

Morphological and Anatomical Studies on South Indian Zingiberaceae



*Thesis submitted to the University of Calicut in part-fulfillment
of the requirements for the degree of*

Doctor of Philosophy
in Botany

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CERTIFICATE

This is to certify that the thesis entitled, "**Morphological and Anatomical studies on South Indian Zingiberaceae**" submitted to the University of Calicut by **Miss. Jayasree S.**, in part-fulfillment for the award of the degree of **Doctor of Philosophy** in Botany is a bona fide record of the research work carried out 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.

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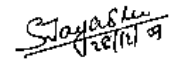
Dr. M. Sabu

DECLARATION

The thesis entitled "**Morphological and Anatomical studies on South Indian Zingiberaceae**" submitted by me in part-fulfillment of the requirements for 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.

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JAYASREE S.

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APPENDIX

Published papers

1. M.G. Prasanthkumar, M. Sabu and S. Jayasree. 2003. *Alpinia fax* B.L. Burtt et. R.M. Sm. (Zingiberaceae) - a new record for India. *Rheedea*. 12(2): 189-183.
2. M. Sabu, M.G. Prasanthkumar, J. Sckornickova and S. Jayasree. 2004. Transfer of *Kaempferia siphonantha* Baker to *Boesenbergia* Kuntze (Zingiberaceae). *Rheedea*. 14: 55-59.
3. S. Jayasree and M. Sabu. 2005. Anatomical studies on the Genus *Curcuma* L. (Zingiberaceae) in India - part 1. *Plant Taxonomy: Advances and Relevance*. 475-492.

INDEX TO THE SCIENTIFIC NAMES

Acorus
Aframomum
Agavaceae
Alpinia
A. abundiflora
A. calcarata
A. calcarata
A. fax
A. floribunda
A. galanga
A. malaccensis
A. neesana
A. nigra
A. nimmonii
A. vittata
A. zerumbet
A. zerumbet
Agave
Alpinieae
Alpinioideae
Amomum
A. cannicarpum
A. floribundum
A. ghaticum
A. hypoleucum
A. masticatorium
A. montanum
A. muricatum
A. pterocarpum
A. zerumbet
Annonaceae
Araceae
Beschorneria
Boesenbergia
B. tiliaefolia
B. pulcherima
Boraginaceae
Calathaea
Catimbium
Costaceae
Costoideae
Costus
C. zerumbet
Curcuma
C. aeruginosa
C. amada
C. aromatica
C. aurantiaca
C. bhatii
C. kannanorensis var. *lutea*
C. coriacea
C. decipiens
C. ecalcarata
C. haritha
C. inodora
C. karnatakensis

C. longa	Garreya
C. montana	Garryaceae
C. mutabilis	Gastrochilus
C. neilgherrensis	G. pulcherrima
C. oligantha var. lutea	Globba
C. oligantha var. oligantha	G. marantina
C. pseudomontana	G. ophioglossa
C. raktakanta	G. orixensis
C. vamaana	G. schomburgkii
C. zanthorrhiza	Globbeae
Cyclanthaceae	Haniffia
Cyperaceae	Hedychieae
Cyperus	Hedychium
Dendrobium	H. acuminatum
Dimerocostus	H. coronarium
Dioscorea	H. flavescens
D. cayenensis	H. scaposum
D. rotunda	H. spicatum var. acuminatum
Doryanthus	H. venustum
Elettaria	Heliconia
E. cannicarpum	Kaempferia
E. cardamomum	K. elegans
E. floribunda	K. galanga
Elettariopsis	K. rotunda
Etlingera	K. scaposa
Euphorbiaceae	Luzulae
Festuca	Maranta galanga
Festucac	M. malaccensis
Fimbristylis	Marantaceae
Fuirena	Monocostus
Furcraea	Monolophus scaposus

Musaceae	Z. montanum
Myrtaceae	Z. neesanum
Orchidaceae	Z. nigrum
Palmae	Z. nimmonii
Pandanaceae	Z. officinale
Paracautleya bhatii	Z. wightianum
Phenacospermum guianensis	Z. zerumbet
Pleuranthallidineae	Zingiberaceae
Poaceae	Zingiberales
Prunus	Zingibereae
Ravenala	Zingiberoideae
Reideliaceae	
Rhizobium	
Rhynchanthus	
Rosaceae	
Sansevieria	
Scaphochlamys kuntsleri	
Siphonochiloideae	
Stahlianthus	
Sterculiaceae	
Strelitzia	
Tamijioideae	
Tapinochilus	
Vulpia	
Yucca glauca	
Zingiber	
Z. capitatum var. elatum	
Z. cassumunar	
Z. cernuum	
Z. elatum	
Z. macrostachyum	

INTRODUCTION

The family Zingiberaceae include perennial rhizomatous herbs, which grow in shady habitats. They are generally called as 'gingers' whereas 'ginger' refers to the ginger of commerce- *Zingiber officinale* Roscoe. This family has been considered as a spice family since time immemorial as it includes many spices.

Zingiberaceae are economically very important as it yields many spices, dyes, medicines, perfumes and ornamentals. Many genera such as *Aframomum* K. Schum., *Amomum* Roxb., *Alpinia* Roxb., *Curcuma* L., *Elettaria* Maton, *Kaempferia* L. etc. are used in Ayurvedic and other systems of medicine. *Elettaria cardamoum* (L.) Maton, is known as the 'Queen of Spices'. *Zingiber officinale* is another important spice as well as medicine. *Curcuma longa* L. is a very important spice and traditional item of exportation from ancient times (Pruthi, 1976). Many species of *Hedychium* Koenig, *Globba* L., *Alpinia*, *Kaempferia* and *Etingera* Giseke are well known ornamentals.

This family is one of the ten largest monocotyledonous families in India and the largest family in the order Zingiberales. The family is characterised by the possession of perennial rhizome and aerial shoots, which usually grow in shady habitats as forest undergrowths or in open grasslands. It occurs chiefly in tropics and has greatest concentration in

China, India, Myanmar, Thailand, Malesia etc. The family includes about 53 genera and 1200 species (Kress *et al.*, 2002). In India, it is represented by 21 genera and about 200 species, mainly seen in Andaman Nicobar islands, North-Eastern and Peninsular India, out of which about 70 species are endemic (Jain & Prakash, 1995). There are 9 genera and about 55 species in South-India (Sabu, 2006) which include many important plants such as *Alpinia* (*A. zerumbet* (Pers.) B.L. Burtt & R.M. Sm., *A. galanga* (L.) Sw., *A. calcarata* Roscoe), *Amomum*, *Curcuma* (*C. longa* L., *C. aromatica* Salisb., *C. amada* Roxb., *C. aeruginosa* Roxb.), *Elettaria* (*E. cardamomum* (L.) Maton), *Hedychium* (*H. coronarium* Koenig), *Kaempferia* (*K. galanga* L., *K. rotunda* L.), *Zingiber* (*Z. officinale* Roscoe, *Z. zerumbet* (L.) Smith) etc.

The flowers of Zingiberaceae members are very delicate and fleshy so that in most cases they wither and crumble forming a gummy mass soon after collection. Thus study of floral morphology and the identification of taxa become difficult. The present work aims to solve the much confused taxonomic problem of many of the taxa in the family based on anatomical characters. This will be of great help in the identification of the species in the vegetative stage itself. Metcalfe (1963) has commented that anatomy, particularly leaf anatomy enables to identify the non flowering specimens, though the taxonomic level to which the identification is possible varies from family to family. This has already been proved by various workers (Tomlinson, 1956, 1961; Hussin *et al.*, 1996, 1998, 2000) for the delimitation of the species in the family Zingiberaceae. Thus an attempt has been made

to study the vegetative anatomy of the members of the family Zingiberaceae occurring in South India.

Problems in Identification

Zingiberaceae are considered as one of the taxonomically most difficult families of monocotyledons. This is mainly due to the close resemblances with vegetative parts of taxa within a genus or family. This is coupled with short flowering period and that too mainly during monsoon. Many gingers are confined to the dense forests, which are impenetrable during rainy season, thus making the collection of fresh flowers difficult. The flowers are very delicate, short lived and form a gummy mass soon after collection, which makes the study of floral morphology difficult. Many characters, like colour, smell, size and shape of rhizome, nature of floral parts *etc.* which are essential for species delimitation are seldom retained in the herbarium specimens. Moreover many of the herbarium specimens deposited in major herbaria in India are fragmentary, *i.e.*, without rhizome, inflorescence, flowers *etc.*

The earlier works on taxonomy were mainly based on external morphology. But now scientists are using data from various branches of science such as anatomy, embryology, cytology, palynology, phytochemistry, molecular biology *etc.* Of these, anatomy has been of much importance to taxonomy even from the time of Linnaeus. Engler and Prantl (1887-1899) have given much importance to the anatomical characters in their 'Die Naturalischen Pflanzen-familien'. The foliar epidermal studies

including the nature of cuticle, shape of epidermal cells, nature of anticlinal wall, special epidermal cells, costal cells, morphology, distribution and disposition of stomata, type and morphology of trichomes in association with other characters act as an aid in solving taxonomic problems (Solereeder, 1908; Metcalfe & Chalk, 1950; Metcalfe 1961 and 1963; Fahn, 1961; Stebbins & Khush, 1961; Dunn *et al.*, 1965; Paliwal, 1969; Tomlinson, 1974; Singh and Jain, 1975; Rajagopal, 1979; Barthlott, 1981; Santhosh Kumar *et al.*, 2001; Edeoga & Ikem, 2001; Edeoga & Amayo, 2001; Edeoga & Ogbemor, 2001).

The other anatomical characters of taxonomic significance include nature of vascular bundles, cellular inclusions, sclereids, nodal anatomy, structure of midrib, structure and organization of xylem vessels, composition of mesophyll tissue *etc.* They have been useful in the identification of plants at different taxonomic level (Solereeder, 1908; Metcalfe & Chalk, 1950, Tomlinson, 1961, 1969, Keating, 2004 a, b), in deducing affinities between families (Nwosu, 2001) and also in classification (Kaeting, 2004 a).

These anatomical characters are useful in the identification of plant materials in paleobotany (Bandulska, 1925; Dilcher, 1974), Pharmacognosy (Datta & Mukerji, 1950; Krishnamoorthy & Sundaram, 1967; Banerjee & Mukherjee, 2001; Das *et al.*, 2004; Thomas & Thomas, 2007), Forensic Science (Bhatia *et al.*, 1973, 1988), Plant-insect relationship (Chapman, 1977; Schoonhoven *et al.*, 2005) and also in the identification of

bioindicators of environmental pollution (Sharma & Butler, 1975; Yunus & Ahmad, 1983; Ahmad & Yunus, 1985).

Objectives of the present study

1. To study the internal structure of the vegetative parts and morphology of Zingiberaceae taxa in South India.
2. Assessing the significance of anatomical characters in the delimitation and identification of species.
3. To formulate a key on the basis of anatomical characters for the species identification. This enables the identification of the taxa even in the vegetative stage or even if fragments of specimens are available.

GENERAL CHARACTERS OF THE FAMILY

Habit

Zingiberaceous plants are rhizomatous, annual or perennial herbs, rarely epiphytes are also seen (*Rhynchanthus* spp., *Hedychium* spp.). Height of the plant ranges from 15 cm or less (*Curcuma bhatii* & *Kaempferia galanga*) to 5 m (*Alpinia* spp., *Amomum* spp. & *Elettaria* spp.). Species of *Curcuma*, *Boesenbergia*, *Globba*, *Hedychium* and *Zingiber* are medium sized plants.

Leafy shoots are unbranched. Genera such as *Aplinia*, *Amomum*, *Elettaria*, *Globba*, *Hedychium* and *Zingiber* possess true aerial stem with nodes and internodes. The base of the stem is covered by green or variously

coloured sheaths. True stem may be very short or absent in *Kaempferia*. Aerial stem is hard and woody in certain genera like *Alpinia*, *Amomum*, *Elettaria*, and *Hedychium* and fleshy in *Zingiber*. In *Curcuma*, pseudostem is formed by the clasping leaf sheaths.

Rhizome

Rhizome may be small, medium or large in size. It is hard, woody and fibrous in *Alpinia*, *Amomum* and *Elettaria* and fleshy in *Curcuma*, *Hedychium*, *Kaempferia* and *Zingiber*. They are white or variously coloured like pale yellow, orange yellow, deep yellow, blue, grey, pink or brown. The main function of rhizome is to store reserve food and help the plant to tide over the unfavourable conditions during dry season. The rhizome occupies a safe and deeper position in the soil. The young rhizome and axillary buds are covered and protected by scale leaves.

In majority of rhizomes, the branching pattern is sympodial. In *Curcuma* small rhizomes are without sessile tubers (*C. coriacea* Mangaly & M. Sabu, *C. neilgherrensis* Wight, *C. oligantha* Trimen and *C. vamana* M. Sabu & Mangaly). The rhizome produces an axillary branch which grows obliquely downward, and the tip becomes swollen and produces new rhizome and an aerial shoot. The rhizomes of *C. vamana* develop long, slender stolon like structure, the tips of which develop into new shoots. This structure is noticed only in *Curcuma*.

Root

In most species, roots develop from the main rhizome and also from the sessile tubers which produce foliage leaves. In some species like *C. longa*, roots are not produced from the secondary or tertiary branches. Roots are fleshy or fibrous and terminating in fleshy tubers (*Curcuma* spp., *Kaempferia* spp., *Zingiber* spp.). They may be oval, spherical, ellipsoid or oblong and sometimes cylindrical and upto 18 cm long in *C. coriacea*. They are white or watery pearl coloured inside. Root tubers are not seen in Tribe Alpinieae. Roots of epiphytic species of *Hedychium* are covered by brown hairs.

Leaves

Leaves are distichous, plane of distichy of leaves is parallel to the rhizome in sub family Zingiberoideae Hassk. and transverse to the rhizome in Alpinioideae Link, Tamijioideae W.J. Kress and Siphonochiloideae W.J. Kress. Leaf sheaths are always open with few exceptions.

Zingiberaceae exhibit many variations in structure, shape, size, texture and venation pattern of leaves. Leaves are sessile or petiolate and length of the petiole varies considerably. In *Zingiber*, the base of the petiole is swollen to form a pulvinus. Ligule is present at the upper end of the sheath. Ligule is entire, membranous, very short or large upto 5 cm in *Amomum masticatorium* Thwaites, *Hedychium flavescens* Carey ex Roscoe and *Zingiber zerumbet* (L.) Smith). It is bifid in some taxa as in *Amomum pterocarpum* Thwaites. Lamina, in most species is oblong, lanceolate,

oblanceolate or linear. Leaf base is oblique, cordate, acute or acuminate and tip acute or acuminate, rarely rounded or cuspidate. Margins of leaves are usually entire, straight or wavy. Usually leaves are green, sometimes with purple patch along the midrib (*Curcuma aeruginosa* Roxb., *C. zanthorrhiza* Roxb.) or mottled with various colours (*Alpinia vittata* Bull., *Kaempferia elegans* Wall. & *K. rotunda* L.).

Leaf surface is glabrous in *Amomum cannicarpum* (Wight) Bentham ex Baker, *A. muricatum* Bedd., densely pubescent in *Curcuma haritha* Mangaly and M. Sabu, *C. coriacea* and *Globba marantina*, sparsely pubescent in *Boesenbergia pulcherrima* (Wall.) Kuntze and *Globba orixensis* Roxb. Pubescence may be on either surface (*Curcuma coriacea* & *C. aromatica*) only on lower surface (*Amomum pterocarpum* Thwaites & *Hedychium* spp.) may be along the margin only (*Alpinia zerumbet* (Pers.) B.L. Burtt & R.M. Sm.). Hairs are always simple, unicellular and often with swollen base.

Inflorescence

Inflorescence is produced terminally (*Alpinia* spp., *Boesenbergia*, *C. montana*, *C. vamana*, *Globba*, *Hedychium*) laterally (*Amomum*, *Elettaria*, *Zingiber*) or both laterally and terminally on same plant in different seasons (*Curcuma* spp.). The inflorescence is produced from the rhizome at the base of the leaf shoot in *Amomum*, *Elettaria* and *Zingiber* spp. They are mostly erect, prostrate or rarely subterranean. In *Curcuma aeruginosa*, *C. zanthorrhiza*, *Zingiber officinale* and *Z. zerumbet*, inflorescence is produced

directly from the rhizome on a separate, erect, leafless shoot which is covered by sheaths.

According to Holttum (1950) the basic inflorescence unit in Zingiberaceae consists of axillary monochasial cyme and each branch with a terminal flower (cincinnus).

Bract

The main bract which possesses flowers in its axils is called fertile bracts and the secondary bracts are called bracteoles. White or brightly coloured sterile bracts called coma bracts are present at the tip of the inflorescence as in *Curcuma* spp.

The bracts are borne directly on the inflorescence axis and are spirally arranged. In some genera the bracts are imbricating (*Amomum*, *Zingiber*) loosely arranged in *Hedychium spicatum* var. *acuminatum* and *Elettaria cardamomum*. Usually they are free or fused about lower 1/3 or 1/2 to form a pouch as in *Curcuma*. In some, the bracts are absent (*Alpinia* spp.) or deciduous. It subtends a single flower (*Kaempferia* spp.) or a monochasial cyme of several flowers as in *Alpinia*, *Curcuma* and *Globba*. In *Boesenbergia*, the bracts are distichously arranged.

Bracteole

Bracteoles may be tubular or non-tubular. Bracteoles are open to the base in *Boesenbergia*, *Curcuma*, *Globba* and *Zingiber*. In *Kaempferia*, there is only one flower in the axil of each primary bract. The only bracteole is

more or less deeply bilobed, but occasionally to the base. In *Zingiber* the bracteole faces its fertile bract in the same way as the first bracteole.

Flower

Flowers are bisexual, zygomorphic, dichlamydeous, trimerous, irregular and epigynous. The flowers of Zingiberaceae have been modified from the type consisting of an outer whorl of 3 sepals, alternating with 3 petals, 6 stamens arranged in 2 alternating whorl of 3 each and trilocular inferior ovary. In India, the flowering of Zingiberaceae is during monsoon, some times during summer or rarely throughout the year. In most cases flowers open in the early morning. Some species of *Curcuma* and *Zingiber* open in the afternoon. *Kaempferia scaposa*, have white flower and opens at night.

Calyx

Three sepals fuse to form a tube which is shortly 3-lobed at apex, sometimes deeply split on one side. The tube may be glabrous or hairy. Calyx tube is shorter than corolla tube as in *Curcuma*, equal to corolla in *Alpinia* and *Amomum*. Calyx may be deciduous, falling with the corolla (*Hedychium venustum*) or persistent (*Amomum pterocarpum*, *Boesenbergia pulcherrima*, *Curcuma oligantha* & *Alpinia fax*).

