such as shape of labellum, colour of staminods and stamen, nature of mesophyll and lumen of pollen.

When species of two groups were compared, it is found that, the first group comprises more heterogenous in species composition. Although it contains the species with long erect lateral spike, also combines the species with terminal and lateral inflorescences, spotted and unspotted labellum, narrow and lanceolate leaves and various shapes of inflorescences. On the contrary the species composition of group ll was more homogeneous.

Discussion

The phenetic analyses of 9 taxa of *Zingiber* were done using 41 multi-state quantitative morphological characters adopting UPGMA algorithm and percent disagreement as the statistical test. The present numerical analysis has yielded a good clustering pattern that reflects the natural relation ship among the taxa. The analysis showed that there are two groups of species in South India.

Group1. species with long lateral spike except *Z. capitatum* var. *elatum*, in which inflorescence is terminal. Baker (1892) placed it along with Sect. *Dymczewiczia*, because of terminal inflorescence and others *viz., Z. montanum, Z. neesanum*, *Z. officinale*, and *Z. zerumbet* in Sec. *Lampuzium*. But Liang (1988) included *Z. capitatum* var. *elatum*, along with others under Sect. *Zingiber* Liang. because of the spherical pollen and cerebroid sculpturing. Numerical analysis indicates that pollen structure and sculpturing are reliable characters and give more evidence toward the relationships of taxa.

Group ll consists of 4 species and two subgroups. Subgroup b_1 consists of two taxa *Z. cernuum* and *Z. nimmonii*. They differ in height, colour of stem, nature of peduncle, colour of spike, thickness of lamina, leaf margin, shape of adaxial midrib, ornamentation of pollen grain, length of flower, nature of muri and lumen and presence of phytochemical compound β-phyllandrene. The sub group II b_2 consists of *Z. roseum* and *Z. wightianum*. They were dissimilar in characters such as shape of labellum, colour of staminodes and stamen, nature of mesophyll and lumen of pollen.

The result clearly shows that the species can be segregated into two major groups representing two sub-generic levels with clusters of closely related species in the following pattern. Group I - Species with terminal or lateral inflorescence, peduncle long, pollen grain spherical with cerebroid sculpturing. Group II - Species with lateral inflorescence, peduncle short, immersed in soil, with ellipsoid pollen grain and spiro-striate or diffuse sculpturing.

SUMMARY

The family Zingiberaceae constitute 53 genera and about 1200 species. They are distributed both tropics and subtropics mainly in Indo-Malayan region, but extending through Africa to central and south America (Kress *et al*., 2002). In India it is represented by 21 genera and about 200 species and the genus *Zingiber* is represented by 20 species. The genus *Zingiber* belongs to the tribe Zingibereae under subfamily Zingiberoideae. The present study showed that the genus is represented by nine species in South India *viz*., *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum*, and *Z. zerumbet*. In the present study the diversity of genus *Zingiber* in South India has been found out. Anatomy, morphology, cytology, molecular studies, palynology, phytochemistry, pollination biology, systematic studies and numerical analysis were conducted as a part of characterization of the taxa.

Zingiber is distinct from other genera of the family in the presence of a single anther with beak or horn-like appendage, which embraces the upper part of the style. The inflorescence usually arises at the base of the leafy stem on a long or a subterranean peduncle. Rarely terminal inflorescence is also present. The bracts are overlapping and each subtends a non tubular bracteole and a single flower. In many species the bracts are green when young, turning to red in the fruiting stage, the flowers are delicate and fragile and lasts only for a few hours.

Anatomical studies shows that the genus *Zingiber* bears certain common characters like swollen pulvinus with collenchymatous bundle sheath, tetracytic stomata, hyaline region of lamina, and presence of vessels in the xylem of root, but each taxon is peculiar with specific characters. The size of epidermal cell, thickness of lamina and hyaline region in the leaf margin are specific for each taxon. Thickest leaf, with a thickness of 340 µm is present in *Z. capitatum var. elatum* and thinnest (140 µm) in *Z. roseum*. Palisade layer is two or more in *Z. capitatum* var. *elatum*, *Z. wightianum* and *Z. zerumbet*. The adaxial side of midrib of *Z. roseum* is very peculiar with V-shaped and abaxial side of *Z. zerumbet* is V-shaped and ribbed, and abaxial side of leaf sheath is boat-shaped. In *Z. neesanum* arc-III bundle is absent but in all others it is present. Bundle arc I, III, and IV are present in the pulvinus of *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum* and *Z. nimmonii.* Arc-II and IV are absent in *Z. roseum.* Arc-IV is absent in *Z. neesanum*, *Z. officinale*, *Z. wightianum* and *Z. zerumbet.* In *Z. nimmonii* leaf margin is 292 µm broad and that of *Z. cernuum* is 170 µm broad. In *Z. cernuum* cortical bundles in stem are arranged in 3–4 rows but in *Z. nimmonii* they are arranged in two rows. The adaxial and abaxial side of midrib of *Z. cernuum* is wide V–shaped but in *Z. nimmonii* concave and wide U-shaped respectively. Shape and size of starch grains present in rhizome and root tubers are charecteristic to each taxon. Detailed anatomical account of nine South Indian taxa is recorded for the first time.

The rhizome in *Zingiber* is well developed, perennial, sympodial, fleshy, often fibrous, aromatic, colour varies white to light yellow to dark yellow and gives rise to shoot system in the rainy season. Branching is upto fourth order except *Z. cernuum*. The longest internodal length is seen in *Z. wightianum* in which rhizome is thin, fibrous and stoloniferous. In *Z. officinale* the subsidiary branches are more spread, where as in *Z. roseum* rhizome is thick, fibrous, and stoloniferous. Spherical rhizome is present in *Z. capitatum*, *Z. neesanum*, *Z. montanum*, and *Z. zerumbet*, while it is finger-shaped in *Z. cernuum* and *Z. nimmonii*. The rhizome of each species has distinct size, shape, colour, morphology and aroma, and it helps in identification of species also.

The chemical profile of the essential oil of each species of *Zingiber* analysed indicates it is very distinct, in support to the distinct morphological features. In chemotaxonomic point of view, rather than closeness of relationship between allied species, the uniqueness of each species is vivid through the chemical profile of their essential oil. The study also throws some light towards the presence of some important chemical compounds such as zerumbone in *Z. zerumbet*, β- caryophyllene in *Z. nimmonii*, (E)-1-(3', 4'- dimethoxy phenyl) butadiene in *Z. neesanum* etc. Such compounds are important with their antimicrobial and pharmacological properties. The present study is very significant since it is also an attempt to unveil the constituents of many unexplored and rather uninvestigated wild relatives of the noteworthy spice and well known drug ginger. Chemical profiling of all taxa in South India is done for the first time.

As per pollen studies there are two groups under genus *Zingiber* of south India. Group 1. with spherical grains and cerebroid ornamentation. Group 2. with elongated grains and striate or incipient ornamentation. In *Z. capitatum* var. *elatum*, *Z. montanum*, *Z. neesanum*, *Z. officinale* and *Z. zerumbet* the pollen grains are spherical with cerebroid ornamentation. Ellipsoidal grains are present in *Z. cernuum*, *Z. nimmonii*, and *Z. wightianum* where the ornamentation is spiro-striate. In *Z. cernuum* muri are arranged obliquely from one end to the other sinuous and noodle-shaped with wide lumen. But in *Z. nimmonii* muri are very close, branching common, branches widely arranged, bracket shaped and lumen is very small. In *Z. roseum,* the grains are ellipsoidal but show incipient ornamentation. But each taxa show characteristic pattern of arrangement of muri and lumen. *Z. capitatum* var. *elatum* of Sect. *Dymczewiczia* exhibit the same ornamentation and shape that of Sect. *Zingiber*. So the division based on the position of inflorescence is not entirely satisfactory. *Z. capitatum* var. *elatum* can be included under Sect. *Zingiber*. Though ornamentation is peculiar for two groups each taxon shows charecteristic arrangement of muri and lumen. The study revealed that morphology of pollen grains can be utilized in plant identification and classification of the species. Palynological studies of *Z. cernuum*, *Z. nimmonii*, *Z. neesanum*, *Z. montanum* and *Z. wightianum* are conducted for the first time.

The cytology of the nine species of *Zingiber viz*., *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet* showed that the chromosome number is constant in all species studied (2n=22), thus not help in species delimitation. The chromosome numbers of *Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. nimmonii*, and *Z. roseum* are reported for the first time.

Molecular studies with *Alpinia* and *Amomum* as the sister group to the genus *Zingiber* of South India received 96% boot strap support. *Z. roseum*, *Z. wightianum*, *Z. cernuum*, and *Z. officinale* are grouped together with 65% boot strap support. *Z. cernuum* (3.2) grouped along with *wightianium* (5.1), *Z. roseum* (21.1 & 21.2) with a boot strap support of 85%. The accession (3.1) *Z. nimmonii,* clustered differently. The clade of *Z. officinale* shows a good boot strap support (95%), showing that South Indian *Z. officinale* had a single origin. *Z. zerumbet* also shows a single origin with 97% boot strap support. This is the first report of molecular data of nine taxa of South Indian Zingiberaceae.

Phenetic analysis revealed that two groups exist in genus *Zingiber* of South India. 1. Species with terminal or lateral inflorescence with long stalk and pollen grains spherical with cerebroid sculpturing. 2. Species with lateral inflorescence and ellipsoid pollen grain with spiro-striate or diffuse sculpturing.

Nine taxa were collected in the present study from South India *viz., Z. capitatum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet.* Of these *Z. cernuum*, *Z. nimmonii* and *Z. neesanum* are endemic to South India. *Z. neesanum*, *Z. nimmonii* and *Z. wightianium* are restricted to high altitude of Western Ghats. *Z. capitatum* var. *elatum* is distributed in hill slops and open grass lands of Karnataka. *Z. roseum* is found only in Northern Circars. *Z. montanum* is found only in hill slopes of Karnataka, Andhra Pradesh and Goa. *Z. officinale* is cultivatd throughout India and *Z. zerumbet* is widely distributed in India. Anatomical, palynological and taxonomical keys were provided in the present study. Ramamoorthy (1976) combined *Z. nimmonii* with *Z. cernuum* with an assumption that leaf pubescence in *Z. nimmonii* and absence of it in *Z. cernuum* are not enough to treat them as distinct species. However, detailed studies on these plants have revealed that they are distinct.

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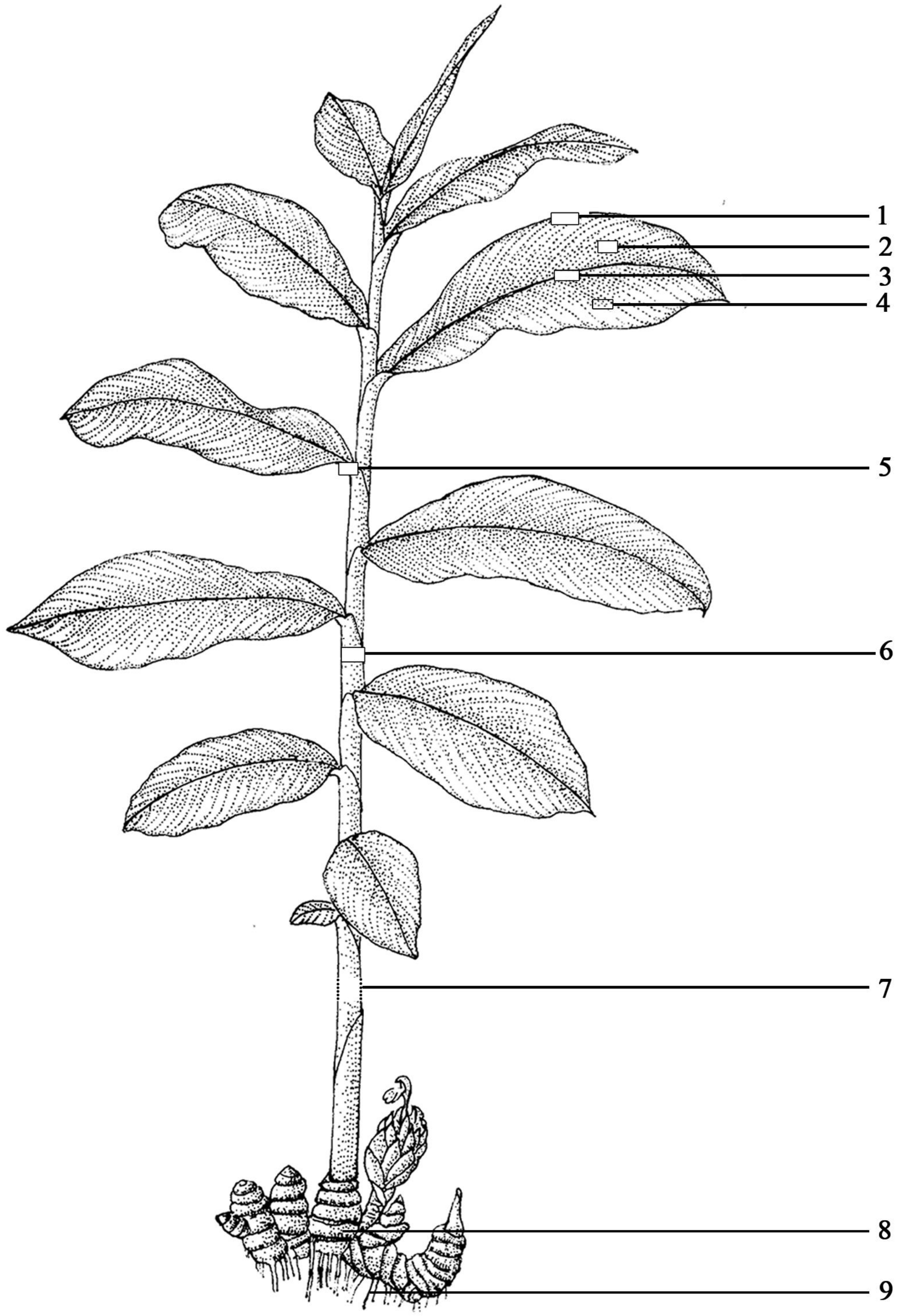


Fig. 01. Diagrammatic representation of a typical *Zingiber* plant showing the portions of various parts taken for study: **1.** Margin; **2.** Lamina; **3.** Midrib; **4.** Epidermis; **5.** Pulvinus; **6.** Sheath; **7.** Aerial stem; **8.** Rhizome; **9**. Root.

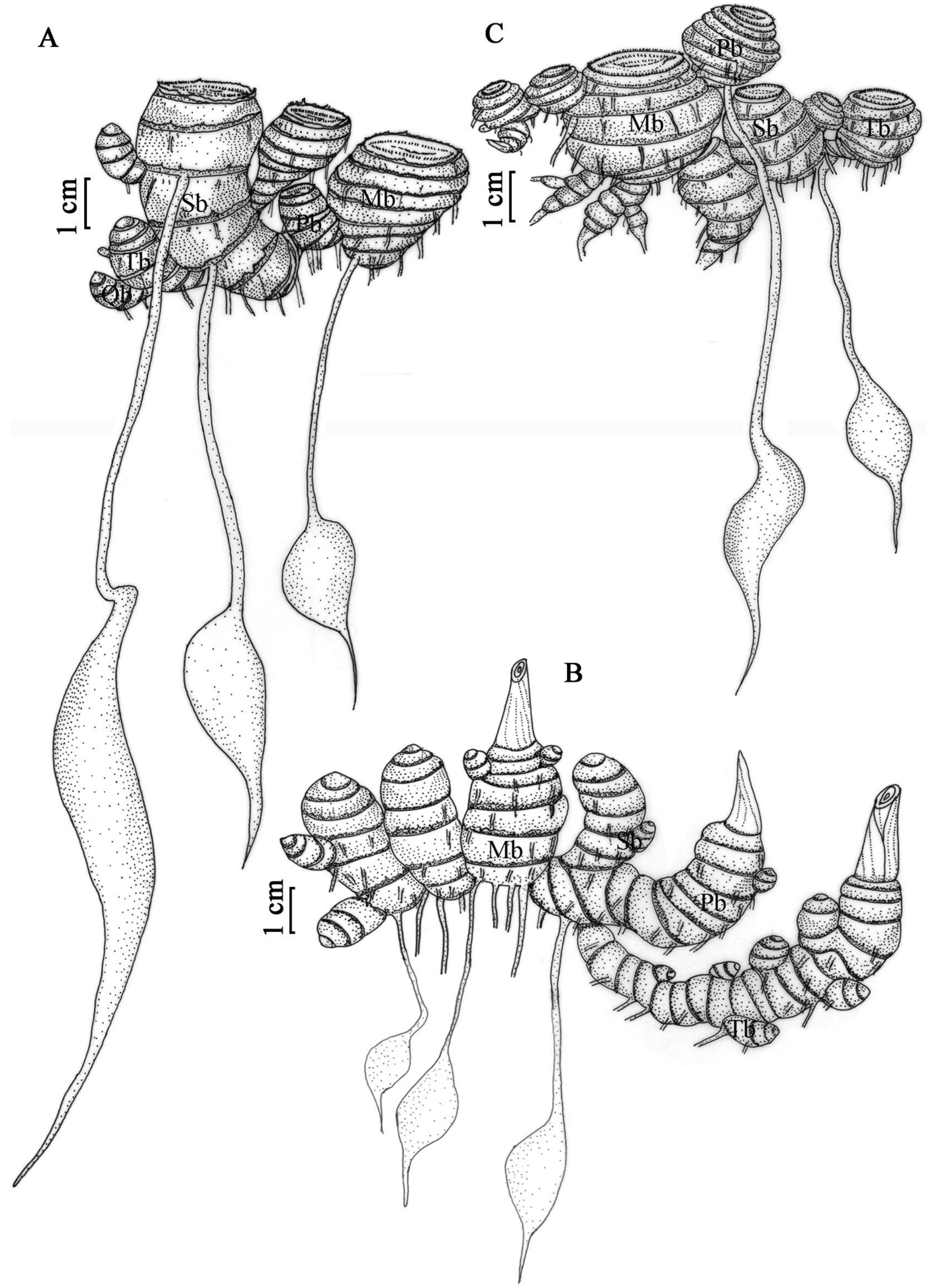


Fig. 02. Rhizome architecture: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **Mb**-Main branch; **Pb**-Primary branch; **Sb**-Secondary branch; **Tb**-Tertiary branch; **Qb**-Quarternary branch.

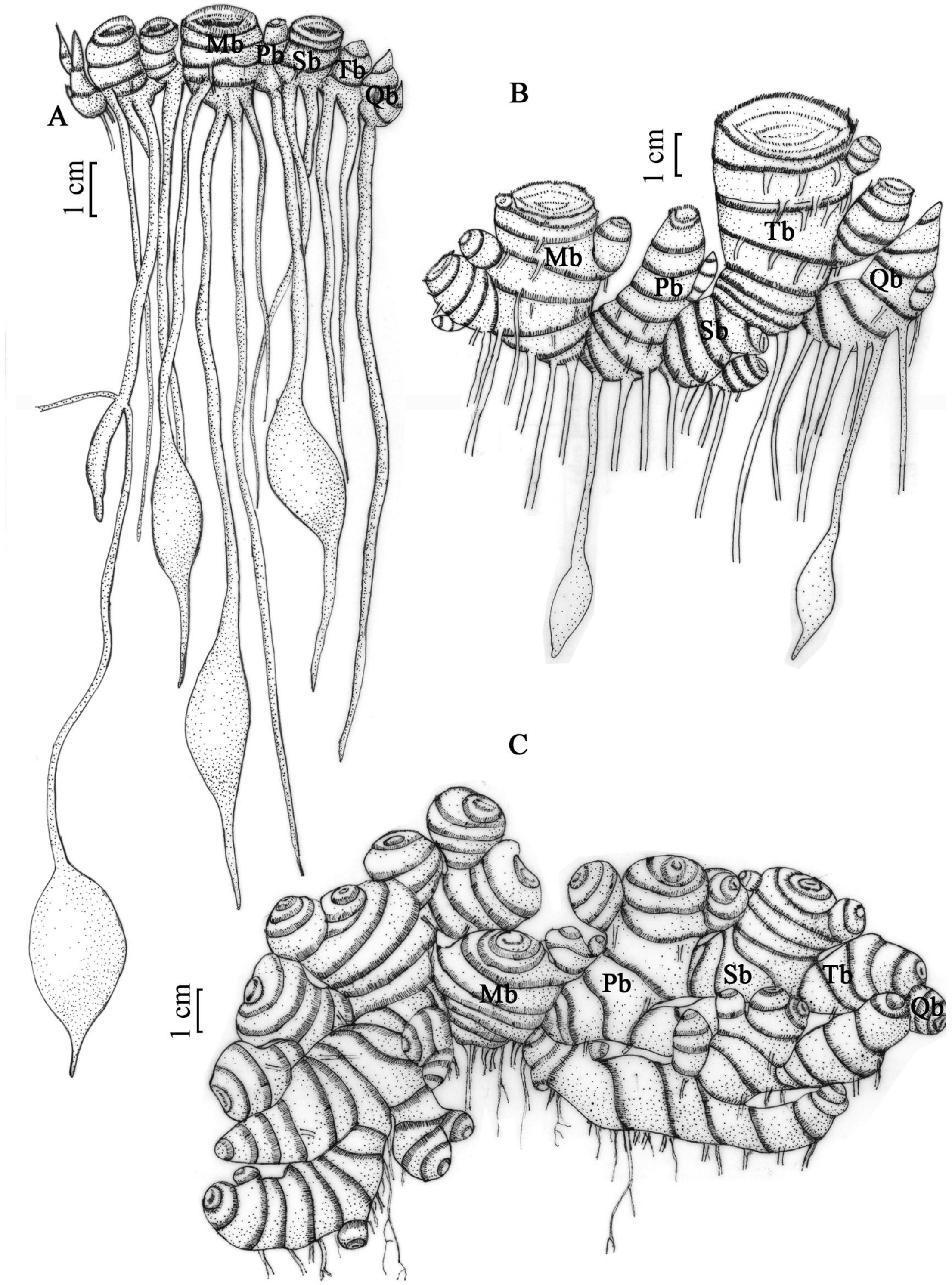


Fig. 03. Rhizome architecture: **A.** *Zingiber neesanum*; **B.** *Z. nimmonii*; **C.** *Z. zofficinale*; **Mb**-Main branch; **Pb**-Primary branch; **Sb**-Secondary branch; **Tb**-Tertiary branch; **Qb**-Quarternary branch.

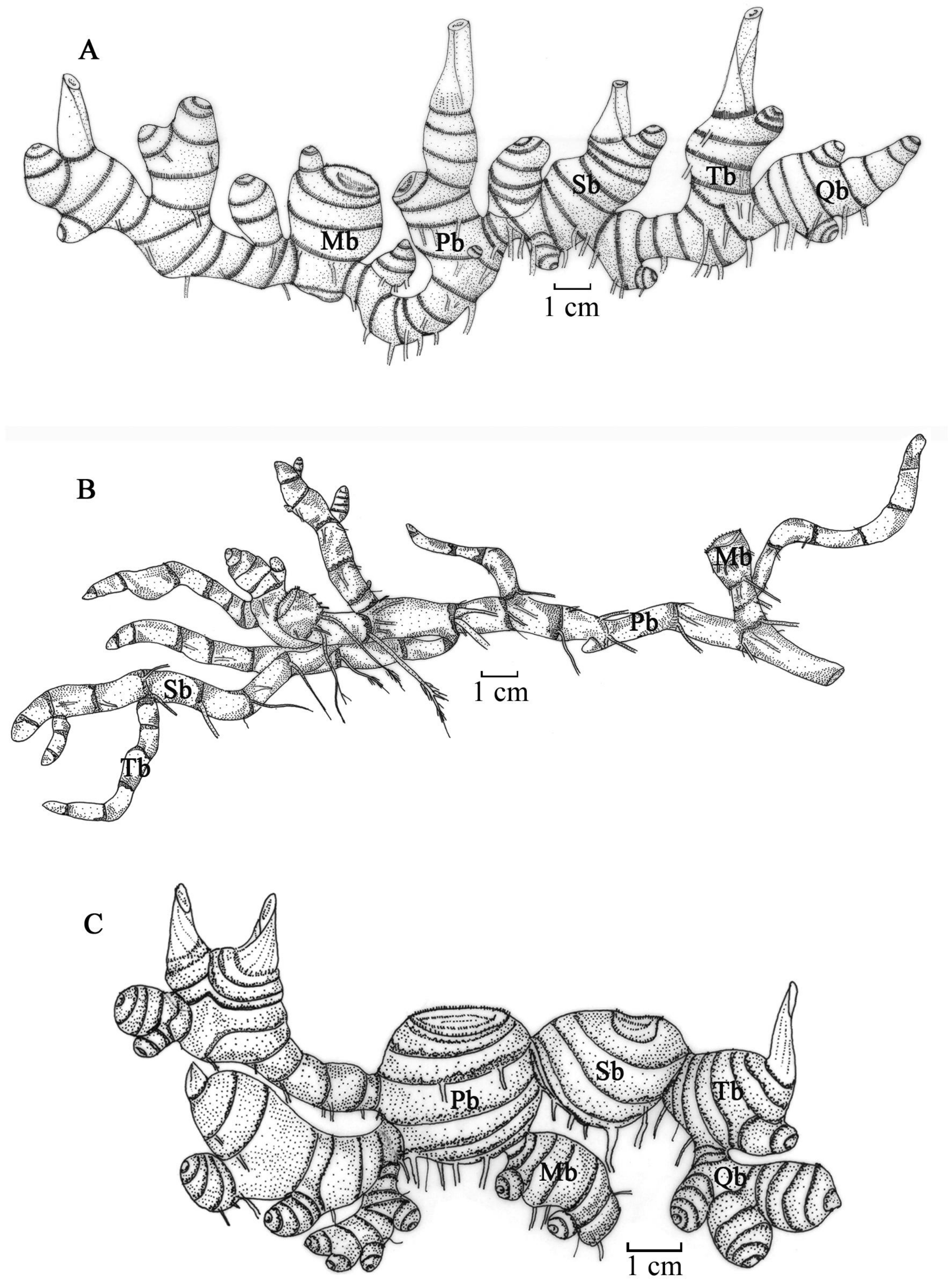


Fig. 04. Rhizome architecture: **A.** *Zingiber roseum*; **B.** *Z. wightianum*; **C.** *Z. zerumbet*; **Mb**-Main branch; **Pb**-Primary branch; **Sb**-Secondary branch; **Tb**-Tertiary branch; **Qb**-Quarternary branch.

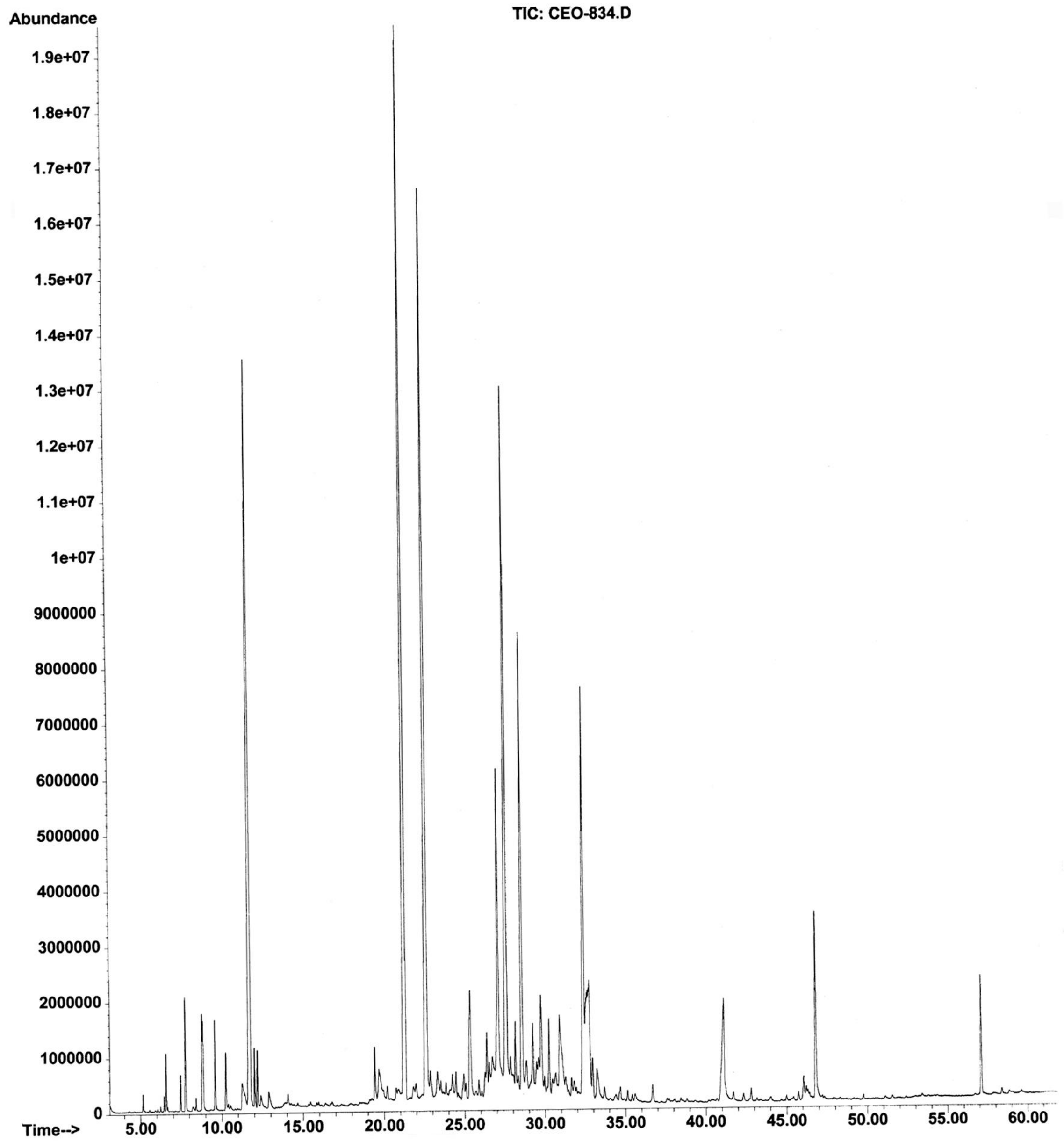


Fig. 06. GC-MS analysis of *Zingiber cernuum*

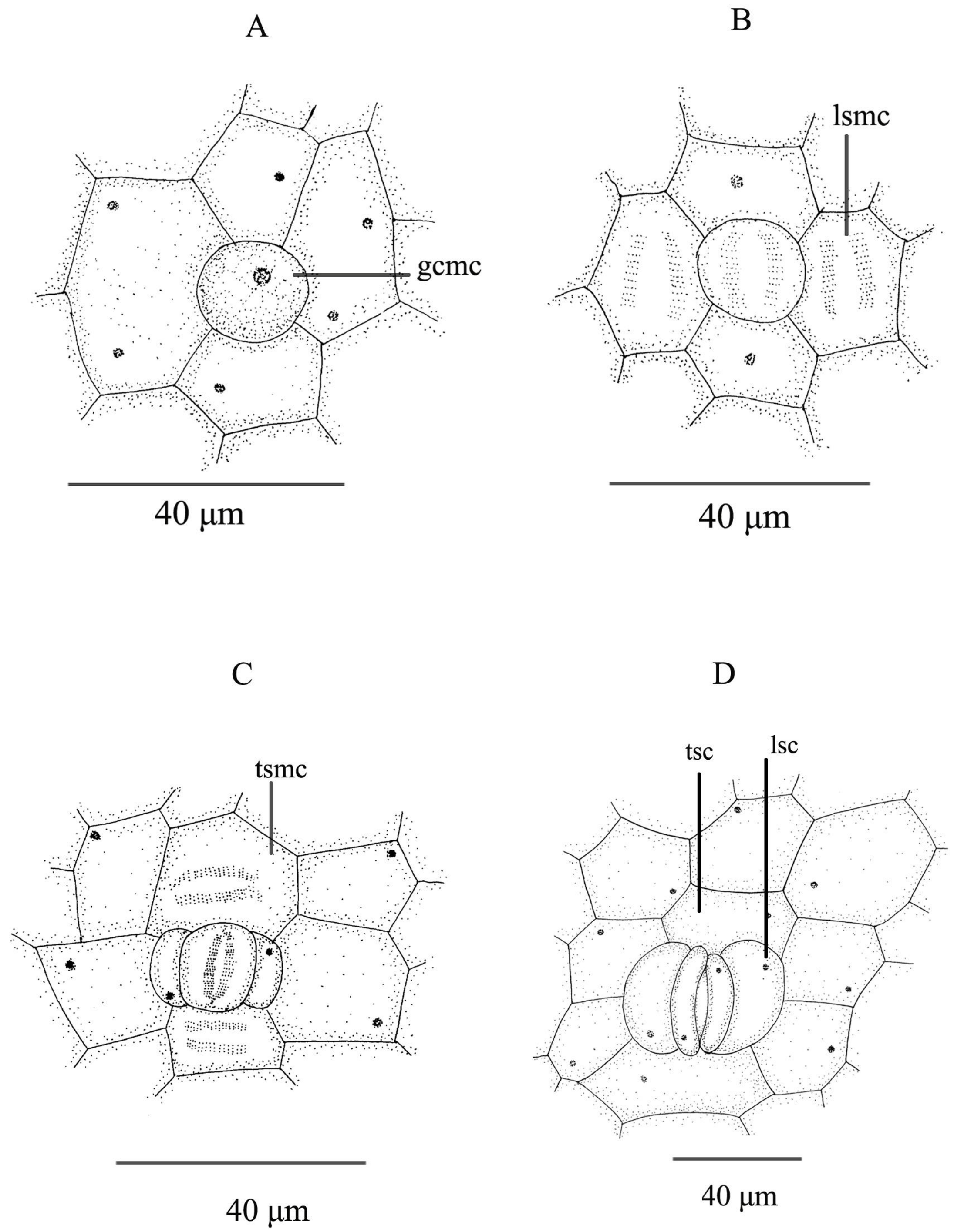


Fig. 05. Stomatal development in *Zingiber cernuum*: gcmc -guard cell mother cell; **lsmc** -lateral subsidiary cell mother cell; **tsmc** -terminal subsidiary cell mother cell; **lsc** -lateral subsidiary cell; **tsc** -terminal subsidiary cell.