Corolla

The petals are three in number and are fused at the base to form a corolla tube. The tube is longer in *Globba*, *Hedychium*, *Kaempferia* and *Zingiber* or shorter as in *Alpinia* and *Amomum*. The upper part of the corolla

tube is funnel- shaped in *Curcuma*. In *Curcuma*, the mouth of the corolla tube is covered by downwardly pointed hairs. Corolla lobes are mostly unequal, the dorsal lobe being larger and hooded as in *Curcuma*. Lateral lobes are similar and smaller than dorsal lobe. Colour varies from white, yellow, orange to pink.

Staminodes

Most of the authors (Van Tiegham, 1868; Eichler, 1875; Rendle, 1930; Willis, 1948) proposed that the inner whorl of androecium is represented by a posterior fertile stamen and a petaloid labellum, which is formed by the fusion of 2 anterio-lateral staminodes of the inner whorl. The anterior stamen of the outer whorl is absent and the 2 posterio-lateral stamens are represented as lateral staminodes.

Lateral Staminodes

Mostly the staminodes are attached to the corolla tube at the same level as the corolla segments. In *Globba*, they are at the base of the long exerted filament. The shape of the lateral staminodes shows much variation, linear in *H. spicatum* var. *acuminatum* or broad in *Curcuma*, *Hedychium* and *Kaempferia*. In *Curcuma*, they are concave with inner margin folded within the dorsal corolla lobe. The colour varies from pure white to yellow, purple or pink. In tribe Alpinieae, they are reduced to small, non-petaloid structures or swelling. In *Zingiber*, the lateral staminodes are united to the lip, its whole length or towards the base and stand erect on either side at the base of the labellum.

Labellum

It is the large and most conspicuous part of the flower. Labellum is held flat in *Kaempferia* or basin or cup-shaped at the base in *Boesenbergia*, clawed at the base (*Hedychium flavescens*) or emarginated (*Curcuma*). In *Globba*, the labellum is joined to the stamen in a peculiar tube about 1 cm above the attachment of the lateral staminodes and corolla lobes with deflexed blade remain close to the corolla tube towards the base. The tip of the labellum can be entire, bilobed or trilobed.

Stamen

The posterior one of the inner whorl is the only fertile stamen. Length of the filament varies considerably. In *Globba* and *Hedychium*, it is very long and curved, or broad and short in *Kaempferia* and *Zingiber*. In *Alpinia* and *Curcuma*, it is medium sized. Versatile anthers are found in *Curcuma*.

Anthers are ditheous, with parallel or divergent thecae. In most cases the anther produces appendages. The common type is an apical extension of the connective into an anther crest as in *Kaempferia*. In *Zingiber*, the crest is very long and distinct; it is elongated, as long as the anther with inflexed sides and entirely encloses the style except near the apex.

The anthers of *Globba* spp. bear narrow, acute, spreading lateral appendages. In *G. schomburgkii* and *G. marantina*, there are 4 appendages, 2 on each side.

In *Curcuma*, anther spurs are found. Usually these spurs are sterile but in *C. vamana* they also bear pollen grains.

Epigynous glands

Just above the ovary, two, elongated, cylindrical structures of varying length are found, called epigynous glands. Typically they are 2 in number, usually narrow, sometimes large and fleshy and fused with each other on one side. They are antero-lateral in position above the ovary. They are absent in *Curcuma vamana*. In Alpinieae, the epigynous glands are cupular or massive glands having varying shapes.

Ovary

Ovary is inferior, usually trilocular with axile placentation (*Curcuma* & *Hedychium*) or unilocular with parietal placentation (*Globba*). In *Boesenbergia*, *Haniffia*, *Stahlianthus*, a tendency towards the reduction or elimination of septa and the ovules are confined to a small basal group or a longer or smaller columnar placenta or one single posterior septum.

According to Hamza (1991) the ovary in many species is basically unilocular, but appears as trilocular in some tribes (Alpinieae, Hedychieae & Zingibereae) because of the intrusion of placenta into the ovary chamber during development.

Style and Stigma

Style is long, filiform, and as long as the stamen and held within the filament below and between the anther thecae above. In *Globba* it is shorter than the filament, and it forms a bow string between the base of the filament and anther. In *Zingiber*, style is much exserted from the anther crest.

Stigma is generally well expanded with a terminal, rounded to elliptic, ciliate opening.

Ovule

Ovule is anatropous, bitegmic and possesses ovular appendages. The appendage may be lacerate or connate as in *Zingiber* or veil-like in *Elettaria*.

Fruit

Fruits are dry or fleshy, dehiscent capsule. They are oval, spherical, oblong or trigonous. Fruit wall may be membranous as in *Curcuma oligantha*, *Bosenbergia* spp. or fleshy and swollen (*Zingiber*), with spinous outgrowths (*Amomum muricatum* & *A. ghaeticum*), warted (*Globba ophioglossa*) and with ridges (*Amomum pterocarpum*). Fruit setting is rare in *Cucuma amada*, *C. longa* and *C. zanthorrhiza*. In *Alpinia*, *Zingiber* and *Hedychium* fruits are attractively coloured. Dehiscence of capsule is mostly loculicidal. When the capsules dehisce, the three valves separate from the apex and spread apart exposing the seeds (*Globba*, *Zingiber* & *Hedychium*). The fruit of *Alpinia* dehisce only when slightly pressed. In *Curcuma bhatii* the capsule dehisces irregularly.

Seeds

The seeds in tribe Alpinieae are angled and closely packed in the ovary, whereas in Zingibereae, they are ovoid or ellipsoid and loosely packed. Seeds are arillate with starchy perisperm and endosperm.

AREA OF PRESENT STUDY

The members of Zingiberaceae of South India were selected for the present study. The South Indian region comprises of 5 states, viz., Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Goa and Union territories of Mahe and Pondicherry. It lies in the North-South between 8⁰-18⁰ North latitudes and East-West between 72⁰-80⁰ East longitudes. South India is surrounded by Madhya Pradesh, Maharashtra and Orissa in the North, Bay of Bengal in the East, Indian Ocean in the South and Arabian Sea in the West. It is divided into 4 major divisions viz., the mountain region in the east west, the midlands with hillocks, the northern plains and the sloping coastal strip.

(Plate 01)

Mountain systems

The main mountain systems of South India are Western Ghats and Eastern Ghats. The Western Ghats or Sahyadri mountains run along the western edge of the Deccan Plateau, and separate the plateau from a narrow costal strip along the Arabian Sea. The range starts from the river valley of the river Tapti near the Gujarat border, and then runs through the states of Maharashtra, Karnataka, Kerala and Tamil Nadu, almost to the tip of peninsular India. The average elevation is around 900 m; with the highest point at Anamudi at 2695 m height. The only gap in the range, the Palghat gap, joins Tamil Nadu to Kerala. The Western Ghats also join the Eastern

Ghats in a series of low hill ranges including the shevaroy and Biligirirangans meeting the Tirumala range.

The mountains intercept the rain bearing monsoon winds, and form an important watershed for peninsular India. The tree cover has also contributed to the precipitation of the area by acting as a substrate for condensation of moist rising wind from the sea. In the south they contain the only rain forest of South India and this is one of the global biodiversity hotspots. Several National Parks lie within the range. The Western Ghats are also home to many endemic species of flora and fauna.

The area possesses numerous streams, waterfalls and the forests help to nourish many perennial rivers in South India including the Godavari, Krishna and Kaveri.

Climate

India is mainly a tropical country but due to altitudinal variations, climate varies significantly from North to South. The 4 seasons include:
1. Winter (December – February) 2. Summer (March – June) 3. South-West Monsoon (June – September) 4. North-East Monsoon (October – November)

Temperature

The mean maximum temperature during the coldest months of December to January is around 29⁰C in some part of the peninsula and minimum is about 24⁰ C in the extreme south. From March to May is a period

of continuous and rapid rise in temperature and comes around 40^o C. During this period most of the gingers survive in the form of rhizomes under the soil. On the onset of premonsoon showers during April-May, the rhizomes start sprouting with the production of leafy shoot or inflorescence. With the advent of South West monsoon in June, there is rapid fall in the maximum temperature. During the withdrawal of monsoon in October-December the weather turns drier and temperature ranges between 34^o C- 28^o C.

Rainfall

Rainfall in South India is dependent on the South-West and North East monsoon. The South West monsoon supply over 80% of Indian annual rainfall and it makes its presence by June in Kerala and by 1st week of July the entire country experience rain. Usually South India receives more rain than Northern India. Before the South West monsoon, pre-monsoon showers during April-May, taxa like *Curcuma*, *Kaempferia* etc. start producing lateral inflorescence. With the onset of South-West monsoon the Zingiberaceae plants starts sprouting and grow luxuriantly.

After the withdrawal of the South West monsoon, the North East monsoon sets in by November. It is very crucial for Tamil Nadu as it receives over 60% of rainfall due to this monsoon. This is the main source of rain for the other states like Andhra Pradesh, South East corner of Karnataka and Orissa.

MATERIALS AND METHODS

Plant specimens of 51 species and 2 varieties belonging to 9 genera of the family Zingiberaceae from South India were studied. Collections were carried out throughout South India, mainly Western Peninsular India. Whole plant and their rhizomes were brought from collection spots and were planted in the Calicut University Botanical Garden (CUBG). Both vegetative and flowering parts were pickled in 50% FAA and stored for further laboratory studies. Herbarium specimens were also prepared and deposited in the Calicut University Herbarium (CALI). Mostly fresh specimens were subjected for anatomical studies.

Table 01. List of specimens used for the present study

Sl. No.	Name of the taxa	Coll. No.	Locality
1.	<i>Alpinia abundiflora</i> B.L. Burtt & R.M. Sm.	86187	Agasthyamalai
2.	<i>A. calcarata</i> Roscoe	103014	CUBG
3.	<i>A. fax</i> B.L. Burtt & R.M. Sm.	86134	Idukki
4.	<i>A. galanga</i> (L.) Sw.	86567	CUBG
5.	<i>A. malaccensis</i> (Burm. f.) Roscoe	86426	Kakkathode
6.	<i>A. nigra</i> (Gaertn.) B.L. Burtt	92172	Rani
7.	<i>A. zerumbet</i> (Pers.) B.L. Burtt & R.M. Sm.	86577	CUBG
8.	<i>Amomum cannicarpum</i> (Wight) Benth. ex Baker	92617	Idukki
9.	<i>A. ghaticum</i> K.G. Bhat	95670	Palaruvi
10.	<i>A. hypoleucum</i> Thwaites	103018	CUBG

11.	<i>A. masticatorium</i> Thwaites	103105	Bhagamandala
12.	<i>A. muricatum</i> Bedd.	86212	Kudajadri
13.	<i>A. pterocarpum</i> Thwaites	86144	Kakkayam
14.	<i>Elettaria cardamomum</i> (L.) Maton	103015	CUBG
15.	<i>Boesenbergia pulcherrima</i> (Wall.) Kuntze	86363	Kanjirappuzha
16.	<i>B. tiliaefolia</i> (Baker) Kuntze	86581	CUBG
17.	<i>Curcuma aeruginosa</i> Roxb.	84130	Kolathara
18.	<i>C. amada</i> Roxb.	84104	Ernakulam
19.	<i>C. aromatica</i> Salisb.	86508	CUBG
20.	<i>C. aurantiaca</i> Zijp	103017	CUBG
21.	<i>C. bhatii</i> (R.M. Sm.) Sckornickova & M. Sabu	73446	Manipal
22.	<i>C. coriacea</i> Mangaly & M. Sabu	84171	Idukki
23.	<i>C. decipiens</i> Dalzell	84179	Maharashtra
24.	<i>C. haritha</i> Mangaly & M. Sabu	84129	Kolathara
25.	<i>C. inodora</i> Blatter	73403	Maharashtra
26.	<i>C. karnatakensis</i> Amalraj <i>et al.</i>	86164	Karnataka
27.	<i>C. longa</i> L.	86536	CUBG
28.	<i>C. montana</i> Roxb.	73425	Orissa
29.	<i>C. mutabilis</i> Sckornickova <i>et al.</i>	84138	Nilambur
30.	<i>C. neilgherrensis</i> Wight	84157	Wayanad
31.	<i>C. oligantha</i> Trimen var. <i>oligantha</i> K.G. Bhat	84144	Kannur
32.	<i>C. oligantha</i> Trimen var. <i>lutea</i> (Ansari <i>et al.</i>) K.G. Bhat	84173	Kannur
33.	<i>C. pseudomontana</i> J. Graham	73402	Maharashtra
34.	<i>C. raktakanta</i> Mangaly & M. Sabu	86519	Ernakulam
35.	<i>C. vamana</i> M. Sabu & Mangaly	86368	Thrissur
36.	<i>C. zanthorrhiza</i> Roxb.	86532	CUBG
37.	<i>Globba marantina</i> . L.	84165	Karnataka
38.	<i>G. ophioglossa</i> Wight	86374	Ponmudi

39.	<i>G. orixensis</i> Roxb.	86256	CUBG
40.	<i>G. schomburgkii</i> Hook. f.	86576	CUBG
41.	<i>Hedychium coronarium</i> Koenig	86184	Nadukanipara
42.	<i>H. flavescens</i> Carey ex Roscoe	95663	Kodaikanal
43.	<i>H. spicatum</i> Hamilton ex Smith var. <i>acuminatum</i> (Roscoe) Wall.	95651	Ponmudi
44.	<i>Kaempferia galanga</i> L.	86567	CUBG
45.	<i>K. rotunda</i> L.	86422	Kakkathode
46.	<i>K. scaposa</i> (Nimmo.) Benth. & Hook. f.	86407	Goa
47.	<i>Zingiber capitatum</i> Roxb. var. <i>elatum</i> (Roxb.) Baker	73466	Jharkhand
48.	<i>Z. montanum</i> (K.D. Koenig) Link ex Dietr.	73429	Jharkhand
49.	<i>Z. neesanum</i> (J. Graham) Ramamoorthy	103205	Munnar
50.	<i>Z. nimmonii</i> (J. Graham) Dalzell	103203	Munnar
51.	<i>Z. officinale</i> Roscoe	103016	CUBG
52.	<i>Z. wightianum</i> Thwaites	95656	Anamalai
53.	<i>Z. zerumbet</i> (L.) Smith	86145	CUBG

1. Dermal Morphology

a) Epidermal Peeling: Peelings were prepared from fresh leaves using scalpel, rarely pickled leaves were also used. Peelings are always taken from the middle portion of the leaf from both surfaces.

b) Observation: The characters of the epidermis such as size and shape of epidermal cell, stomata, special epidermal cells, orientation of cells, trichomes *etc.* were observed and measured with Olympus OIC compound light microscope using various magnifications (eye piece 10x; objectives 10x

and 40x). Ocular micrometer was used for all measurements and the calculations were made by calibrating with stage micrometer.

The Epidermal details and trichomes were hand drawn using camera lucida apparatus and the magnifications were indicated at the appropriate places in figures.

Stomatal index was calculated for both the surfaces. Stomatal indices were determined on the basis of average value obtained from 15 readings. Size of the guard cells is measured in μm .

Stomatal Index was calculated by Salisbury's (1927) formula

$$\text{Stomatal Index} = \frac{\text{Number of Stomata}}{\text{Number of Stomata} + \text{Number of Epidermal Cells}} \times 100$$

Photomicrographs were taken using Sony Digital Camera (DSC 7.6) attached to Zeiss Stemi DV₄ stereo microscope and Nikon Trinocular Microscope Model Eclipse E 400 Image Analyser.

2. Foliar Anatomy: Free hand sections of the middle part of the sheath, petiole, midrib, lamina and leaf margins were taken from the middle leaf. Sections were stained with safranin and observed under the microscope for details.

3. Aerial Stem: As many genera lack a true aerial stem, study was conducted only at generic level.

4. Rhizome Anatomy: Sections were taken using microtome and stained with safranin. The occurrence of starch grains in these region, their size, shape *etc.* were studied.

5. Root anatomy: Transverse sections of mature roots were taken. Nature of the cortex, presence of starch grains and other cellular inclusions were studied.

6. Maceration: To study the xylem elements in the various genera, maceration of petiole, stem, rhizome and roots were done using Jeffrey's method (Johansen, 1940).

7. Silica bodies: Several methods employed for the staining of silica bodies include Phenol-Safranin method, Silver amine chromate method, Methyl red and Crystal violet staining *etc.* For the present study Phenol Safranin method is employed.

Fresh leaves were cut into small pieces and were put in a test tube. About 3 ml of phenol and 3 or 4 drops of safranin were added to the test tube containing leaf pieces and were boiled in a water bath for at least 30 minutes. The cleared leaf segments were mounted in phenol and observed under a compound microscope.

Various parts taken for anatomical study are given in Fig 1.

PRESENTATION OF DATA

The introductory part of this work begins with the general features of the family Zingiberaceae and the importance of anatomy in relation to the taxonomy of the family. This is followed by salient features of the area of study, detailed analysis of the earlier works related to the family in particular and others in general are dealt with. This is followed by the latest infrafamilial classification of the family based on the evidences from molecular data. The 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. Present anatomical studies also support this classification.

After classification, the general anatomical characters are explained. The characters include the arrangement of epidermal cells, types of trichomes, stomata, distribution of bundles in sheath, petiole, midrib, structure of bundles, assimilating tissue and air canals, lamina, hypodermis, and veins of lamina. This is followed by results and discussion of the work with the following details.

Within tribe the genera and species are arranged alphabetically. Each genus has a short taxonomic description followed by description and ecology. A key to the different species based on morphological character is provided. For each species description, distribution, ecology and the details

of the species studied is given. It is followed by the detailed description of the leaf anatomical characters under the following headings: epidermis, trichomes, stomata, sheath, petiole, midrib, lamina and margin. After each genus a comparison of the anatomical characters is made and a key to the different species based on the anatomical character is provided. A separate key based on anatomical characters for subfamilies, tribes and genera are provided.

The anatomy of aerial stem, rhizome and root is done only at generic level. General characters of these are given under separate heading followed by the description of the selected representative of each genus. A general description of the xylem elements found in various parts of the plants under study is also provided.

A total of 27 plates and 74 figures are provided. The figures include the anatomy of different parts of individual species and comparison of different parts of species under a genus.

REVIEW OF LITERATURE

The studies on the anatomy of Zingiberaceae were initiated by pharmacognosists working on ginger rhizomes and those observations were summarised by Futterer (1896 a & b). Subsequent works on the anatomy of the family were also concerned with the underground parts. Peterson (1893) made the first general anatomical examinations of a few representatives of the family.

Schumann (1904) in his Monograph on Zingiberaceae included notes on the anatomy of the rhizomes of Zingiberaceae.

Tomlinson (1956) conducted an extensive study on the anatomy of vegetative parts of 41 species belonging to 20 genera of Zingiberaceae collected from the green house of Royal Botanical Garden, Kew which includes only 7 genera and 4 species as representatives for South India. In this paper he included the morphology, taxonomy, geographical distribution and economic uses of Zingiberaceae. The anatomy of lamina, midrib, petiole, aerial stem, rhizome, root *etc.* was worked out in detail.

Based on anatomical characters he could separate the subfamily Costoideae with four genera *Costus*, *Dimerocostus*, *Monocostus* and *Tapeinochilus* from Zingiberoideae and strongly suggested its elevation to the rank of a family (*Table 02*).

Table 02. Comparison of anatomical characters of Costoideae and Zingiberoideae.

Zingiberoideae	Costoideae
Adaxial hypodermis is moderately developed or absent	Greater development of adaxial hypodermis in leaf with reference to the number of layers and size of cells
In the midrib, in addition to the main arc, subsidiary arcs are seen adaxially, abaxially or both.	In <i>Costus</i> , there is a principal adaxial arc of larger vascular bundles accompanied by single, small, median, abaxial bundle. Air space between the vascular bundle in the main arc is absent
In epidermis, cell files and subsidiary cells are regular. Cells above veins are modified	Cell files and subsidiary cells of stomata are less precise. Cells above veins not modified.
In petiole, main arc is seen abaxially. Bundle sheath is sclerenchymatous (except <i>Zingiber</i>).	Main arc is seen adaxially. Bundle sheath is always collenchymatous.
Hairs are usually sunken, always unicellular (except, 2-celled hairs on the rhizome of <i>Curcuma</i>).	Hairs never sunken, frequently multicellular (uniseriate).
Silica bodies generally dermal in position.	Silica bodies never dermal in position.
Oil cells present in all parts of Zingiberoideae.	Oil cells completely absent.

Datta and Mukerji (1950) studied the anatomical characters of the rhizomes of *Curcuma longa*, *Zingiber officinale* and *Alpinia galanga* with respect to their pharmacognosy. They also highlighted the anatomical characters which help to identify adulterants in drugs and also explained chemical tests for the identification of chemical constituents.

Pillai *et al.* (1961) studied the root apical organization of some members of Zingiberaceae and found that the structural configuration is similar to the grass roots and he emphasized the importance of cyto-physiological state of cells of root apex.

Remashree *et al.* (1997) studied the vascular pattern of under ground rhizome of ginger at different stages of development. It showed 2 zones separated by intermediate layers. Collateral bundles were found more in the inner zone.

Comparative rhizome anatomy of 4 species of *Curcuma* was studied by Sherlija *et al.* (1998). Though they are basically similar in structure, some variations were found between the species. The number and arrangement of vascular bundles, orientation of endodermoid layers, number and shape of starch grains and curcumin cells and number of companion cells were found to be useful in species identification.

Remashree *et al.* (1998) described the developmental anatomy of ginger rhizome – mainly the ontogeny of buds, roots and phloem. They studied the cytohistological zonation of rhizome buds and adventitious roots.

Remashree *et al.* (1999) carried out studies on development of oil cell and ducts in ginger and found that the oil cells are developed from a group of meristematic cells before the development of vascular tissue. Oil cells are mostly spherical and their occurrence varies in different regions. The oil ducts develop both schizogenously and lysogenously.

Remashree and Indira (2006) studied the comparative anatomy and histological aspects of the rhizomes of 4 species of *Curcuma*, viz., *C. longa*, *C. aromatica*, *C. amada* and *C. zedoaria* for pharmacognostic purpose. They found that variation occurs in the number and arrangement of primary and secondary bundles, orientation of tissues, number and shapes of curcumin cells, starch grains and oil cell and keys are prepared based on different characters for proper identification.

Raju *et al.* (1975) conducted studies on the stomata of ginger, turmeric and mango ginger.

Indira (1976) studied the structure and development of stomata and structure of epidermis of 26 species of South Indian Zingiberaceae covering 9 genera including *Costus*. Her studies also supported the separation of *Costus* from Zingiberaceae and the formation of a distinct family Costaceae by Nakai (1941).

Mercy *et al.* (1977) conducted an anatomical study on *Elettaria cardamomum* and gave detailed anatomical description of the aerial stem, rhizome, leaf sheath and root. They also compared anatomy of rhizome and aerial stem, as they are said to be the analogous organs.

Interspecific anatomical variations between certain *Zingiber* spp. have been reported by Hussin and Widjaja (1987). This helped to draw interrelationship between species as well as in species identification (Hussin & Ibrahim, 1989).

Hussin *et al.* (1996) studied the anatomy of three morphological variants of *Scaphochlamys kuntsleri* (Baker) Holttum. They could clearly demarcate these 3 variants based on the anatomical characters of midrib and petiole. These characters along with morphological characters were useful in the delimitation and identification of the 3 variants and they also suggested their elevation to the status of variety.

Hussin *et al.* (2000) studied the comparative leaf anatomy of 20 species of *Alpinia* from China. They revealed that interspecific variation in the structure of midrib, petiole and leaf margin can be used for species identification and certain characters like presence of adaxial hypodermis in the lamina was consistent for the genus *Catimbium*.

Achra and Lakoet (2001) compared the leaf anatomy of 11 species of *Kaempferia* from North East Thailand and were able to formulate a key for identification based on the anatomical characters.

Anatomical variations in leaves of *Boesenbergia* and *Kaempferia* were studied by Hussin *et al.* (2001) and noted that characters such as type of stomata, structure of midrib, outline of leaf margin and petiole and presence or absence of hypodermis and trichomes in the lamina when used in combination can help in species identification.

Das *et al.* (2004) carried out studies on foliar morphology and anatomy of three species of *Curcuma* and *Kaempferia galanga* and provided

the distinctive micromorphological and anatomical features which are useful in taxonomy and also in pharmacognosy.

Rajagopal (1979) investigated the distribution patterns of foliar stomata embracing their orientation and dispersion in relation to the costal cells and distinguished 8 groups consisting of 11 types in angiosperm plants represented in Flora of Hyderabad. He also found that the stomatal distribution pattern along with other epidermal characters can be used as an important taxonomic tool.

Structure and development of stomata in Zingiberaceae were studied by Olatunji (1980) and described 4 types of stomata and 4 types of stomatal development. In Zingiberaceae tetracytic type is commonest, while in Costaceae it is polycytic type.

Cheadle (1953) discussed the origin of vessels in monocotyledons and dicotyledons, based on the structure of vessels and their perforation plate. He further concluded that the vessels first originated in roots, then stem and later in leaves. He included Zingiberaceae in families having some species with vessels in roots only and other species with vessels in the roots and elsewhere.

A literature survey on the vessel types occurring in roots, stem and leaves of monocotyledons was presented by Wagner (1977). An agreement between type and distribution of vessels, systematic position and habit was

given. Based on the vessel characters some minor modifications in the classification of the monocotyledons (Dahlgren, 1975) were suggested.

Prychid *et al.* (2004) studied the distribution and diversity of silica bodies in monocotyledons and their use in systematics based on their structure and position.

The anatomical works on several related families of monocotyledons by various workers (Tomlinson, 1959 & 1960; Decker, 1964; Govindarajalu, 1961 a, b; Keating 2004 a, b; Goncalves *et al.*, 2004) have made much realignment in the position of several genera and species.

The main anatomical difference between the family Cyperaceae and Juncaceae is the presence of silica bodies in the former and its absence in the latter.

Silica bodies are of systematic value in the family Poaceae. Such silica body containing cells called 'stegmata' have been used for systematic purpose even at the specific level by Tomlinson in Zingiberaceae (1956) Musaceae (1959) and Palmae (1961 c).

Metcalf (1960) showed that the histological characters of grass leaves do provide good characters for the separation of panicoid and festucoid grasses and to recognize the bamboos as a distinct group within Poaceae.

According to Carlquist (1961) leaf is perhaps anatomically the most varied organ of angiosperms, and it possesses many anatomical features of

taxonomic significance. Leaf anatomy helped systematists to solve many taxonomic problems such as assigning proper position to a taxon and also in classification.

Govindarajalu (1969 a, b) investigated the systematic anatomy of South Indian Cyperaceae and formulated a key based on leaf anatomy to distinguish various species of *Fuirena* and *Cyperus*.

Paliwal & Kakkar (1970) justified the erection of separate family Garryaceae for the genus *Garrya* on the basis of leaf venation, stomata, and scleried type occurring in the leaves.

Studies on the stem anatomy (Ayensu, 1970) of two *Dioscorea* species, *D. cayenensis* and *D. rotundata*, provided histological evidences that assisted in keeping them as two distinct species. Stem anatomy has also provided clue in identification of different hybrids and tracing their parents even at the generic level (Stace, 1970).

Tomlinson (1959) conducted anatomical studies on the family Musaceae and its obeyance on the classification and the affinities between the different genera were also drawn based on these characters.

Tomlinson (1960) described the anatomy of vegetative parts of *Phenakospermum guianensis* and the systematic position of the genus was established along with *Ravenala* and *Strelitzia* and confirmed its position in the family Musaceae.

Morphological and anatomical characters of the family Marantaceae were studied by Tomlinson (1961 b) and he concluded that there are no anatomical characters sufficient enough to differentiate between the two tribes Maranteae and Calathea but character of taxonomic significance are present to identify the taxa at generic level.

Brown (1961) studied the leaf anatomy of Poaceae and found that the leaf anatomy is correlated with its physiological process of photosynthesis and recognised 6 types of tissue arrangements correlated with the different taxonomic groups. Since leaf anatomy is intimately associated with physiology it is the most reliable character useful in grass systematics.

Systematic anatomy of tribe Festucae (Poaceae) was studied by Decker (1964). Anatomy of 135 grass genera was studied along with morphological characters, and a more acceptable phylogenetic system of classification was proposed. Thus he divided the family into 4 sections and the positions of many genera were revised.

Metcalf (1969) conducted an extensive anatomical study on vegetative organs of more than 280 species belonging to 90 genera of Cyperaceae. The anatomical differences from other related families were discussed. Based on anatomy, the family is classified into 7 tribes. The division into genera and species were based on Transverse sections of lamina, mesophyll, shape of silica bodies, presence of vascular commissures, number of vascular bundles, nature of bundle sheath, sclerenchyma *etc.*

Blunden and Binns (1970) gave a detailed anatomy of *Yucca glauca* and the most useful diagnostic features of the species were the papillose epidermal cells, large acicular crystals of calcium oxalate, partially lignified fibres and structure of cells from modified leaf margin.

Sharma and Mehra (1972) investigated the systematic anatomy of 14 Indian *Fimbristylis*. The leaf anatomical characters that helped in distinguishing different species included shape of subsidiary cells in surface view, dermal appendages, outline of blade, and stem in transection, adaxial epidermis and nature of air canals.

Blunden and Jewers (1973) studied the comparative leaf anatomy of *Agave*, *Beschorneria*, *Doryanthes* and *Furcraea* (Agavaceae). Anatomically these genera can be distinguished easily based on epidermal characters such as type of papillae, extend of cell elongation, and stomatal characters. Sufficient anatomical characters were observed which helped to distinguish between the species of *Agave*.

Singh and Jain (1975) conducted epidermal studies on *Prunus* (Rosaceae) and the epidermal characters, reticular striations *etc.* were found to be useful in taxonomy and could be used for the identification of different species studied.

Studies on the anatomical variation of the *Vulpia* (Cotton & Stace, 1977) revealed the occurrence of 5 well defined groups which were given

sectional status and the affinities between them were discussed. The anatomical characters clearly serve to differentiate taxa at all levels.

Distributional patterns and the taxonomic importance of foliar stomata of 505 flowering plants included in the Flora of Hyderabad was investigated (Rajagopal, 1979) and they were classified into 16 groups. Zingiberaceae comes under group V where the stomata are oblique or at right angles to the longitudinal vein of the leaf (parallel to the lateral vein) and the costal cells are distinct.

Fifteen species of *Fimbristylis* occurring in Calicut district were examined for the anatomical characters of taxonomic importance by Abdul Majeed (1979) and the characters such as number of rings of vascular bundles, bundle sheath, air cavities and outline of the leaf in Transverse section *etc.* in combination were useful in taxonomic delimitation of the different species.

Pridgeon (1982) revealed the diagnostic anatomical characters of 200 species under 22 genera belonging to the subtribe Pleurothallidinae of Orchidaceae and the leaf anatomical characters like features of trichome, cuticle, epidermis, hypodermis, spiral thickenings and number of vein series *etc.* were found useful. He could correlate the anatomical characters with the morphological characters.

Denton (1983) studied the leaf anatomy of Luzulae group of *Cyperus* and proved that the leaf anatomical characters also supported the present

classification of the Luzulae group. The important characters included the structure of vascular bundles, arrangements of schlerenchyma, mesophyll and air spaces in leaf transverse section *etc.*

Wilder (1985 a, b, c & d) conducted an extensive study of the non-costal portion of the lamina of family Cyclanthaceae. The different aspects studied include the epidermis, crystal sac, periderm, boundary layers of the mesophyll, and veins of intercostal areas, expansion tissue, and adaxial and abaxial ridges. The subdivision of subfamily by Harling is supported by the anatomical evidence. Tomlinson and Wilder (1984) in an overview of this anatomical approach provided the anatomical characters that distinguished this family from other two families such as Pandanaceae and Palmae.

Koller and Rost (1988) studied the anatomy of 49 taxa of *Sansevieria* and detailed description of the genus was given and the anatomical characters were correlated with its function.

Anatomical studies on the 25 species of Indian Araceae were conducted by Sabu (1992) and a key based on micromorphological characters that allowed the identification of different genera were provided and the position of *Acorus* is discussed in the light of anatomical characters.

Stern *et al.* (1994) studied the anatomy of leaves in *Dendrobium* (Sect. Rhizobium) and the important features of the section are the tetracytic stomata, crassulaceous leaves, laminated exodermal cell walls, thin ramificulae and leaves with an adaxial foliar groove or enclosed canal. Based

on these characters, the monophyletic origin of the section was also suggested.

Aiken and Consaul (1995) studied the leaf sections of 30 taxa of *Festuca* of North America. The most obvious characters which are useful for the delimitation of the species are the presence or absence of sclerenchyma. It was found to be significant even at subgeneric level.

Anatomical characters of *Heliconia* (Musaceae) were studied by Simao and Scatena (2001) and the characters such as air canal in different organs, the distribution of fibres in leaves and scape were found to be of taxonomic value.

Hussin *et al.* (1992, 1996 a, 1996 b, 1997, 1998 & 2000) studied the comparative leaf anatomy of different genera belonging to Myrtaceae, Sterculiaceae, Euphorbiaceae and Annonaceae. The characters such as type of stomata, shape of leaves in Transverse section, shape of midrib bundle, sclerenchyma sheath, cutinization of outer epidermal wall, presence of sclereids, idioblasts, hypodermis, number of palisade layers *etc.* were found to be useful in identification and assigning systematic position of certain genera.

Vijaya Kumar (1998) conducted an extensive anatomical investigation on 48 species belonging to 18 genera representing the 4 subfamilies of Boraginaceae. The foliar epidermis, foliar anatomy and foliar architecture were studied in detail and formulated a key for the identification of different

species studied. These characters were found to be taxonomically significant.

Kasturi *et al.* (2001) conducted epidermal studies on some members of the family Oleaceae and found that characters such as nature of epidermal cells, number of epidermal cells, stomatal frequency and stomatal index are useful in species identification. Taxonomic significance of three components *viz.*, epidermal complex, stomatal complex and trichome complex were also evaluated and trichome complex was proved to be of greater taxonomic significance.

Goncalves *et al.* (2004) examined the presence of collenchyma in the petioles of Araceae and classified 115 species from 56 genera into 3 groups and its obedience on the classification into tribes by earlier workers were discussed.

Keating (2004 a) discussed the agreement of vegetative anatomical data to the revised classification of Araceae. The anatomical characters studied are the type and position of conducting and mechanical tissue, aerenchyma, raphide crystals and laticifers. These data were superimposed on three lines of evidences using DNA sequences. Thus a new classification was obtained with fewer anomalous generic placements.

The presence of raphide crystals and its use in the systematics of Araceae was studied by Keating (2004 b). Raphide types are recognised and the 106 genera were grouped, this grouping is posted against the new

classification of the family. Features of raphide crystals were found to be useful in generic diagnosis.

Recently Morrone *et al.* (2007) and Zuluoga *et al.* (2007) published two genera in Poaceae and Rajkumar and Janarthanam (2007) identified a new genus in Clusiaceae based on morphological, molecular and anatomical characters.

Petra Hoffmann and Pherson (2007) revised the genus *Wielandia* Baill. of Western Indian Ocean and recognised 13 species including a new species *W. unifex* Petra Hoffm. and Mc Pherson. Leaf venation and leaf anatomy also provide sufficient characters for the recognition of new species.

CLASSIFICATION

Based on both vegetative and floral characters, many scientists have classified the Zingiberaceae into 4 tribes (Peterson, 1889; Schumann, 1904; Holttum, 1950; Burt & Smith, 1972; Larsen *et al.*, 1998). Although a number of morphological features have been used to distinguish 4 tribes, the characters are often inconsistent and variable. Peterson (1889) and Schumann (1904) included the family Costaceae in Zingiberaceae but with a number of distinctive characters such as lack of aromatic oils, branched aerial stem and spiral monostichous phyllotaxy (Specht, 2001) it is now accepted as the sisterclade to the gingers (Kress, 1990, 1995; Kress *et al.*, 2001).

Kress *et al.* (2002) used molecular sequence data to find out the phylogenetic relationship among the genera of Zingiberaceae in order to evaluate the past classification and proposed a new phylogenetic classification. The taxa used for the present study are arranged according to this classification.

Key to the Subfamilies and Tribes (Kress *et al.*, 2002)

1. Plane of distichy of leaves perpendicular to rhizome.....2
1. Plane of distichy of leaves parallel to the rhizome.....
.....Sub fam. 1. **Zingiberoideae**

- 2. Lateral staminode well developed and fused to the labellum.....3
- 2. Lateral staminode reduced or absent.....Sub fam. 2. **Alpinioideae**
- 3. Plants evergreen with fibrous rhizome; ovary unilocular with parietal placentation.....Sub fam. 3. **Tamijioideae**
- 3. Plants with seasonal dormancy period and fleshy rhizome; ovary trilocular with axile placentation.....Sub fam. 4. **Siphonochiloideae**

Alpinioideae

Key to the tribes

- 1. Extra floral nectaries present on leaf blades; fruits siliqua-like, opening by longitudinal slit**Riedelieae**
- 1. Extra floral nectaries absent; fruits fleshy or indehiscent.....
..... **Alpinieae**

Zingiberoideae

Key to the tribes

- 1. Ovary trilocular with axile, basal or free columnar placentation; labellum usually not connate to the filament**Zingibereae**
- 1. Ovary unilocular with parietal placentation; labellum often connate to the filament in a slender tube**Globbeae**

Tribe: Alpinieae

Key to the genera

1. Inflorescence terminal on the leafy shoot (rarely on long, separate, erect peduncle) tightly congested or lax, each subtending a cincinnus of 2-many flowers; anther connective crested or not.....1. **Alpinia**
1. Inflorescence borne separately from the leafy shoot; peduncle short or long; bracts 1-many flowered; anther crested or sometimes small and inconspicuous2
2. Inflorescence partially subterranean or raised above the ground; each bract subtends a single bracteolate flower; anther usually crested2. **Amomum**
2. Inflorescence prostrate, much elongated; each bract subtends a several flowerd cincinnus; anther crest small and inconspicuous3.