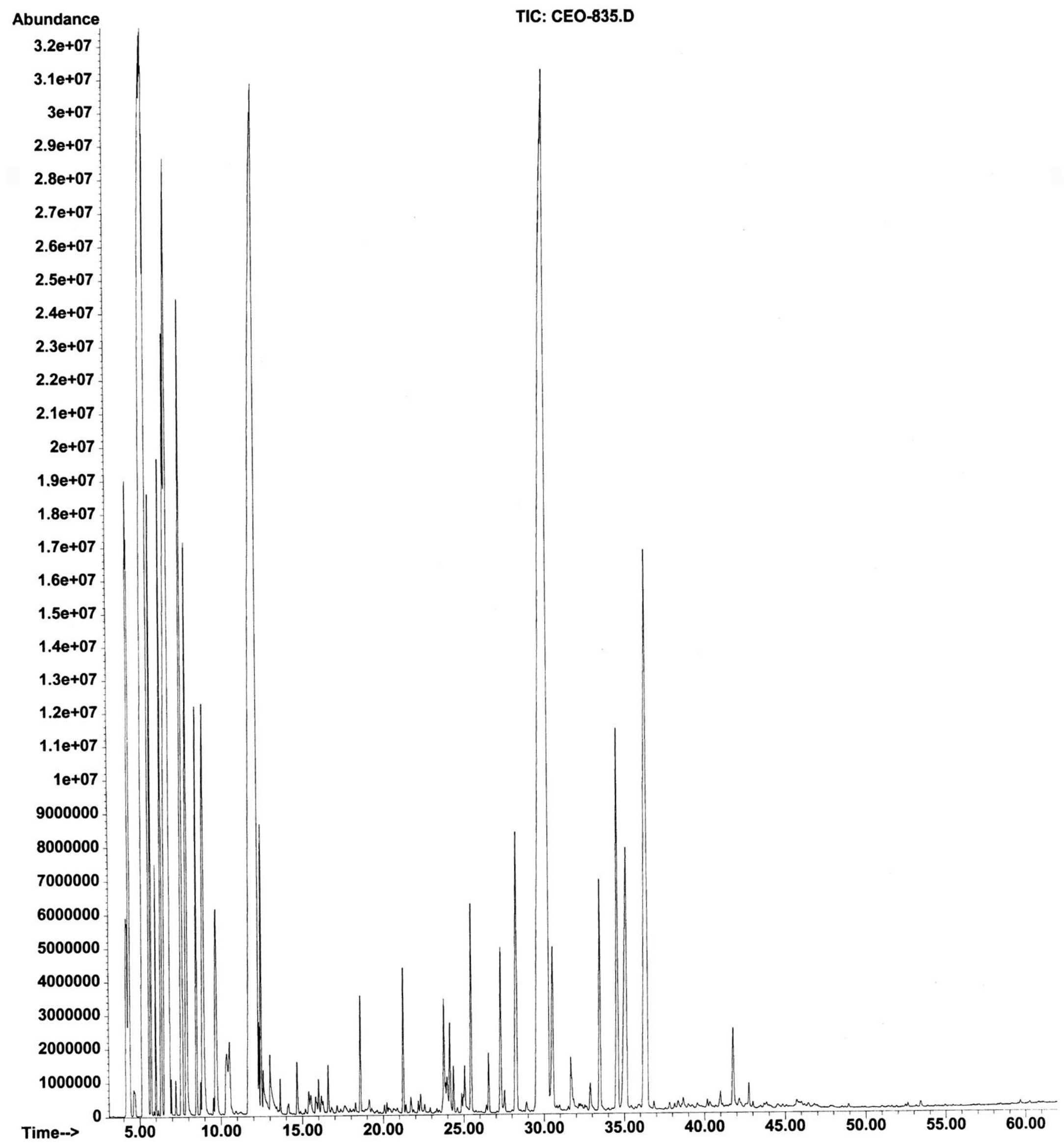


Fig 07. GC-MS analysis of *Zingiber montanum.*

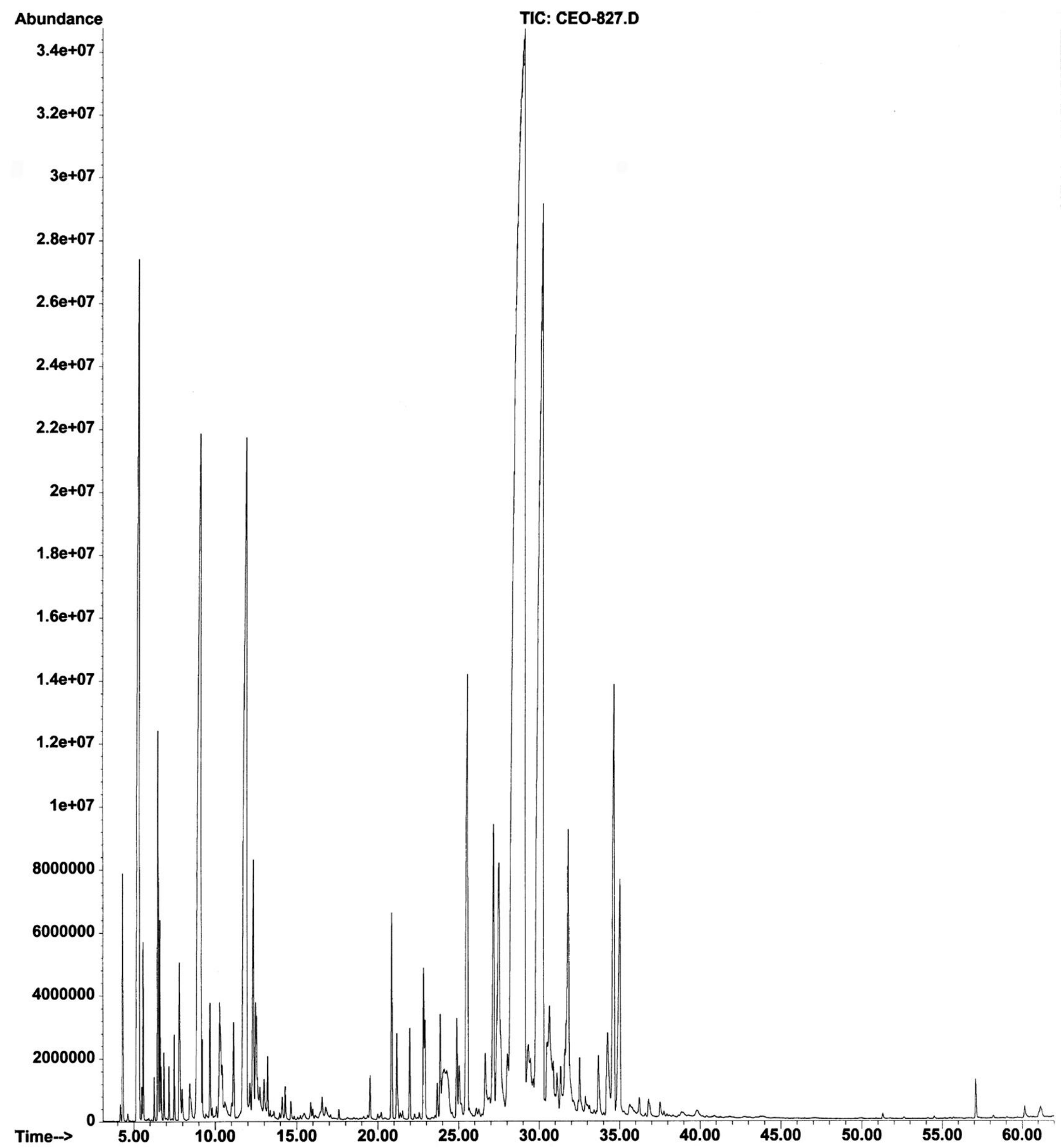


Fig. 08. GC-MS analysis of *Zingiber neesanum.*

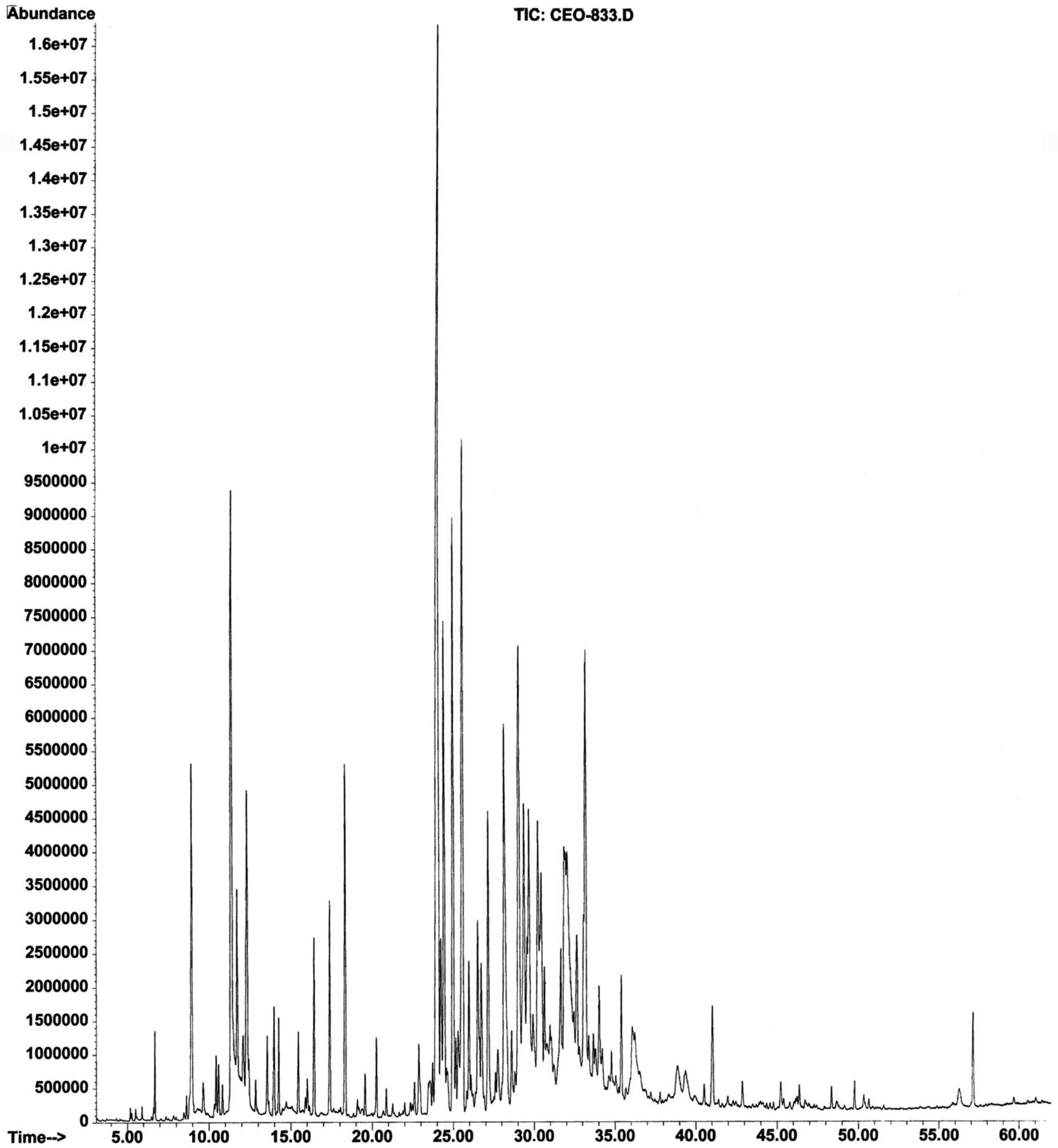


Fig. 10. GC-MS analysis of *Zingiber officinale.*

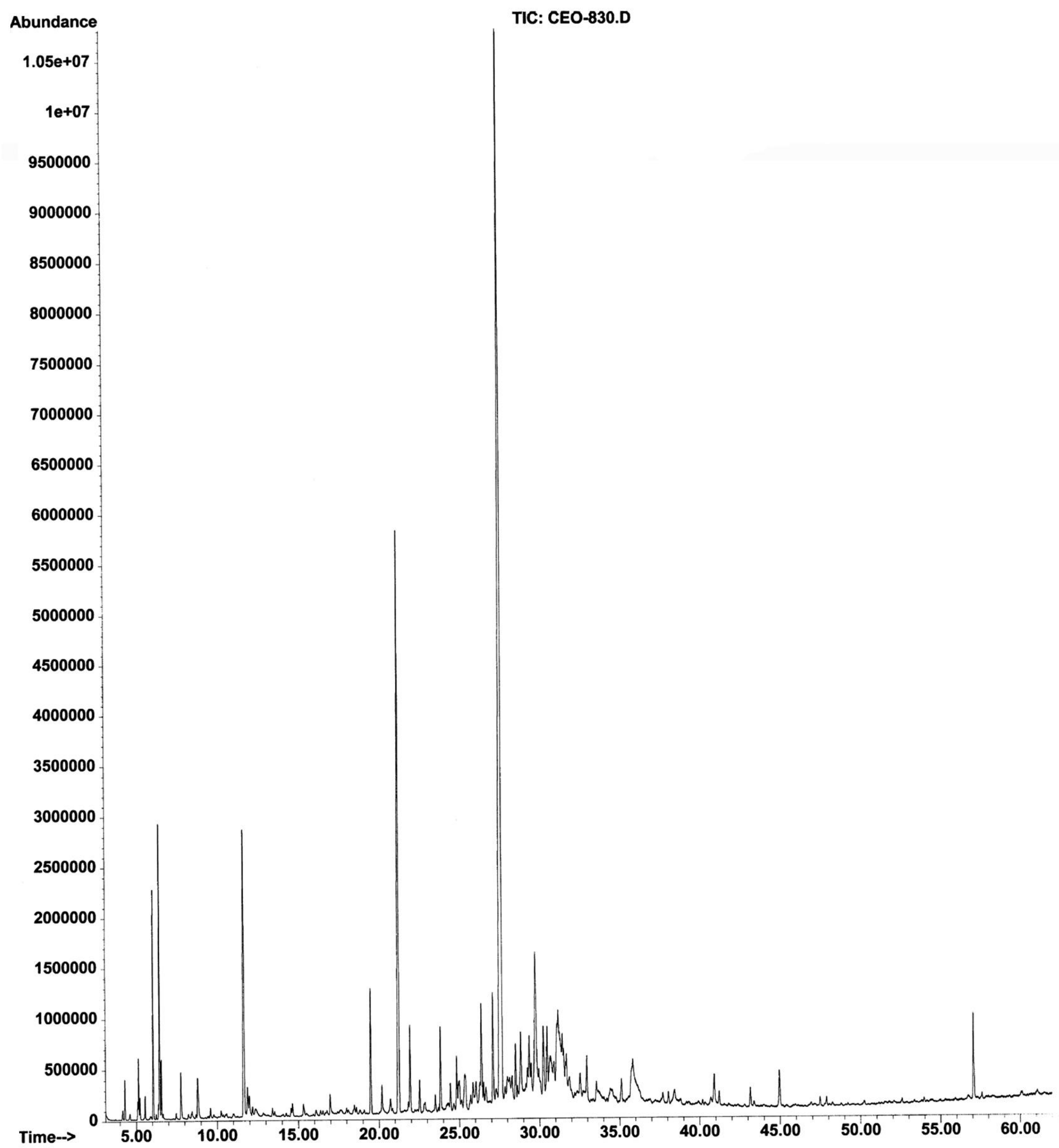


Fig. 09. GC-MS analysis of *Zingiber nimmonii*

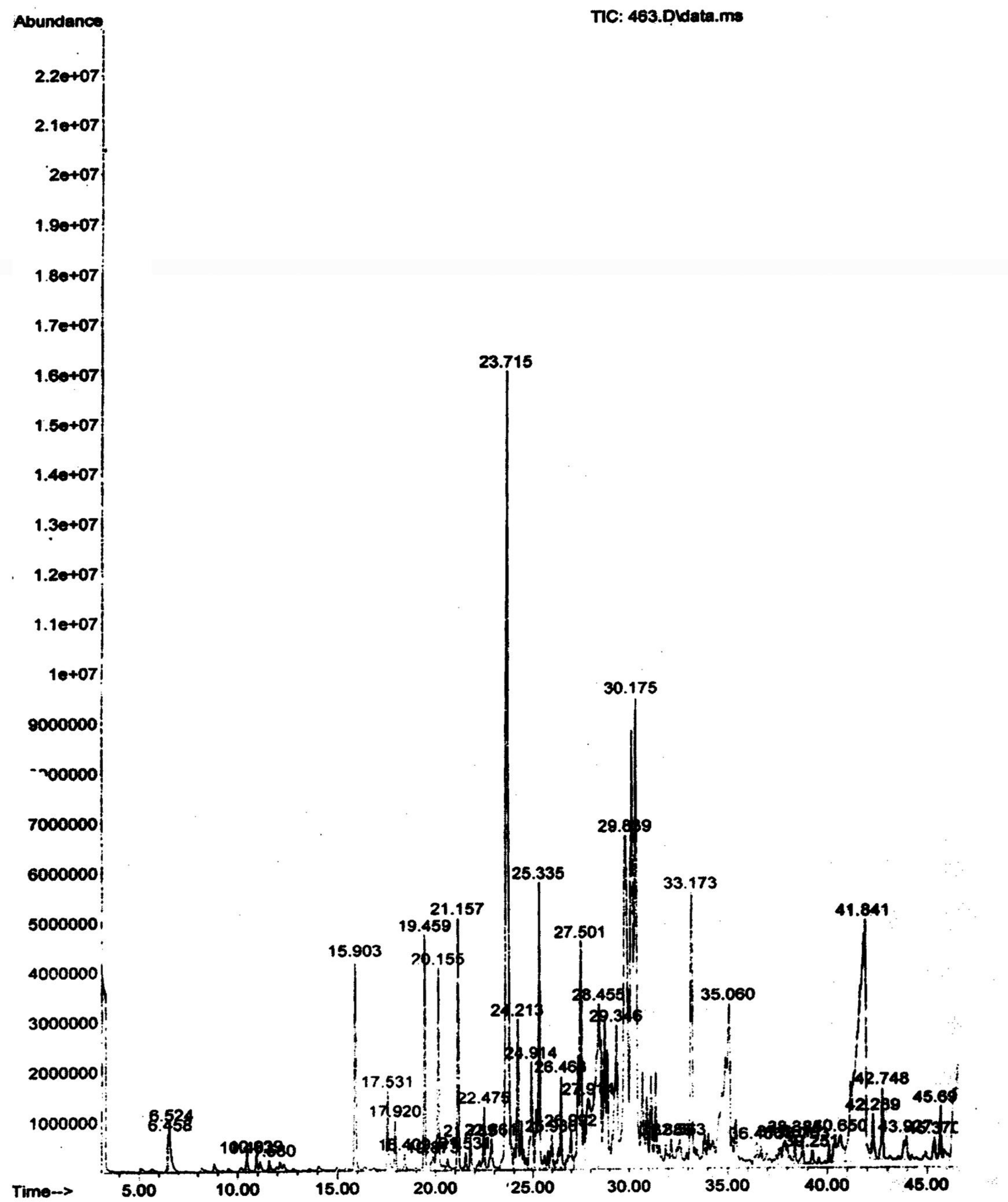


Fig. 12. GC-MS analysis of *Zingiber wightianum*

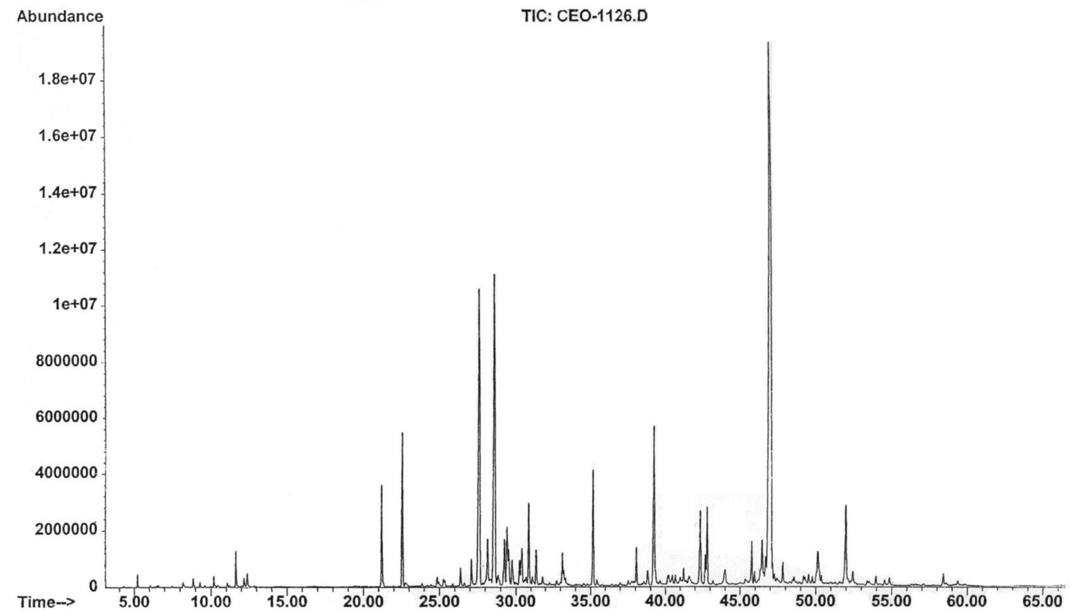


Fig. 11. GC-MS analysis of *Zingiber roseum*

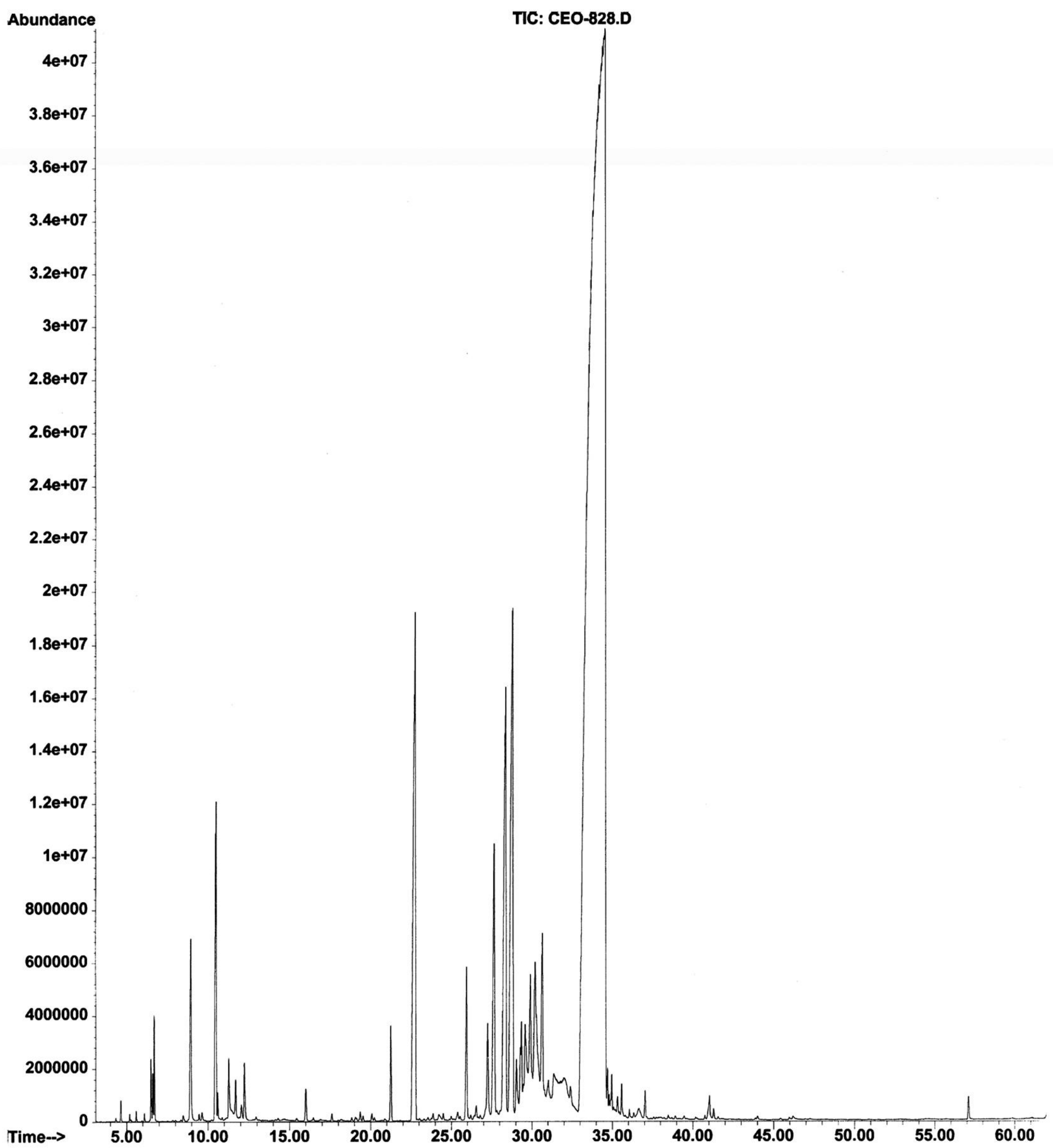


Fig. 14. GC-MS analysis of *Zingiber zerumbet* (Ponmudi)

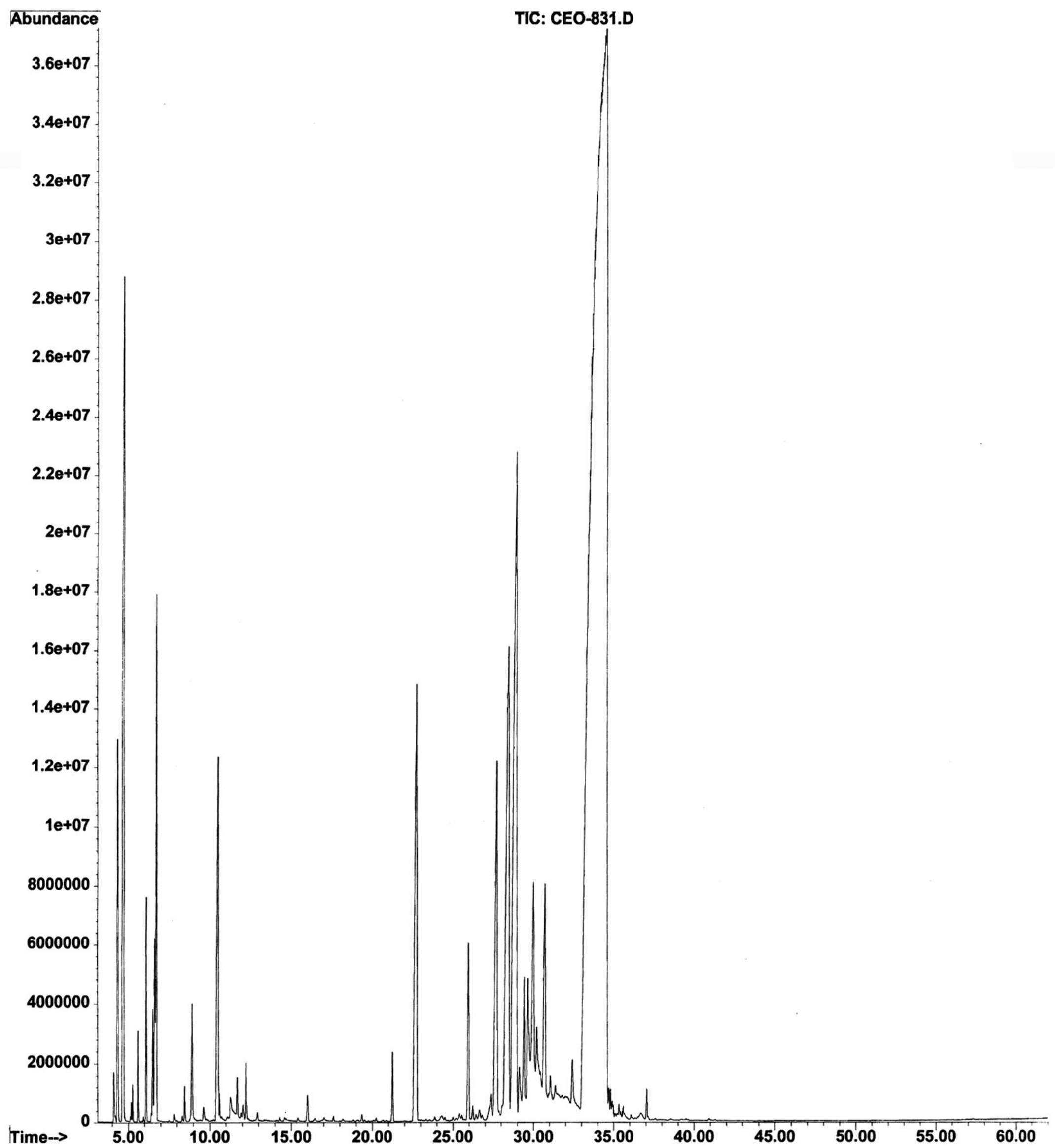


Fig. 13. GC-MS analysis of *Zingiber zerumbet* (Kozhikode).

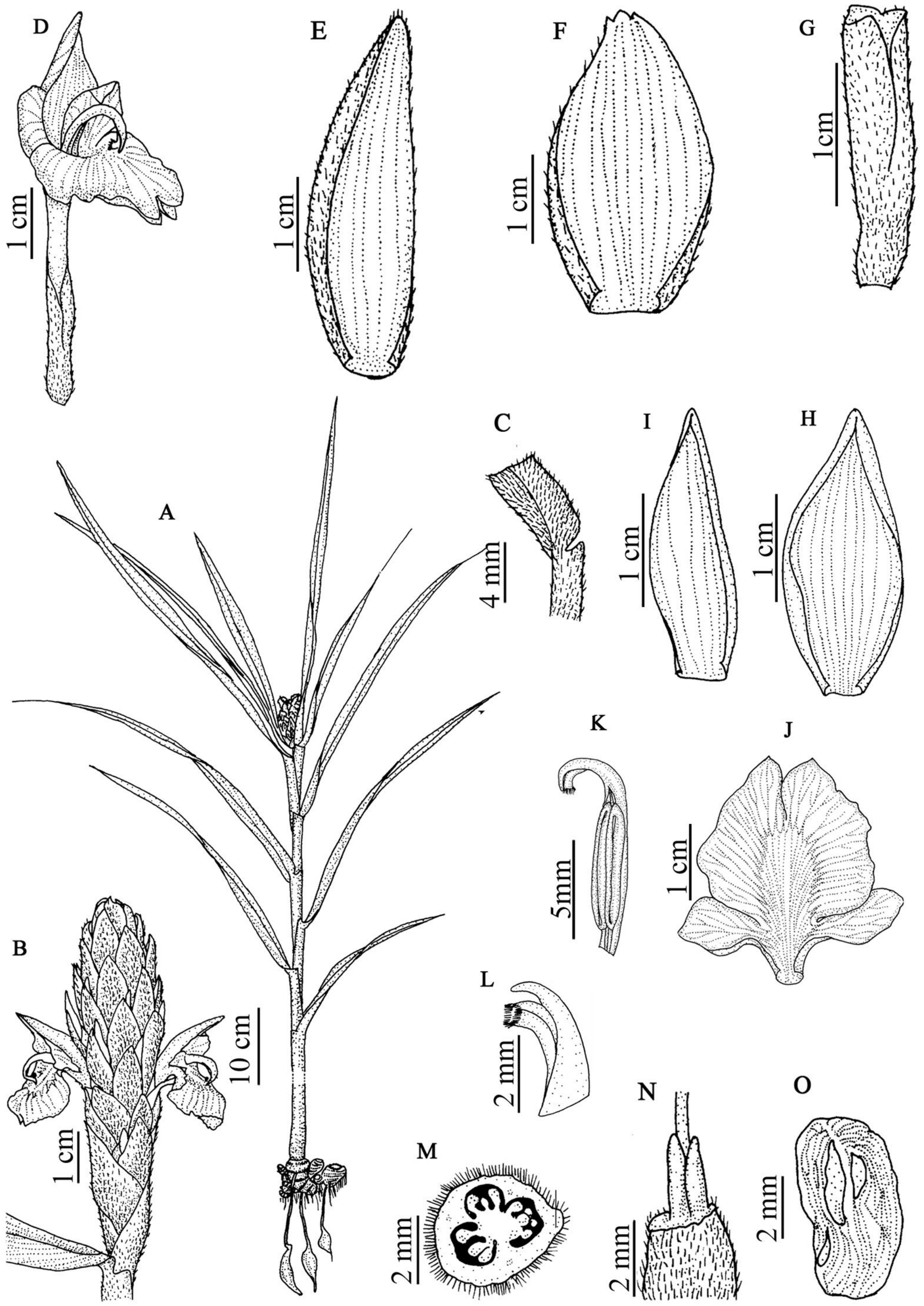


Fig. 19. ***Zingiber capitatum*** Roxb.*var.* ***elatum*** *(*Roxb.) Baker: **A.** Habit; **B.** Infloresence; **C.** Ligule; **D.** Flower; **E.** Bract; **F.** Bracteole; **G.** Calyx; **H.** Dorsal corolla lobe; **I.** Lateral corolla lobe; **J.** Labellum; **K.** Anther lateral view; **L.** Stigma and tip of anther hood; **M.** C.S. of ovary; **N.** Ovary with epigynous glands; **O.** seed with aril.