Elettaria

Tribe: Zingibereae

Key to the genera

1. Lateral staminodes adnate to the labellum; anther crest elongate, embracing the style 5. **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 forming a pouch **2. Curcuma**
2. Primary bracts not adnate laterally **3**
3. Stem well developed; corolla tube long, exerted from the bracts **3. Hedychium**
3. Stem short, poorly developed or absent; corolla tube short or long, sometimes exceeding the bracts **4**
4. Bracts distichously arranged; bracts mature from tip to base; anther-crest short or absent**1. Boesenbergia**
4. Bracts spirally arranged; bracts mature from base to tip; anther-crest petaloid **4. Kaempferia**

GENERAL ANATOMICAL CHARACTERS

Epidermis

Inter costal cells of the adaxial epidermis of leaves are usually polygonal, longer than broad with their longer axis perpendicular to the longitudinal veins. Costal cells seen above the veins are much smaller, as long as broad or broader, cell files are distinct in these regions (*Alpinia*, *Amomum*, *Elettaria*, *Curcuma*, *Globba*, *Hedychium*, *Zingiber* etc.) (Plate 02 A). Abaxial epidermal cells are smaller than upper ones and the cell files are indistinguishable. Costal cells of both the epidermis contain silica bodies (*Alpinia*, *Elettaria* & *Amomum* spp.) or silica sand (*Amomum* spp.) (Plate 02 B, C & D). Cuticular striations are present on the epidermis of *Kaempferia* spp. (Plate 04 F).

Trichomes

Trichomes are always simple and unicellular. Its length varies from a few microns (*Alpinia* spp.) to 2.5 mm (*Hedychium* spp.). The commonly found hair types are:

- (1) 'Borste' type (bristle) of Staudermann (1924). They are defined as one or more celled, cylindrical, generally pointed and stout hairs, but with certain elasticity and a length five to fifteen times the basal diameter. Usually they have thick walls and narrow lumen. This type of hair is seen in *Alpinia*, *Amomum*, *Elettaria*, *Curcuma* etc. (Plate 04 A).

- (2) 'Weichhaare' (soft or delicate hair). They are one or more celled, simple, blunt or pointed hair, it differs from 'Borste' in their greater average length and in having the cell walls strongly thickened at their bases. The most distinctive feature is that they are easily detached at the slight constriction of wall and lumen at the surface of the leaf. This type of hair is seen in *Hedychium*, *Kaempferia*, *Globba* and *Zingiber*. Petiole, midrib, sheath *etc.* may also possess trichomes (Plate 04 C, D & E).
- (3) 'Borsten' (prickle). They are very minute hairs (12-20 μm), the base of which are sunken and only the tip project on the surface. The leaves of *Alpinia galanga* and *A. nigra* appear to be glabrous, but such prickle type hairs are seen on both surfaces of *A. galanga* and on the abaxial surface of *A. nigra* (Plate 03 C & D).

Stomata

Stomata are typically tetracytic with the exception of *Boesenbergia* having polycytic stomata *i.e.*, the guard cells are surrounded by 6-10 subsidiary cells (Plate 03 E & F). The long axis of the pore is parallel to the longitudinal veins and they are abundant on the abaxial epidermis. In majority of the taxa studied, stomata are distributed evenly between the veins. But in *Alpinia zerumbet*, stomata are seen on either side of the veins (Plate 02 F).

Leaf sheath

Leaf sheaths are always winged. Ground tissue is similar to that of petiole. Bundle arcs I, II and III may be present. At the base of the sheath, 3 types of bundles based on size are distinguished in *Elettaria cardamomum*. In the wings of the sheath arcs I and II are present, which usually appear as a single arc of alternating large and small bundle. In the wings of sheath, the ground parenchyma cells beneath the epidermis are arranged in layers resembling hypodermis, which together with the assimilating tissue, resemble the mesophyll of leaves. Petioles may be winged or not; its shape and size show variation.

Distribution of bundles

The bundles of petiole, sheath and midrib are arranged in several arcs and are numbered I-IV (Tomlinson, 1956) (*Plate 05 A-F*). Arc I is the main arc near the abaxial surface; and its bundles are of the same size in the median region, gradually becoming smaller towards the margin. Between these bundles air canals are seen. Abaxial to this may be an arc of much smaller bundles of arc II, often made up of alternating larger and smaller bundles, the largest alternating with the bundles of arc I. Adaxial to arc I, there are many bundles which constitute the central system, arc III, consisting of medium size bundles arranged irregularly. Arc IV is distinguishable as a plexus of small bundles close beneath the adaxial epidermis as in *Alpinia*, *Amomum*, *Globba*, *Hedychium* etc.

The degree of development of the bundle arcs varies with the level of section and species. Arc IV, if present, shows its maximum development in the petiole and is absent from midrib and lower part of the sheath.

Arc III also shows maximum development in the petiole but poorly represented in the midrib.

Structure of Bundle

The individual bundle of the main arc is designated as '*Musa-Type*' (Solereeder & Meyer, 1930). Bundles of this type are roughly pear-shaped in section and somewhat constricted across the centre. The abaxial half is somewhat wider or even upto twice as wide as the adaxial half (*Plate 06 B*).

The dominant feature is the single, large metaxylem element. Sometimes two of these appear at levels where the tapering ends of two super imposed elements overlap. Adaxial to this element is the protoxylem of 1-3 elements showing evidences of extension and collapse. The earliest of the protoxylem elements may be obliterated, and the enlargement of the xylem parenchyma in this region suggests that they have expanded into the resulting space. Tracheal elements which develop later are more persistent. The degree of development of this protoxylem region varies considerably. Around the large metaxylem element, the parenchyma cells exhibit a very regular concentric arrangement. Below that there is a group of small tracheal elements, mostly angular in section.

A single layer of conjunctive parenchyma separates the xylem from the abaxial phloem. This phloem together with the surrounding bundle sheath is much wider than the part of the bundle containing xylem (*Amomum muricatum*) (Plate 08 F). The phloem consists of sieve tube elements, companion cells and parenchyma.

The bundle sheath is incomplete and is generally separated into an upper and lower fibre cap by a ring of parenchyma at the region of xylem. These lateral parenchyma cells are colourless and frequently deposited with either starch grains, calcium oxalate crystals or silica. The thickness of the walls of the cells of the upper and lower cap varies with the species. In most of the species of *Alpinia*, *Amomum*, *Elettaria* etc. the walls are thick and the lumen is small, but in some other like *Kaempferia* the walls are thin with large lumen. Generally fibres of the adaxial cap are larger and thinner walled than abaxial fibres.

The bundles of arc II have only a single tracheal element and very rarely contain protoxylem. Xylem parenchyma may be developed or absent. A small phloem group completes the vascular tissue. The bundle sheath consists of a complete sheath of fibres and whole bundle is circular in outline (Plate 06 C & D).

The bundles of arc III are often obliquely or inversely oriented (Plate 06 E). Bundles of arc III have a continuous or interrupted bundle sheath. A single large tracheal element and several smaller elements are present.

The bundles of arc IV are characterised by reduced vascular tissue and a well-developed mechanical sheath (*Plate 07 C & D*). Bundles without vascular tissues are also present along with normal bundles. These bundles also show reverse orientation of xylem and phloem. Petioles of *Alpinia galanga* shows a continuous fibrous band formed by the fusion of the abaxial cap of arc I bundles (*Plate 07 A*). The genus *Zingiber* is unique as it possesses collenchymatous bundle sheath in the petiole (*Plate 07 E, F & H*).

Ground tissue

Parenchymatous cells of the ground tissue are smallest in the sub epidermal layers; there is gradual transition to the larger central cells.

Assimilating tissue and air canals

Alternating with the bundles of arc I is a system of air canals. They extend from the base of the sheath to some level of midrib. These air canals are well developed in *Curcuma*, *Kaempferia*, *Boesenbergia* etc. and smaller in others. Surrounding the main arc bundles is a band of chlorenchyma; the air canals are also lined by the cholrenchyma cells. The air canals contain elongated, loosely arranged chlorophyllous tissue forming partitions called diaphragm or trabeculae. Diaphragms are usually without vascular tissue as in *Curcuma* (*Plate 07 B*) or it is interrupted by transverse vascular bundles as in *Kaempferia*. Diaphragm in which vascular tissues are absent, develop from a single layer of rounded cells which get partially separated from one

another by the enlargement of air canal. They maintain contact only at the ends of extended arms.

The chlorenchyma band and air space system shows a maximum development in the petiole and upper part of the sheath.

Midrib

The difference between different species in the anatomy is due to the level of divergence of the midrib bundles into the lamina. Midrib region is usually raised on the abaxial surface. In a few instances the subepidermal ground parenchyma cells are thick walled (*Alpinia* spp.) (Plate 08 A, C & D).

The bundles of midrib also show bundle arcs I-IV. Some of the arcs may be absent in transverse sections. All species possess a main arc of large bundles (Arc I). Then there may be either arc II or arc III only or both (Plate 08 B & D). In *Alpinia zerumbet*, bundle arc IV also is seen (Plate 08 G). Ground parenchyma of the adaxial side may become enlarged. The presence of or absence of arcs II, III and IV differ from species to species. Bundles may end blindly or fuse with one another. In the former case, the bundles end in a strand of fibres and vascular tissues and finally disappear.

Lamina

The epidermis bears a thin cuticle. The epidermal cell walls are slightly thicker than those of internal cells; the outer most cells are thickest. The epidermal cells above the veins are smaller and thick walled.

Hypodermis

It may be completely absent in *Alpinia calcarata*, *A. galanga* (Plate 09 A), *Curcuma vamana*, *Kaempferia scaposa* etc. or present on both surfaces as in *Kaempferia galanga*, *Curcuma* spp., *Hedychium* spp. etc. (Plate 09 D & I). Adaxial hypodermis is seen in *Amomum hypoleucum* (Plate 09 B). Abaxial hypodermis alone is present as in *Globba* spp., *Curcuma* spp. etc. (Plate 09 G).

The individual hypodermal cells are large and transversely stretched, colourless and occasionally contain calcium oxalate crystal or tannin. The relative size of the epidermis and hypodermis is variable. Generally the hypodermal cells are much larger than epidermal cells (*Kaempferia* spp.) (Plate 09 D). In some, the size of the epidermal cells is almost equal to the hypodermis, but never larger than the hypodermis. In species without hypodermis, epidermal cells are larger *Boesenbergia* spp. (Plate 09 H), *Curcuma vamana* etc.

The number of hypodermal layer varies from one to a maximum of three. The hypodermis in a precisely defined position in the leaf has a characteristic appearance which is diagnostic for the species.

Mesophyll

Leaves show a dorsiventral structure. The mesophyll is divisible into a distinct palisade and spongy layer of compact, rounded or lobed nature. Palisade generally consists of vertically elongated, cylindrical cells, 2-3 times

as high as wide and compact in varying degrees. Where the palisade consists of more than one layer, the cells of the lowest layer are the shortest, often a transitional in shape to those of the spongy cells below.

Veins of lamina

The size of vascular bundles of lamina vary from large, medium to small and are arranged in roughly alternating manner, in a row.

Each of the largest vascular bundle has a single large xylem element and abaxially one or more small, angular xylem elements. They are separated from the phloem group by one or two rows of small-celled conjunctive tissue.

The bundles are flanked laterally by one or sometimes two layers of parenchyma cells which are rounded in shape (*Plate 09 F*). They are colourless, but may contain calcium oxalate crystal, silica or starch. In larger bundles the bundle sheaths are completed above and below, by thick walled fibre like cells. The sheaths of smaller bundle may be entirely parenchymatous. In medium sized bundles the fibres are generally confined to the abaxial part of the sheaths. In largest bundles the fibres of the cap continue as a bundle sheath extension to form complete buttress across the mesophyll (*Plate 09 A*). The bundle may be connected to both the epidermis in *Amomum* spp., *Alpinia* spp., *Globba* spp. etc. and to the adaxial epidermis only as in *Hedychium* spp. and *Curcuma* spp. (*Plate 09 I*).

The smaller bundles have a very simple structure. They consist of one or two narrow xylem and phloem elements and a continuous one-layered parenchyma sheath and are seen among the spongy tissue as in *Kaempferia*, *Curcuma*, *Hedychium* etc. In *Amomum pterocarpum* and *A. hypoleucum*, the largest bundles and smaller bundles possess abaxial fibrous cap only, which is in contact with the abaxial epidermis only (Plate 09 C).

Calcium Oxalate Crystals

Calcium oxalate crystals are distinguished from the silica inclusion by their bi-refrangent nature. Crystals vary in shape from rhombohedral, prismatic or rod-shaped. The crystals range in size from minute bodies, which aggregate into groups (*Curcuma* spp.), to single, large crystals, one in each cell (*Globba* spp.) (Plate 09 G). In lamina, they are abundant the ground tissue of petiole, sheath and midrib. Very few crystals are seen in the mesophyll and hypodermis or very rare in epidermis. Aerial stem (*Hedychium coronarium*, *Amomum masticatorium* etc.) and rhizome also possess crystals but they are absent in roots.

Silica bodies

Silica bodies are visible by the light they reflect and they are not bi-refrangent. In Zingiberaceae, they are usually epidermal in position (Tribe Alpinieae). Silica bodies in the costal cells are large, spherical with an irregular granular surface. Usually they are arranged in rows (eg. *Alpinia*

spp.) (*Plate 02 B*). In *Amomum* silica sand is common in the costal cells (*Plate 02 D*). In other parts silica inclusion is associated with vascular bundles (*Globba* and *Kaempferia*). In petiole and sheath it is present in the ground parenchyma cells surrounding the bundle. Silica is completely absent in roots.

RESULTS AND DISCUSSION

51 species and 2 varieties of Zingiberaceae seen in South India were subjected to anatomical studies. The parts studied are leaf, aerial stem, rhizome and root. Leaf anatomy of all taxa was studied in detail. Aerial stem, rhizome and root anatomy were studied on selected species of each genus as they did not show much infrageneric variation. Xylem elements were studied by maceration method. The results obtained are given under separate headings.

I. LEAF

1. ALPINIA Roxb. (*nom. cons.*)

Alpinia Roxb., *Asiat. Res.* 11: 350. 1801; *Fl. Indica* 1: 58. 1820; M. Sabu, *Zingiberaceae and Costaceae of S. India* 45. 2006.

Rhizome fleshy or hard; root tubers absent. Leaf shoots many, 2-4 m tall. Leaves, oblong or lanceolate, plane of distichy transverse to rhizome. Inflorescence raceme or panicle, usually terminal, when young covered by 1-3 sheaths. Bracts absent or when present open to the base, each subtending a single flower or cincinnus of 2-many flowers. Bracteoles deciduous. Calyx tubular, unilaterally split. Corolla tube equal or shorter than calyx, lobes usually unequal. Labellum petaloid, attractively coloured and showy. Lateral staminodes small or absent. Anther sessile or with short filament; connective sometimes crested. Epigynous glands rarely free from

each other. Ovary trilobular with axile placentation. Capsule spherical, yellow-orange or black. Seeds many, angular with lacerate aril.

Distribution: China, India, Japan, Myanmar, Malesia, Philippines, Sri Lanka, Thailand, Australia, Fiji and Samoa. In South India, it is widely distributed in Kerala and Karnataka; poorly represented in Tamil Nadu and Andhra Pradesh.

Key to the species based on morphological characters

- 1 Inflorescence capitate, borne separately on a leafless peduncle, surrounded by sterile bracts.....2
1. Inflorescence paniculate or racemose, terminal on the leafy shoot, sterile bracts absent.....3
2. Inflorescence globose; outer bracts large, forms a cup-shaped structure1. **A. abundiflora**
- 2 Inflorescence elongates considerably with age, spike long; outer bracts not forming cup-shaped structure 3. **A. fax**
3. Fertile bracts well developed.....4
3. Fertile bracts absent.....6
4. Bracteoles tubular, persistent; fruits black.....6. **A. nigra**
4. Bracteoles open to the base, quickly deciduous; fruits red.....5

5. Inflorescence branched; labellum long clawed.....4. **A. galanga**
5. Inflorescence unbranched; labellum obovate, without claw.....2. **A. calcarata**
6. Bracteoles white, open to base, 1.5-2 x 1-5 cm; lower surface of lamina pubescent.....5. **A. malaccensis**
6. Bracteoles white with pink tip, lower 1/3 fused to form a cup, 3-3.5 x 2.5-3 cm; lamina hairy along the margin only.....7. **A. zerumbet**

1. *Alpinia abundiflora* B.L. Burtt & R.M. Sm., Notes Roy. Bot. Gard. Edinburgh 34: 179. 1975; M. Sabu, Zingiberaceae and Costaceae of S. India 48. 2006. **(Plate 10 A)**

Rhizome fibrous. Leafy stem 3-4 m high. Leaves shortly petiolate, petiole upto 2 cm long; lamina 60-70 x 10-13 cm, oblong or lanceolate, glabrous. Ligule 1.5-1.8 cm long, membranous. Inflorescence globose, peduncle long. Sterile bracts large, red, forms a cup-shaped structure. Outer fertile bracts subtending single flower; inner ones longer than sterile bracts, narrower, subtending a cincinni of 7 flowers. Labellum small, obovate unequally 3-lobed, white with pink stripes. Lateral staminodes absent. Fruit small, spherical-oblong, thin walled, smooth.

Distribution: Sri Lanka and South India.

Ecology: Seen in dense wet evergreen forest above 1000 m along Southern Western Ghats.

Specimen studied: KERALA: Thiruvananthapuram Dt.: Vazhukkampara, Sanoj 86187.

Anatomical features

(Fig. 2)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, higher than broad (56-80 x 32-40 μm) with their longer axis perpendicular to the longitudinal veins. Cell files are regular. Costal cells are twice or thrice broader than high (16-20 x 32-48 μm) and the cell files are more or less regular. About 4 rows of cells are seen above the veins. Intercostal cells of the abaxial epidermal cells are also higher than broad (49-88 x 28-32 μm) and more or less regularly arranged. Costal cells are twice broader than high (28-32 x 48-60 μm) and are seen in definite rows. Costal cells of both epidermis contain one small (less than 4 μm wide) silica body in them.

Stomata: Stomata are abundant on the abaxial epidermis and are evenly distributed between the veins. Guard cells are 40 μm long. Stomatal index is 12.17. Few stomata are present on the adaxial epidermis also (SI = 1.72).