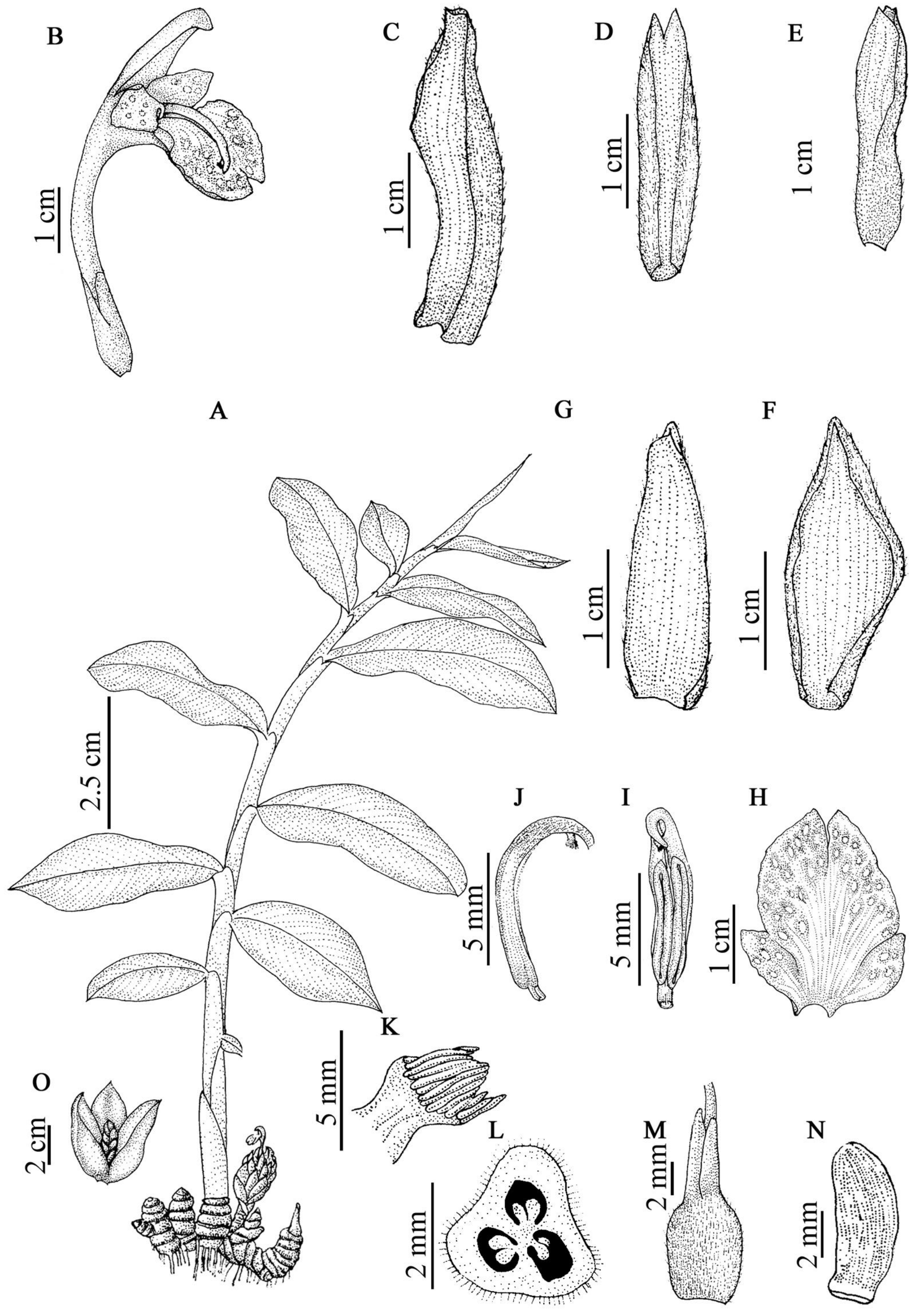


Fig. 20. ***Zingiber cernuum*** Dalzell : **A.** Habit; **B.** Flower; ; **C.** Bract; **D.** Bracteole; **E.** Calyx; **F.** Dorsal corolla lobe; **G.** Lateral corolla lobe; **H.** Labellum; **I.** Anther front view; **J.** Anther lateral view; **K.** Stigma; **L.** C.S. of ovary; **M.** Ovary with epigynous glands; **N.** Seed; **O.** Fruit.

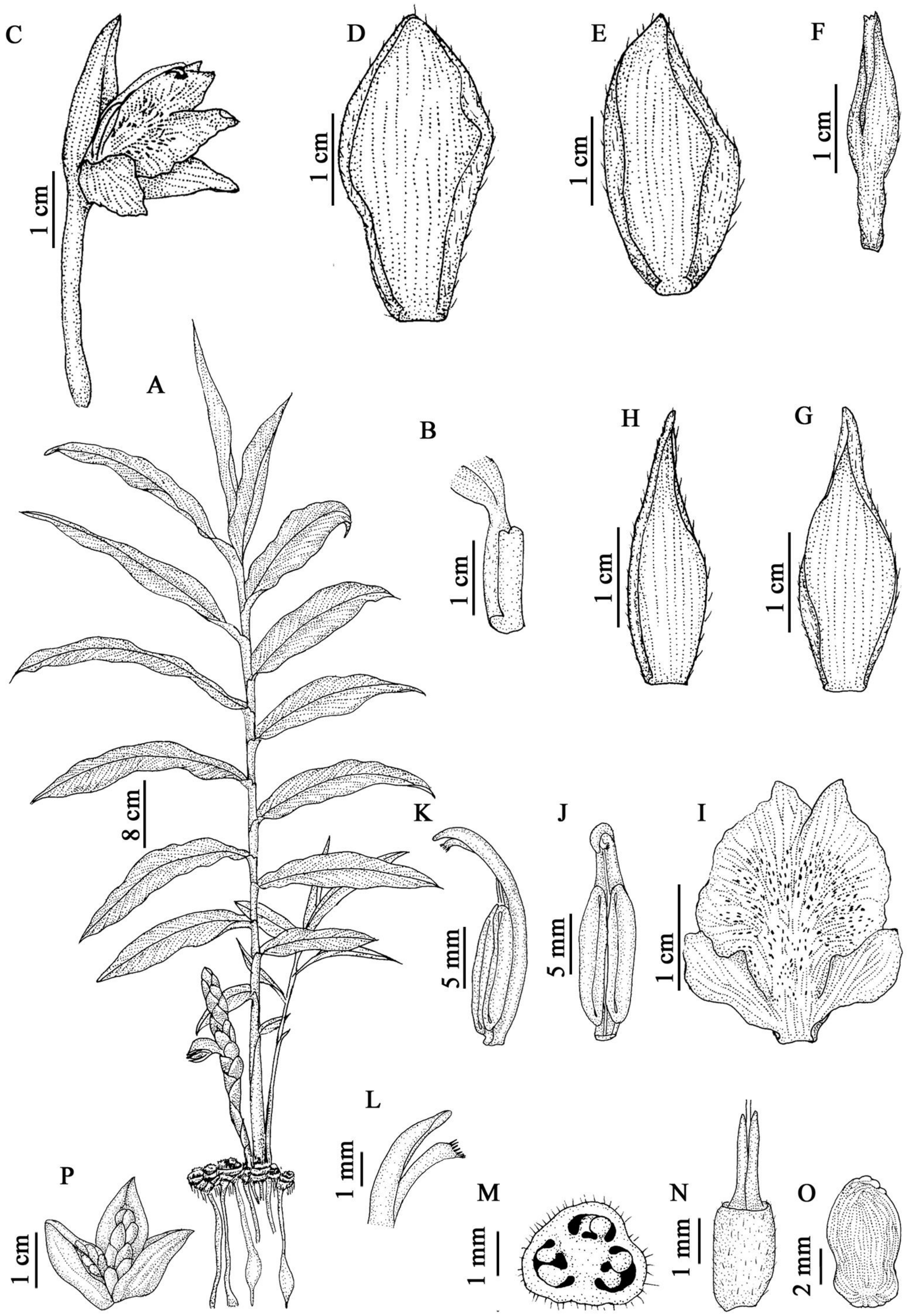


Fig. 22. *Zingiber neesanum* (J. Graham) **Ramamoorthy**.: **A.** Habit; **B.** Ligule; **C.** Flower; ; **D.** Bract; **E.** Bracteole; **F.** Calyx; **G.** Dorsal corolla lobe; **H.** Lateral corolla lobe; **I.** Labellum; **J.** Anther front view; **K.** Anther lateral view; **L.** Stigma; **M.** C.S. of ovary; **N.** Ovary with epigynous glands; **O**. Seed; **P**. Fruit.

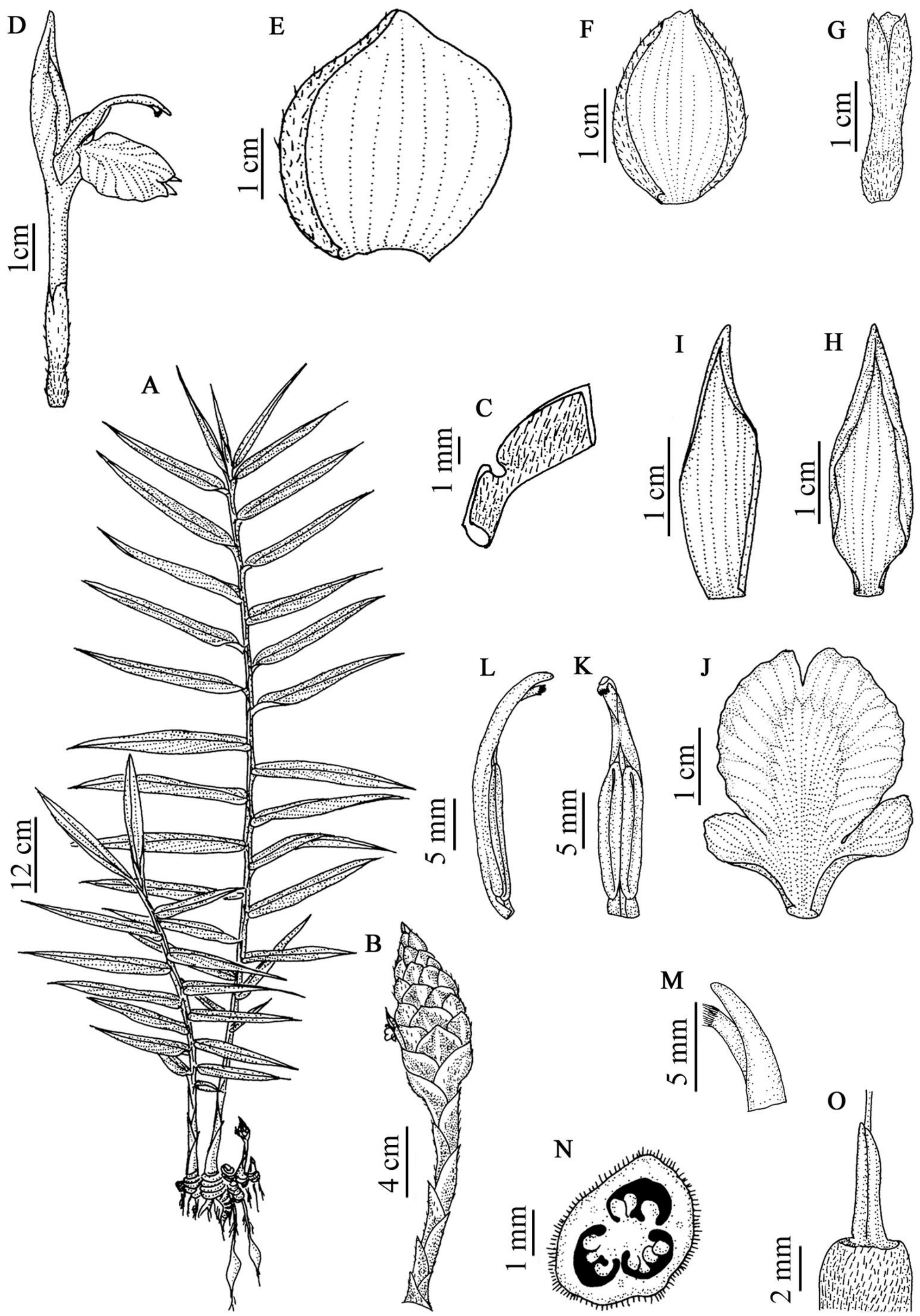


Fig. 21. *Zingiber montanum* (K.D. Koenig) Link ex Dietr.: **A.** Habit; **B.** Infloresence; **C.** Ligule; **D.** Flower; **E.** Bract; **F.** Bracteole; **G.** Calyx; **H.** Dorsal corolla lobe; **I.** Lateral corolla lobe; **J.** Labellum; **K.** Anther front view; **L.** Anther lateral view; **M.** Stigma; **N.** C.S. of ovary; **O.** Ovary with epigynous glands.

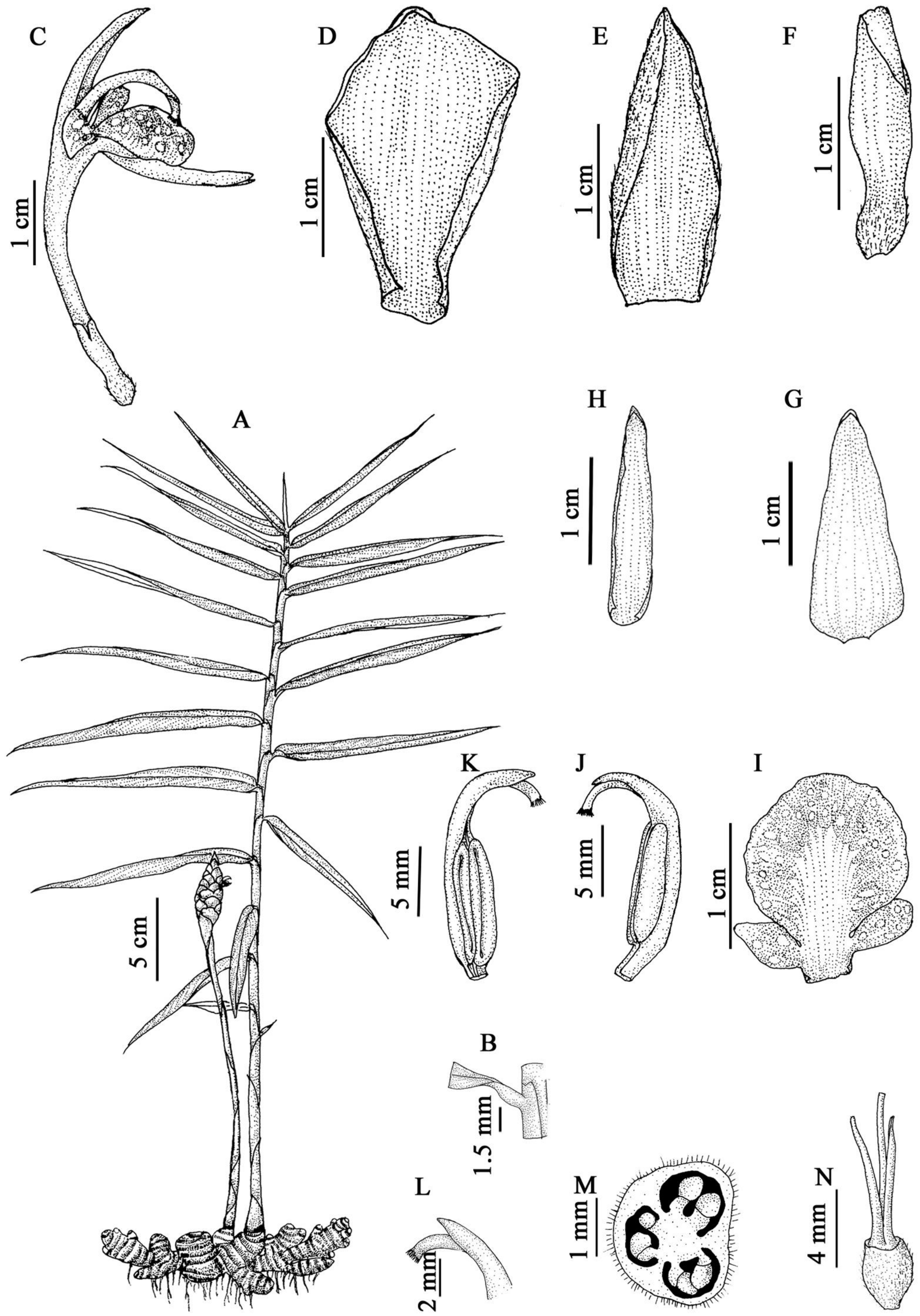


Fig. 24. ***Zingiber officinale*** **Roscoe**: **A.** Habit; **B.** Ligule; **C.** Flower; **D.** Bract; **E.** Bracteole; **F.** Calyx; **G.** Dorsal corolla lobe; **H.** Lateral corolla lobe; **I.** Labellum; **J.** Anther lateral view; **K.** Anther front view; **L.** Stigma; **M.** C.S. of ovary ; **N.** Ovary with epigynous glands.

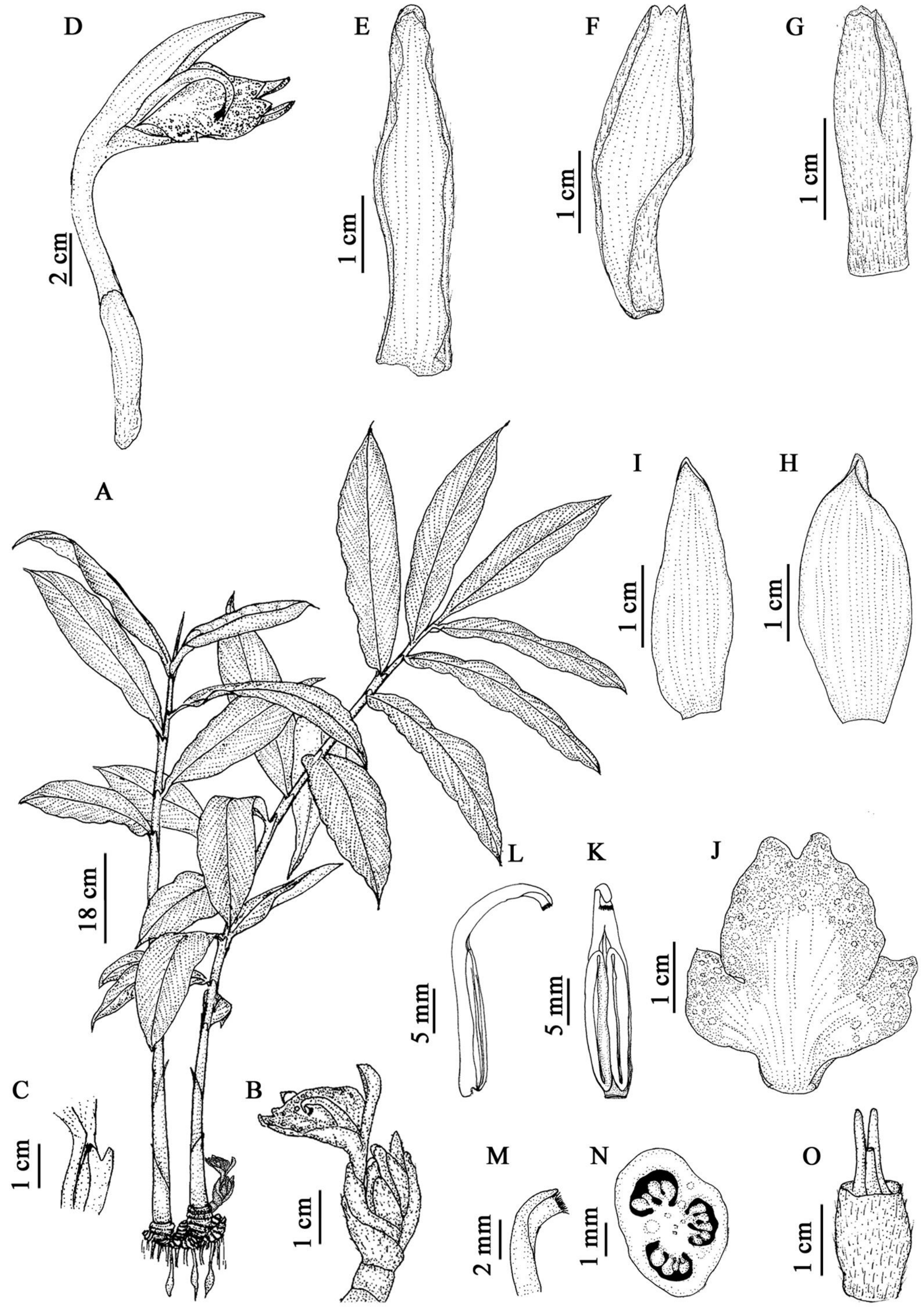


Fig. 23. ***Zingiber nimmonii*** **(J. Graham) Dalzell**: **A.** Habit; **B.** Inflorescence; **C.** Ligule; D. Flower; **E.** Bract; **F.** Bracteole; **G.** Calyx; **H.** Dorsal corolla lobe; **I.** Lateral corolla lobe; **J.** Labellum; **K.** Anther front view; **L.** Anther lateral view; **M.** Stigma; **N.** C.S. of ovary; **O.** Ovary with epigynous glands.

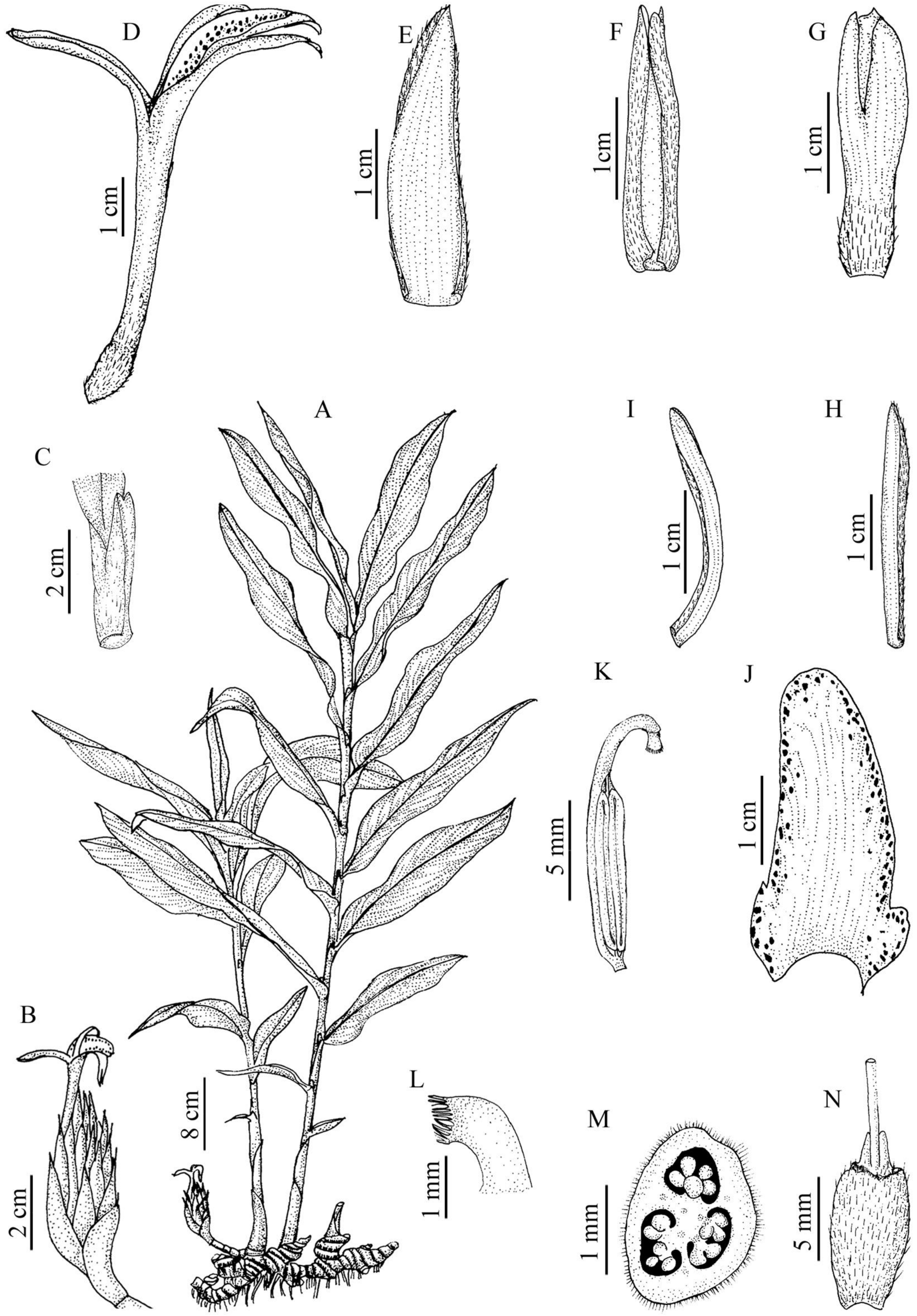


Fig. 25. ***Zingiber roseum*** **(Roxb.) Roscoe**: **A.** Habit; **B.** Infloresence; **C.** Ligule; **D.** Flower; **E.** Bract; **F.** Bracteole; **G.** Calyx; **H.** Dorsal corolla lobe; **I.** Lateral corolla lobe; **J.** Labellum; **K.** Anther; **L.** Stigma; **M.** C.S. of ovary; **N.** Ovary with epigynous glands.

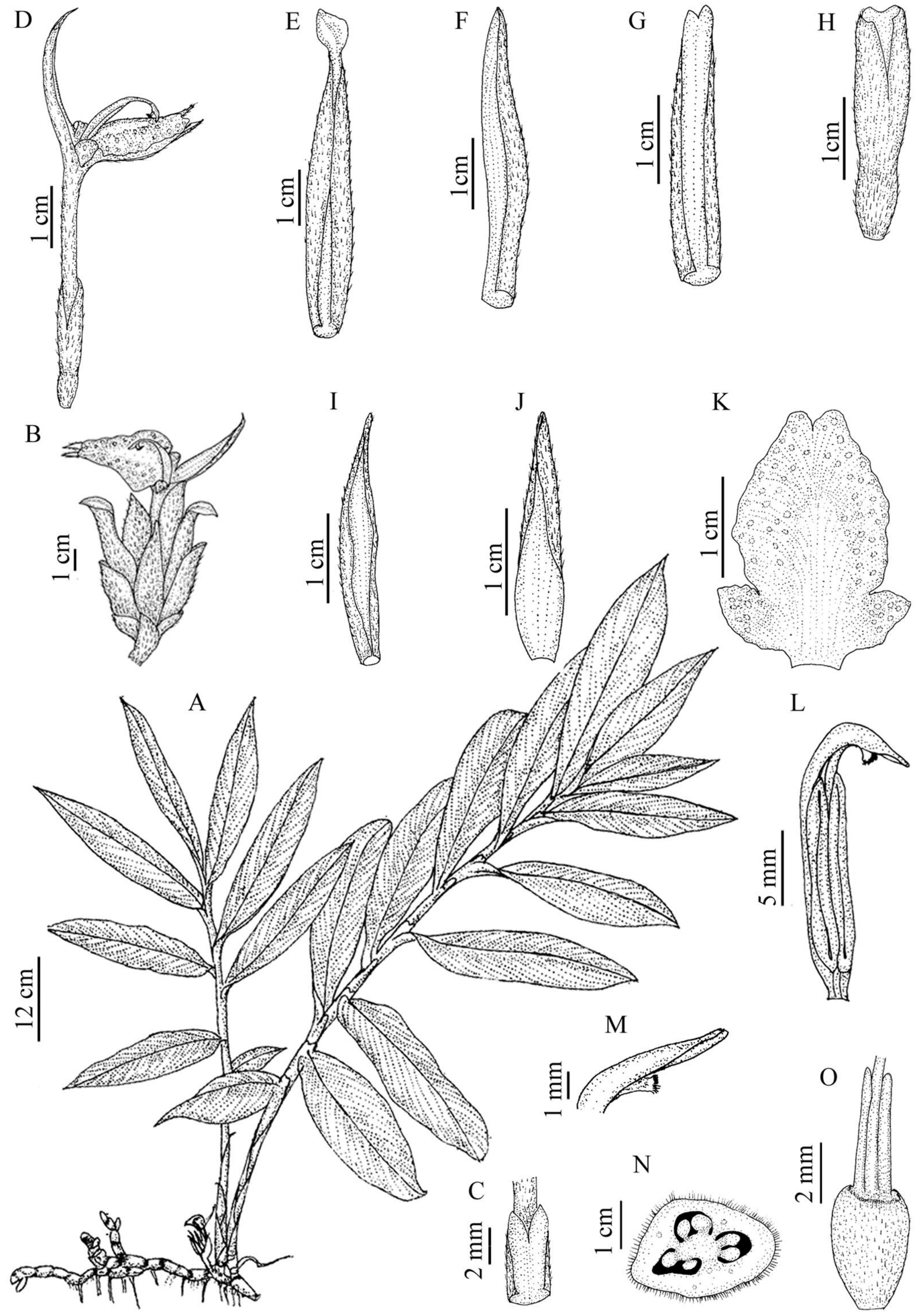


Fig. 26. ***Zingiber wightianum*** **Thwaites**: **A.** Habit; **B.** Infloresence; **C.** Ligule; **D.** Flower; **E.** First bract; **F.** Bract; **G.** Bracteole; **H.** Calyx; **I.** Dorsal corolla lobe; **J.** Lateral corolla lobe; **K.** Labellum; **L.** Anther; **M.** Stigma; **N.** C.S. of ovary; O. Ovary with epigynous glands.

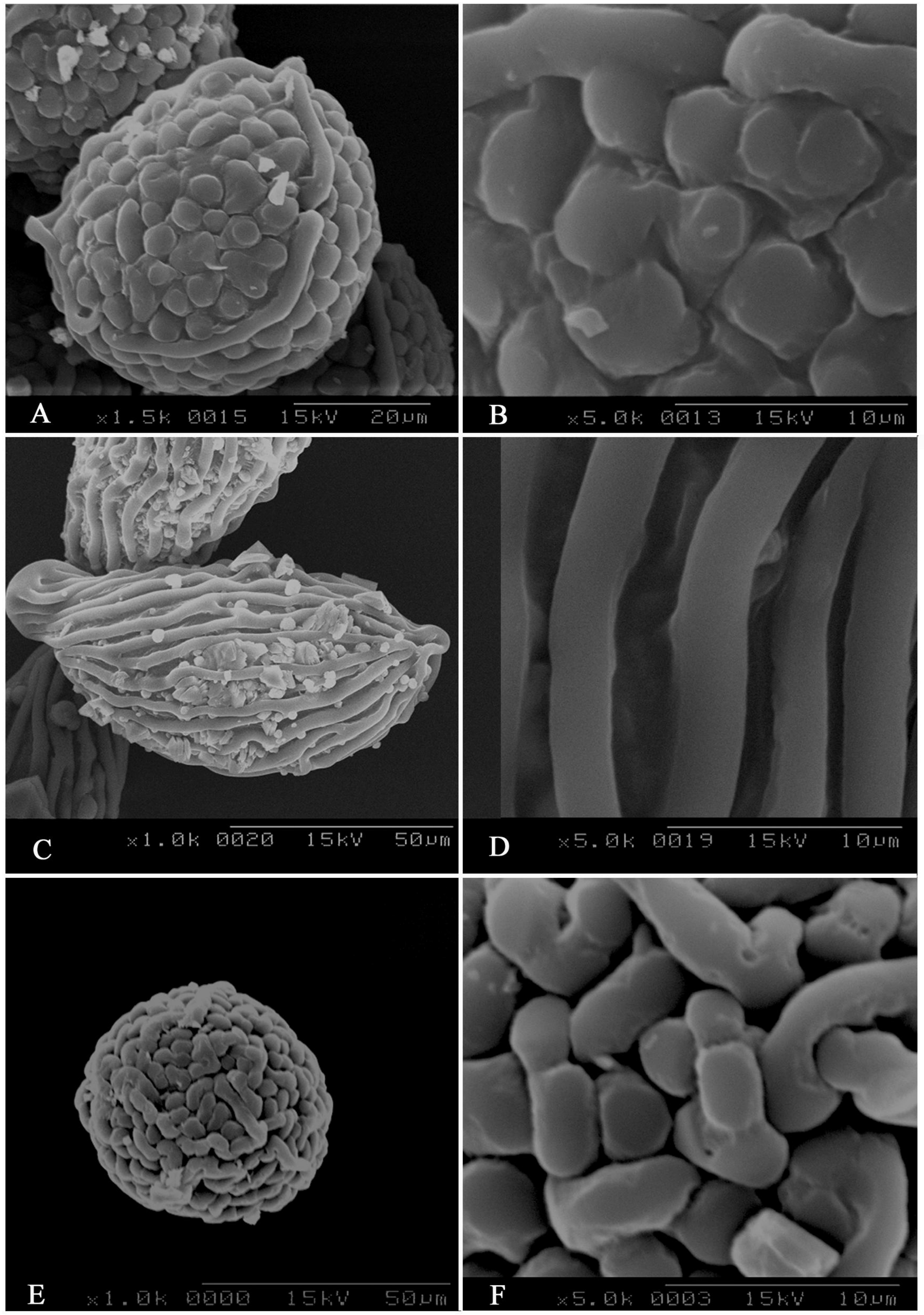


Plate 31. SEM of pollen grains of *Zingiber* species: A-B. *Z. capitatum* var. *elatum*; C-D. *Z. cernuum;* E- F. *Z. montanum.*

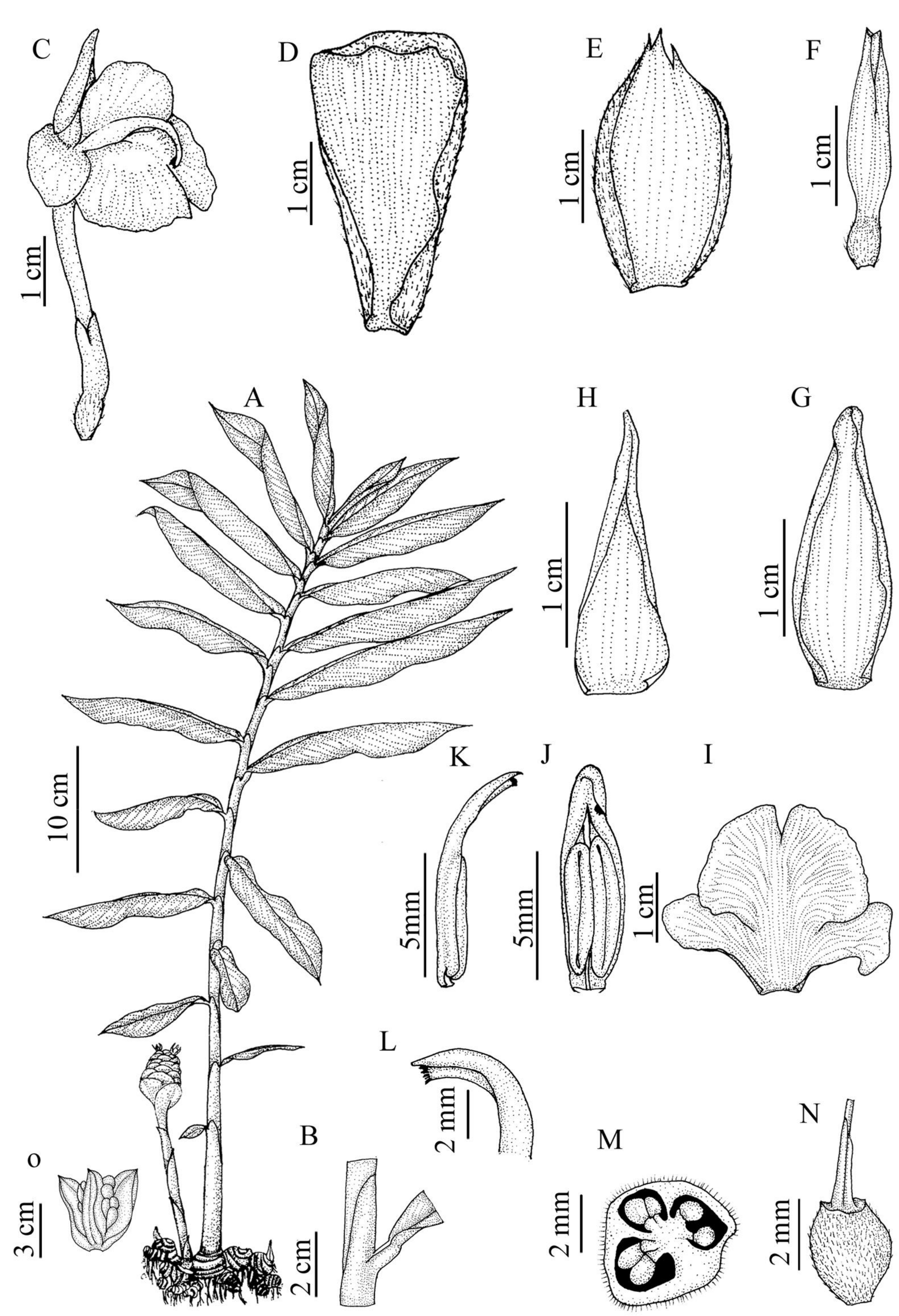


Fig. 27. ***Zingiber zerumbet*** **(L.) Smith**: **A.** Habit; **B.** Ligule; **C.** Flower; **D.** Bract; **E.** Bracteole; **F.** Calyx; **G.** Dorsal corolla lobe; **H.** Lateral corolla lobe; **I.** Labellum; **J.** Anther front view; **K.** Anther lateral view; **L.** Stigma; **M.** C.S. of ovary ; **N.** Ovary with epigynous glands; O. Fruit.