Trichomes: Trichomes are completely absent on the lamina, but hairs upto 70 μm long are seen on the abaxial surface of the wings of sheath.

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. The abaxial surface is wavy towards the distal part. Bundle arcs I, II and III are present. The air canals between the bundles are larger. Crystals of various shapes

are seen in groups in some of the cells of ground tissue. Metaxylem of the main bundle is 60-72 μm wide. Oil cells are few.

Petiole: Abaxial surface is wide U-shaped and adaxial surface is wide V-shaped. Bundle arcs I, II, III and IV are present. Cells of the ground tissue possess crystals. Metaxylem is 56-72 μm wide. Oil cells are also seen. Petiole wings are broad, blunt and unequal.

Midrib: Both abaxial and adaxial surfaces are wide U-shaped. Bundle arcs I and III are present. Some cells of the ground tissue contain either a single or few crystals in groups. Metaxylem is 48 μm wide. Chlorenchyma cells seen around the air canal and bundle posses starch grains.

Lamina: Lamina is 300 μm thick at the bundle and 244 μm in other portions. Adaxial epidermal cells are as high as broad or slightly broader (48 x 60-80 μm) cells above the veins are much smaller. Abaxial epidermal cells are smaller than adaxial ones and are slightly broader than high (32-40 x 48-80 μm). Mesophyll is 128 μm thick and is divisible into 2-layered palisade and 3-layered spongy. The cells of second layer of palisade are shorter than the normal cells. Hypodermis is absent adaxially. Though a continuous hypodermis is absent, sometimes non chlorophyllous cells are seen abaxially. The bundle cap is in contact with both abaxial and adaxial epidermis. Metaxylem is 32 μm wide. Smaller bundles are surrounded by thin walled prechyma and they are in contact with the abaxial epidermis. Oil cells are present in the mesophyll.

Margin: Adaxial epidermal cells are usually higher than broad and abaxial cells are smaller than adaxial ones. 1-layered palisade and 2-layered spongy constitute the mesophyll. Abaxial cap of the last bundle is in contact with the epidermis. Metaxylem is 48-52 μm wide. The portion beyond last bundle consists of mesophyll and few parenchyma cells. The tip is gradually tapering, almost straight and pointed. Hyaline portion is multiseriate (4-celled at the base) and 160-192 μm wide.

2. *Alpinia calcarata* Roscoe, Trans. Linn. Soc. London 8: 347. 1807; M. Sabu, Zingiberaceae and Costaceae of S. India 50. 2006. **(Plate 10 B)**

Leafy shoot 1-1.5 m high. Leaves sessile; lamina 40-50 x 2-2.5 cm, linear-lanceolate, glabrous, narrowed towards base, tip acuminate, margin with short bristles placed 1-2 cm apart; ligule c. 1cm long, shortly bifid. Inflorescence terminal, 10-15 cm long, densely paniculate. Bracteoles membranous, open to base, deciduous. Labellum obovate, c. 3 cm long, tip emarginate, variegated with dark purple and yellow. Lateral staminodes small subulate, at the base of the labellum. Stamen shorter than the labellum. Style slightly projected above the anther; stigma rounded. Epigynous glands 2, free from each other. Ovary densely pubescent. Fruit globose, pubescent, orange red.

Distribution: Native of India also occurs in Myanmar, Thailand, Indonesia and New Guinea. In South India it is seen in Karnataka, Kerala and Tamil Nadu. Cultivated in Sri Lanka, Malay Peninsula and China.

Specimen studied: KERALA: Malappuram Dt.: C.U. Botanical Garden, Jayasree 103014.

Anatomical features

(Fig. 3)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal (48 x 16-32 μm) with their longer axis perpendicular to the longitudinal veins. Costal cells are much smaller (16 x 20 μm). Cell files are very regular in both regions. Abaxial epidermal cells of the intercostal region are also polygonal (32-48 x 16-32 μm) but less stretched than upper ones. Costal epidermal cells are smaller (16 x 16-32 μm). Costal epidermal cells of both surfaces contain single, spherical silica body (4 μm) in them.

Trichomes: Completely absent

Stomata: Large number of stomata are seen on the abaxial epidermis. They are distributed between the veins with more stomata near the veins and less in the centre. Length of the guard cell varies from 32-36 μm (usually 32 μm). Stomatal Index is 9.24. Very few stomata are found on the adaxial epidermis (SI = 0.28)

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Epidermal cells are as high as broad. Bundle arcs I, II and III are present. Metaxylem is 80-88 μm wide. Oil cells are very few. Very rarely few small crystals are seen in some cells of the ground tissue.

Petiole: Abaxial surface is U-shaped and adaxial surface is flat in the middle. There are two wings on either side, wings are triangular and pointed. Bundle

arcs I, II, III and IV are present. Air canals in between the bundles of arc I are rounded and smaller than bundles.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is concave. Bundle arcs I and III are present. 2 or 3 layers of cells just below the adaxial epidermis are thick walled.

Lamina: Lamina is 172 μ m thick. Adaxial epidermal cells are broader than high (16-24 x 32-40 μ m). Abaxial epidermal cells are also similar in size. Hypodermis is present adaxially and is represented by 1 or 2 cells between the bundles. Bundle caps are connected to both epidermis. Smaller bundles are connected to the adaxial epidermis through girders. Mesophyll is 96 μ m thick and consists of 1-layered palisade and 2 or 3 layered spongy cells. Cells of the spongy tissue contain few calcium oxalate crystals.

Margin: Cells of both epidermis are as high as or slightly broader. A continuous hypodermis is present adaxially, beyond the last bundle. The bundle is connected to both epidermis by 2-layered cap. Metaxylem of the last bundle is 30 μ m wide. Margin is straight and blunt. Hyaline portion is multiseriate (3-4 celled) and 36-48 μ m wide.

3. *Alpinia fax* B.L. Burtt & R.M. Sm., Roy. Bot. Gard. Edinburgh 34: 177. 1975; M. Sabu, Zingiberaceae and Costaceae of S. India 52. 2006.

(Plate 10 C)

Leafy shoot 2-3 m high. Leaves 7-8, sessile; lamina 50-55 x 12-13 cm, lanceolate, tip acuminate, attenuate at base, upper surface glabrous,

lower surface densely pubescent along the midrib. Ligule c. 1 cm long, greenish. Inflorescence radical spike; covered with coriaceous bracts. Spike elongates considerably with age. Fertile bracts smaller, each subtends a cincinnus of 4-5 flowers. Bracteole tubular. Flower white, longer than bracts. Calyx bidentate, persistent, densely pubescent. Corolla tube shorter than calyx. Labellum orbicular, obscurely 3-lobed, white with purple red lines radiating from the centre, margin crumpled; lateral staminodes reduced to two pointed structures. Filament c. 3 mm long; anther crest c. 0.5 cm long. Capsule 2.5 x 1 cm, light red, obovate, glabrous with persistent calyx. Seeds bean-shaped.

Distribution: Recently collected from Periyar Tiger Reserve, Kerala which forms a new record for India (Prasanth Kumar, *et al.*, 2002).

Specimen studied: KERALA: Idukki Dt.: Deviyarmettu, *Prasanth Kumar 86134*.

Anatomical features

(Fig. 4)

Epidermis: Intercostal cells of the adaxial epidermis are higher than broad (40-64 x 16-32 μm). Costal cells are broader than high (8-16 x 32-40 μm). Abaxial epidermal cells are also higher than broad but slightly smaller in size (40-56 x 20-28 μm). Costal cells are broader than high (16 x 24-36 μm). Costal cells of both the epidermis contain single spherical silica body in them (less than 4 μm wide).

Trichomes: Upto 320 μm long hairs are seen on the sheath, petiole, midrib and lamina.

Stomata: Stomata are evenly distributed between the veins on abaxial epidermis (SI = 13.14). Guard cells are 28-32 μm long. Very few stomata are seen on the adaxial epidermis also (SI < 0.3).

Sheath: Both abaxial and adaxial surfaces are U-shaped, abaxial surface is ridged and furrowed. Upto 320 μm long hairs are seen in the furrow region. Bundle arcs I, II and III are present. Metaxylem of the Arc I bundle is 100-120 μm wide.

Petiole: Both surfaces are U-shaped. Abaxial surface possess 160 μm long hairs. Epidermal cells are as high as broad or higher. Bundle arcs I, II, III and IV are present. Petiole wings are broad and blunt. Metaxylem of the Arc I is 72-80 μm wide.

Midrib: Both abaxial and adaxial surfaces are U-shaped. Abaxial surface is densely hairy, hairs upto 0.75 mm long. Bundle arcs I, III and IV are present.

Lamina: Lamina is 368 μm thick at the bundle and 304 μm at other portions.

Adaxial epidermal cells are broader than high (24 x 32-48 μm). Cells above the veins are higher than broad (32 x 16 μm). Abaxial epidermal cells are also broader (16-24 x 48 μm). Hypodermis is present on both surfaces. Adaxial hypodermal cells are larger (32 x 48-64 μm) than the abaxial hypodermis (32 x 32-48 μm). 176 μm thick mesophyll is composed of 1-layered palisade and 5 or 6 layered spongy cells. Large bundles are

connected to both epidermis, smaller ones to the abaxial epidermis only. Metaxylem of the main bundle is 32 μm wide.

Margin: Abaxial epidermal cells are as high as broad and higher than broad towards the tip. Hypodermis is present both adaxially and abaxially. 1-layered palisade and 5-layered spongy constitute the mesophyll. Bundle is connected to both epidermis. Metaxylem of the last bundle is 40 μm wide. The portion beyond last bundle consists of mesophyll and parenchyma cells. The tip is gradually tapering, curved downwards and blunt at the tip. Hairs can be seen towards the margin. Hyaline portion is 4-celled at the base and 128 μm wide.

4. *Alpinia galanga* (L.) Sw., Obs. Bot. 6. 1791; M. Sabu, Zingiberaceae and Costaceae of S. India 57. 2006.

Maranta galanga L., Sp. Pl. ed. 2, 3. 1762.

(Plate 10

D)

Rhizome aromatic. Leafy shoots more than 2 m high. Leaves large, 60-70 x 10-15, oblong-lanceolate, acuminate at apex, base cuneate, glabrous; petiole short, 5 mm long, pubescent; ligule 7-8 mm long, entire. Inflorescence a terminal panicle, 25-30 cm long. Bracts 2-2.5 cm long, membranous, deciduous, each subtending 4-5 flowers. Bracteoles smaller, open to base. Calyx c. 1 cm long, greenish white. Corolla tube slightly longer than calyx. Labellum c. 2 cm long, clawed, tip emarginate, margin wavy, white, with a few oblique lines. Lateral staminodes small, subulate.

Epigynous glands 2. Ovary ellipsoid, glabrous. Fruit orange-red, smooth, globose.

Distribution: Wild in India, Indo-China, Philippines and Borneo. Cultivated throughout S.E. Asia, Malesia, Sri Lanka and in some parts of India.

Specimen studied: KERALA: Malappuram Dt.: C. U. Botanical Garden, Jayasree 86567.

Anatomical features

(Fig. 5)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, higher than broad (64-80 x 16-32 μm) with their longer axis perpendicular to the veins. Costal epidermal cells are much smaller (20 x 16-24 μm). The cell files are more or less regular. Intercostal cells of the abaxial epidermis are polygonal, having varying sizes and are very irregularly arranged. Costal cells are smaller (24-28 x 20-28 μm) more or less regularly arranged. Costal cells of both epidermis contain single large spherical silica body of about 12 μm diameter.

Trichomes: Very small unicellular bulbous based hairs that are 12 μm long are very frequent on abaxial epidermis. Very few hairs may be seen on the adaxial epidermis also.

Stomata: Stomata are abundant on the abaxial epidermis and they are evenly distributed between the veins. The length of the guard cells ranges from 28-32 μm (usually 32 μm). Stomatal index for the abaxial surface is 12.5. Adaxial epidermis also possess few stomata (SI = 2.43).

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Epidermal cells are broader than high. Bundle arcs I, II and III are present. Bundle sheaths of arc I is joined together to form a continuous fibrous band just above the abaxial epidermis. Oil cells are seen in the ground tissue. Metaxylem of the arc I is 148 μm wide. Cells of the ground tissue surrounding the bundles and chlorenchyma cells possess few crystals.

Petiole: Abaxial surface is wide U-shaped and adaxial surface is flat or slightly convex. Bundle arcs I, II, III and IV are present. Only 2 or 3 bundles represent arc II and sometimes it may be absent. Air cavity in between the bundle arc I are very small when compared to the size of the bundle. The abaxial fibre caps of the bundles of arc I touch the abaxial epidermis forming a continuous band.

Midrib: The abaxial surface is U-shaped and adaxial surface is wide V-shaped. Bundle arcs I, II and III are present. The continuous fibrous band is seen in the midrib also.

Lamina: Lamina is 240 μm thick. Adaxial epidermal cells are twice as broad as high (32 x 40-64 μm). Cells above the bundles are much smaller. Abaxial epidermal cells are smaller (16 x 16-32 μm). Hypodermis is completely absent. Mesophyll is 160 μm thick and is divisible into 1-layered palisade and 5-layered spongy tissue. Abaxial cap of the bundle is in contact with the abaxial epidermis. Girders connect the bundles to adaxial epidermis.

Margin: Adaxial epidermal cells are as high as broad, but higher than broad towards the tip. Last bundle is connected to both epidermis by 2 or 3 layered sclerenchymatous cap. A continuous hypodermis is present both abaxially and adaxially towards the tip. Margin is beak-like. The portion beyond last bundle consists of mesophyll and colourless parenchyma. Metaxylem of the last bundle is 80 μ m wide. Hyaline portion is multiseriate (4-celled at the base) and 288 μ m wide.

5. *Alpinia malaccensis* (Burm. f.) Roscoe, Trans. Linn. Soc. 8: 345. 1808; M. Sabu, Zingiberaceae and Costaceae of S. India 58. 2006.

Maranta malaccensis Burm. f., Fl. Ind. 2.1768.

(Plate 10 E)

Rhizome unbranched, woody, strongly aromatic. Leafy stem robust upto 3 m tall. Leaves long petioled; petiole 3-3.5 cm, pubescent; lamina 50-60 x 6-7 cm, lanceolate, pubescent or not, margins wavy, fringed with sparse, short brown hairs. Ligule 0.5-1cm long, ovate, entire, coriaceous. Inflorescence on erect peduncle, densely pubescent. Bracts absent. Bracteoles white. Calyx white, 1.8-2 cm long, shortly 3-lobed. Corolla shorter than calyx, white, lobes almost equal. Labellum 3-4 cm long, yellow, striped scarlet, sides incurved, apex emarginate. Lateral staminodes subulate. Filament c. 1 cm long. Ovary pubescent. Capsule turning red at maturity, pubescent. Seeds ovate or obovate.

Distribution: Throughout South India, Indo-China, Malesia and Sri Lanka.

Specimen studied: KERALA: Pathanamthitta Dt.: Kakkathode, *Prasanth Kumar 86462*.

Anatomical features

(Fig. 6)

Epidermis: Cells of the adaxial epidermis are polygonal (36-48 x 16-24 μm) higher than broad, with their longer axis perpendicular to the longitudinal veins. Epidermal cells of the costal region are much smaller (16 x 20-24 μm). Both these regions show regular cell arrangement. Intercostal cells of the abaxial epidermis are also polygonal (36-48 x 16-24 μm). Costal cells are much smaller (16 x 16 μm). Cell files are more or less regular in these regions. Costal cells of both epidermis contain single silica body (8-12 μm) in them.

Trichome: Simple, unicellular hairs are seen on the abaxial epidermis. The length of the hair varies between 160-200 μm . Hairs are also seen on both surfaces of petiole and midrib and on the abaxial surface of sheath.

Stomata: Stomata are found in large number on the abaxial epidermis in between the veins with more stomata on either side of the vein and much less in between. Guard cell is 48 μm long. Stomatal index is 11.42. Stomata are rare on adaxial epidermis (SI < 0.28).

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Numerous hairs, upto 240 μm long, are found on the abaxial surface. Epidermal cells are as high as broad and outer wall is convex. Bundle arcs I, II and III are

present. Oil cells can be found in the ground tissue and some cells possess crystals in them.

Petiole: Abaxial surface of the petiole is U-shaped and adaxial surface is concave. Numerous hairs are seen on both surfaces whose length varies from 96-288 μm . Crystals in groups are seen inside the cells of ground tissue. Bundle arcs I, II, III and IV are present.

Midrib: Both adaxial and abaxial surfaces are wide U-shaped. Hairs, upto 160 μm long, are seen on both surfaces. Bundle arcs I and III are present in the midrib. 1-3 layers of cells, whose walls are thickened, are found just below the adaxial epidermis.

Lamina: Lamina is 144-160 μm thick. Cells of the adaxial epidermis are higher than broad (32 x 20-32 μm) or as high as broad. Abaxial epidermal cells are broader than high (16-24 x 48 μm). Mesophyll, which is 96-112 μm thick, is divided into 2-layered palisade (2nd layer of very short cells) and 2 or 3-layered spongy cells. Crystals are present in the mesophyll. Main bundles possess abaxial cap and the bundle is connected to the adaxial epidermis through girders. Smaller bundles are connected to abaxial epidermis only. Sclerenchymatous cells are seen just below the epidermis, opposite to the bundle. Hypodermis is completely absent.

Margin: Adaxial epidermal cells are higher than broad, abaxial epidermal cells slightly broader than high. The epidermal cells towards the margin possess 208 μm long hairs. Mesophyll is composed of 2-layered palisade

and 2 or 3 layered spongy cells. Bundle is connected to both epidermis by sclerenchymatous caps. Metaxylem of the last bundle is 16-32 μ m wide. The portion beyond last bundle consists of mesophyll and parenchyma cells. Hypodermis is absent. Margin is gradually tapering, slightly bent downwards and tip is rounded. Hyaline portion is multiseriate (4-celled at the base) and 48 μ m wide.

6. *Alpinia nigra* (Gaertn.) B.L. Burtt, Notes Roy. Bot. Gard. Edinburgh 35 : 213. 1977; M. Sabu, Zingiberaceae and Costaceae of S. India, 6. 2006.

Zingiber nigrum Gaertn., Fruct. 1: 35. t. 12.1788.

(Plate 10

F)

Rhizome highly branched, aromatic. Leafy shoot 2-3 m high. Leaves sessile, 30-50 x 9-15 cm, linear-lanceolate, glabrous. Ligule c. 5 mm long, entire, pubescent. Inflorescence terminal, 20-30 cm long, paniculate, erect or slightly bent, cincinni remote. Bracts membranous. Bracteoles tubular membranous. Flowers pedicellate, small, 3-3.5 cm long. Calyx, 3-toothed, persistent. Corolla tube smaller or equal to the calyx; lobes equal, linear-oblong. Labellum 2-2.2 cm long, clawed, limb cuneiform. Lateral staminodes subulate. Filament upto c. 1 cm long. Ovary pubescent. Capsule globose, glabrous, black when ripe.

Distribution: Throughout India, Malesia and Sri Lanka. In South India it is reported from the Western Ghats in Tamil Nadu upto 1200 m.

Specimen studied: ARUNACHAL PRADESH: East Siam Dt.: Rani, Sanoj 92172. (No specimens from South India were available for the present study).

Anatomical features

(Fig. 7)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, higher than broad (32-48 x 16-24 μm). The cell files are regular. The costal cells are very small (16 x 20 μm). Intercostal cells of the abaxial epidermis are smaller than upper ones (32-40 x 24-28 μm) cell files are obscure. Costal cells are smaller (16 x 16). Costal cells of both epidermis contain single, large spherical (8-12 μm) silica body in them.

Trichomes: On abaxial epidermis, minute hairs (12 μm long) are seen.

Stomata: They are distributed evenly in between the veins on the abaxial epidermis. Guard cells are 28-32 μm long. Stomatal index is 10.46. Few stomata are seen on the adaxial epidermis also (SI = 1.35).

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Abaxial surface is ridged and furrowed. Hairs upto 36 μm long are seen on the epidermis. Epidermal cells are higher than broad. Bundle arcs I, II and III are present. Metaxylem of the main bundle is 116 μm wide. Air canal in between the bundle arc I is very large. Oil cells are abundant. Ground parenchyma cells contain numerous crystals of various size and shapes and are plate-like.

Petiole: A true petiole is absent, but the junction between the leaf base and ligule shows the following features. Abaxial surface is wide V-shaped and adaxial surface is convex, edges are blunt. Epidermal cells are higher than broad. Bundle arcs I, II, III and IV are present. Arc IV bundles are well developed. Air canal in between the bundles of arc I is very small and rounded or oval in shape. Metaxylem of the arc I is 100 μm wide. A single layer of highly thick-walled cells are seen just inner to the abaxial epidermis.

Midrib: Abaxial surface is U-shaped, and adaxial surface is concave. 2-4 sclerenchymatous layers are seen just below the adaxial epidermis. 1 or 2 crystals are found in the cells of ground tissue and chlorenchyma cells. Bundle arcs I, II and III are present. Bundle caps of arc I bundles form discontinuous band above the abaxial epidermis.

Lamina: Lamina is 204 μm thick. The adaxial epidermal cells are broader than high (16 x 16-32 μm). Hypodermis is seen below the adaxial epidermis only. They are twice higher than the epidermal cells (32 x 48 μm). Abaxial epidermis is as high as broad (16 x 16 μm). The main as well as smaller bundles are connected to abaxial epidermis by 2-layered sclerenchymatous cap. Smaller bundles are connected to the abaxial epidermis only. Sclerenchymatous patch is seen below the adaxial epidermis, opposite to these bundles, which are not in contact with the bundles. Mesophyll is 144 μm thick and is divided into 2-layered palisade (the 2nd layer is composed of short cells) and 3 or 4-layered spongy cells. Mesophyll tissue possesses oil

cells. Single calcium oxalate crystal is seen in the epidermis and spongy tissue.

Margin: Adaxial epidermal cells are as broad as, or broader than high. Abaxial epidermal cells are smaller and broader than high. Hypodermis is present adaxially. Bundle at the top is connected to both epidermis by 2-layered sclerenchymatous cap. Portion beyond the last bundle consists of mesophyll and parenchyma cells. Metaxylem of the last bundle is 32-40 μm wide. Tip is gradually tapering, slightly bent downwards and pointed. Hyaline portion is multiseriate (4-celled at the base) and 240 μm wide.

7. *Alpinia zerumbet* (Pers.) B.L. Burtt & R.M. Sm., Notes Roy. Bot. Gard. Edinburgh 3: 204. 1972; M. Sabu, Zingiberaceae and Costaceae of S. India 73. 2006.

Costus zerumbet Pers. Synops. 1: 3. 1805.

(Plate 11

A)

Rhizome, fibrous. Leafy shoot upto 3 m tall. Leaves large; lamina 60-80 x 10-15 cm, oblanceolate, ciliate along margins, otherwise glabrous. Petiole rounded, c. 1 cm long, hairy; ligule c. 1.5 cm long, coriaceous, tip slightly bifid. Inflorescence terminal, pendulous. Bracteoles large, 3-3.5 x 2.5-3 cm, fused at base to form a cup, white with pink tip. Calyx tube, shortly 3-lobed. Corolla tube shorter than calyx, lobes almost equal. Labellum 4.5-5.5 cm long, tip narrow and emarginate, yellow, heavily lined with red, sides

incurved; lateral staminodes subulate. Anther thecae glandular hairy on back. Ovary 6-7 x 2 mm, densely hairy. Capsule large, orange-red hairy.

Distribution: This species is considered to be a native in N.E. India, Burma and Indo-China. Widely cultivated in South India as an ornamental plant.

Specimen studied: **KERALA:** Malappuram Dt.: C.U. Botanical Garden. *Jayasree 86577.*

Anatomical features

(Fig. 8)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, higher than broad (40-48 x 12-16 μm) and the cell files are regular. Costal cells are smaller, higher than broad (20-24 x 8-12 μm) and are arranged in regular cell files. Abaxial epidermal cells of the intercostal region are also polygonal, longer than broad (32-48 x 16-24 μm), more or less regular in arrangement. Costal cells are as high as or slightly broader (16-20 x 24-28 μm) and show regular cell files. Costal cells of both epidermis contain single, spherical silica body which is 4-6 μm in diameter.

Trichomes: Unicellular trichomes which may be upto 480 μm long, are seen on the abaxial epidermis of leaf margin.

Stomata: Stomata are frequent on abaxial epidermis and are distributed between the veins. Stomata are more concentrated on either side of the vein, and is absent in the middle. Guard cell is 28 μm long. Stomatal index is 6.4. Stomata are very rare on adaxial epidermis (SI = 0.47).

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Epidermal cells are broader than high. Bundle arcs I, II and III are present. Air canals in the arc I are very small, rounded or elliptic. Metaxylem of the arc I is 120 μm wide. In some cells of the ground tissue and chlorenchyma, 1-few crystals are seen.

Petiole: Abaxial surface is U-shaped and adaxial surface is concave. Petiole has one rounded wing on one side. Bundle arcs I, II, III and IV are present. Bundle arc II was absent in some sections. Air canal in between the bundles of arc I is very small when compared to the size of the bundle.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is concave. Bundle arcs I, III and IV are present.

Lamina: Lamina is 240-256 μm thick. Cells of the adaxial and abaxial epidermis are broader than high (16 x 32 μm). Hypodermis is present both abaxially and adaxially. The adaxial hypodermis is much bigger (48 x 48-64 μm) than abaxial hypodermis (12 x 32 μm). 144 μm thick mesophyll is divisible into 2-layered palisade (2nd layer of cells shorter) and 4 or 5 layered spongy cells. Major bundle is connected to both epidermis, girders are seen adaxially. Smaller bundles are connected to adaxial hypodermis through girders.

Margin: Adaxial and abaxial epidermis are as high as broad. Hypodermis is present below both surfaces. The portion beyond last bundle consists of mesophyll and parenchyma. Bundle is connected to the abaxial epidermis

only. Metaxylem is 48 μm wide. Margin is broad, blunt and tip is upcurved. Upcurved hairs are seen arising from the abaxial epidermis and they are about 480 μm long. Hyaline portion is multiseriate (5-celled at the base) and 128 μm wide.

ALPINIA: COMPARATIVE ANATOMY (Fig. 9, 10 & 11)

Epidermal cells of the abaxial surface are usually polygonal with straight anticlinal wall, and are transversely stretched *i.e.* perpendicular to the longitudinal veins (Tomlinson, 1956; Indira, 1976; Sabu, 1991; Hussin *et al.*, 2001). The cell files are more regular and distinct. In contrast, the abaxial epidermal cells are smaller and less transversely stretched. The cell files are mostly irregular or obscure. Costal epidermal cells are smaller than the cells in between. Transverse orientation and smaller size of the cells over the veins is more evident on the upper epidermis. This character was noticed in *A. galanga* (Indira, 1976). All the 7 species of *Alpinia* studied, contain single large spherical silica body in the costal epidermal cells (Tomlinson, 1956, Hussin *et al.*, 2001). This genus can be easily distinguished from other related genera of the family like *Amomum*, *Elettaria* and *Etilingera* by the single large silica body in the costal epidermal cells. In *Amomum* spp., the costal epidermal cells contain single small silica body about 4 μm diameter. In some species like *A. cannicarpum*, *A. muricatum* etc. silica sand is seen in these cells. In *Elettaria* the costal epidermal cells are rectangular and contain 1 or 2 (1 big of 4 μm and 1 small) silica bodies. In *Etilingera* some

costal cells of the lower epidermis contain 1-few, smaller silica bodies (size may be upto 4 μm). Silica bodies can be seen in the intercostal cells also.

Stomata are tetracytic with long axis of the guard cells parallel to the veins. Four subsidiary cells are present around each stoma; two lateral and two terminal. The size of the stomata varies from 28-32 μm . Stomata are generally much more frequent on abaxial than adaxial surface. Stomatal Index is minimum in *A. zerumbet* (6.4) and maximum in *A. galanga* (12.5). Stomata are distributed near to the veins in *A. zerumbet*. Similar observation was made by Hussin *et al.* (2001). In all other species studied stomata are distributed randomly in between the veins.

The size, nature of hairs and their distribution on the lamina play an important role in the delimitation of the species. Simple unicellular hairs of 352-368 μm length are seen on the lamina of *A. fax* and *A. malaccensis*. Margins of *A. fax*, *A. malaccensis* and *A. zerumbet* possess 352-512 μm long hairs. Petioles of *A. malaccensis* possess hairs which are upto 512 μm long. Midrib of *A. fax* has 256 μm long hairs on its abaxial surface. This type of hair is the only type recorded for the family Zingiberaceae (Tomlinson, 1956). The type of hair present in *Alpinia* is 'Borste' (Bristle) type of Staudermann (1924). These are defined as 1 or more celled, cylindrical pointed and stout hair. Indira (1976) while studying the dermal morphology of South Indian Zingiberaceae, recorded the presence of hairs on the margins of *A. galanga*, but in the present study, hairs were absent on the leaf margins of *A. galanga*, whereas leaf margins of *A. zerumbet*, *A.*

malaccensis and *A. fax* possess hairs. In *A. galanga*, both surfaces of leaf possess prickle type of hair. The base of the hairs are much dilated and they are sunken below the epidermal level, a short point projecting above the leaf surface which is upto 12 μm long. This type of hair is frequent on lower epidermis, though few hairs are seen on the upper epidermis also. Abaxial surface of *A. nigra* also possess this type of hairs (Prickle type) that are upto 12 μm long.

Hussin *et al.* (2001) reported the presence of adaxial hypodermis in *A. calcarata* and *A. zerumbet*. In the present study it was found that the hypodermis in *A. calcarata* is interrupted and is represented by 1-2 cells in between the veins. The presence of upper and lower hypodermis is noted in *A. fax* and *A. zerumbet*. According to Hussin *et al.* (2001) variation occur in the presence of hypodermis in different cultivars of *A. zerumbet*. Hypodermis was completely absent in *A. galanga* (Hussin *et al.*, 2001). Indira (1976) reported the presence of upper and lower hypodermis in *A. galanga*. But present study agrees with the former observation (Hussin *et al.*, 2001). In *A. nigra* hypodermis is present adaxially.

Palisade is 2-layered in most of the species, *A. abundiflora*, *A. nigra*, *A. zerumbet*, *A. galanga* etc. The second layer is much smaller and resembles mesophyll cells, but is compactly arranged. This agrees with the observations of Tomlinson (1956) and Hussin *et al.* (2001). 1-few calcium oxalate crystals are seen in the mesophyll cells, while Hussin *et al.* (2001) recorded only single crystal in the mesophyll cells.

The sub-epidermal ground parenchyma in the midrib of most of the species is thickened. This was reported by Tomlinson (1956) also. Abaxial bundle caps extend to form a layer in *A. galanga*. Similar observation was made by Hussin *et al.* (2001). In *A. nigra* this layer is discontinuous. Tomlinson (1956) recorded the presence of arc III bundles in addition to arc I. Similar observations were made by Hussin *et al.* (2001) in all species except *A. zerumbet*, where bundle arcs I, III and IV are present. In the present study also *A. zerumbet* showed the presence of I, III and IV bundle arcs but in *A. galanga* and *A. nigra*, bundle arcs I, II and III are seen. Midrib is thinnest in *A. calcarata* (0.5-0.6 mm) and thickest in *A. fax* (2.5 mm).

Interspecific variations occur in the shape and general structure of petiole and midrib. In T. S. of petiole, certain species can be identified by the general shape. The presence or absence of wings and their number is constant for a species. A prominent petiole is absent in *A. fax* and *A. nigra*. Wings are totally absent in *A. galanga*, *A. nigra* and *A. malaccensis*, whereas triangular and pointed wings are seen in *A. calcarata*, which agrees with the observations of Hussin *et al.* (2001). In the present study *A. zerumbet* has one rounded wing on one side. But the studies of Hussin *et al.* (2001) showed the presence of 2 triangular, pointed wings for *A. zerumbet*. The 2 cultivars 'Springle' and 'Variegata' have blunt edges or a very small wing is present on one side. Presence of bundle arc IV in the petiole is another character which is similar to *Amomum* and *Elettaria*. Petioles of all species of *Alpinia* studied possess bundle arcs I, II, III and IV. Hussin *et al.*

(2001) reported the absence of arc II bundles in the petioles of *A. calcarata*. Presence of abaxial fibrous layer below arc bundle I in *A. galanga* was noted by Hussin *et al.* (2001). In the present study also fibrous layer is observed in *A. galanga*. The size of the petiole also varies from the smallest in *A. calcarata* and largest in *A. zerumbet*.

The shape of the leaf margin is quite distinct for certain species such as *A. galanga* which is beak-like, agrees with the observations of Hussin *et al.* (2001). In *A. zerumbet* the tip is upcurved and possess hairs which are curved upwards from lower epidermis. In their study the margins of *A. zerumbet* and the 2 cultivars 'Springle' and 'Variegata' were almost straight and few hairs are seen on the lower epidermis. In *A. calcarata* the margin is straight and blunt. This agrees with the reports of Hussin *et al.* (2001).

The anatomical characters somewhat agrees with the infrageneric classification by Smith (1990). *A. abundiflora* and *A. fax* of the section *Fax* share some common characters like the presence of radical inflorescence and the broader costal cells that contain small silica bodies (upto 4 μm). Though *A. galanga* and *A. nigra* share some characters such as the prickle type of hair and the fibrous band below the arc I of petiole and midrib (thinner and discontinuous in *A. nigra*), they are placed under different sections- *A. galanga* in section *Alpinia* and *A. nigra* in *Allughas*. The other three species viz., *A. calcarata*, *A. malaccensis* and *A. zerumbet* are included in section *Catimbium*.

Key to the species based on anatomical characters

1. Costal cells broader than high, containing small silica body (less than 4 μ m).....2
1. Costal cells as high as broad, containing large silica body (4-12 μ m)3
2. Abaxial surface of the leaf pubescent; both abaxial and adaxial hypodermis present; margin slightly curved downwards.....3. **A. fax**
2. Abaxial surface of the leaf glabrous; hypodermis absent; margin straight1. **A. abundiflora**
3. Petiole winged.....4
3. Petiole not winged5
4. Wing on one side, rounded; both abaxial and adaxial hypodermis present; margin with upcurved hairs7. **A. zerumbet**
4. Wings on both sides, triangular and pointed; hypodermis adaxial, not continuous; margin straight and blunt without hairs2. **A. calcarata**
5. Petiole densely hairy; abaxial leaf surface with bristle type hair; margin almost straight, hairy5. **A. malaccensis**

5. Petiole glabrous; abaxial leaf surface with prickly type hair; margin bent downwards, glabrous6
6. Abaxial epidermis with regular cell files; hypodermis absent; margin beak-like, blunt at the tip.....4. **A. galanga**
6. Abaxial epidermis without regular cell files; hypodermis present adaxially; margin gradually tapering, pointed.....6. **A. nigra**

2. **AMOMUM** Roxb. (*nom. cons.*)

Amomum Roxb., Fl. Indica 1: 37. 1820; M. Sabu, Zingiberaceae and Costaceae of S. India 75. 2006.

Rhizome hard, woody, fibrous, extensively creeping; intervals between leafy shoots short or long. Leafy shoot 1-5 m high. Leaves sessile or petiolate. Ligule entire or bilobed. Inflorescence borne on the rhizome near the base of the leafy shoot. Sterile bracts absent. Spike globose, ovoid or oblong. Bracts imbricating, each subtending a single flower. Flowers bracteolate. Calyx tubular. Corolla lobe as long as the tube, unequal; dorsal lobe broader and hooded. Labellum longer than corolla, obovate, yellow orange with red lines. Staminodes small like a subulate teeth or absent. Stamen shorter than lip; connective produced into a 3-lobed crest. Stigma subglobose. Ovary, smooth ribbed or warted. Fruit a berry or capsule.

Distribution: About 150 species, distributed in India, Sri Lanka, Malesia, New Guinea, Australia, Philippines China, Japan, Borneo, Java and Queens- land.

Notes: The genus is distinguished from other genera in the absence of involucre of sterile bracts, elongating inflorescence, and uniform, large bracts. They possess broad, concave lip, yellow or white with red markings. The anther is crested. Fruits may be smooth or spiny.

Six species are reported from South India, of which three are endemic.

Ecology: Majority of species occur in dense forests at high altitudes; above 1000 m, seen in swampy areas, near ponds or along streams.

Key to the species based on morphological characters

1. Leaves silvery-silky below; inflorescence 1-3 flowered on long, slender, underground runners produced from the rhizome.....3. **A. hypoleucum**
1. Leaves not silvery-silky below; glabrous or pubescent below; inflorescence many flowered and developed directly from the base of the leafy shoot, near the rhizome.....2
2. Ligule bifid; bracts deciduous; ovary and capsule with 9 undulating ribs, ribs winged6. **A. pterocarpum**
2. Ligule entire; bracts persistent; capsule densely echinate.....3

3. Ligule 4 cm long; much longer than the petiole; upper part of the ligule deciduous4. **A. masticatorium**
3. Ligule shorter or as long as the petiole; upper part of the ligule not deciduous.....4
4. Leaves pubescent below; inflorescence oblong-cylindrical; labellum 1.2 x 1 cm; anther-crest 5 mm wide.....2. **A. ghaticum**
4. Leaves glabrous beneath; inflorescence ovoid or subglobose; labellum 2.5-3.5 cm long; anther-crest 0.8-1.5 cm wide.....5
5. Leafy shoots upto 5 m high; inflorescence ovoid; labellum elliptic to obovate, entire, emarginate; anther crest quadrate, more or less 3-lobed.....1. **A. cannicarpum**
5. Leafy shoots upto 1.75 m high. inflorescence subglobose, labellum broadly obovate, deeply lobed, midlobe emarginate; anther crest lunulate, entire5. **A. muricatum**

1. Amomum cannicarpum (Wight) Benth. ex Baker in Hook. f., Fl. Brit. India 6: 240. 1892; M. Sabu, Zingiberaceae and Costaceae of S. India 81. 2006.