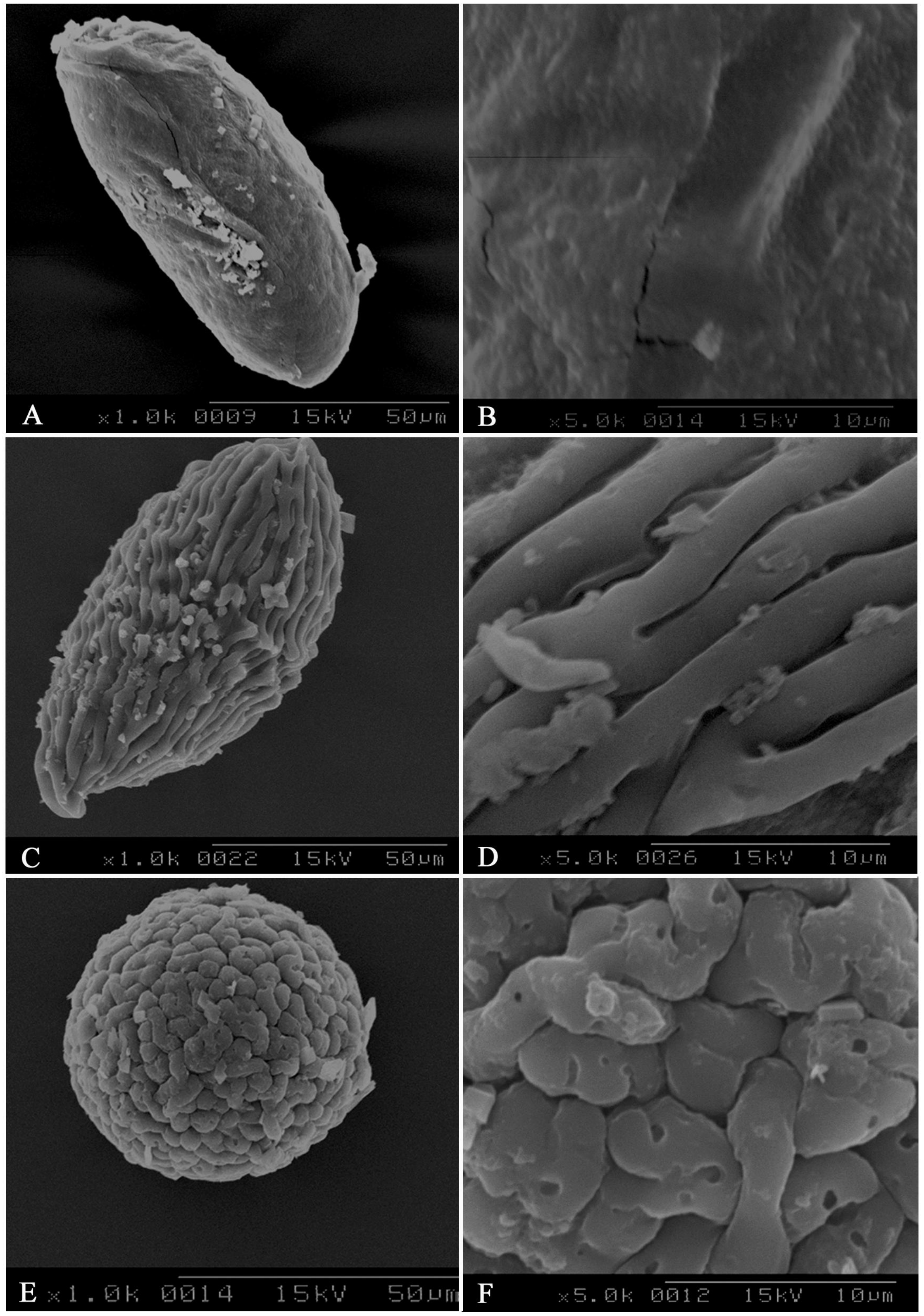


Plate 33. SEM of pollen grains of *Zingiber* species: A-B. *Z. roseum*; C-D. *Z. wightianum;* E-F. *Z. zerumbet.*

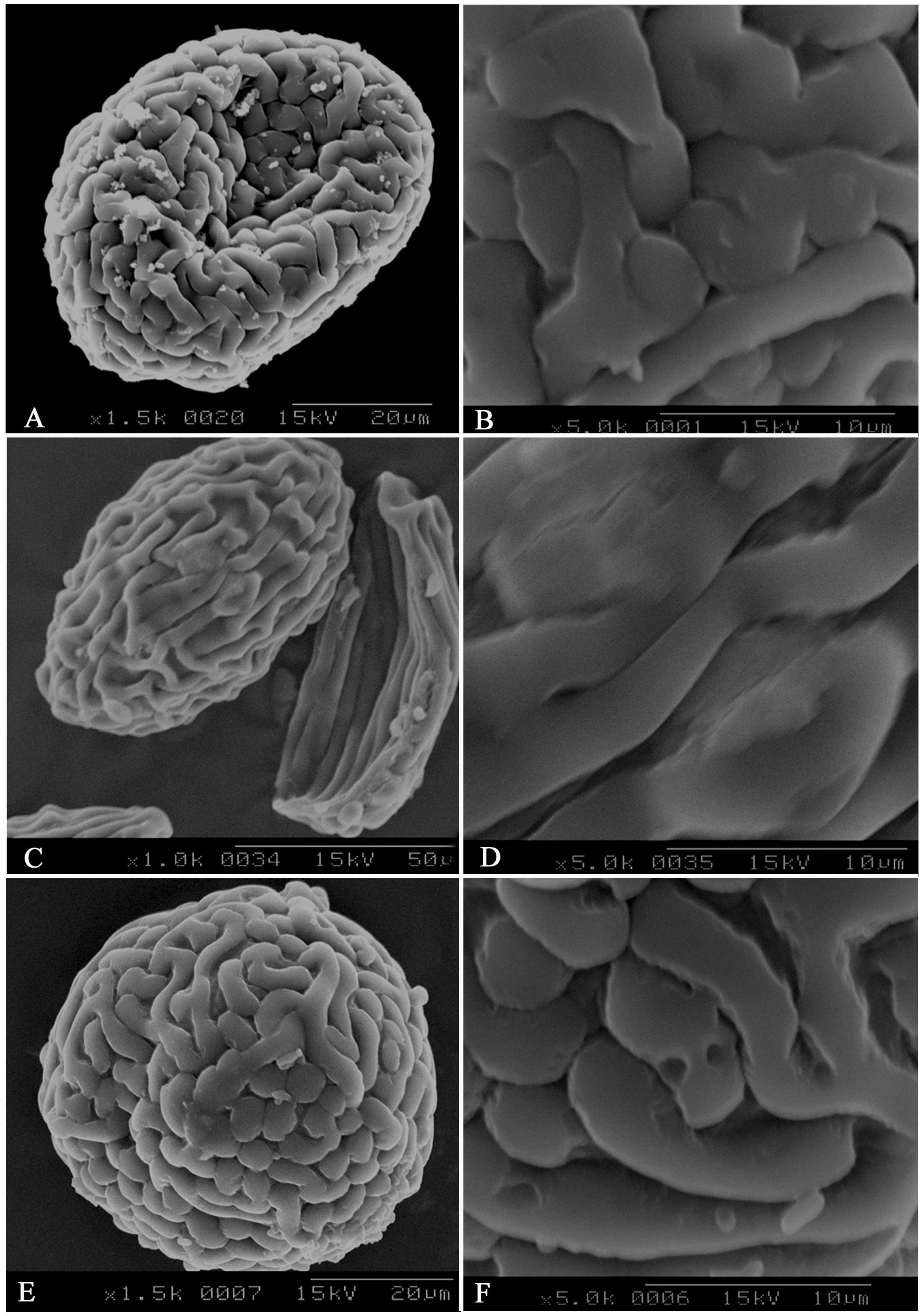


Plate 32. SEM of pollen grains of *Zingiber* species: A-B. *Z. neesanum*; C-D. *Z. nimmonii;* E-F. *Z. officinale.*

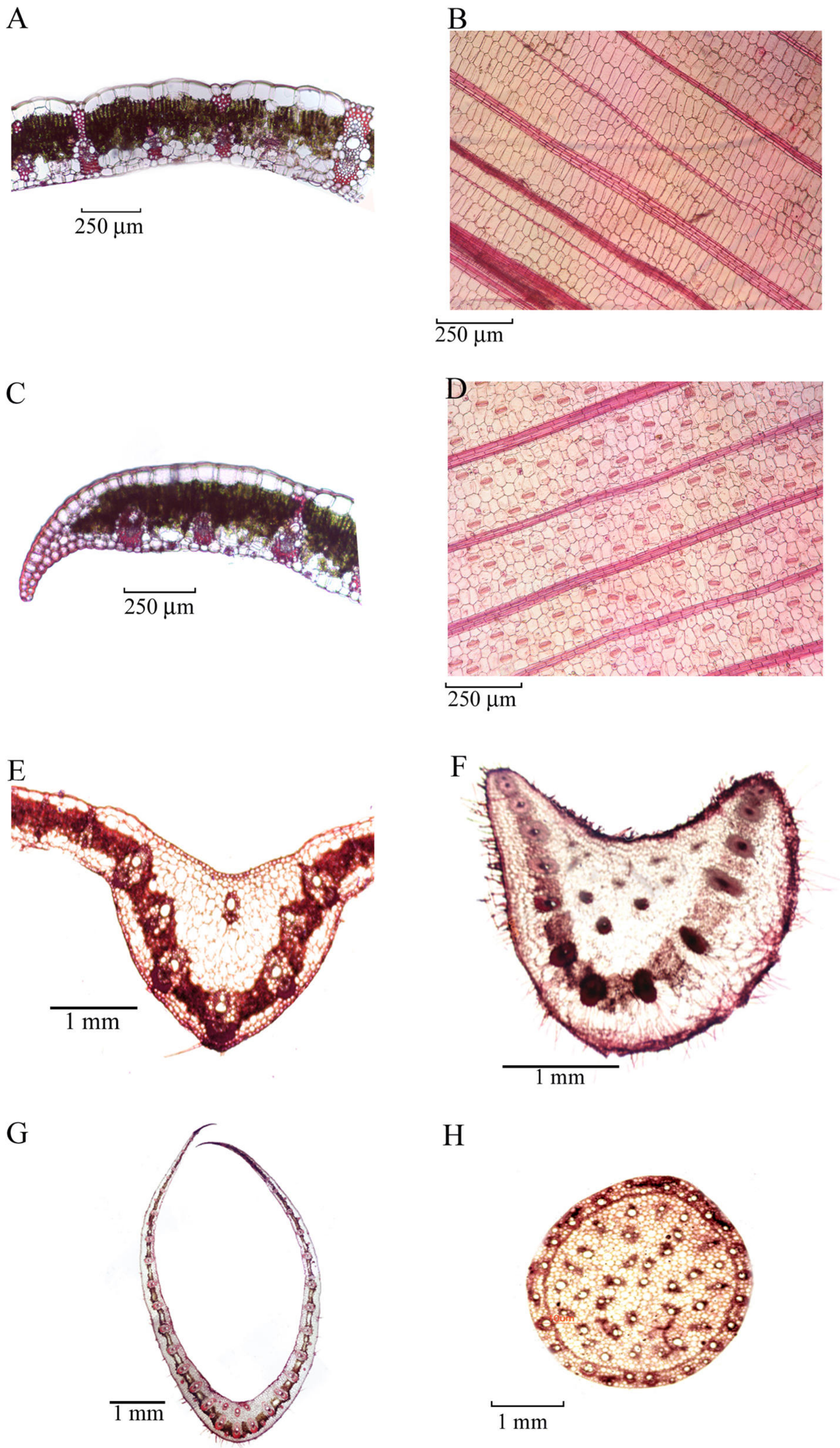


Plate 02. ***Zingiber capitatum*** **var.** ***elatum*** - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

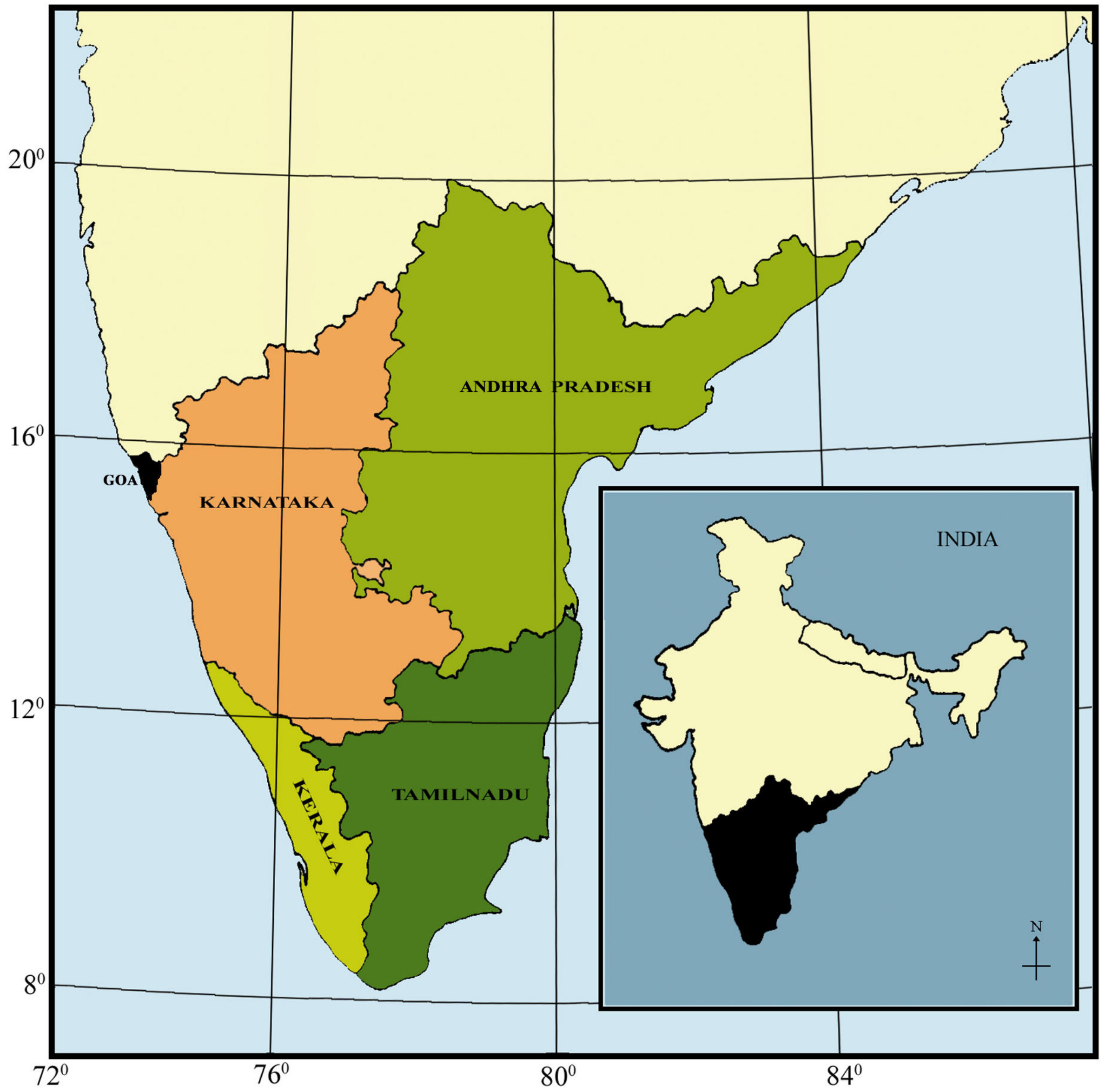


Plate 01. Map of South India

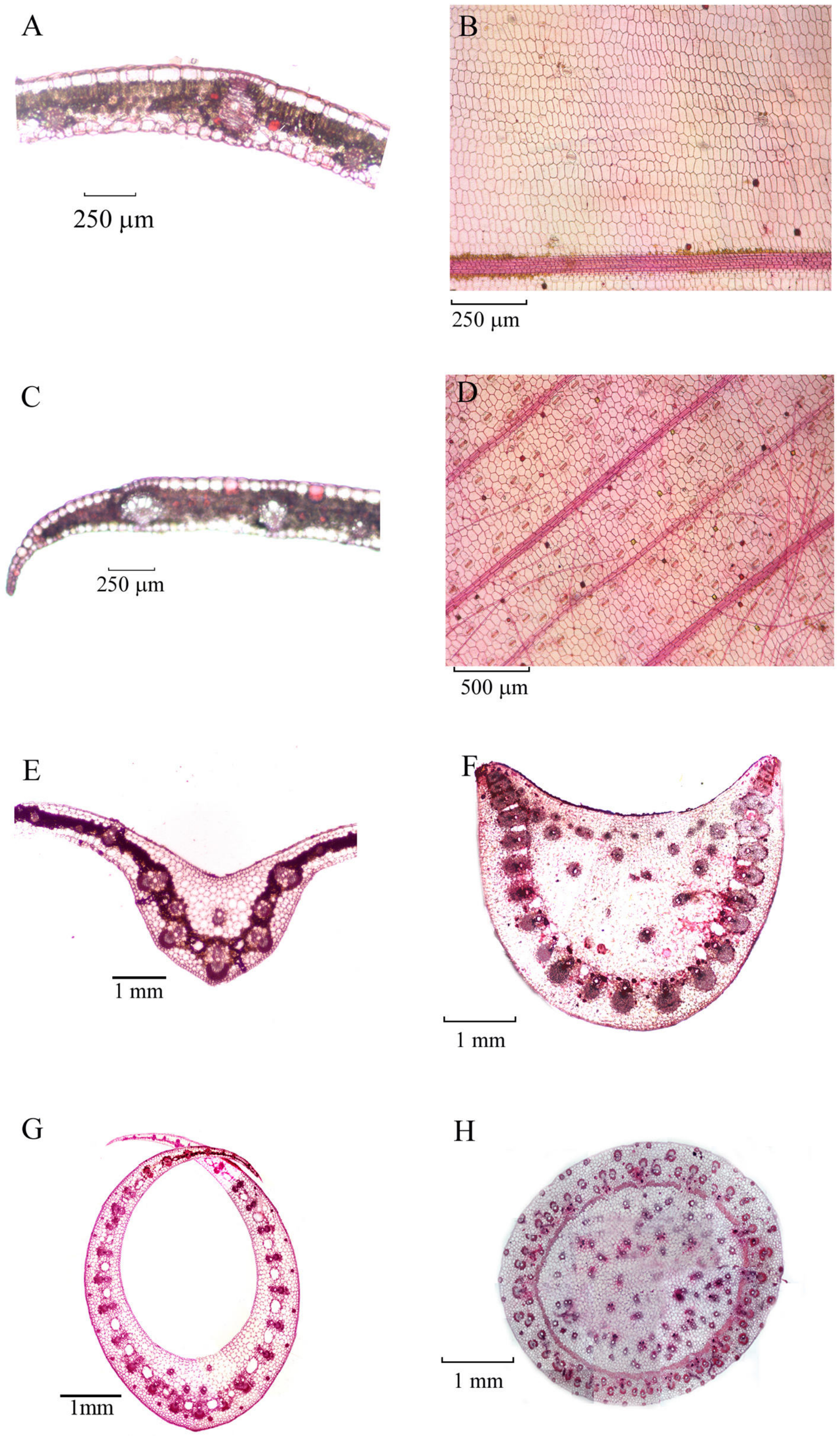


Plate 04. *Zingiber cernuum* - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

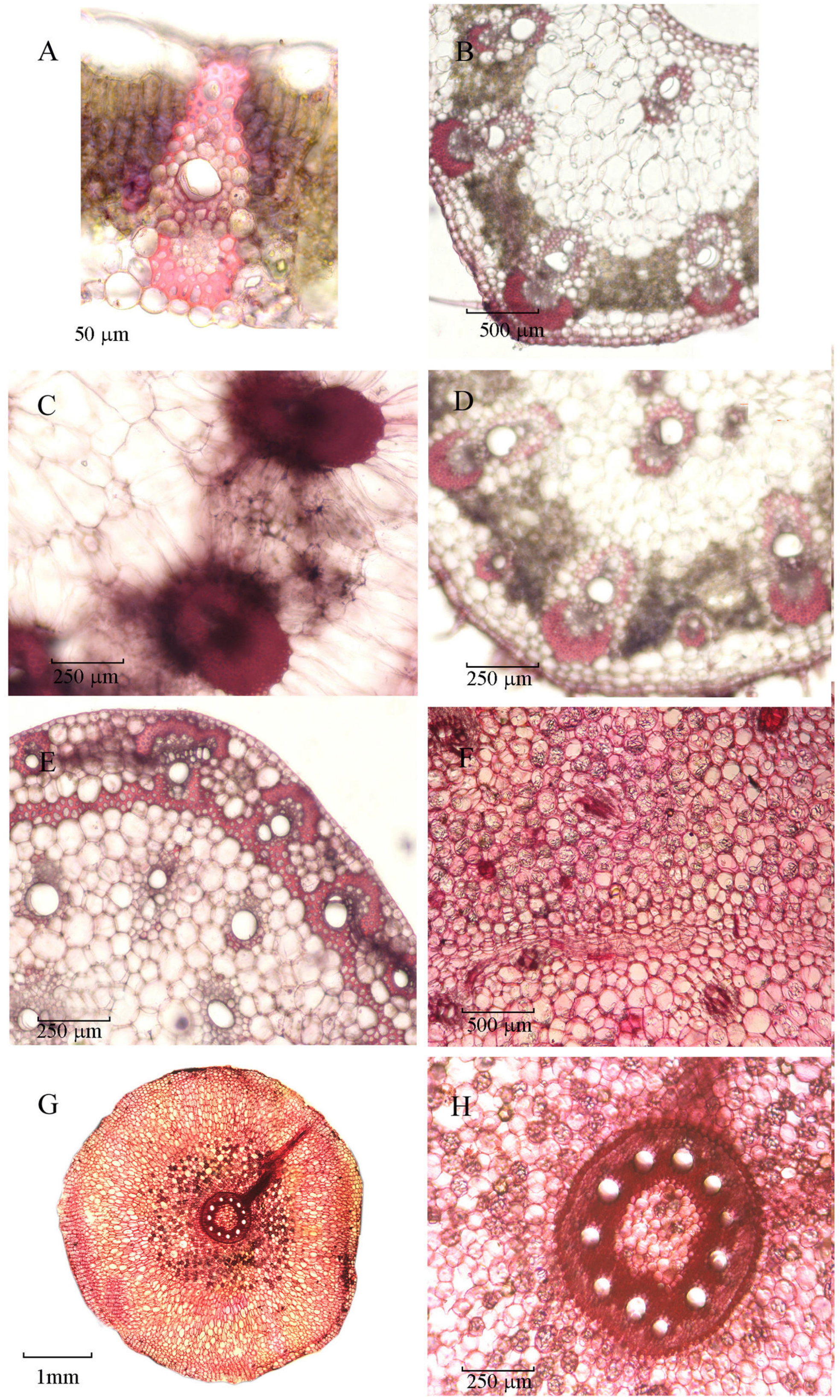


Plate 03. *Zingiber capitatum* var. *elatum* - T. S. of **A.** Leaf; **B.** Midrib; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stele.

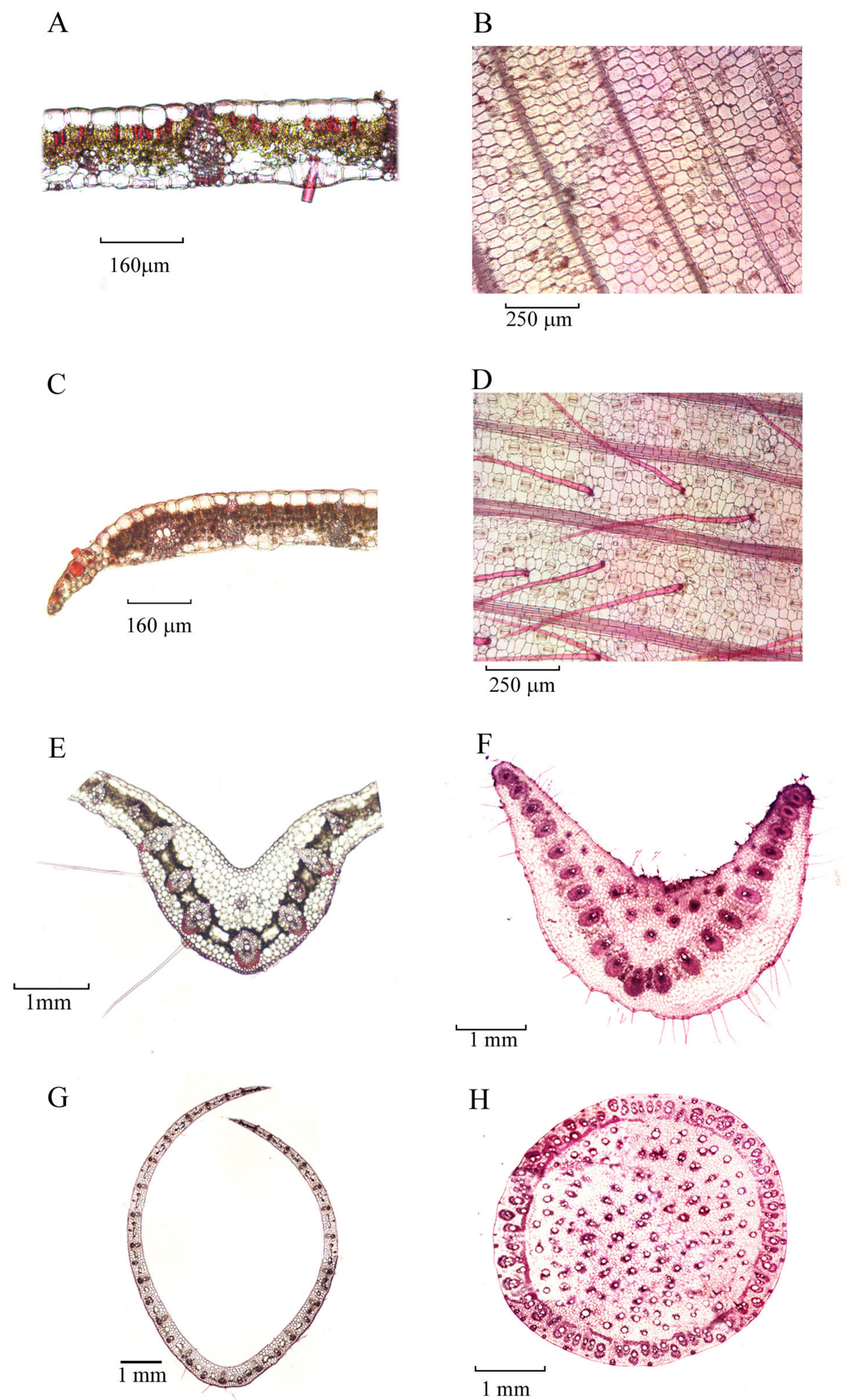


Plate 06. ***Zingiber montanum*** - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

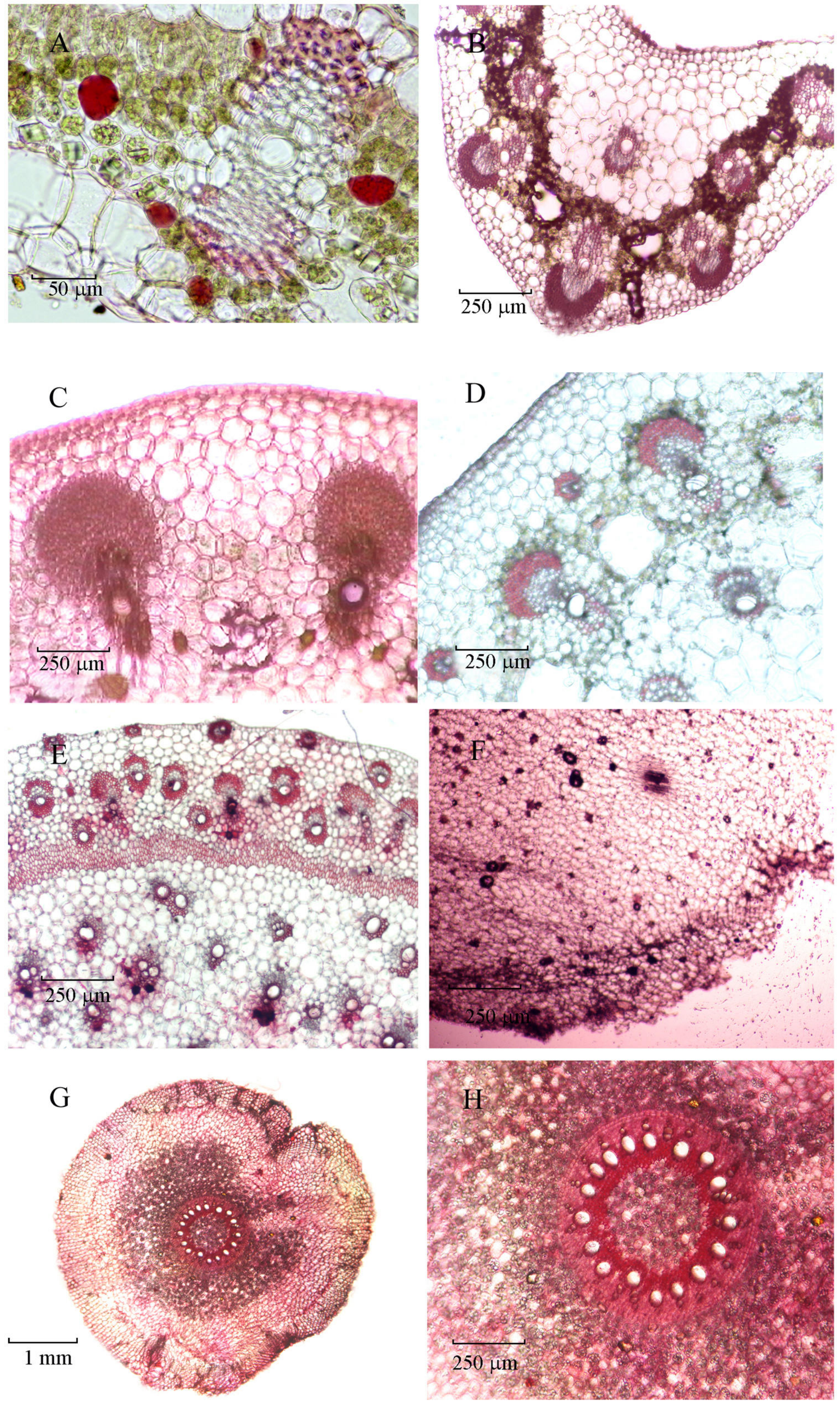


Plate 05. ***Z.ingiber cernuum*** **-** T. S. of **A.** Leaf; **B.** Midrib ; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stele.

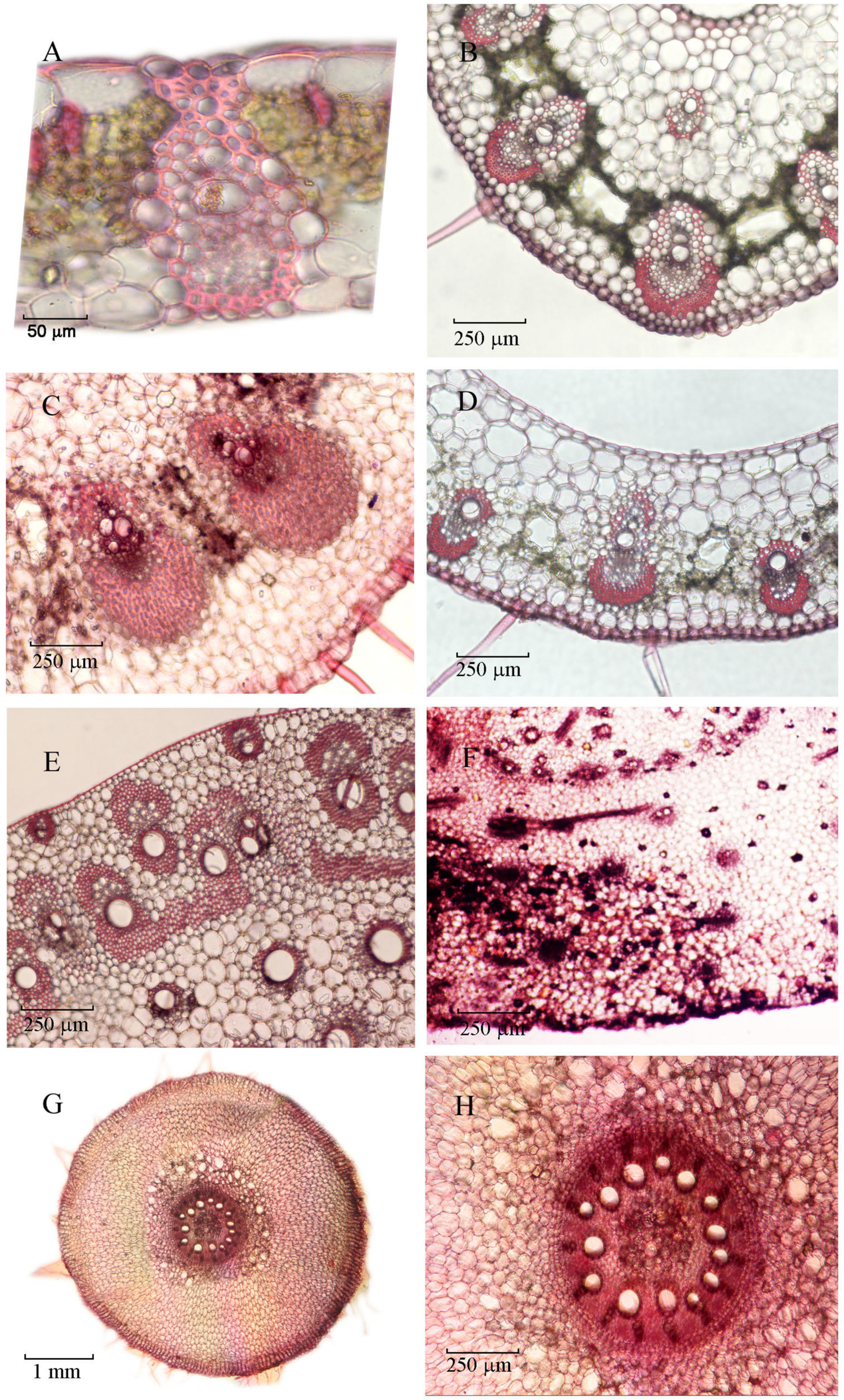


Plate 07. *Zingiber montanum* - T. S. of **A.** Leaf; **B.** Midrib ; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stele.

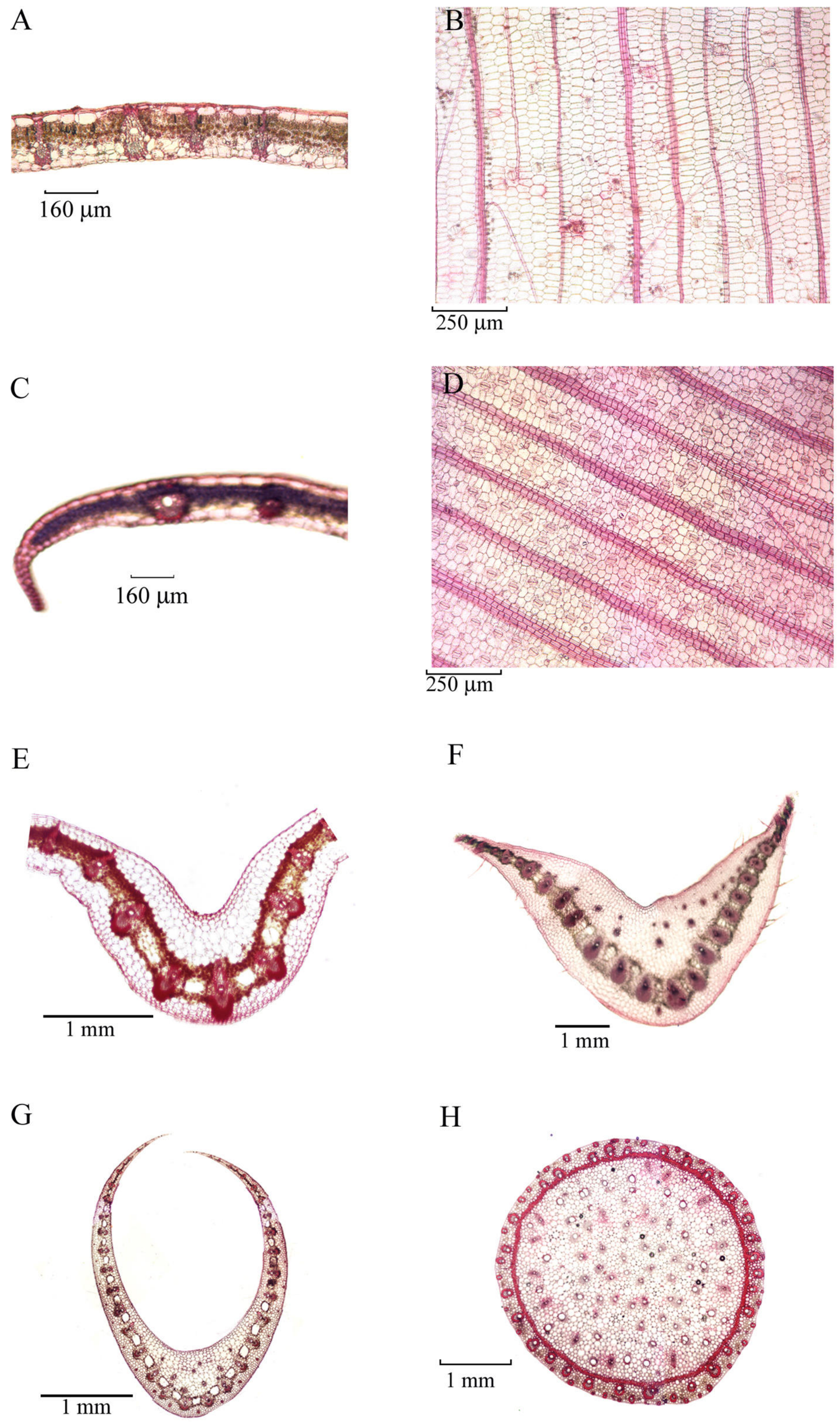


Plate 08. *Zingiber neesanum* - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

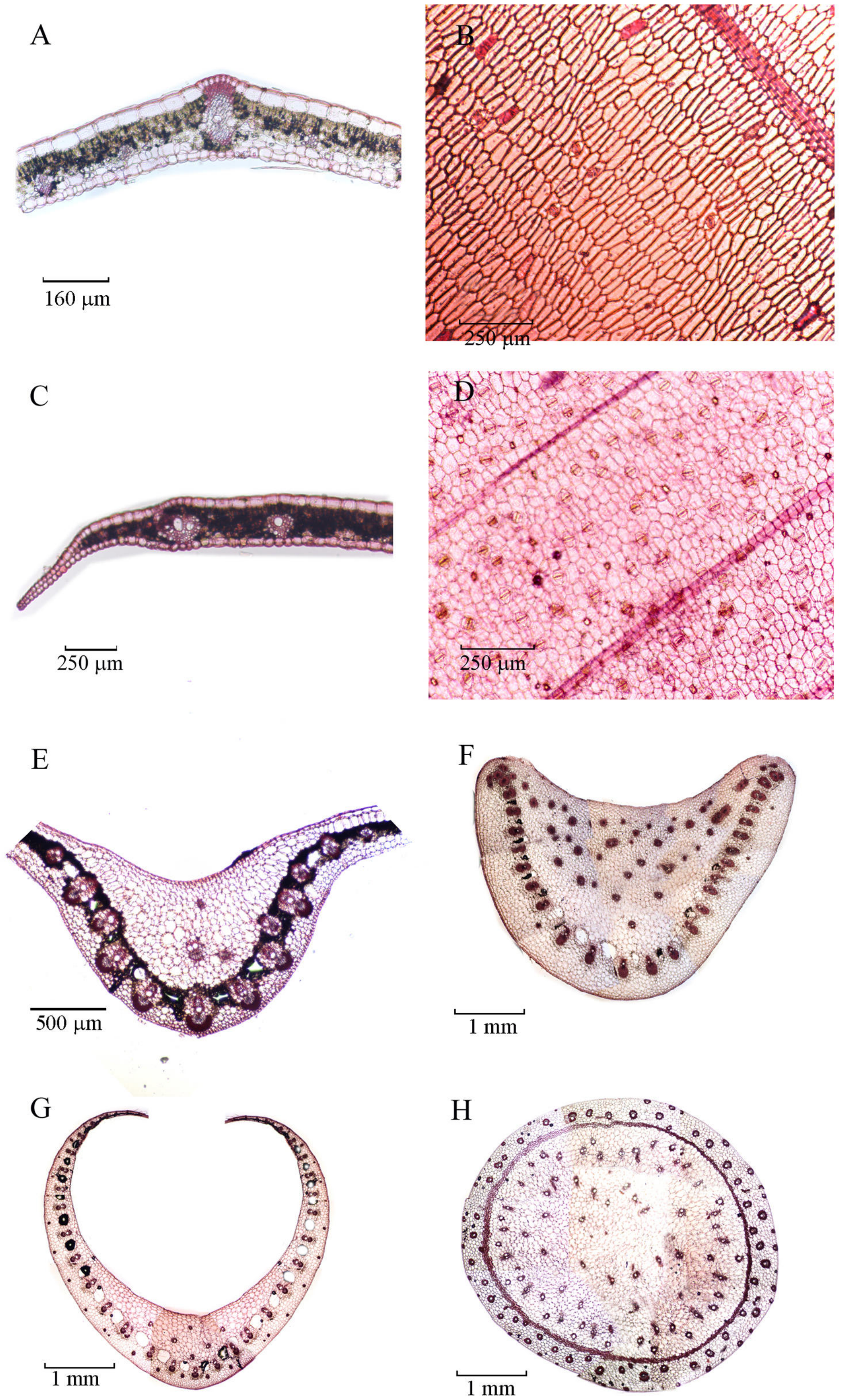


Plate 10. ***Zingiber nimmonii*** - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

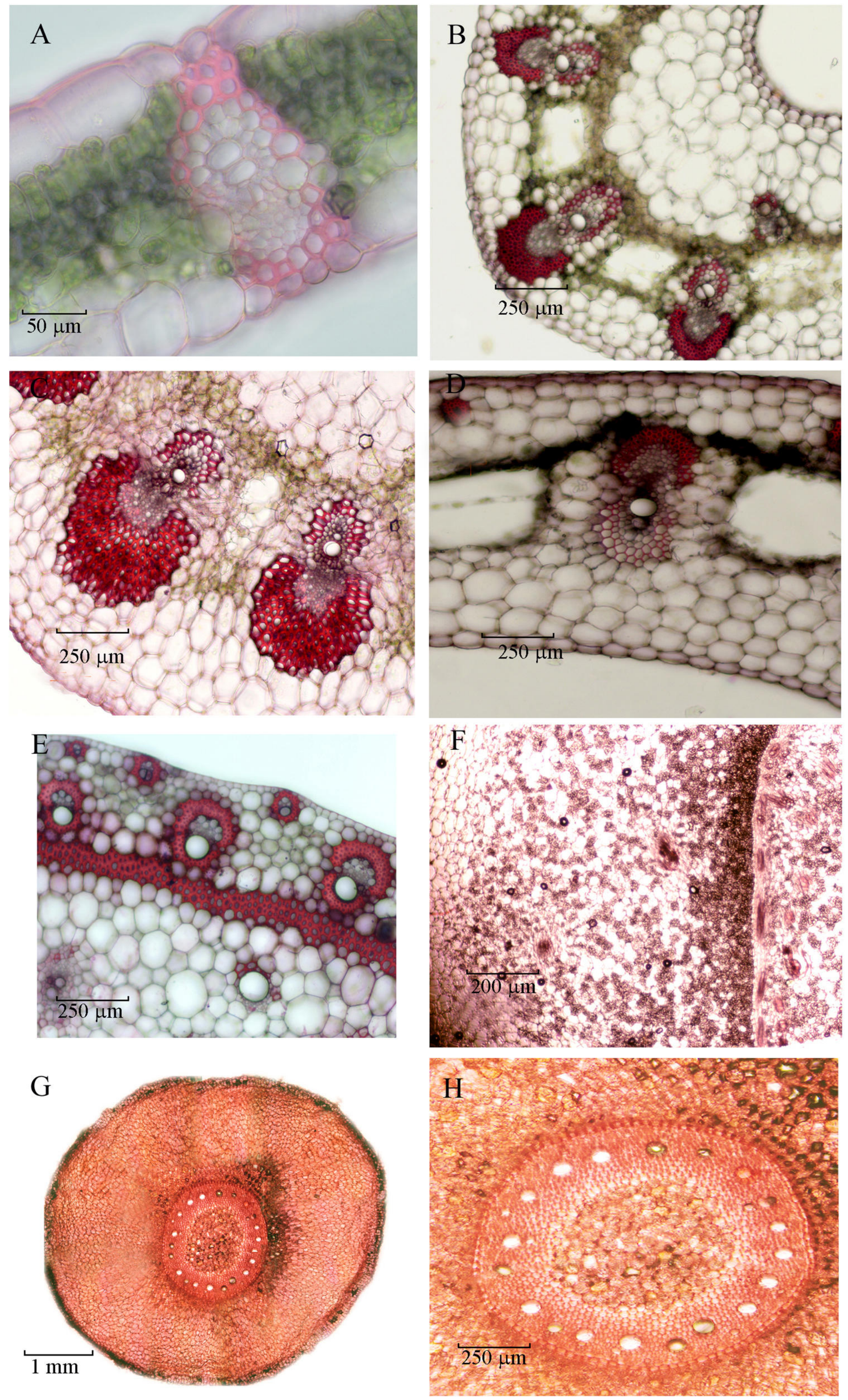


Plate 09. ***Zingiber neesanum*** **-** T. S. of **A.** Leaf; **B.** Midrib ; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stele.

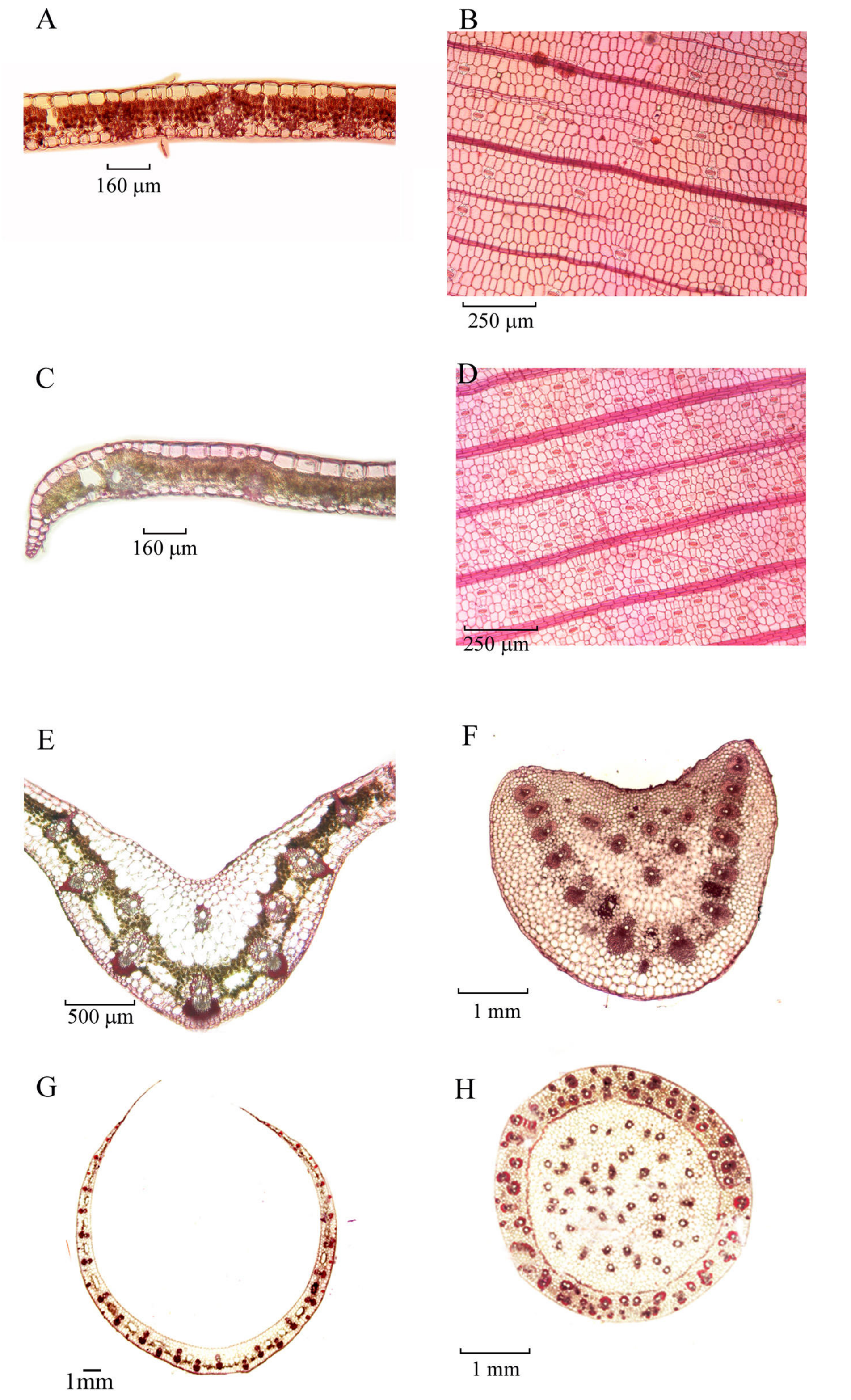


Plate 12. *Zingiber officinale* - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

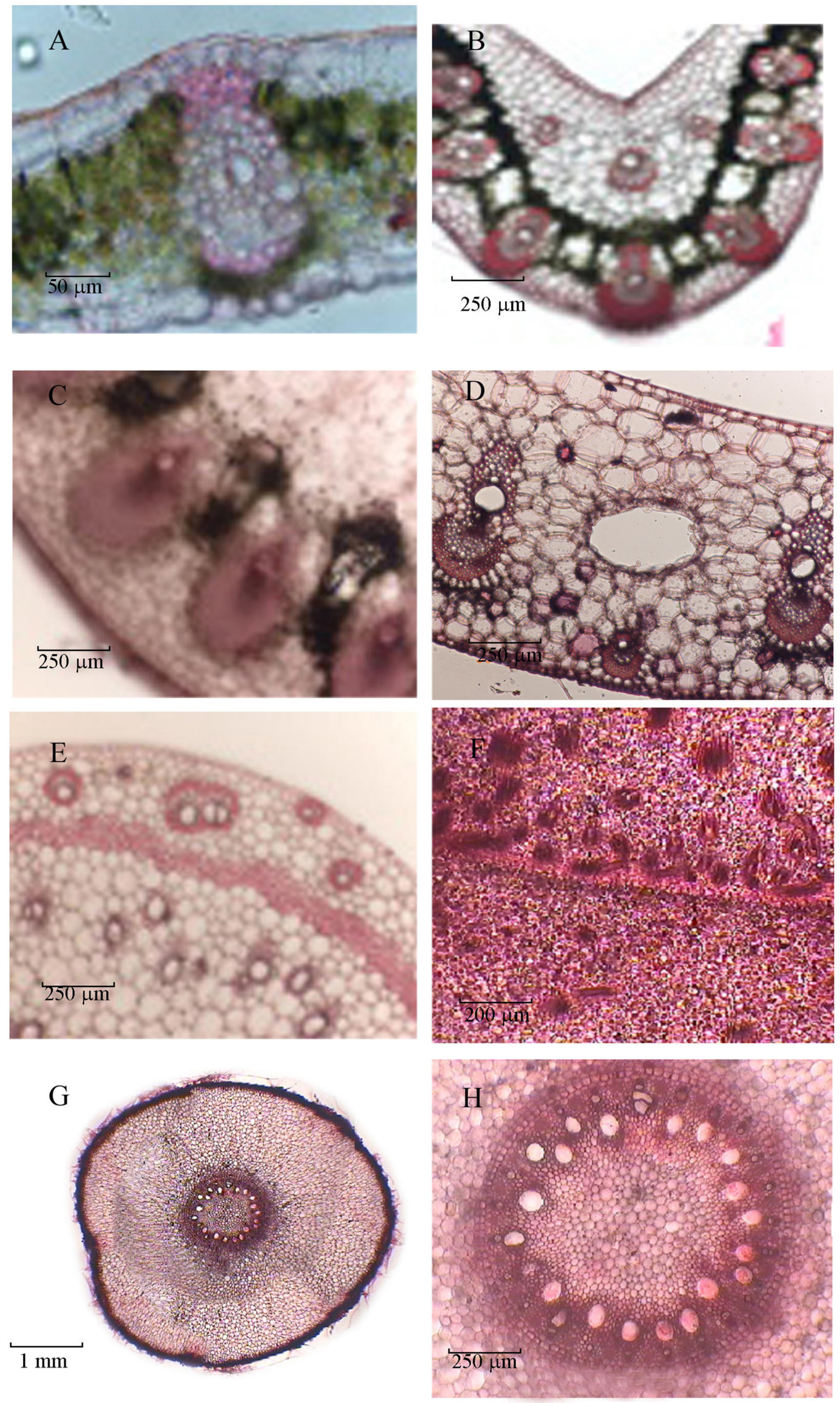


Plate 11. *Zingiber nimmonii* - T. S. of **A.** Leaf **B.** Midrib ; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stele.

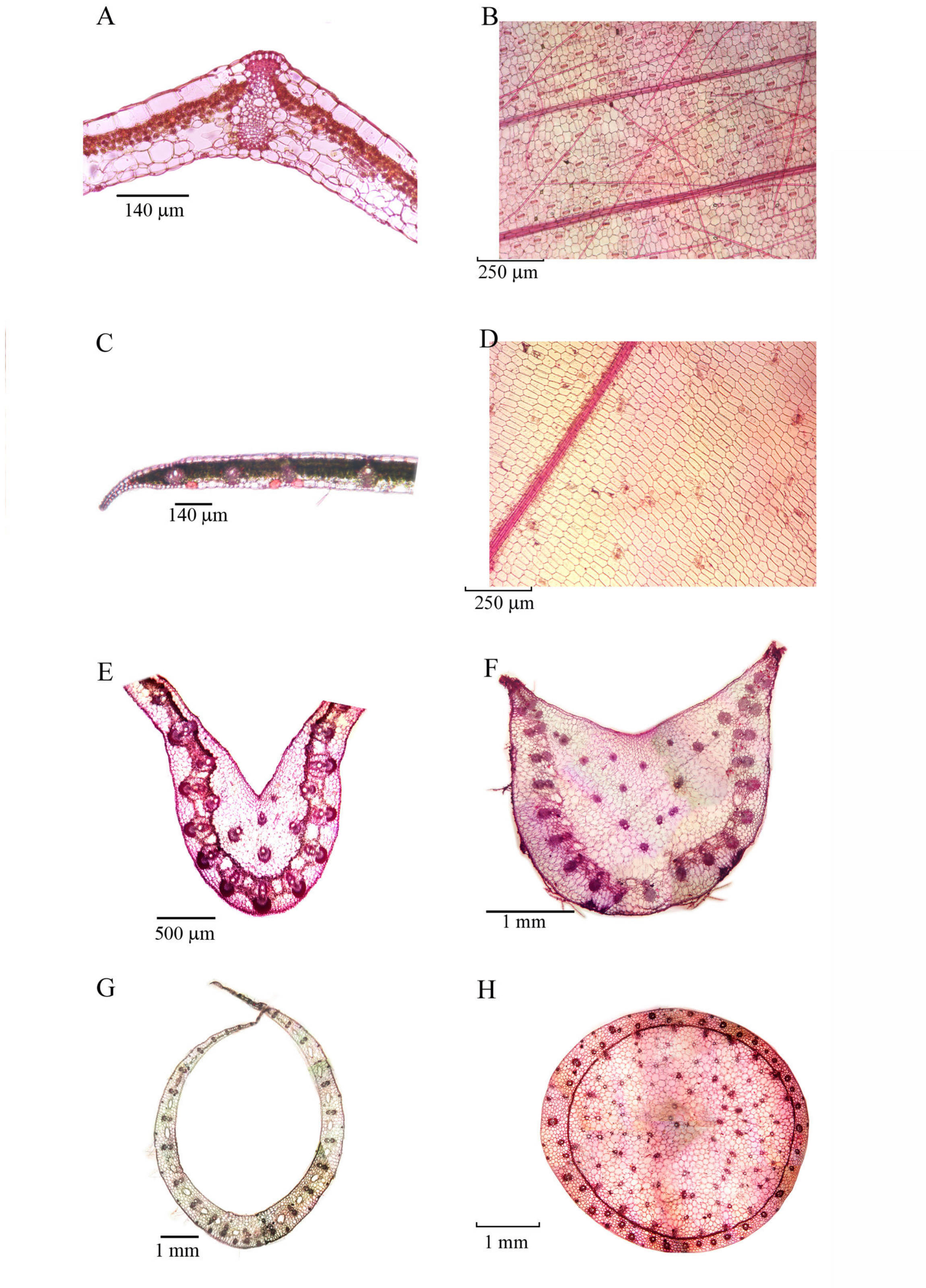


Plate 14. *Zingiber roseum* - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

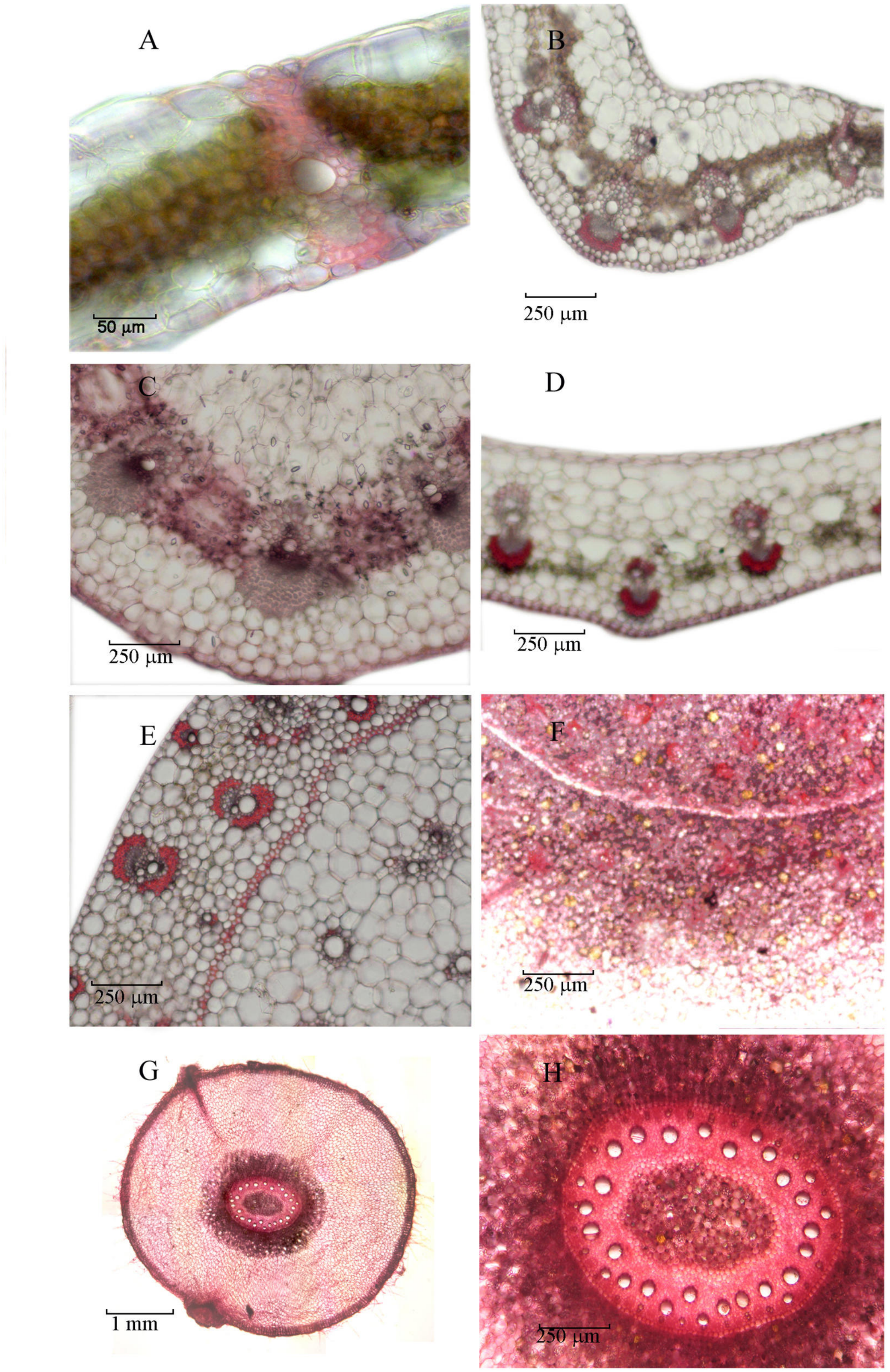


Plate 13. *Zingiber officinale* - T. S. of **A.** Leaf; **B.** Midrib ; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stele.