Elettaria cannicarpum Wight, Icon. Pl. Indiae Orient, t. 2007. 1853. ('*cannaecarpum*') **(Plate 11**

B)

Rhizome with persistent, reddish-brown bracts. Leafy shoots upto 5 m high, swollen at base. Leaves petiolate, ligulate; ligule shorter than petiole, 6-7 mm long; lamina 30-45 x 6-8 cm, oblong-lanceolate, glabrous. Inflorescence produced from the base of the stem, ovoid. Bracts reddish brown to dark pink, persistent. Calyx and corolla white. Labellum elliptic to obovate, 3.5 x 3 cm, emarginate, reddish spots towards centre. Lateral staminodes subulate. Connective of the anther prolonged into a 1.5 cm broad, quadrate, obscurely 3-lobed yellow crest. Ovary densely hairy. Capsule dark reddish, densely echinate. Seeds ovoid.

Distribution: Endemic to South India, especially on the Western Ghats.

Specimen studied: **KERALA:** Kottayam Dt.: Mukkuzhi, *Prasanth Kumar* 92617.

Anatomical features

(Fig. 12)

Epidermis: Intercostal cells of the adaxial epidermis is polygonal, higher than broad (48-60 x 12-24 μm), with their longer axis perpendicular to the longitudinal veins. Costal cells are smaller, as high as broad or slightly higher (20-24 x 12-20 μm). The costal cells contain silica sand in them. Cells of costal and intercostal region show regular arrangement. Cells of the abaxial epidermis are also polygonal but smaller than upper ones. Cells of costal region are distinguishable by their smaller size and absence of stomata. Oil cells are seen in the abaxial epidermis.

Trichomes: Completely absent.

Stomata: Stomata are distributed evenly in between the veins on abaxial epidermis. Length of the guard cell is 28 μm . Stomal Index is 9.28. Few stomata can be seen on the adaxial epidermis also (SI = 1.76).

Sheath: Both abaxial and adaxial surfaces are U-shaped. Bundle arcs I, II and III are present. In the ground tissue oil cells are seen. Some cells of the ground tissue contain acicular crystals in them.

Petiole: Abaxial surface of the petiole is V-shaped and adaxial surface is convex. Bundle arcs I, III and IV are present.

Midrib: Abaxial surface is U-shaped; adaxial surface is concave. Bundle arcs I, III and IV are present in the midrib also.

Lamina: Lamina is 208 μm thick and 224 μm at the bundle. Cells of the adaxial epidermis are broader than high (32 x 48-64 μm). Cells above the veins are much smaller. Abaxial epidermal cells are also broader but smaller than upper ones (24 x 32-48 μm). 1-layered palisade and 5-layered spongy cells constitute the mesophyll tissue, which is 160 μm thick. Oil cells are present in the mesophyll. Sclerenchymatous caps of the main bundles are in contact with both abaxial and adaxial epidermis, whereas in small bundles it is in contact with abaxial epidermis only.

Margin: Cells of the adaxial epidermis higher than broad. Abaxial epidermal cells are smaller than upper ones. Mesophyll can be divided into 1-layered palisade and 5-layered spongy cells. The portion beyond last bundle consists of mesophyll only. Sclerenchymatous cap is in contact with both

abaxial and adaxial epidermis. The tip is gradually tapering, slightly bent downwards and rounded. Hyaline portion is 32 μm broad.

2. *Amomum ghaticum* K.G. Bhat, Indian J. Forestry 11: 322. 1988; M. Sabu, Zingiberaceae and Costaceae of S. India 82. 2006. **(Plate 11**

C)

Rhizome fleshy, Leafy shoots upto 4.5 m high in dense clumps. Leaves petiolate, pubescent; ligule shorter than petiole, 1 cm long, entire, coriaceous, lamina 50-60 x 10-12 cm, upper surface glabrous, lower surface pubescent. Inflorescence developed from the base of the stem, oblong-cylindrical. Bracts obovate, pink, margin shortly ciliate, persistent. Bracteoles bilobed, 2-keeled. Calyx white, corolla pale yellow. Labellum streaked red, obovate, 1.2 x 1 cm, 3-lobed. Lateral staminodes subulate. Connective prolonged into a semilunar crest, c. 1.5 x 0.5 mm. Ovary densely pubescent. Capsule globular, densely echinate, reddish.

Distribution: Endemic to South Karnataka and Kerala.

Specimen studied: KERALA: Pathanamthitta Dt.: Palaruvi, *Sanoj 95670*.

Anatomical features

(Fig. 13)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal (40-64 x 12-24 μm) with their longer axis perpendicular to the longitudinal veins. Costal epidermal cells are much smaller, as high as broad or higher (16-20 x 12-20 μm). Cells of these two regions are arranged in regular files.

Intercostal cells of the abaxial epidermis are polygonal (40-72 x 8-24 μ m).
Cells of the costal region are broader *i.e.*, stretched parallel to the veins (16

x 32-48 μm). Cell files are distinguishable in the intercostal and the costal region. Cells of costal region on both the epidermis contain silica sand in them.

Trichomes: Simple unicellular hairs of 64-352 μm length are present on abaxial epidermis. Hairs are also present on both abaxial and adaxial surfaces of petiole and abaxial surface of the midrib and sheath.

Stomata: Tetracytic stomata are distributed evenly between the veins on abaxial epidermis. Length of the guard cell falls between 24-28 μm . Stomatal index is 17.41. Few stomata are also seen on the adaxial epidermis also (SI = 2.03).

Sheath: Abaxial surface is wide V-shaped and adaxial surface is wide U-shaped. Upto 1 mm long hairs are seen on the abaxial surface, Bundle arcs I, II and III are present. Metaxylem is 72-80 μm wide. Crystals in cluster are found in the ground tissue cells and chlorenchymatous cells.

Petiole: Abaxial surface of the petiole is V-shaped; adaxial surface is nearly straight. Petiole wings absent. Bundle arcs I, III and IV are present. The air canal in between the bundles of arc I are very small and oval in outline. Various shaped crystals in groups are seen in the ground tissue.

Midrib: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Bundle arcs I and III are present. Single or few crystals are seen in the ground tissue and also in the sclerenchymatous bundle sheath.

Lamina: Lamina is 208 µm thick (224 µm at the bundle). Adaxial epidermal cells are as high as broad or slightly broader (40 x 40-48 µm). Cells above veins are much smaller and square. Abaxial epidermal cells are also broader than high, but smaller than the upper ones (10 x 32-48 µm). 1-layered palisade and 5 or 6 layered spongy cells constitute the mesophyll tissue and it is 144 µm thick. Girders connect smaller bundles to the adaxial epidermis. Hypodermis is completely absent. Oil cells are abundant in the mesophyll.

Margin: Cells of the adaxial epidermis is higher than broad. Abaxial epidermal cells are smaller and as high as or slightly broader than high. A hypodermis composed of very short cells is present adaxially. The abaxial hypodermis is seen towards the extreme tip *i.e.* beyond the last bundle. Mesophyll is composed of 1-layered palisade and 3 or 4 layered spongy cells. Oil cells are abundant. The bundles are in contact with both abaxial and adaxial epidermis. The portion beyond last bundle is composed of mesophyll and parenchymatous cells. The tip is broad, blunt and slightly bent towards the end. The hyaline portion is (6-7) multiseriate and about 48 µm wide.

3. *Amomum hypoleucum* Thwaites, Enum. Pl. Zeyl. 318. 1861; M. Sabu, Zingiberaceae and Costaceae of S. India 84. 2006. **(Plate 11 D)**

Rhizome slender, extensively creeping. Leafy shoot 1-1.75 m tall. Leaves petiolate, ligulate; ligule bilobed; lamina 30-65 x 5-11 cm, oblong lanceolate, acuminate, silvery silky pubescent below, upper glabrous. Inflorescence borne on long, slender, creeping, underground runners. Spike

narrow, 1-3 flowered. Bracts, trilobed. Calyx trilobed. Corolla white; lobes equal. Labellum yellow with pink lines. Anther crest truncate. Ovary sericeous; capsule globose. Seeds black.

Distribution: Occurs in Kerala and Karnataka in South India and Sri Lanka.

Specimen studied: KERALA: Malappuram Dt.: C. U. Botanical Garden, *Jayasree 103018*.

Anatomical features

(Fig. 14)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal (48-80 x 10-24 μm) with their longer axis perpendicular to the longitudinal veins. Costal cells are smaller and are stretched parallel to the veins (8-16 x 16-32 μm). Cells of both the regions are regularly arranged. Cell files are regular. Intercostal cells of the abaxial epidermis are also polygonal (48-80 x 16-32 μm). Costal cells are broader than long (16 x 24-32 μm). A single, small spherical silica body is present in the costal epidermal cells.

Trichomes: Simple unicellular hairs which are 240-288 μm long are abundant on the abaxial epidermis. It forms a mat like layer on the abaxial surface. Tip of the hair is pointed. Adaxial surface is completely glabrous.

Stomata: Stomata are distributed randomly in between the veins on the abaxial epidermis. Very few stomata are seen on the adaxial epidermis also. The length of the guard cell is between 24-28 μm . Stomatal index is 11.09. Very few stomata are seen on the adaxial epidermis also (SI = 1.46).

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Epidermal cells are broader than high. Bundle arcs I, II and III are present. Air canals in between the bundles of arc I are large. Few oil cells are found in the ground tissue. Some ground tissue cells possess 1- few crystals in them.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Petiole wings are unequal – 1 short and 1 long. Wings are broad and blunt. Bundle arcs I, II, III and IV are present. Smaller bundles are present in arc II. Cells of the ground tissue possess numerous crystals. Crystals can be seen in the chlorenchymatous cells also.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is concave. 1-3 layers of sclerenchyma cells are seen in groups below the adaxial epidermis. Very small hairs are present on the abaxial epidermis of the midrib towards the upper part. Cells of the ground tissue and chlorenchymatous tissue contain crystals (in groups). Bundle arcs I and III are present.

Lamina: Lamina is 224 μm thick (240 μm at the bundle). Cells of the adaxial epidermis are small, twice or thrice broader than high (10-16 x 32-64 μm). A hypodermis is present adaxially which is composed of larger cells which are as high as or slightly broader (40-48 x 40-64 μm). Hypodermal fibres are also seen. Cells above the bundles are as high as or slightly broader than high. Abaxial epidermal cells are much smaller (10 x 16-32 μm). Mesophyll is 144 μm thick. Palisade is 2-layered (1 long and 1 short) and spongy tissue is 3 or 4 layered. Sclerenchymatous cap of the bundle is in contact with the

abaxial epidermis only. Numerous hairs are seen in the abaxial epidermis. Some of the spongy cells and epidermal cells contain single crystal in it.

Margin: Cells of the adaxial epidermis is as high as or higher than broad. Abaxial epidermal cells are smaller. Abaxial hypodermis and hypodermal fibres are also seen. 2-layered palisade and 2 or 3 layered spongy cells constitute the mesophyll. Crystals can be seen in the epidermal cells. The portion beyond the last bundle consists of mesophyll and parenchymatous cells. The tip is gradually tapering, slightly bent and rounded. Hyaline portion is multiseriate (4-celled at the base) and 160 μm broad.

4. *Amomum masticatorium* Thwaites, Enum. Pl. Zeyl. 317. 1861; M. Sabu, Zingiberaceae and Costaceae of S. India 87. 2006. **(Plate 11 E)**

Rhizome with membranous sheath. Leafy shoot 2-3 m high. Leaves petiolate; petiole less than 5 mm long. Ligule c. 4.5 cm long; the membranous upper third or half deciduous. Lamina 20-35 \times 5-7 cm, oblong-lanceolate, glabrous. Inflorescence developed from the base of the stem, globose. Bracts obovate, margin pubescent, persistent. Calyx pubescent. Corolla tube not exceeding the calyx, white. Labellum yellow, clawed at base, 3-lobed. Lateral obscurely 3-lobed. Epigynous glands united. Ovary shortly pubescent. Capsule globose, echinate.

Distribution: Reported from Kerala, Karnataka, Tamilnadu and in Sri Lanka.

Specimen studied: KARNATAKA: Coorg Dt.: Bhagamandala, *Thomas 103105*.

Anatomical features

(Fig. 15)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal with their longer axis perpendicular to the longitudinal veins (40-56 x 8-20 μm). Costal cells are much smaller (24 x 12-16 μm). Cell files are regular. Intercostal cells of the abaxial epidermis are also polygonal with their longer axis perpendicular to the longitudinal veins (40-60 x 12-24 μm). Costal cells are much smaller, as high as broad or slightly broader (20-24 x 12-40 μm). The cell files are regular.

Trichomes: Trichomes are totally absent on lamina.

Stomata: Stomata are abundant on the abaxial epidermis and are evenly distributed between the veins. Length of the guard cell varies between 28-32 μm . Stomatal Index is 11.53. Very few stomata are seen on the adaxial epidermis also (SI = 0.65).

Sheath: Abaxial and adaxial surfaces are wide U-shaped. Abaxial surface is ridged and furrowed. Hairs, upto 0.5 mm are seen on the abaxial surface. Bundle arcs I, II and III are present. A continuous band of sclerenchymatous tissue is present just above the abaxial epidermis in young sheath and it forms a broken loose ring when mature. In young sheath, cells of the ground tissue also contain starch grains in them. Numerous crystals can be seen in the cells of ground tissue.

Petiole: Abaxial surface is wide U-shaped and adaxial surface is almost straight. Bundle arcs I, III and IV are present. Arrangement of xylem and phloem is reversed in some of the bundles of arc IV.

Midrib: Both abaxial and abaxial surfaces are wide U-shaped. Bundle arcs I, III and IV are seen in the midrib also. Adaxial epidermis and 1 or 2 layer of cell below it is thick walled. Arc III bundles are embedded in the chlorenchymatous tissue. A single bundle of arc IV is seen.

Lamina: Lamina is 240 μm thick and 224 μm at the bundle region. Adaxial epidermal cells are broader than high (32 x 48-64 μm). Cells above bundle are much smaller and twice broad as high (16-24 x 32-48 μm). Abaxial epidermal cells are also broader but smaller than upper ones. Hypodermis is absent. Mesophyll is composed of 1-layered palisade and 5-layered spongy and 180 μm thick. Adaxial surface is sunken at the position of bundles. The sclerenchymatous cap is in contact with both adaxial and abaxial epidermis.

Margin: Cells of the adaxial epidermis is as high as or slightly higher than broad. Abaxial epidermal cells are smaller than upper ones. Hypodermis is absent. 1-layered palisade and 3-5 layered spongy constitute the mesophyll tissue. The margin is gradually tapering, slightly bent and tip is rounded. The portion beyond last bundle consists of mesophyll and 1 or 2 parenchymatous cells. Cap of the bundle is in contact with the abaxial epidermis only. Hyaline portion is triseriate and 64-80 μm wide

5. Amomum muricatum Bedd., Madras J. Sci. Ser. 3. 1: 59. 1864; M. Sabu, Zingiberaceae and Costaceae of S. India 88. 2006. **(Plate 11**

F)

Leafy shoot 1-1.75 m high. Leaves sessile or shortly petiolate. Ligule very short, entire. Lamina 20-40 x 5-10 cm, broadly lanceolate, both surfaces glabrous. Inflorescence on creeping peduncle, developed from the base of the leafy shoot; spike subglobose. Bracts light pinkish, persistent. Calyx hairy towards tip. Corolla tube shorter than calyx. Labellum 2.5 cm long, broadly ovate, deeply 3-lobed, midlobe deeply split. Anther crest semilunar, entire, yellow. Stigma produced above anther thecae. Ovary hairy. Fruit stalked. Capsule globose, densely echinate.

Distribution: Endemic to South India, particularly on Western slopes of Western Ghats at low to high altitudes.

Specimen Studied: KARNATAKA: Shimoga Dt.: Kudajadri, *Prasanth Kumar 86121*.

Anatomical features

(Fig. 16)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal with their longer axis perpendicular to the longitudinal veins (48-56 x 16-24 μm). Costal cells are smaller, broader than high (12-16 x 16-32 μm). Cells of both these region are arranged in regular files. Intercostal cells of the abaxial epidermis are also polygonal but smaller than upper ones (32-40 x 16-20 μm). Costal cells are smaller and broader than high (16 x 32 μm). Cell files

are regular. Costal cells of both adaxial and abaxial epidermis contain silica sand in them.

Trichomes: Completely absent on the lamina.

Stomata: Stomata are abundant on the abaxial epidermis. They are evenly distributed between the veins (SI = 6.9). The adaxial epidermis also possesses few stomata. Stomatal index is 3.5. Length of the guard cells is 24-28 μm (24 μm is common).

Sheath: Abaxial and adaxial surfaces are wide U-shaped. Wings of the sheath are broad and abruptly tapering. Bundle arcs I, II and III are present. Numerous crystals can be seen inside the cells of ground parenchyma and also in the chlorenchymatous tissue.

Petiole: Abaxial surface is wide U-shaped and adaxial surface is concave. Bundle arcs I, III and IV are present. The arrangement of xylem is reversed in the bundles of arc IV compared to the arrangement in the bundles of arc I. Air canal between the bundles is very small or absent. Cells of the chlorenchymatous tissue and ground tissue contain many crystals in groups.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is concave. Bundle arc I and III are present. Bundles of arc III are seen embedded in the chlorenchymatous tissue alternating with the larger bundles of arc I.

Lamina: Lamina is 224 μm thick (208 μm at the bundle). Cells of the adaxial epidermis are broader than high (24 x 32-48 μm). Abaxial epidermal cells are broader than high and are smaller than upper ones (16 x 32 μm).

Mesophyll consists of 1 or 2 layered palisade and 4 or 5 layered spongy tissue and is 160 μm thick. Sclerenchymatous bundle cap is in contact with both the epidermis. Hypodermis is completely absent. In the case of smaller bundles girders are found connecting them to the adaxial epidermis. Oil cells are seen in the mesophyll tissue.

Margin: Adaxial epidermal cells are as high as or slightly broader than high. Abaxial epidermal cells are broader than high and smaller than upper ones. Hypodermis is completely absent from both the epidermis. 1-layered palisade and 3 or 4 layered spongy cells constitute the mesophyll tissue. The bundle is in contact with the abaxial epiderms only. The portion beyond last bundle consists of mesophyll and 1 or 2 parenchyma cells. Tip is slightly bent, broad and blunt. Hyaline portion is 16-32 μm wide.