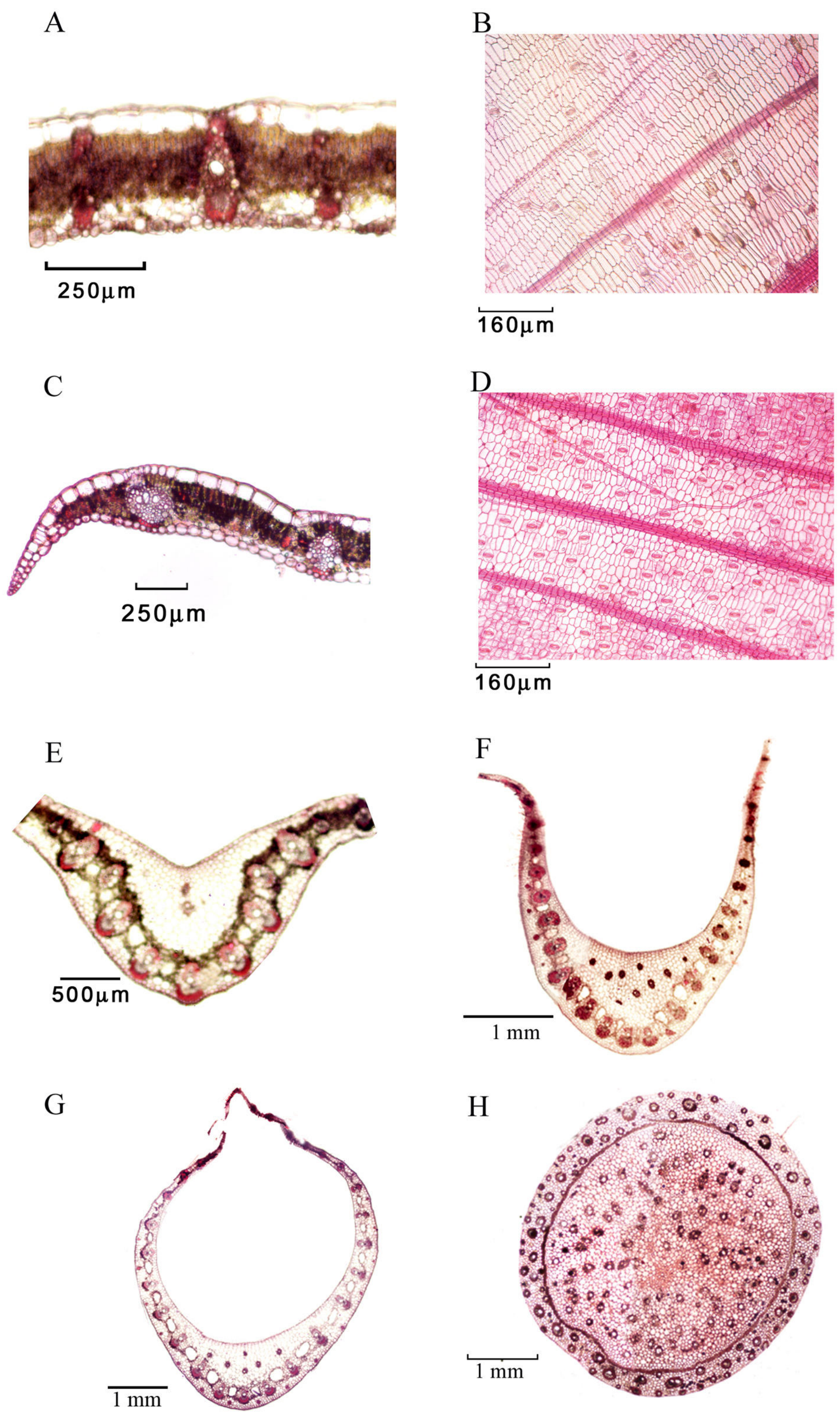


Plate 16. *Zingiber wightianum* - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

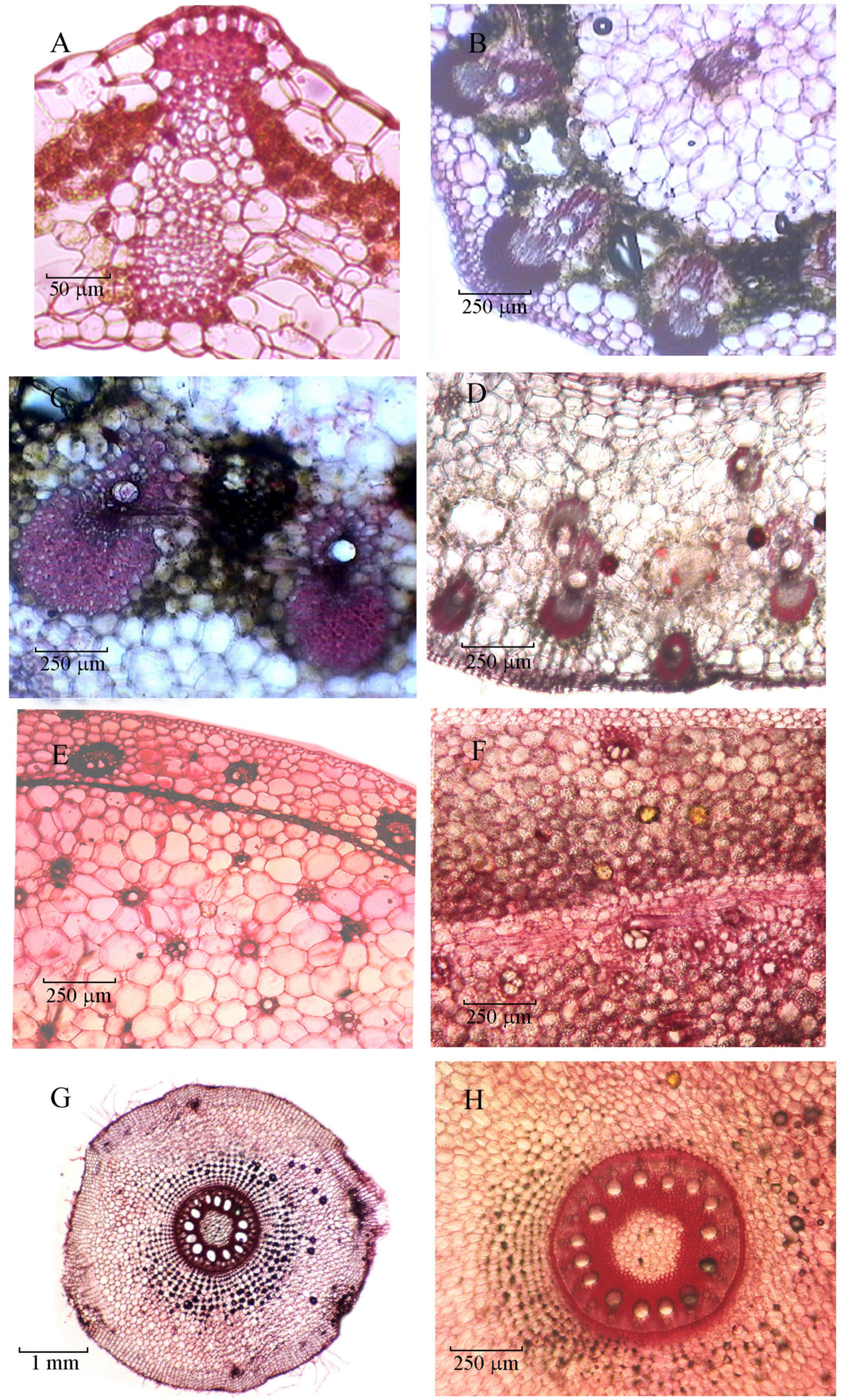


Plate 15. *Zingiber roseum* - T. S. of **A.** Leaf; **B.** Midrib ; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stele.

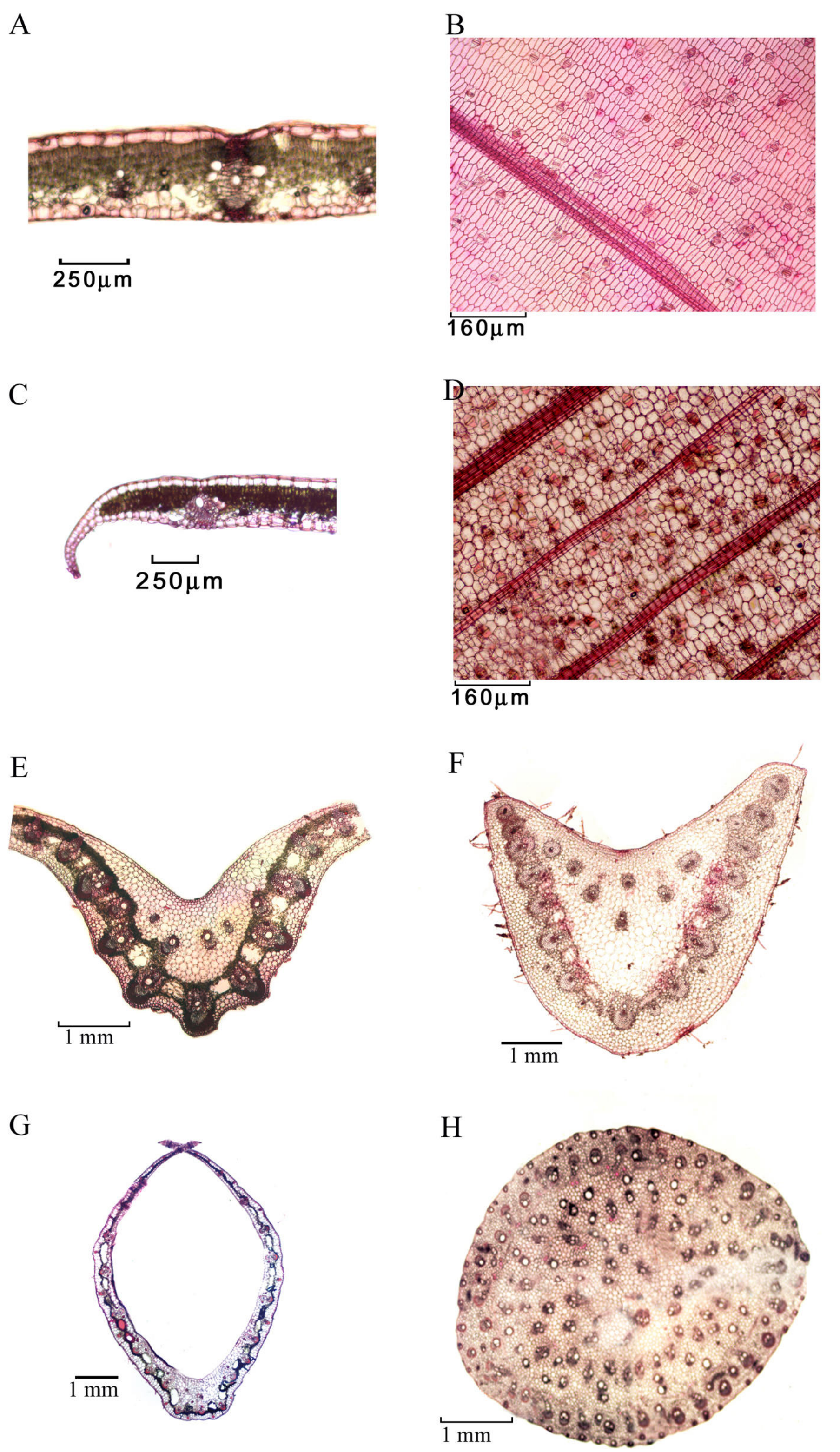


Plate 18. ***Zingiber zerumbet*** - Transverse sections and epidermal peelings of aerial parts: **A.** Lamina; **B.** Adaxial epidermis; **C.** Margin; **D.** Abaxial epidermis ; **E.** Midrib; **F.** Pulvinus; **G.** Leaf sheath; **H.** Stem.

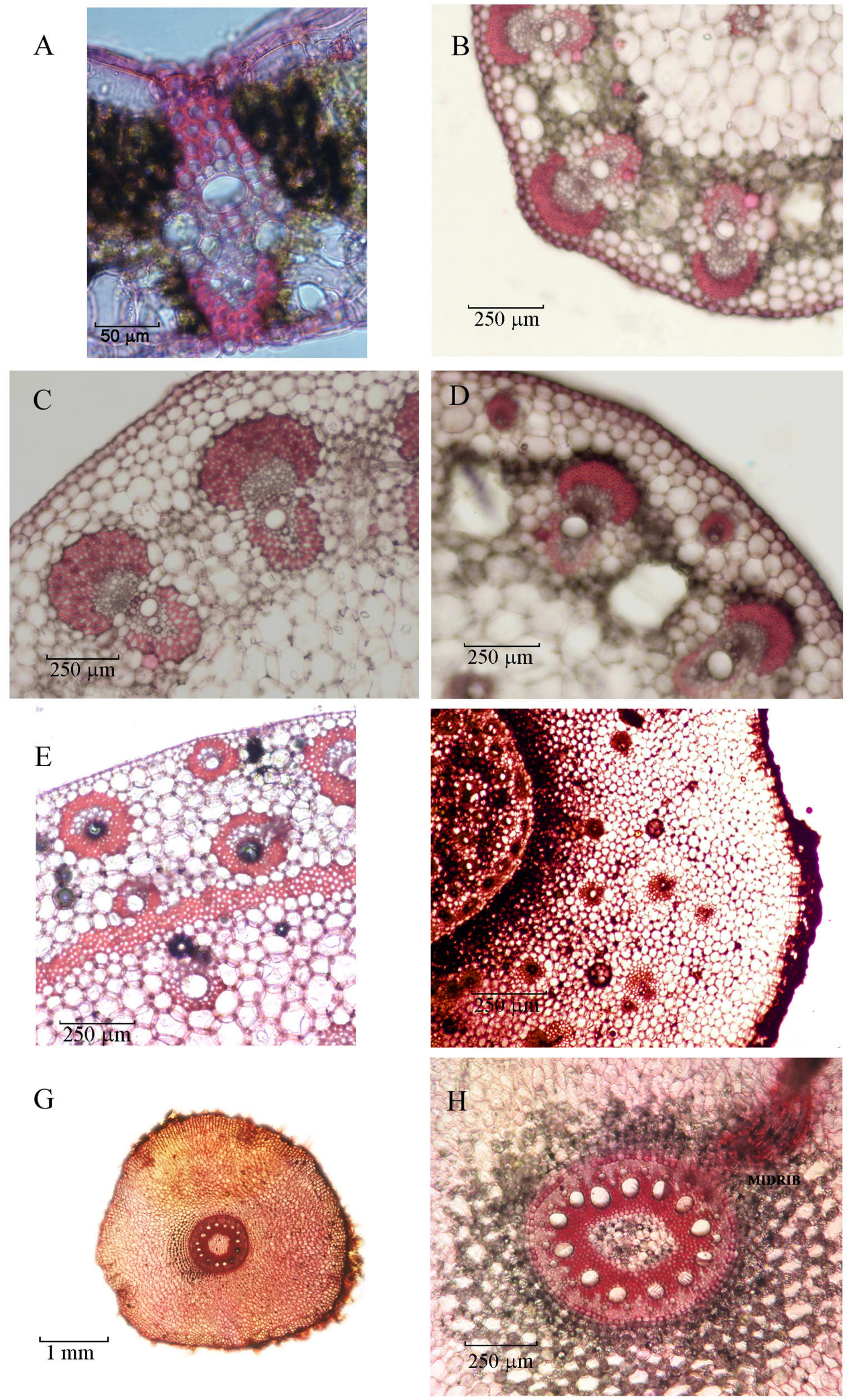


Plate 17. ***Zingiber wightianum*** **-** T. S. of **A.** Leaf **B.** Midrib ; **C.** Pulvinus; **D.** Leaf sheath; **E.** Stem; **F.** Rhizome; **G.** Root; **H.** Stem.

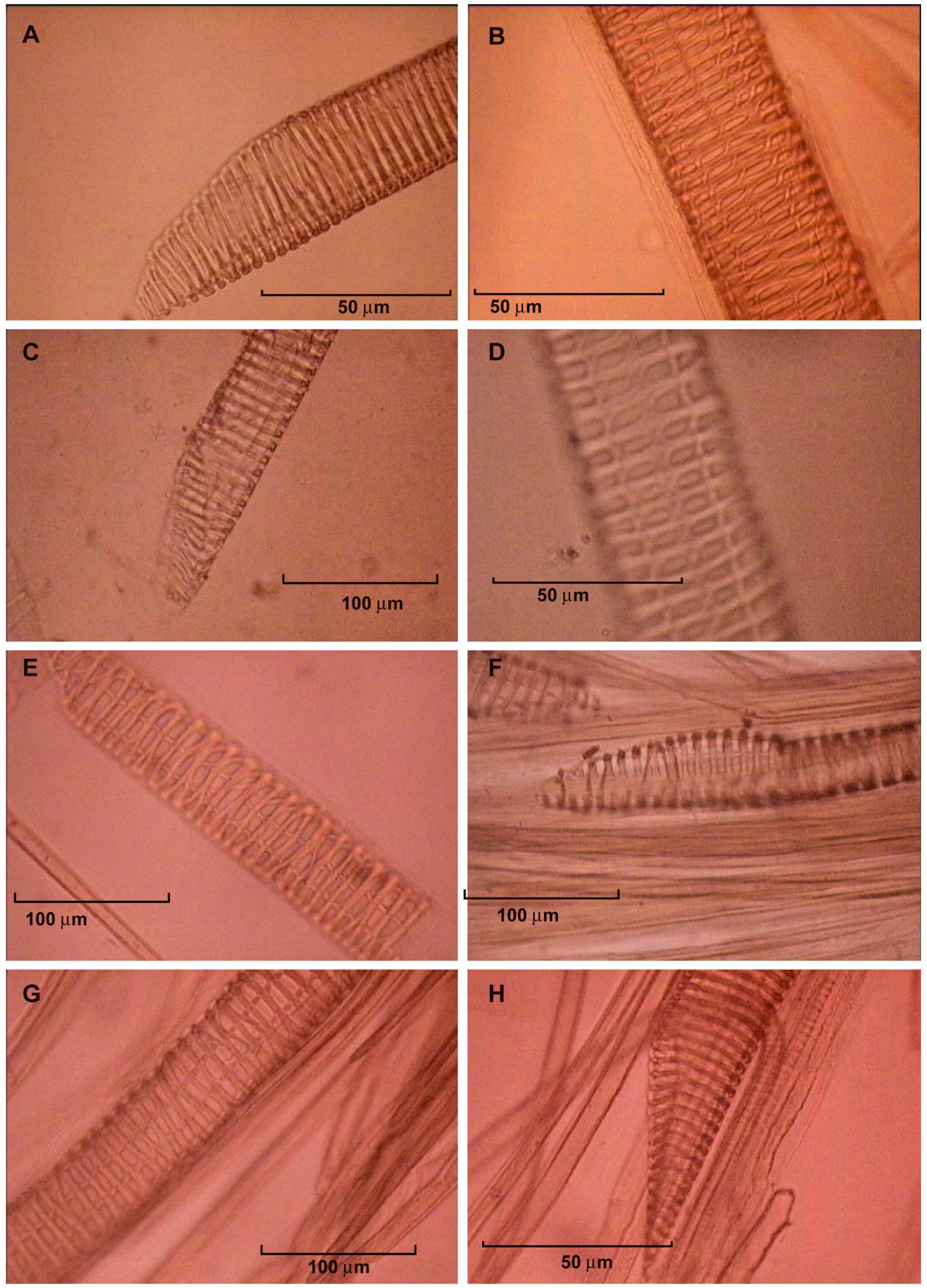


Plate 20. Xylem elements of various parts: **A&B**. *Zingiber capitatum* var. *elatum*; **C&D**. *Z. cernuum*; **E&F**. Z. montanum; **G&H**. *Z. neesanum*.

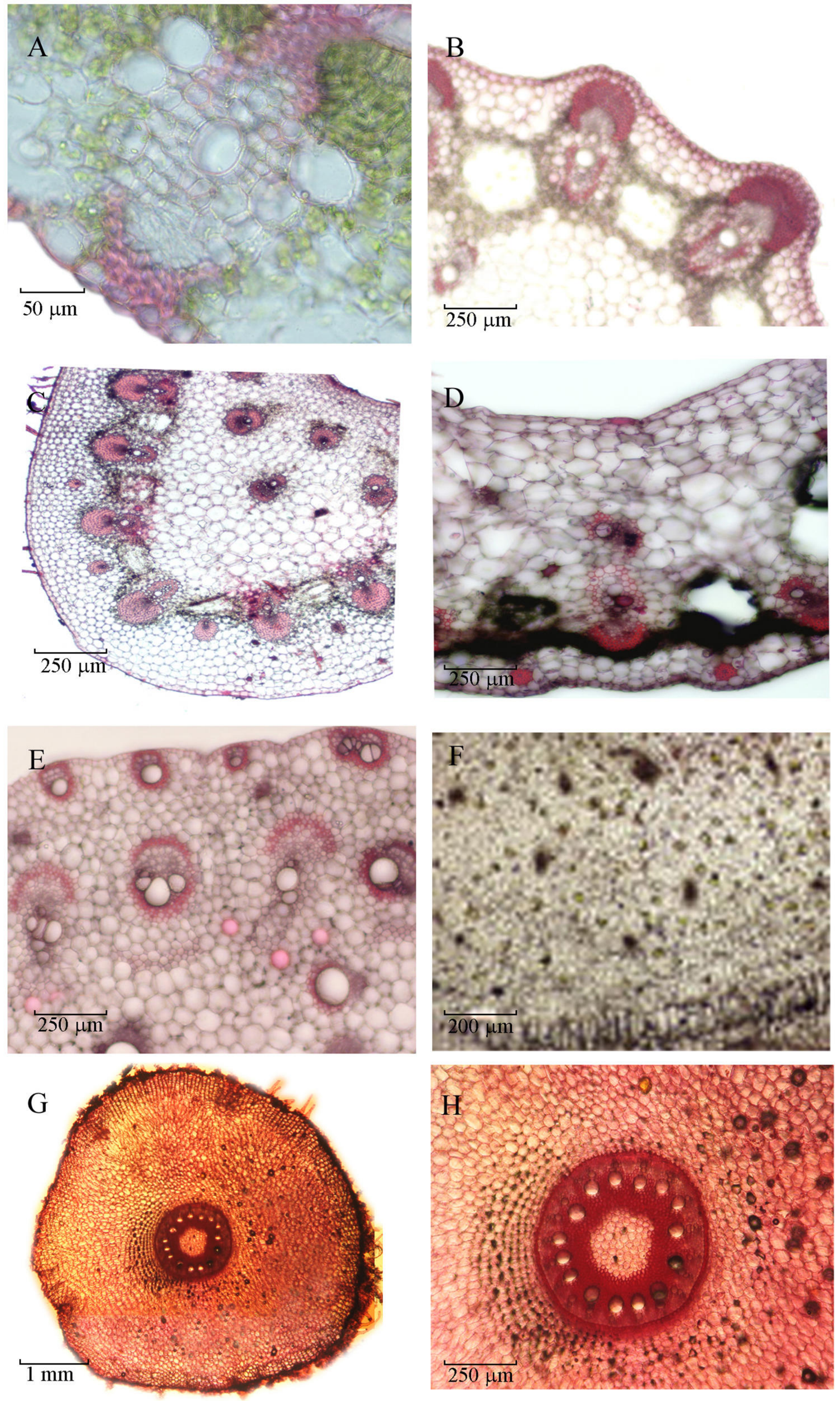


Plate 19. *Zingiber zerumbet* - T. S. of **A**. Leaf **B**. Midrib ; **C**. Pulvinus; **D**. Leaf sheath; **E**. Stem; **F**. Rhizome; **G**. Root; **H**. Stele.

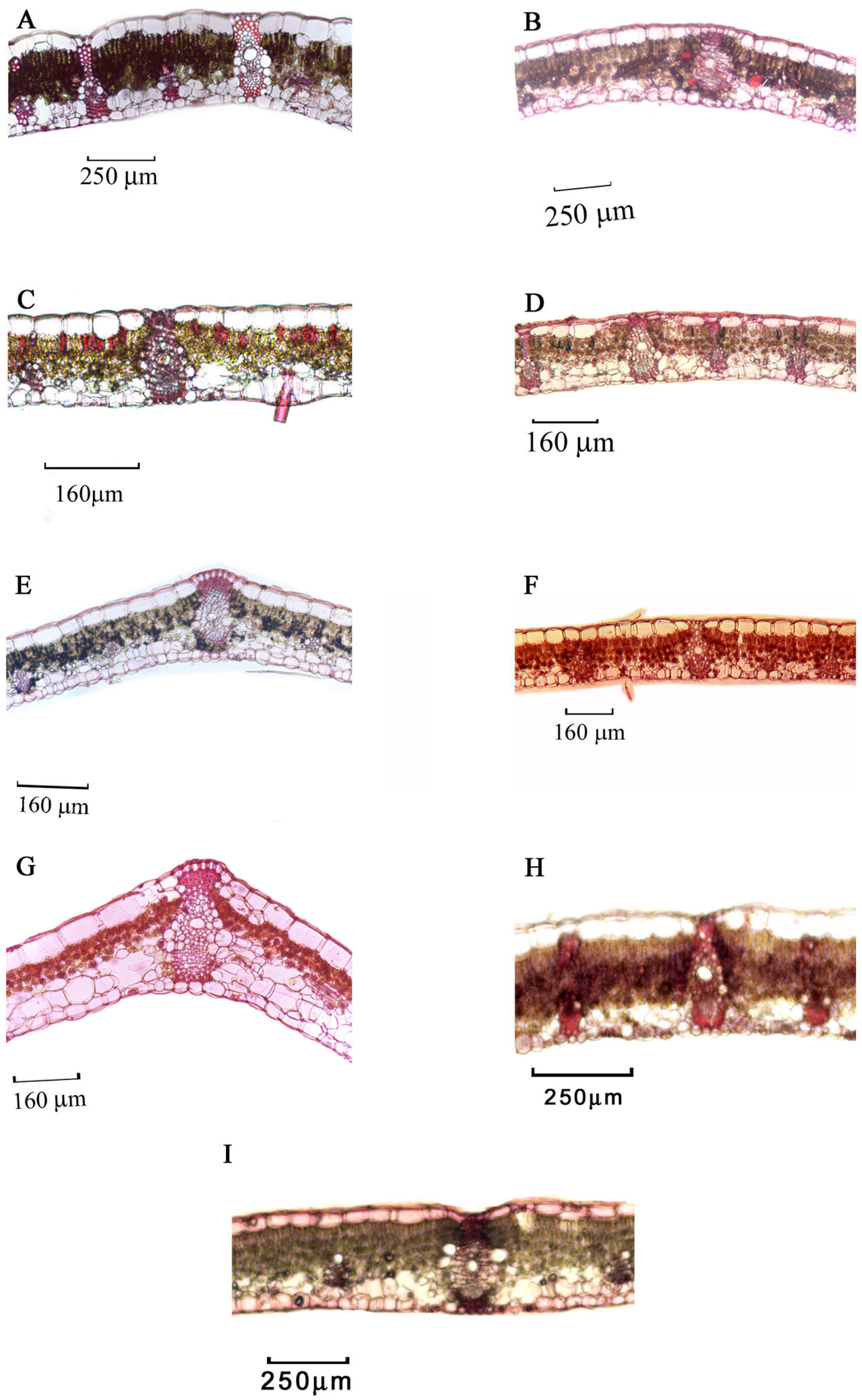


Plate 22. Comparison of T. S. of lamina: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **D.** *Z. neesanum*; **E.** *Z. nimmonii*; **F.** *Z. officinale*; **G.** *Z. roseum*; **H.** *Z. wightianum*; **I.** *Z. zerumbet*.

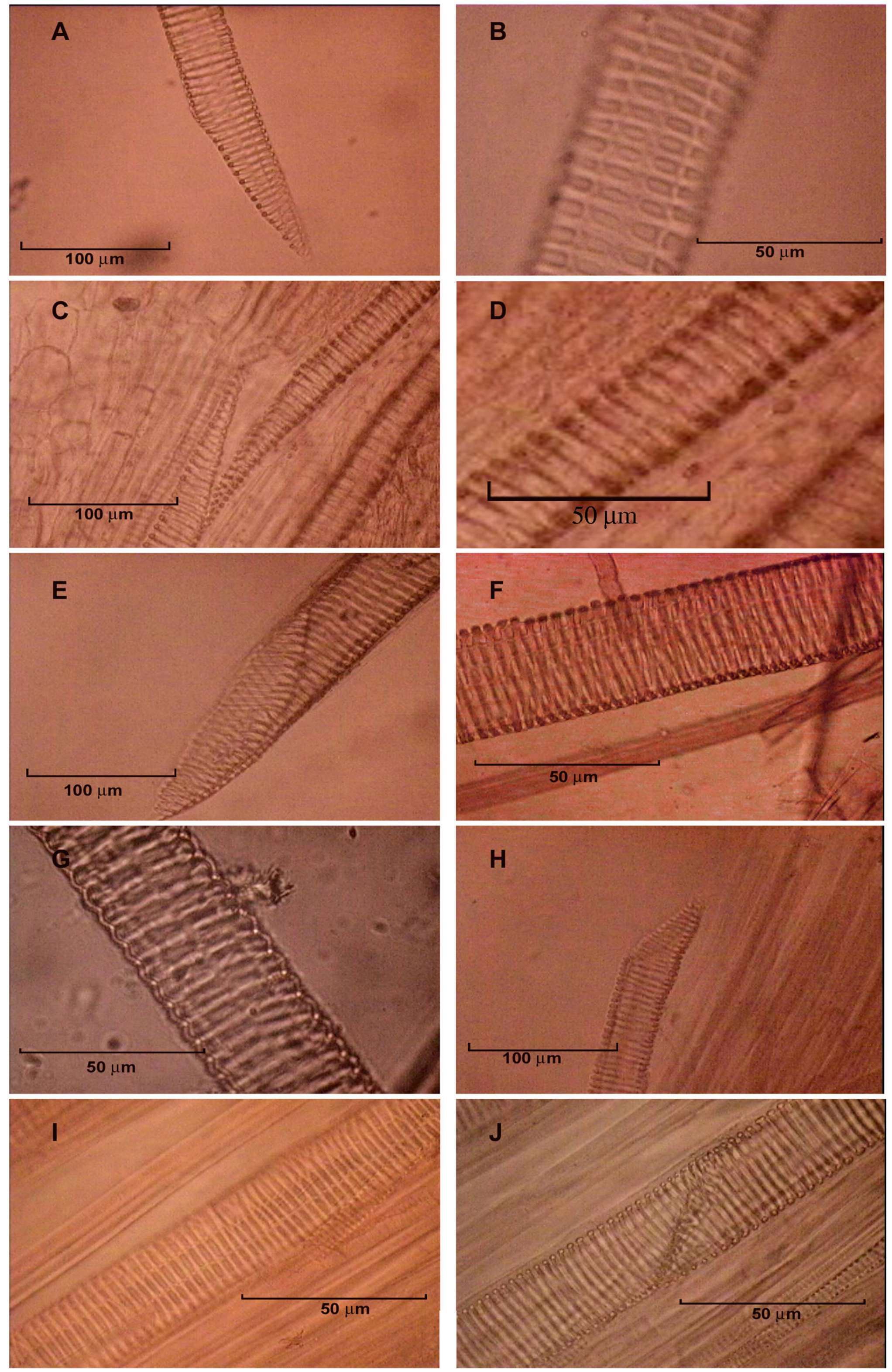


Plate 21. Xylem elements of various parts: **A&B**. *Zingiber nimmonii*; **C&D**. *Z. officinale*; **E&F**. *Z. roseum*; **G&H**. *Z. wightianum*; **I&J**. *Z. zerumbet*.

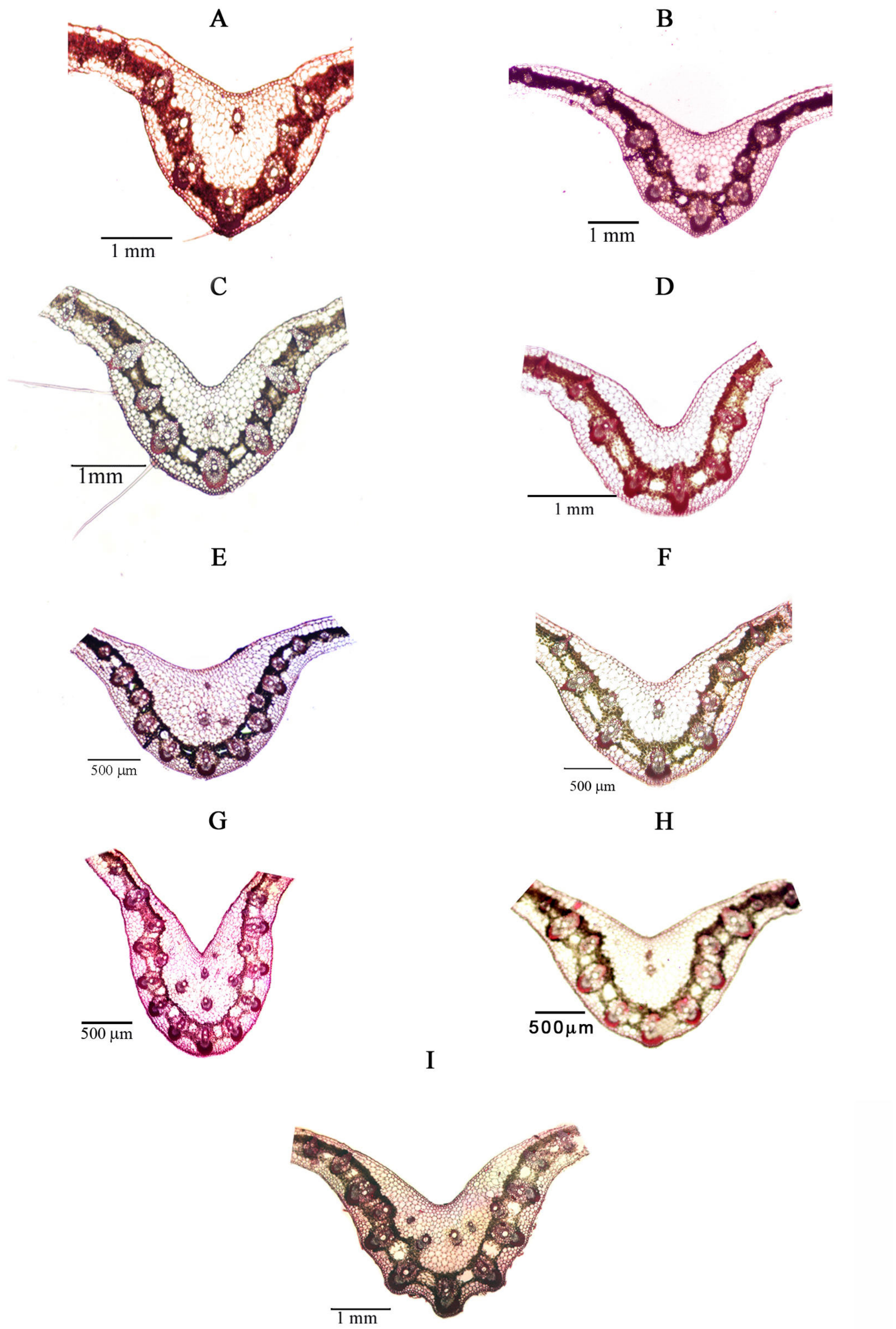


Plate 24. Comparison of T. S. of Midrib: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **D.** *Z. neesanum*; **E.** *Z. nimmonii*; **F.** *Z. officinale*; **G.** *Z. roseum*; **H.** *Z. wightianum*; **I.** *Z. zerumbet*.

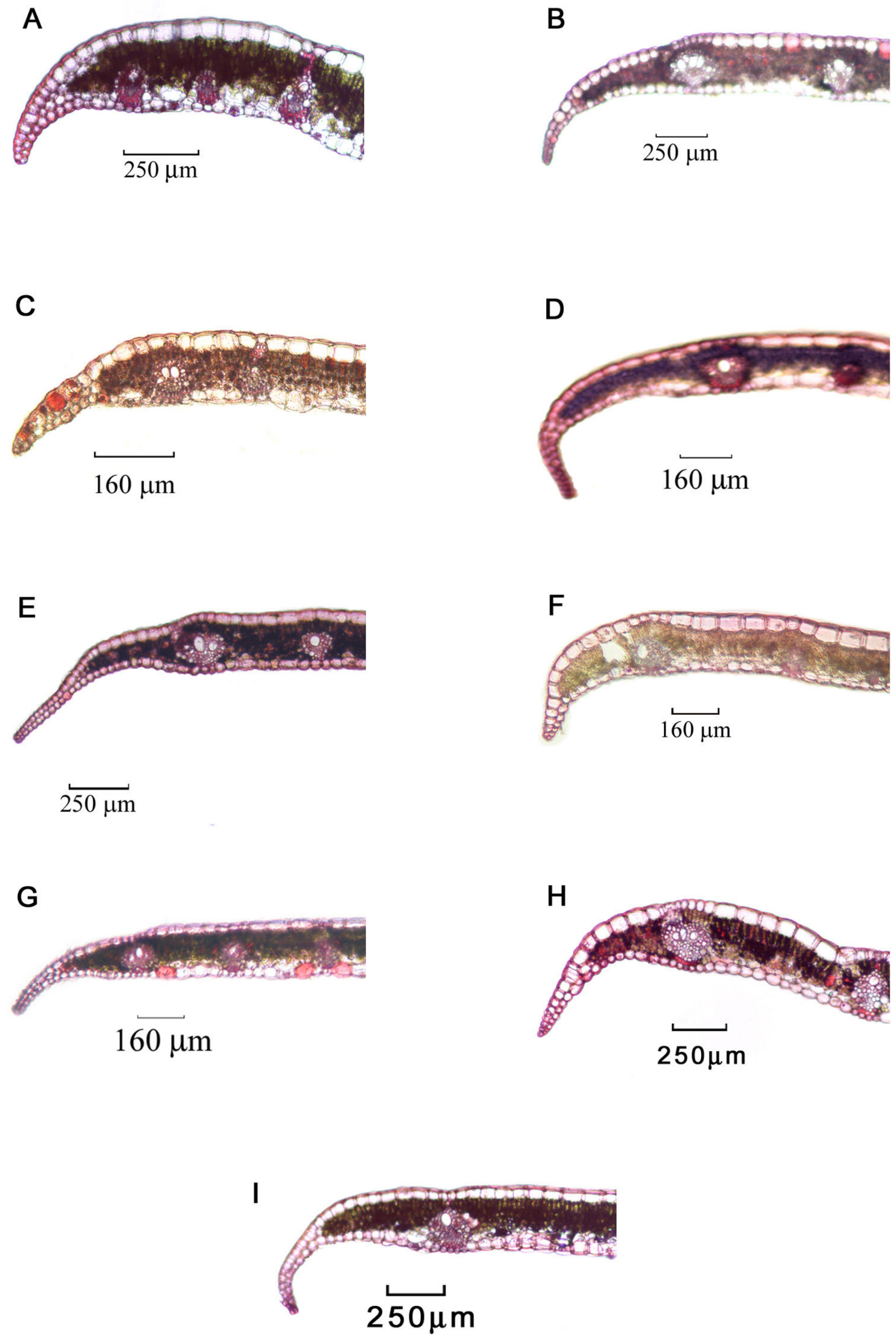


Plate 23. Comparison of T. S. of Leaf margin: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **D.** *Z. neesanum*; **E.** *Z. nimmonii*; **F.** *Z. officinale*; **G.** *Z. roseum*; **H.** *Z. wightianum*; **I.** *Z. zerumbet*.

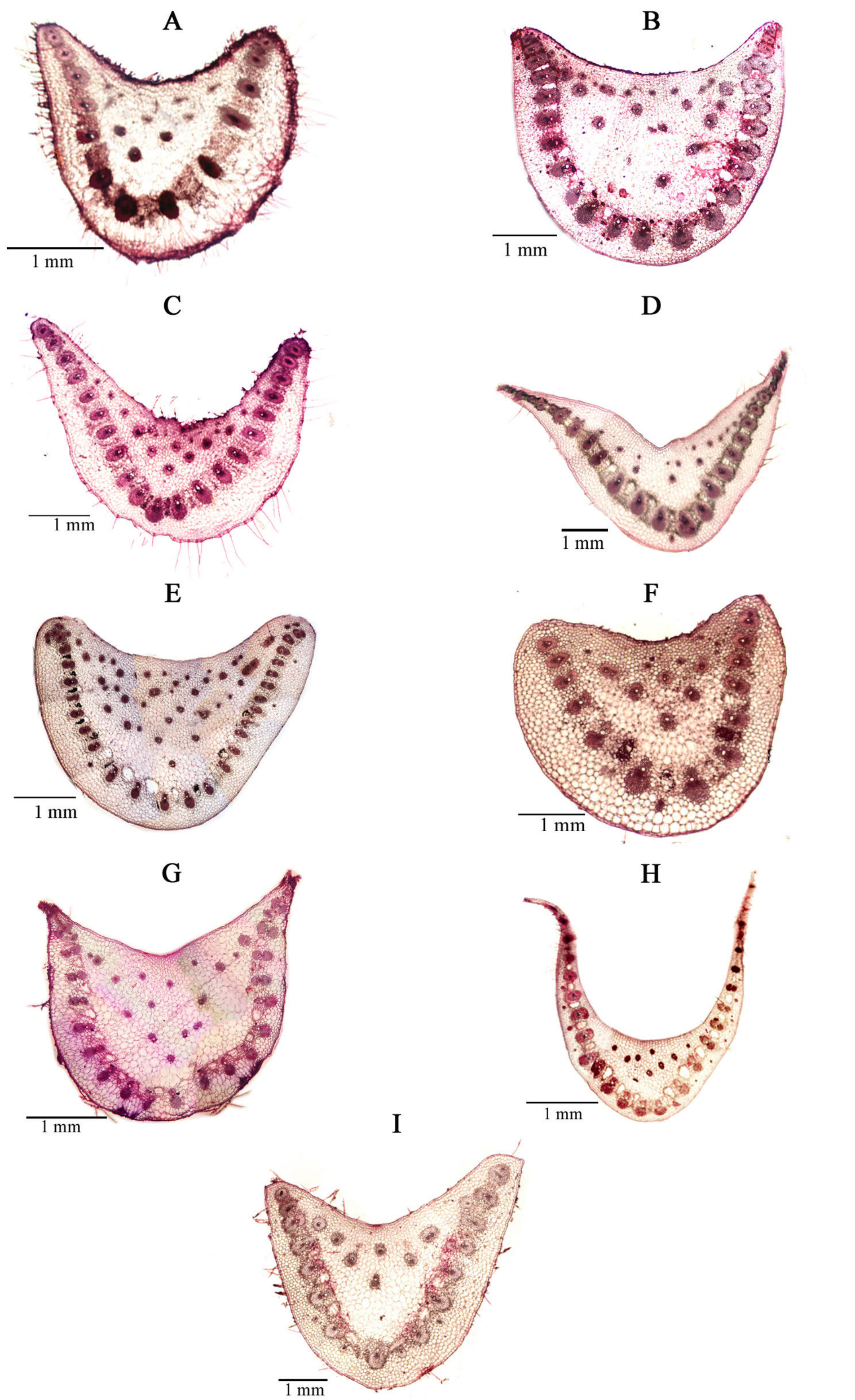


Plate 25. Comparison of T. S. of Pulvinus: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **D.** *Z. neesanum*; **E.** *Z. nimmonii*; **F.** *Z. officinale*; **G.** *Z. roseum*; **H.** *Z. wightianum*; **I.** *Z. zerumbet*.

Plate 26. Comparison of T. S. of Leaf sheath: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **D.** *Z. neesanum*; **E.** *Z. nimmonii*; **F.** *Z. officinale*; **G.** *Z. roseum*; **H.** *Z. wightianum*; **I.** *Z. zerumbet*.

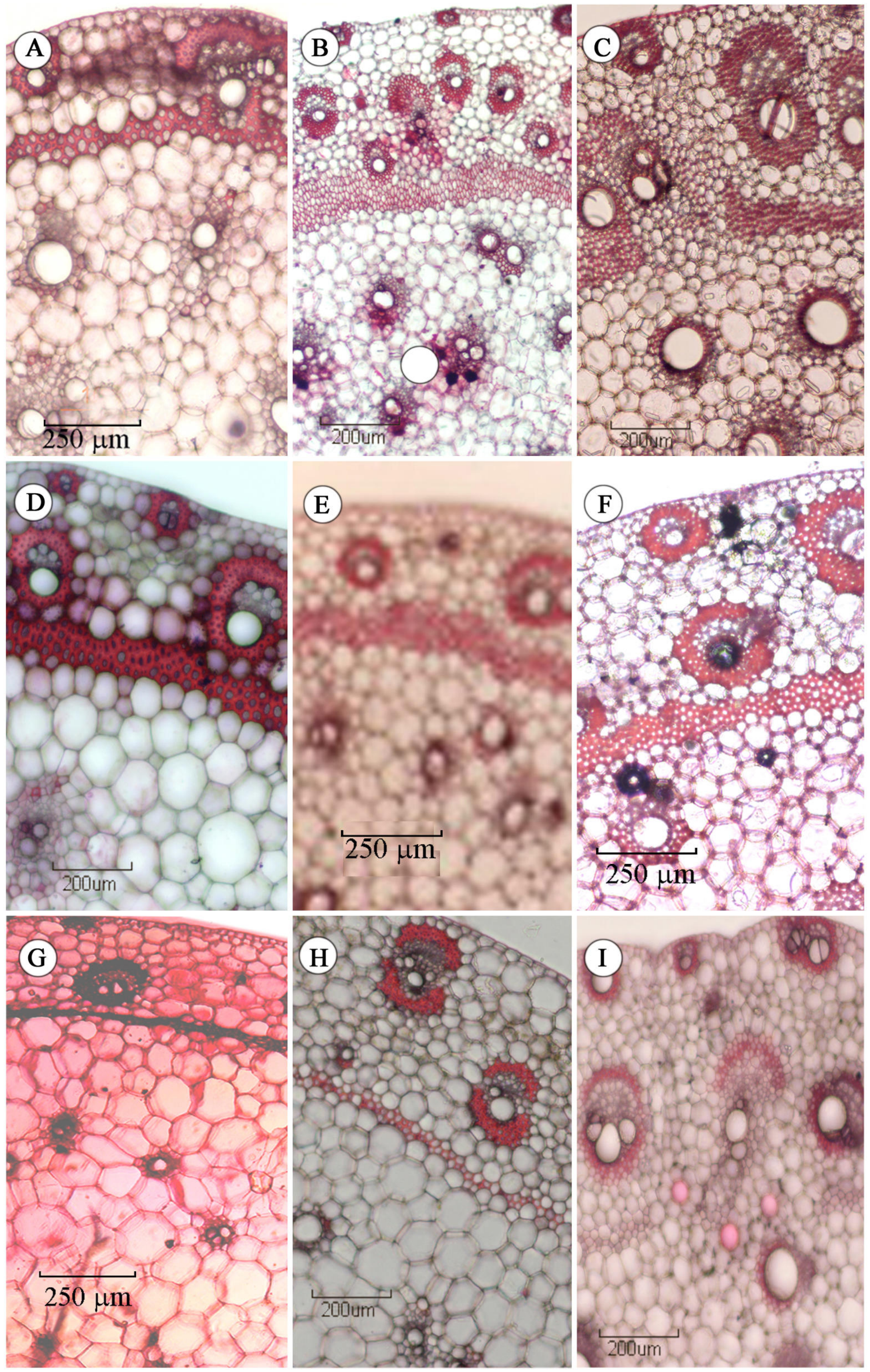


Plate 27. Comparison of T. S. of Stem: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **D.** *Z. neesanum*; **E.** *Z. nimmonii*; **F.** *Z. officinale*; **G.** *Z. roseum*; **H.** *Z. wightianum*; **I.** *Z. zerumbet*.

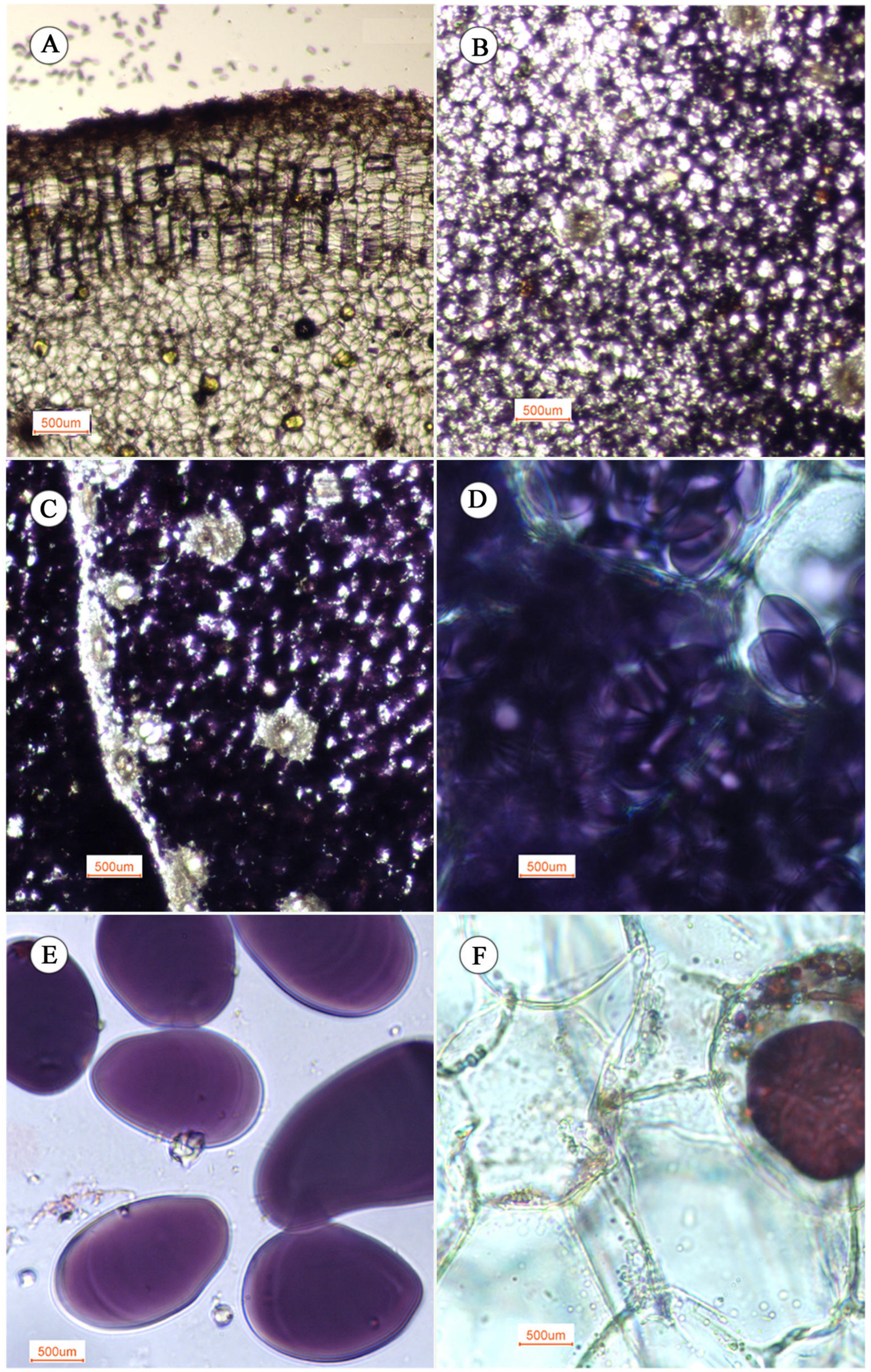


Plate 28. T. S. of Rhizome: **A.** Periderm; **B.** Cortex; **C.**Centre cylinder; **D.** Strach grains; **E.** Strach grains enlarged; **F.** Silica granules.

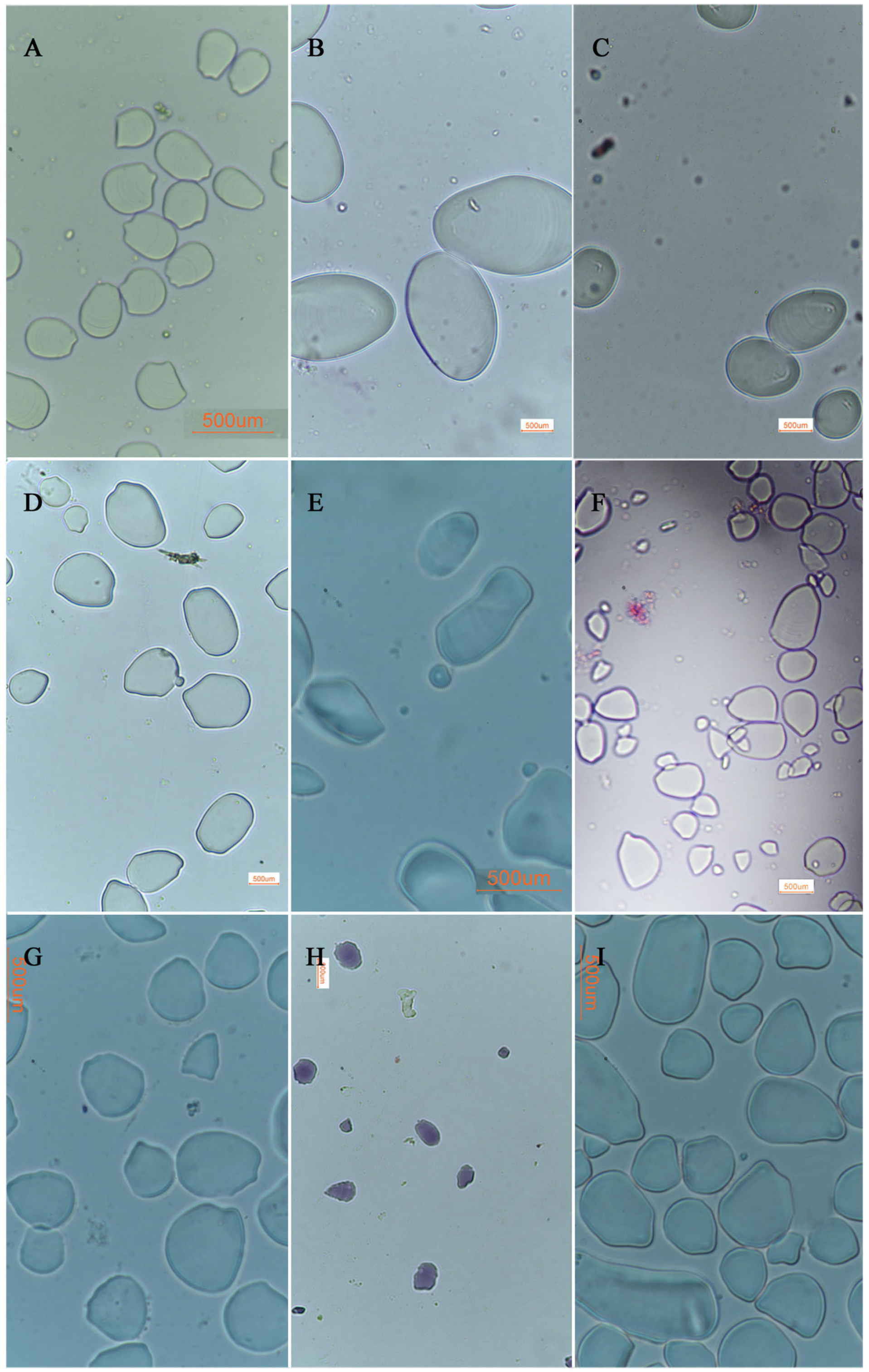


Plate 29. Starch grains of: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; C. *Z. montanum*; D. *Z. neesanum;* E. *Zingiber nimmonii*; F. *Z. officinale*; G. *Z. roseum*; H. *Z. wightianum*; I. *Z. zerumbet.*

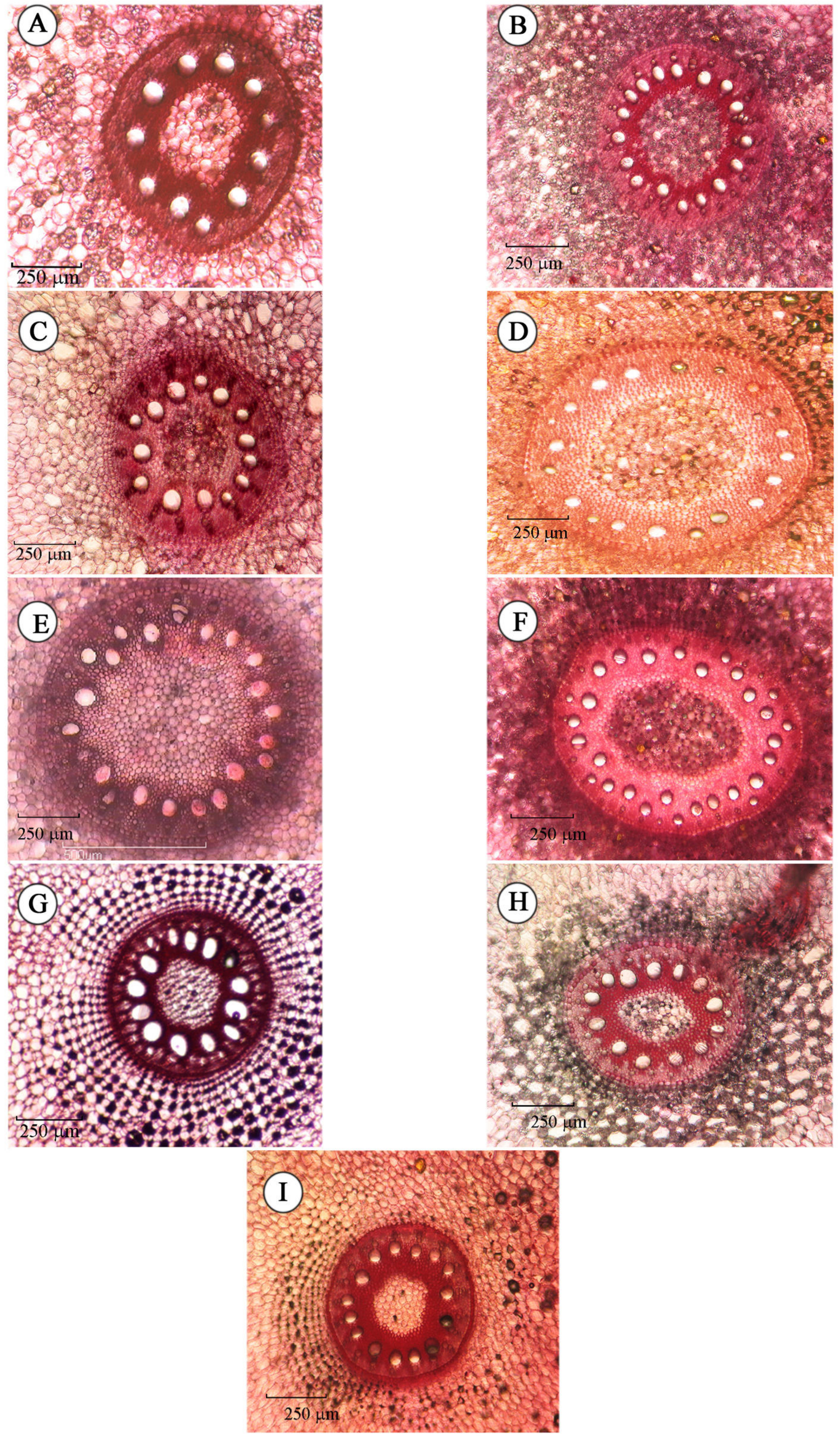


Plate 30. Comparison of T. S. of root: **A.** *Zingiber capitatum* var. *elatum*; **B.** *Z. cernuum*; **C.** *Z. montanum*; **D.** *Z. neesanum*; **E.** *Z. nimmonii*; **F.** *Z. officinale*; **G.** *Z. roseum*; **H.** *Z. wightianum*; **I.** *Z. zerumbet*.

Plate 35. Pollination biology: A. *Apis dorsata* feeding nectar from flower of *Zingiber zerumbet*; B. SEM of Pollen grains; C. Fruit; D. Bee feeding nectar from flower of *Z. cernuum* ; E. SEM of Pollen grain; F. Fruit

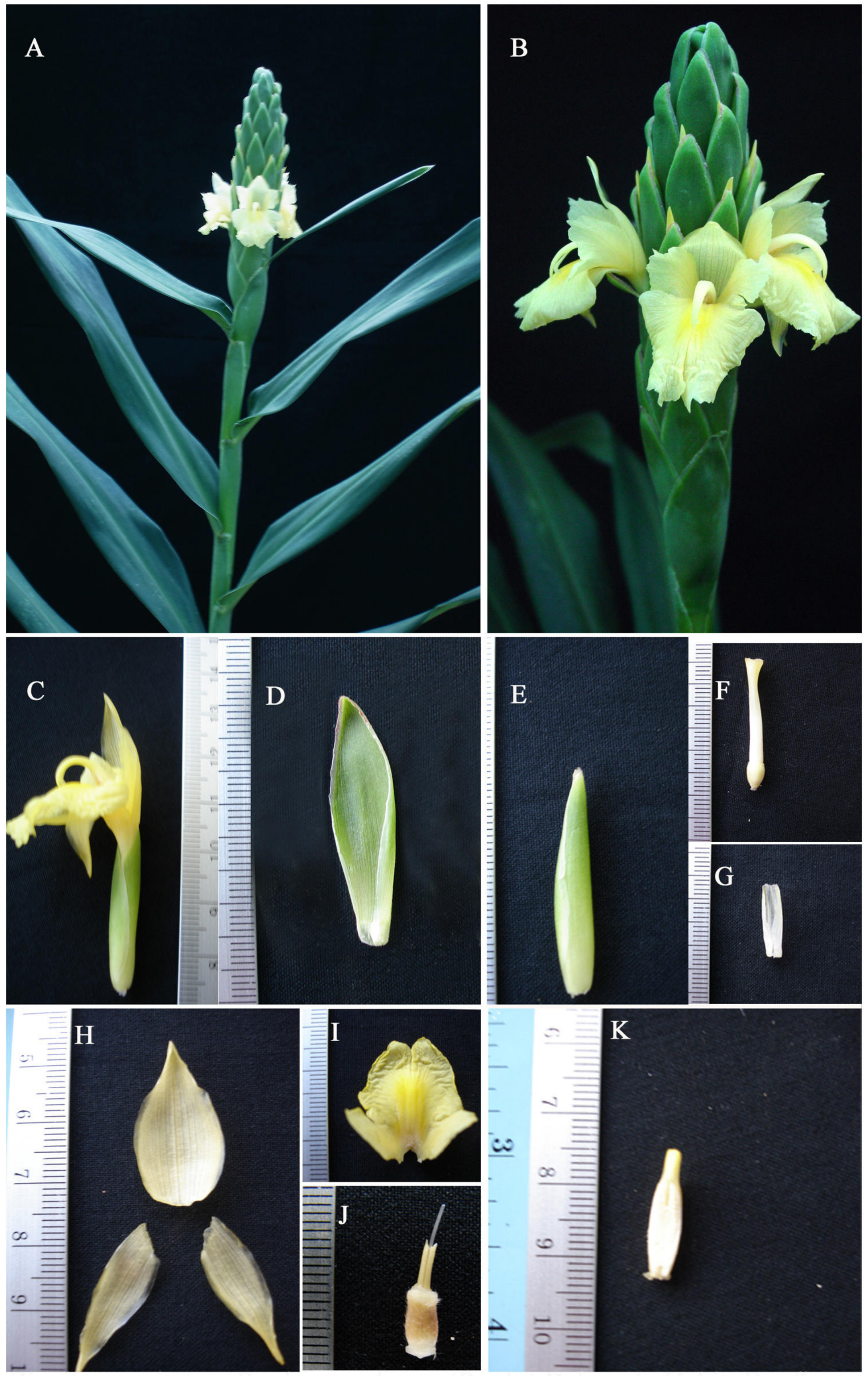


Plate 36. *Zingiber capitatum* Roxb. var. *elatum* (Roxb.) Baker: A. Habit; B. Inflorescence; C. Flower; D. Bract; E. Bracteole; F. Corolla tube; G. Calyx; H. Corolla lobes; I. Labellum; J. Ovary with epigynous glands; K. Anther front view.

Plate. 37. ***Zingiber capitatum*** Roxb. **var.** ***elatum*** Roxb. Iconotype-Icones Roxburghianae *t. 1509.* (CAL).

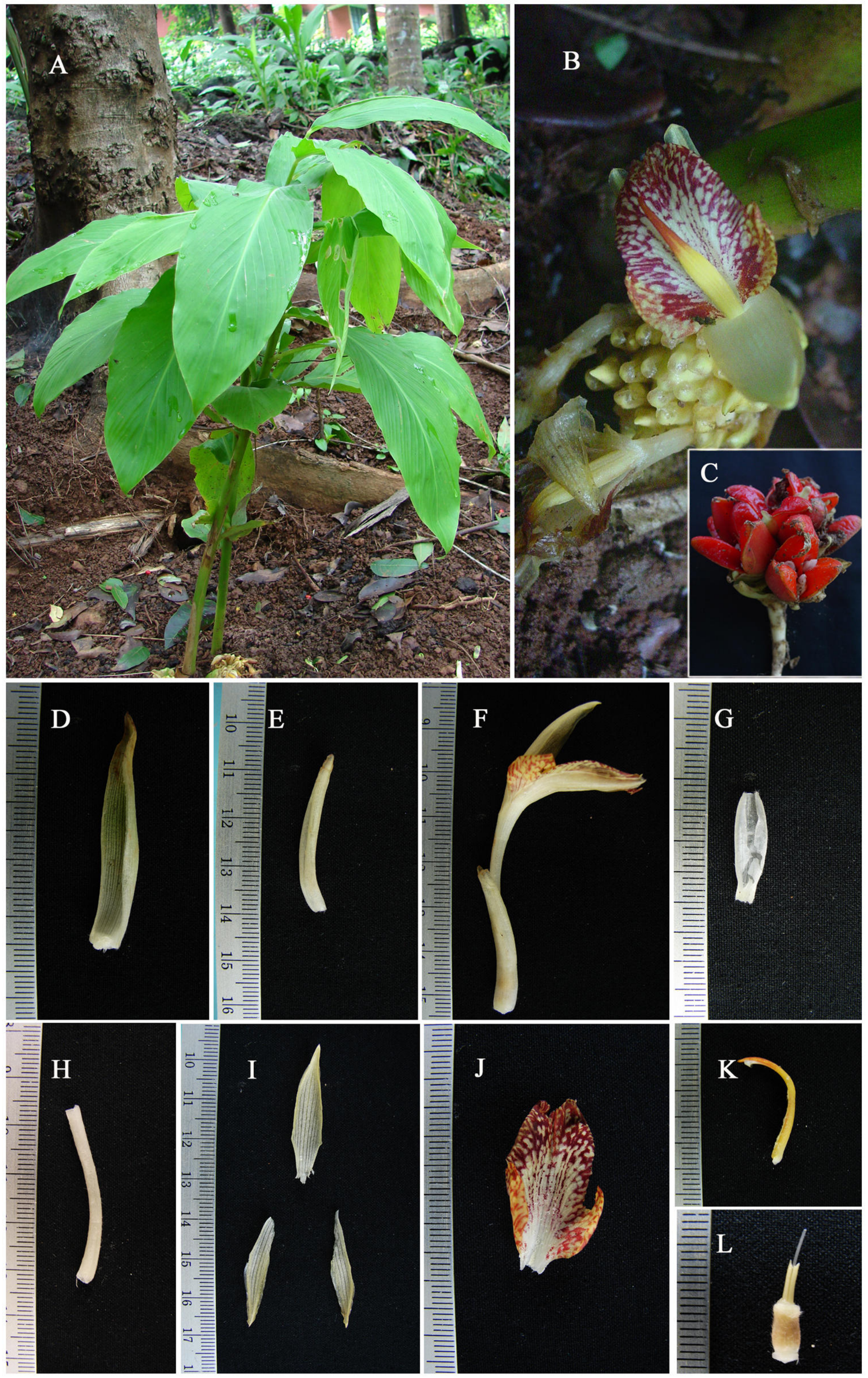


Plate 38. ***Zingiber cernuum*** **Dalzell**: **A.** Habit; **B.** inflorescence; **C.** Infructescence; **D.** Bract; **E.** Bracteole; **F.** Flower; **G.** Calyx; **H.** Corolla tube; **I.** Corolla lobes; **J.** Labellum; **K.** Anther lateral view; **L.** Ovary with epigynous glands.

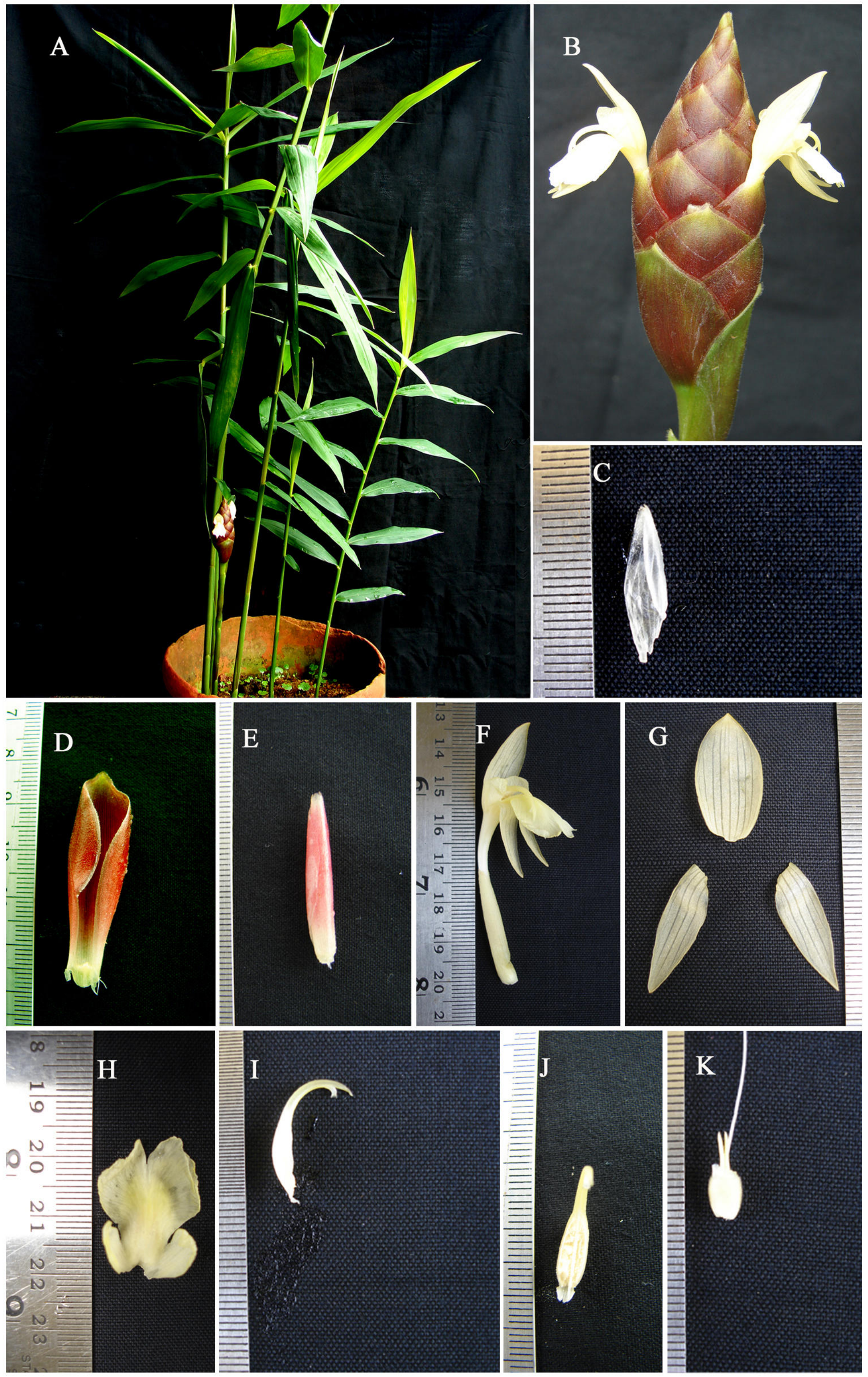


Plate 39. *Zingiber montanum* (K. D. Koenig) Link ex Dietr: **A.** Habit; **B.** Inflorescence; **C.** Calyx; **D.** Bract; **E.** Bracteole; **F.** Flower; **G.** Corolla lobes; **H.** Labellum; **I.** Anther lateral view; **J.** Anther front view; **K.** Ovary with epigynous glands.

Plate 40. *Zingiber neesanum* (J. Graham) Ramamoorthy: **A.** Habit; **B.** Inflorescence; **C.** Infructescence; **D.** Bract. **E.** Bracteole; **F.** Calyx; **G.** Flower; **H.** Corolla tube; **I.** Corolla lobes; **J.** Labellum; **K.** Anther Lateral view; **L.** Ovarywith Epigynous glands.

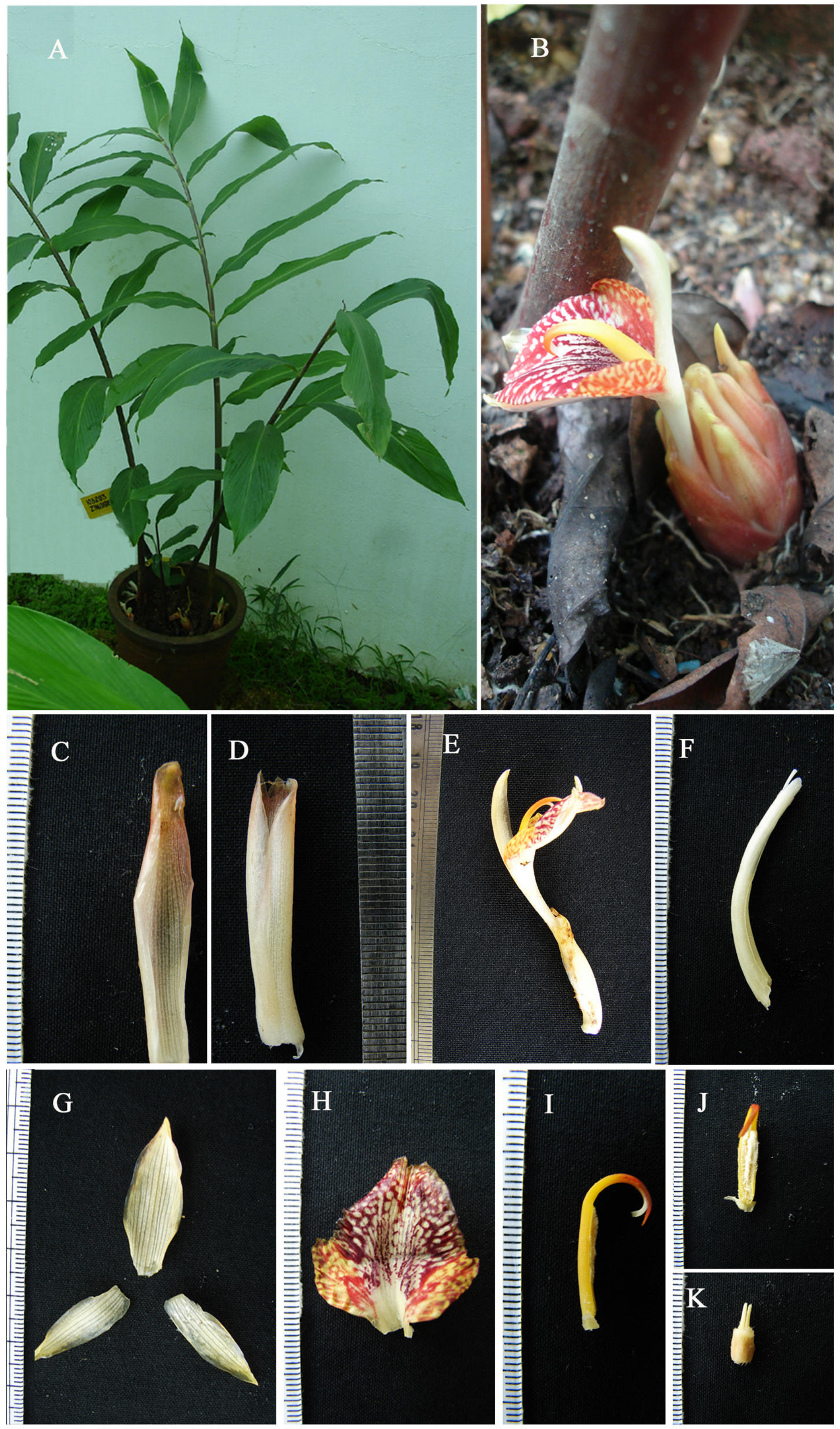


Plate 41. ***Zingiber nimmonii*** **(J. Graham) Dalzell.: A.** Habit; **B.** Inflorescence; **C.** Bract; **D.** Bracteole; **E.** Flower; **F.** Corolla tube; **G.** Corolla lobes; **H.** Labellum; **I.** Anther lateral view; **J.** Anther front view; **K.** Ovary with

Plate 42. ***Zingiber nimmonii*** **(J. Graham) Dalzell. Lectotype. Malabar, Concan, Law Sn. (k)**

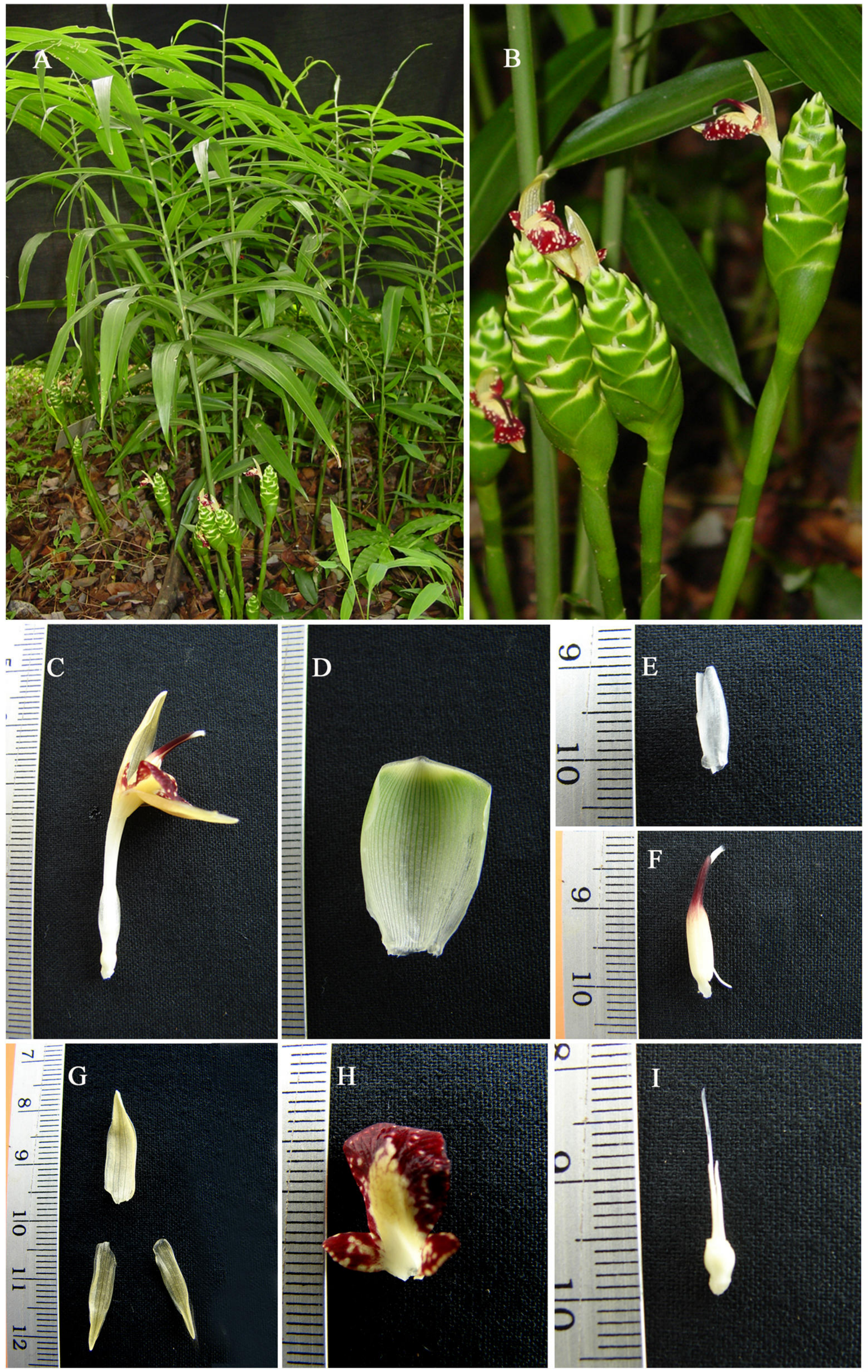


Plate 43. ***Zingiber officinale*** **Roscoe**: **A.** Habit; **B.** Inflorescence; **C.** Flower; **D.** Bract; **E.** Calyx; **F.** Anther lateral view; **G.** Corolla lobes; **H.** Labellum; **I.** Ovary with epigynous glands.

Plate. 44. ***Zingiber roseum*** **(Roxb.) Roscoe**.: **A.** Habit; **B.** Inflorescence; **C.** Bract; **D.** Bracteole; **E.** Calyx; **F.** Corolla lobes; **G.** Flower; **H.** Labellum; **I.** Anther Front view; **J.** Ovary with epigynous glands.

Plate 45. ***Zingiber roseum*** **(Roxb.)** Roscoe. Iconotype- Icones Roxburghianae *t. 502* (CAL).

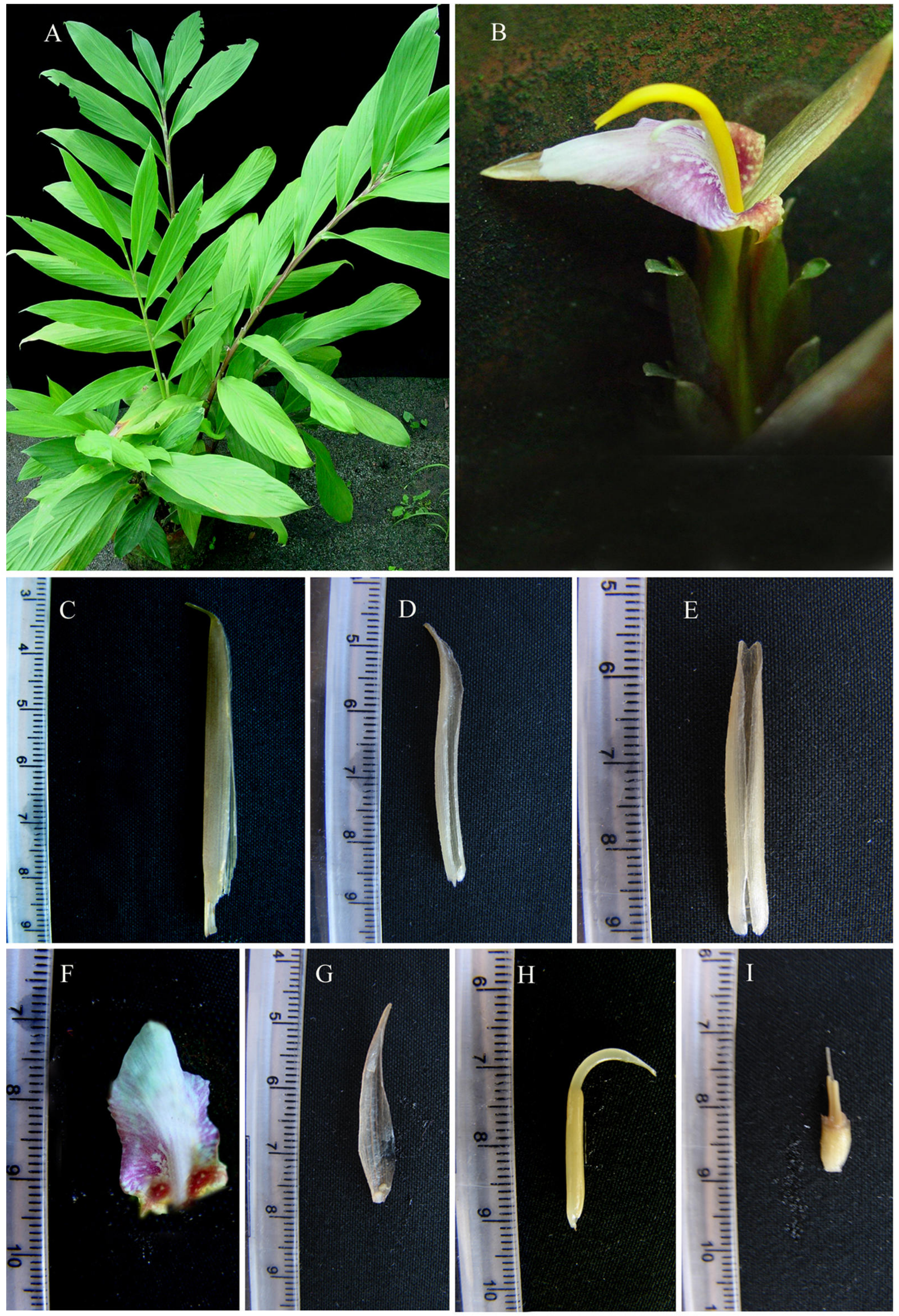


Plate 46. ***Zingiber wightianum*** **Thwaites.: A.** Habit; **B.** nflorescence; **C.** outermost bract; **D.** Bract; **E.** Bracteole; **F.** Labellum; **G.** Dorsal corolla lobe; **H.** Anther lateral view; **I.** Ovary with epigynous glands.

Plate 47. *Zingiber wightianum* Thwaites. Lectotype - *C.P. 2286* (PDA).

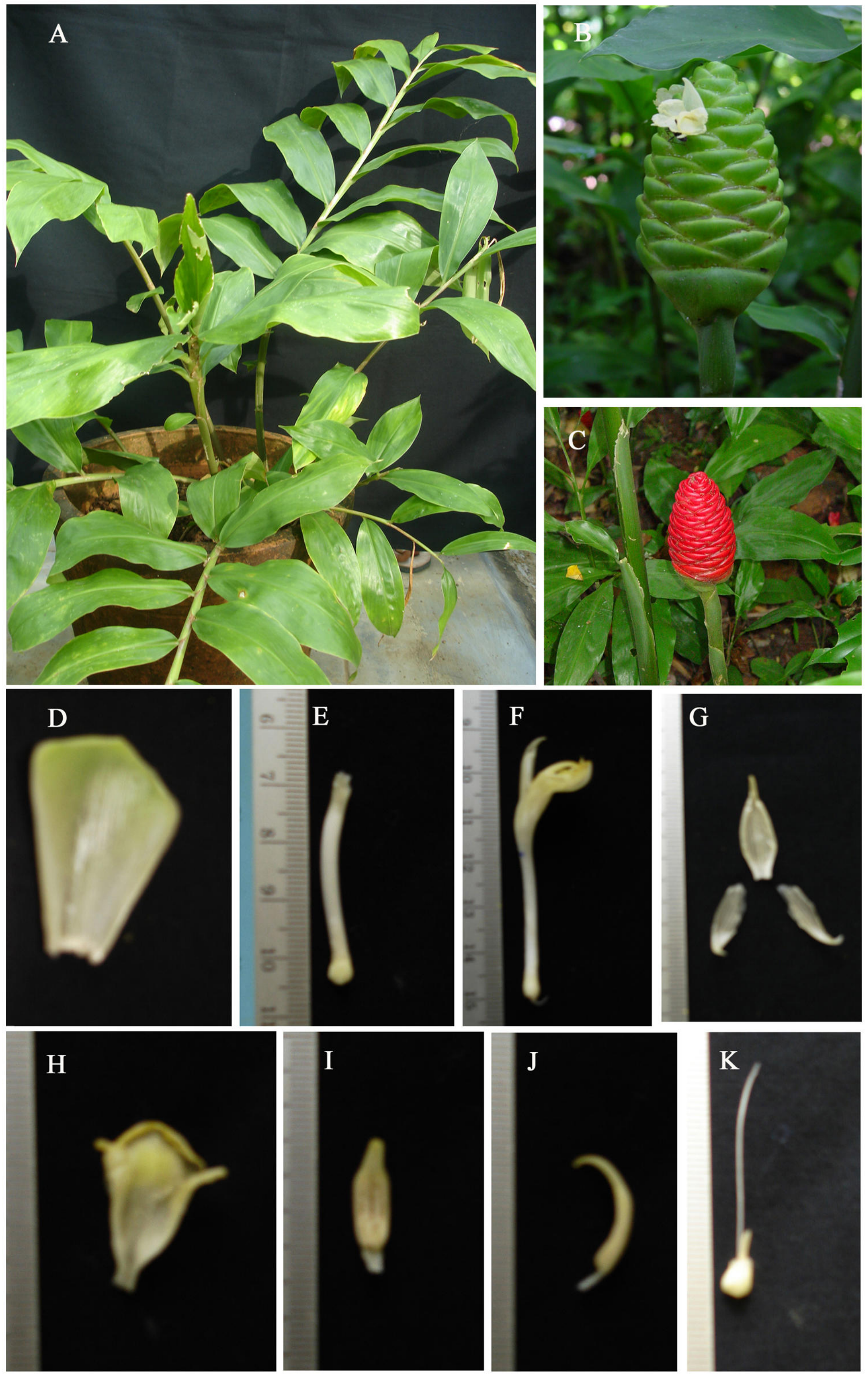
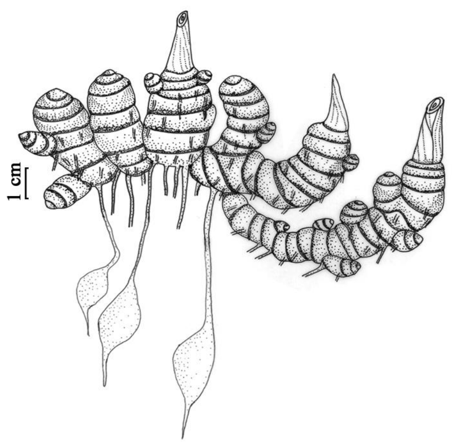


Plate 48. *Zingiber zerumbet* (L.) Smith.: A. Habit; **B.** Inflorescence; **C.** Infrutescence; **D.** Bract; **E.** Corolla tube; **F.** Flower; **G.** Corolla lobes; **H.** Labellum; **I.** Anther front view; **J.** Anther lateral view; **K.** Ovary with epigynous glands.

Summary

Pollination Biology



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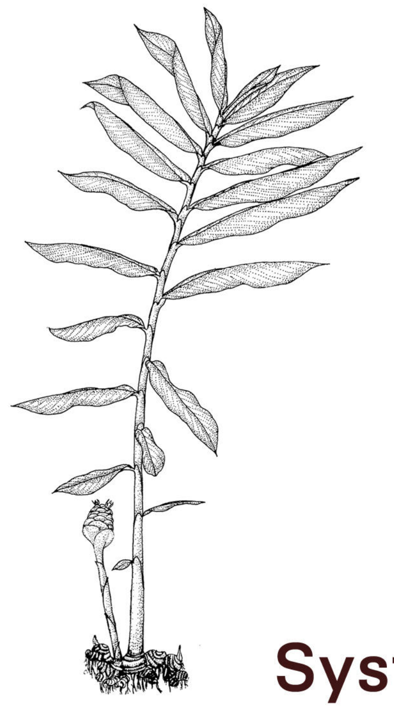
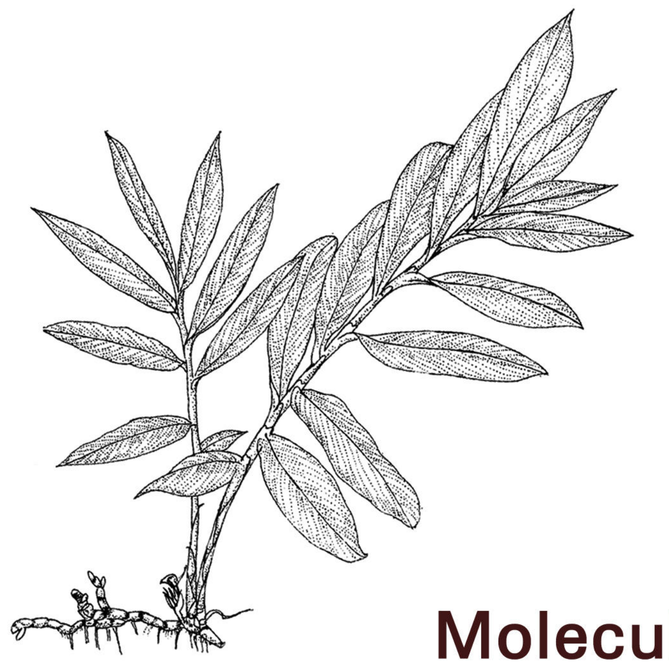
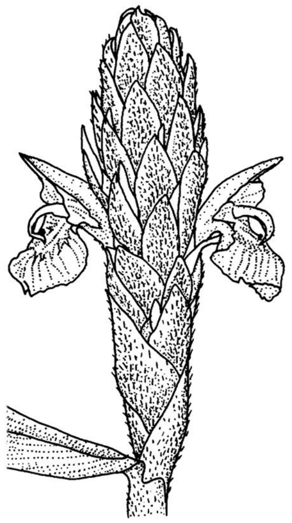


Systematic Treatment

Review of Literature

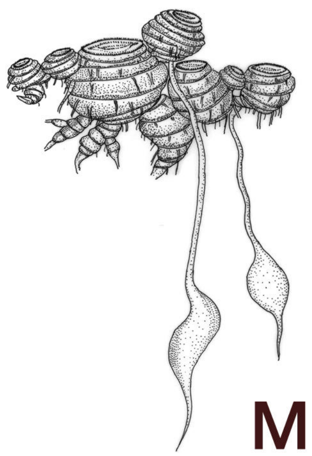


Molecular Studies



Classification

Comparative Morphology

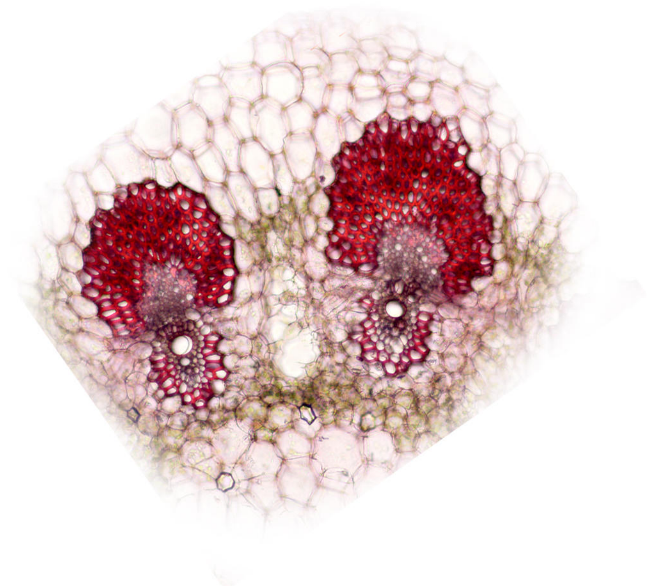


Morphology of Rhizomes

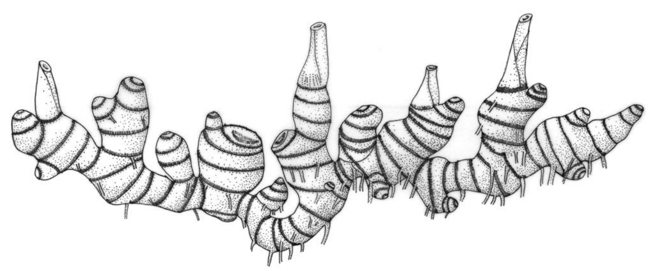
Introduction

Index to Scientific Names

Area of Study



Anatomy



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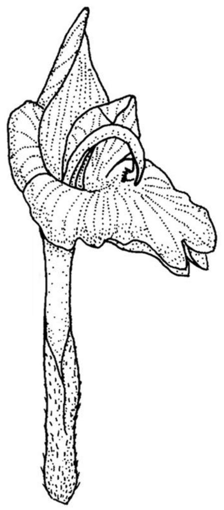
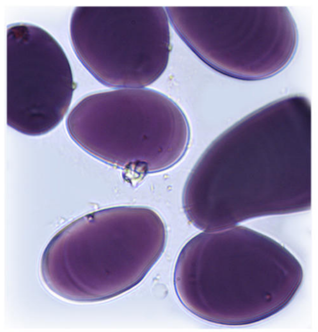


Phenetics

Materials and Methods



References

Palynology

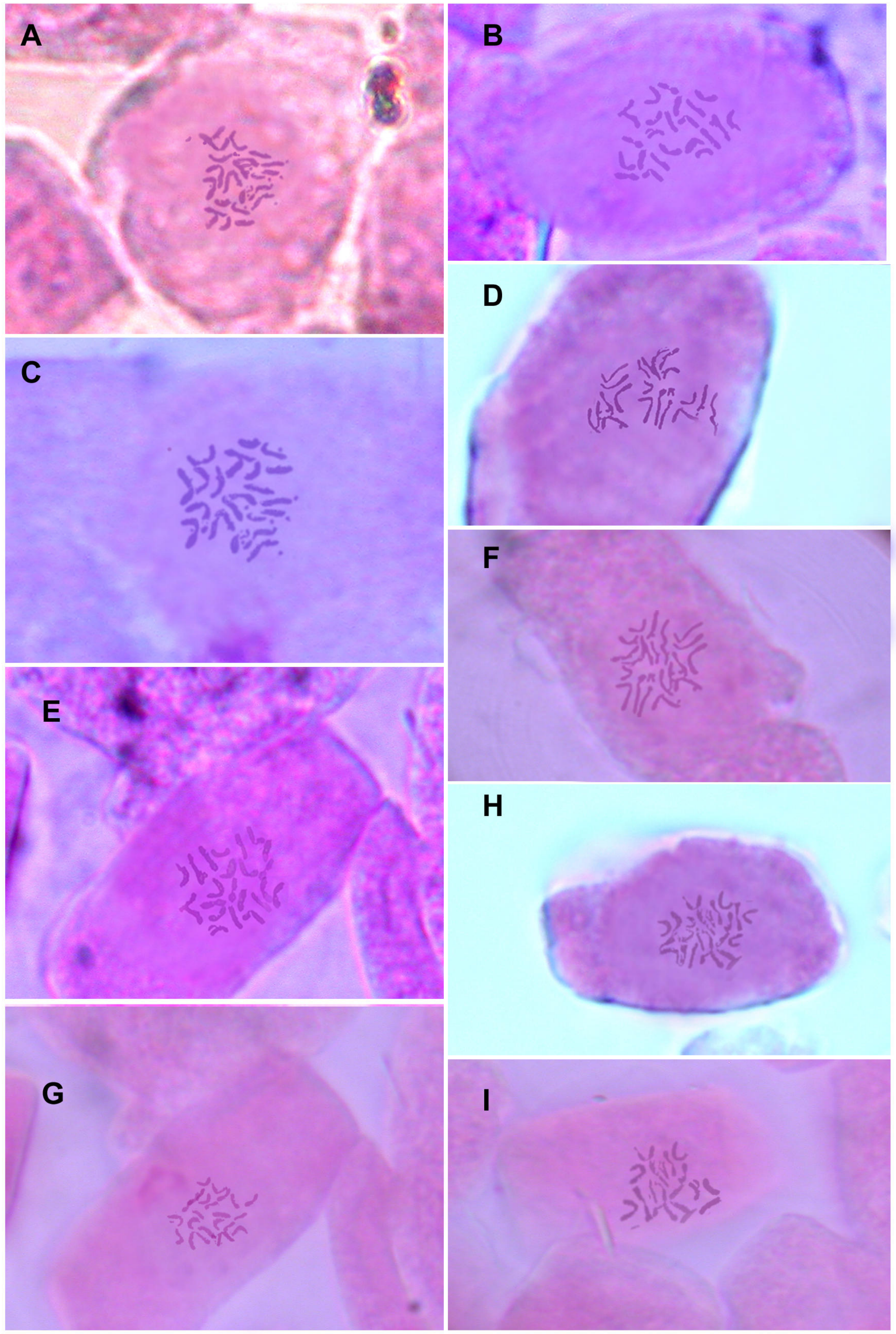


Plate 25 Somatic metaphase plates of A. *Zingiber capitatum* var. *elatum*; B. *Z. cernuum*; C. *Z. montanum*; D. *Z. neesanum*; E. *Z. nimmonii*; F. *Z. officinale*; G. *Z. roseum*; H. *Z. wightianum*; I. *Z. zerumbet*.

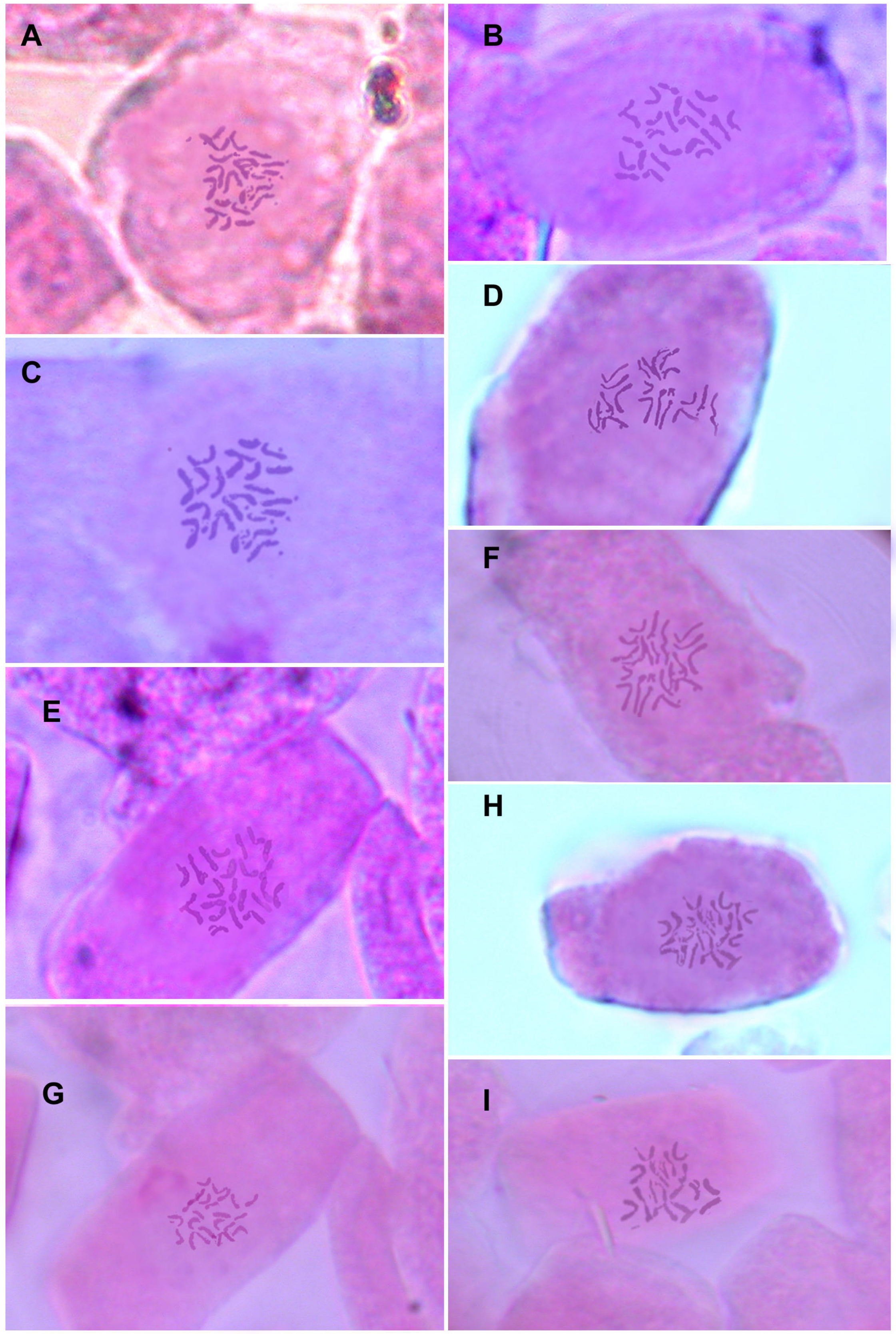


Plate 25 Somatic metaphase plates of A. *Zingiber capitatum* var. *elatum*; B. *Z. cernuum*; C. *Z. montanum*; D. *Z. neesanum*; E. *Z. nimmonii*; F. *Z. officinale*; G. *Z. roseum*; H. *Z. wightianum*; I. *Z. zerumbet*.