6. Amomum pterocarpum Thwaites, Enum. Pl. Zeyl. 377. 1861; M. Sabu, Zingiberaceae and Costaceae of S. India 89. 2006. **(Plate 12 A)**

Creeping portion of the rhizome c. 2.5 cm in diameter. Leafy shoot 2-2.5 m tall. Leaves petiolate. Ligule 1.5-2.5 cm, bifid. Lamina 20-60 x 8-12 cm, oblong-lanceolate, narrowed and unequal at base, upper surface glabrous, lower surface densely pubescent or not. Inflorescence developed directly from the base of the leafy shoot. Bracts very small, early deciduous. Bracteoles absent. Flowers white. Calyx lobes with sub-apical spur. Corolla equal to the calyx. Labellum clawed, white with yellow in the centre. Lateral staminodes reduced to short appendage. Anther crest semilunar, obscurely

3-lobed. Ovary elongated, densely pubescent. Capsule 9-ribbed, ribs winged.

Distribution: Throughout Peninsular India and Sri Lanka.

Specimen studied: KERALA: Kozhikode Dt.: Kakkayam, *Prasanthkumar* 86144.

Anatomical features

(Fig. 17)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal with their longer axis perpendicular to the longitudinal veins (64-72 x 16-32 μm). Cells are arranged in regular rows. Costal epidermal cells are much smaller, as high as broad or slightly broader (12-16 x 16-24 μm). Costal epidermal cells contain single spherical silica body in them. Intercostal cells of the abaxial epidermis are polygonal (40-48 x 16-32 μm). Costal epidermal cells are smaller, as high as broad or slightly higher (16 x 10-16 μm). They are arranged in regular files and contain single small spherical silica body (4-8 μm wide) in them.

Trichomes: Simple unicellular trichomes, 244-448 μm long, are seen only on the abaxial epidermis. Its wall is thick and tip is pointed. They are seen in between the veins.

Stomata: The guard cells have an average length of 28 μm and stomata distributed evenly between the veins on the abaxial epidermis. Stomatal index is 7.37. Very few stomata are seen on the adaxial epidermis (SI= 0.59).

Sheath: Abaxial surface is U-shaped and wavy. 64-80 μm long hairs can be found in the furrows. Adaxial surface is wide U-shaped. Bundle arcs I, II and III are present. Air canal in between the bundles of arc I is larger than the bundles. Metaxylem is 112-140 μm wide. Cluster of crystals are present in the ground tissue.

Petiole: Abaxial surface of the petiole is U-shaped, and adaxial surface is wide U-shaped. Many layers of thick walled cells are seen below the adaxial epidermis. Bundle arcs I, II, III and IV are present in the petiole. The air canals in between the arc bundle I are rounded or oval in shape. The abaxial surface is slightly ridged and furrowed. Cells of the ground tissue and the chlorenchymatous cells contain few crystals. The arrangement of xylem and phloem is reversed in arc III.

Midrib: Abaxial surface U-shaped and adaxial surface is wide U-shaped. Bundle arcs I and III are present. A few cells that have thick walls are seen just below adaxial epidermis in groups. Cells seen below the arc I are thick walled. 1 or 2 crystals are present in the ground parenchyma cells.

Lamina: Lamina is 240 μm thick at the bundle (176 μm at other positions). Adaxial and abaxial epidermal cells are broader than high (28 x 40-84 μm). Hypodermal fibres are seen below the adaxial epidermis. A discontinuous hypodermis of 1-6 cells is seen in adaxially between the veins. 2-layered palisade (2nd layer very short) and 3 or 4 layered spongy constitute the mesophyll tissue which is 112 μm thick. Hypodermis like layer is seen abaxially also in between the veins. 6-9 hypodermal fibres are seen just

below the adaxial epidermis at the position of bundle. Sclerenchymatous bundle cap seen adaxially is not in contact with the adaxial epidermis. The abaxial cap is in contact with the abaxial epidermis. Abaxial epidermis bears hairs.

Margin: Adaxial epidermal cells are as high as or slightly broader. Hypodermal fibres either solitary or in groups of 2 or 3 are seen just below the adaxial epidermis. Abaxial epidermal cells are also as high as broad, but smaller than upper ones. Discontinuous hypodermis is seen adaxially, which is composed of only 1 or 2 cells between the bundles. Abaxial hypodermis is absent. The tip is gradually tapering, rounded and curved downwards. The portion beyond last bundle consists of mesophyll and colourless parenchyma. The hyaline portion is multiseriate (4-celled at the base) and 320 μm wide. 96-128 μm long hairs are seen on the abaxial epidermis.

AMOMUM: COMPARATIVE ANATOMY (Fig. 18 & 19)

Intercostal cells of abaxial and adaxial epidermis are polygonal with their longer axis perpendicular to the longitudinal veins in all species studied. Costal epidermal cells are much smaller, as high as broad or slightly broader. The costal cells contain either a single silica body (*A. hypoleucum* and *A. pterocarpum*) or silica sand in them (*A. cannicarpum*, *A. ghaticum*, *A. masticatorium* and *A. muricatum*). According to Solereder & Meyer (1930) stigmata were absent in the genus *Amomum* and no records were available

to confirm the presence of silica sand. Indira (1976) observed the presence of some crystalline inclusions in some epidermal cells of *A. muricatum*.

Simple unicellular trichomes are present on the abaxial epidermis of *A. hypoleucum*, *A. pterocarpum* and *A. ghaticum*. Adaxial epidermis is usually glabrous. Trichomes are also seen in the petiole and midrib of *A. ghaticum*. Trichomes are totally absent in all other species. Trichomes are described as 'Borste' type (Staudermann, 1924). There is no considerable variation in the size of the guard cell (between 24-32 μm). Stomatal index is maximum for *A. ghatium* (17.41) and minimum in *A. muricatum* (6.9).

Abaxial surface of petiole is U-shaped in *A. pterocarpum* and *A. hypoleucum*, wide V-shaped in all other species. Adaxial surface is U-shaped in *A. pterocarpum* and wide V-shaped in *A. hypoleucum*. Petiole wings are unequal and broad; tip is blunt in *A. hypoleucum* and pointed in *A. pterocarpum*. In the other 4 species adaxial surface is nearly flat or slightly concave. Petiole of *A. petrocarpum* shows slightly ridged and furrowed abaxial surface. Bundle arc IV is present in all species, typical of the tribe Alpinieae. Bundle arc II is absent in *A. cannucarpum*, *A. masticatorium*, *A. muricatum* and *A. ghaticum* but present in all other species.

Abaxial surface of the midrib is U-shaped in all species studied; in *A. muricatum* it is very wide U-shaped. Bundle arc II is absent in all species. Arc IV is seen in *A. ghaticum*, *A. cannucarpum* and *A. masticatorium* and is absent in all other species.

In lamina T. S, adaxial epidermal cells are always broader than high in all species except *A. muricatum* and *A. ghaticum*, where cells are higher than broad. A continuous hypodermis below adaxial epidermis is seen only in *A. hypoleucum* in which the epidermal cells are smaller than the hypodermal cells. Indira (1976) reported the presence of adaxial hypodermis in *A. muricatum*, but in the present study, the hypodermis was found to be absent. Hypodermal fibres, usually, solitary which are distinct from the bundle sheath are seen in *A. hypoleucum*. Presence of such hypodermal fibres was also noticed by Indira (1976). Palisade is mostly 2-layered (1 long and 1 short cells). Bundles are connected to both the epidermis in all species except *A. pterocarpum* and *A. hypoleucum*; girders connect the adaxial cap to the adaxial epidermis, Trichomes are seen on the abaxial epidermis of *A. hypoleucum*, *A. ghaticum* and *A. pterocarpum*.

In margin T. S. adaxial epidermal cells are higher than broad. Hypodermis is absent. Tip is slightly bent downwards in all species studied.

Key to the species based on anatomical characters

1. Costal cells contain single silica body; hypodermal fibres present in the lamina2
1. Costal cells contain silica sand; hypodermal fibres absent in the lamina3
2. Lamina silvery silky pubescent below; midrib glabrous; hypodermis present in the lamina3. **A. hypoleucum**

- 2. Lamina pubescent, not silvery silky; midrib hairy; hypodermis absent in the lamina6. **A. pterocarpum**
- 3. Sheath hairy4
- 3. Sheath glabrous5
- 4. Petiole and midrib densely hairy; adaxial epidermal cells of the lamina as high as broad or higher2. **A. ghaticum**
- 4. Petiole and midrib glabrous; adaxial epidermal cells of lamina broader than high4. **A. masticatorium**
- 5. Costal cells as high as broad or higher; portion beyond last bundle consists of mesophyll only1. **A. cannicarpum**
- 5. Costal cells broader than high; portion beyond the last bundle consists of mesohyll and few parenchyma cells5. **A. muricatum**

3. **ELETTARIA** Maton

Elettaria Maton, Trans. Linn. Soc. London 10: 250. 1811; M. Sabu, Zingiberaceae and Costaceae of S. India 93. 2006.

Rhizome hard and woody. Leafy shoot 2-3 m tall. Leaf lamina 50-100 x 6-8 cm, lanceolate. Inflorescence a panicle. Bracts 2-ranked, each subtending several flowered cincinnus. Bracteole tubular. Calyx membranous. Corolla tube cylindrical, equal to the calyx. Labellum obovate.

Lateral staminodes small. Anther sessile. Ovary trilobular, capsule globose or oblong, indehiscent.

Distribution: About seven species are known, which are distributed from Sri Lanka to Malaysia and Indonesia. One species is native of South India.

Ecology: As undergrowth in dense wet evergreen forest above 1000 m.

Notes: The genus is characterised by very long, prostrate inflorescence. This genus is related to *Elettariopsis*.

Elettaria cardamomum (L.) Maton, Trans. L. Soc. London 10: 254. t. 5. 1811; M. Sabu, Zingiberaceae and Costaceae of S. India 94. 2006.

Amomum cardamomum L., Sp. Pl. 1. 1753.

(Plate 12 B)

Rhizome perennial, woody, horizontal. Leafy shoot 3-4 m tall. Leaves shortly petiolate; petiole 1-2 cm long; lamina 40-80 x 6-9 cm, linear-lanceolate, tip acuminate, glabrous above, slightly pubescent below; ligules short. Inflorescence produced directly from the rhizome, very rarely terminal; peduncle 30-40 cm long, prostrate. Bracts lanceolate, persistent, each subtends a cincinnus of 3-7 flowers. Calyx 1-1.5 cm, shortly 3-lobed. Dorsal corolla lobe wider than lateral lobe. Labellum 1.5-2 x 1 cm, white with violet stripes in the centre. Lateral staminode inconspicuous. Anther sessile; thecae 6-8 mm long; connective prolonged into c. 1 mm long crest. Style long, stigma bilipped. Ovary with many ovules. Capsule subtrigonous, 1-3 cm long, striate. Seeds many, aromatic.

Distribution: Wild in South India and Sri Lanka. The Western Ghat forest of Kerala is the centre of origin and diversity of cardamom. Widely cultivated in South India at high altitudes.

Notes: The cardamom commonly known as Malabar cardamom, true cardamom or small cardamom called as the "Queen of spices".

Specimens studied: KERALA: Malappuram Dt.: C. U. Botanical Garden, *Jayasree 103015*.

Anatomical features

(Fig. 20)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, longer than broad (48-72 x 24-32 μm), longer axis perpendicular to the veins and are arranged in definite rows. Costal cells are rectangular, broader than long (20-40 x 12 μm) and are seen in regular files. 5-6 rows of cells are seen over the veins. The costal cells contain one or rarely two small spherical silica bodies (4 μm) in them. Abaxial epidermal cells of the intercostal region are shorter than the cells on adaxial epidermis and are irregularly arranged. Costal cells are rectangular and stretched parallel to the veins. They are arranged in definite rows and contain 1 or 2 small silica bodies.

Trichomes: Simple, unicellular hairs are present only on abaxial epidermis. Length of the hairs ranges from 256-320 μm ; walls are thick with narrow lumen and pointed tip.

Stomata: Tetracytic, abundant on the abaxial epidermis. Length of the guard cell varies between 20-28 μm . Stomata are more frequent closer to the vein with very few stomata distributed in the middle of intercostal region. Stomatal index is 11.17. Stomata are very rare on the adaxial epidermis, when present, seen close to the veins. Stomatal index is 0.45 or less.

Sheath: Both abaxial and adaxial surface are U-shaped. Bundle arcs I, II and III are present. Smaller bundles of different sizes are present in arc II. Cells of the ground tissue contain large number of crystals in groups.

Petiole: Both abaxial and adaxial surfaces are U-shaped. Petiole winged, wings broad, abruptly tapering and recurved. Bundle arcs I, II, III and IV are present. Air canal in between the bundles of arc I is very small, elliptic. Cells of the ground tissue contain 1-few crystals in them.

Midrib: Abaxial surface is U-shaped with few, 100 μm long unicellular hairs. Adaxial surface is slightly grooved. Bundle arcs I and III are present. Cells of the ground tissue contain 1-3 crystals.

Lamina: Adaxial epidermal cells are rectangular, 2-3 times broader than high (48 x 16 μm). Abaxial epidermal cells are smaller than upper ones. Epidermal cells above and below bundles much smaller. Adaxial hypodermal cells are similar to the epidermal cells. Abaxial hypodermis is absent. Mesophyll is 96 μm thick and consists of 2-layered upper palisade and 3 or 4 layered spongy tissue. 1-few crystals are frequent in the spongy tissue. Large bundles are connected to both the epidermis by 2 or 3 layered

sclerenchymatous bundle cap. Smaller ones are connected to abaxial epidermis only.

Margin: Adaxial epidermal cells are as high as or higher than broad (16-32 x 16 μm) some cells above the veins contain small silica bodies. Abaxial epidermal cells are much smaller than the upper ones, as high as or slightly broader. 2-layered palisade (2nd layer of cells very short) and 2 or 3 layered spongy cells constitute the mesophyll. The portion beyond last bundle consists of mesophyll and colourless parenchyma. The tip is tapering, beak-like and blunt. Hyaline portion is multiseriate (4-celled at the base) and 80-90 μm wide.

ELETTARIA: COMPARATIVE ANATOMY (Fig. 20)

Adaxial epidermal cells are usually polygonal and the longer axis is perpendicular to the veins and are arranged in definite rows. Cells above veins are rectangular and stretched parallel to the veins. Abaxial epidermal cells show irregular arrangement. Costal epidermal cells contain 1 or 2 (1 big and 1 small) silica bodies in them. Silica bodies are of 4 μm diameter whereas Tomlinson (1956) reported the size of silica body to be 5 μm . The presence of single large silica body in the costal cells is restricted to the Tribe Alpinieae (Tomlinson, 1956). The genus *Elettaria* can be distinguished from other related genera like *Alpinia* (large silica body in square shaped or isodimetric cells) and *Amomum* (silica sand is common with some exceptions) by the presence of long rectangular cells above the veins that contain 1 or sometime 2 small silica bodies. Hairs are abundant on the

adaxial surface of leaves (Tomlinson, 1956; Indira, 1976) but the plants studied show glabrous upper surface. Hairs are of 'Borste' type (Staudermann, 1924). According to Tomlinson (1956) the thick walled hairs are lignified in *Alpinia*, *Amomum* and *Elettaria*.

The average length of the stomata shows slight variation from earlier studies 23 μm and 25 μm as reported by Tomlinson (1956) and Indira (1976) respectively. Present studies revealed that the average length as 24 μm , intermediate between the two earlier reports.

The bundles of the main arc I and of subsidiary arcs (II and III) are often pectinated so that a single arc of alternating large and small bundle is present in the midrib (Tomlinson, 1956). In the present study the arc II bundles are absent in the midrib. The arc III is embedded in the chlorenchymatous tissue, not alternating with arc I bundles.

Another common feature seen in tribe Alpinieae is the presence of the arc IV bundles in the petiole. Petiole does not show ribbing as observed by Tomlinson (1956). Petiole can be easily distinguished by the shape and recurved wings.

Tribe: Globbeae

1. GLOBBA L.

Globba L., Mant. Pl., 2: 170. 1771; Roxb., Fl. Indica 74. 1820; M. Sabu, Zingiberaceae and Costaceae of S. India 104. 2006.

Rhizome small, yellow-grey inside; roots fleshy with root tubers. Leafy shoots 30-90 cm tall. Leaves 3-8, produced towards the upper 2/3; sessile or very shortly petiolate, ligulate; ligule 0.1-1.2 cm long; lamina oblong to lanceolate. Inflorescence terminal. Bracts imbricating or lax. Flowers small, sessile or shortly petiolate, Calyx funnel-shaped, shortly trilobed. Corolla tube slender, much longer than calyx. Labellum joined to the stamen in a slender tube about 1 cm above the attachment of staminodes and corolla lobes. Staminodes attached to the corolla tube. Filament long, slender, curved, embracing style; anther with or without appendages. Ovary unilocular with parietal placentation. Fruit globose or sub globose capsule.

Distribution: About 110 species. Occur in India, Thailand, Sri Lanka, China, Malesia, Myanmar, Indonesia and New Guinea. In India it is distributed in all states, but greatest numbers occur in N.E. India. 5 species have been reported from South India of these *G. canarensis* is an imperfectly known species. Hence it is not included in the present study.

Ecology: All South Indian species are seen in evergreen or deciduous forest or teak plantations, both at low and high altitudes.

Notes: The genus can be easily recognised by its small flowers, long arching filaments and unilocular ovary with parietal placentation. The most striking feature of the flower is the union of lip and filament for some distance. The infrageneric classification of *Globba* is mainly based on the presence or absence of anther wings and the number and position of wings.

Key to the species based on morphological characters

1. Anther not winged; bracts deciduous.....2
1. Anther with spreading bifid wings; bracts persistent.....3
2. Ovary and capsule verrucose.....3. **G. orixensis**
2. Ovary wall smooth; capsule globose, slightly warted 2. **G. ophioglossa**
3. Bracts closely imbricating; ovary wall smooth1. **G. marantina**
3. Bracts lax, spreading; ovary wall warted.....4. **G. schomburgkii**

1. *Globba marantina* L., Mant. Pl. 2: 170. 1771; M. Sabu, Zingiberaceae and Costaceae of S. India 106. 2006. **(Plate 12 C)**

Rhizome conical, yellow inside. Leaves 6-8, shortly petioled; ligule 2 mm long; lamina 10-15 x 4-5 cm, oblanceolate, tip acuminate, base acute, upper surface glabrous, lower surface minutely pubescent. Inflorescence terminal, 6-10 cm long, straight. Bracts many, closely imbricating, persistent, subtend densely hairy bulbils; upper bracts smaller, subtend cincinni of 8-10 flowers on small stalk. Bracteole small, triangular. Flower c. 4 cm long, orange. Calyx truncate. Lateral staminodes longer than corolla lobes, spreading, orange. Anther with two triangular appendages on either side. Ovary c. 2 mm long, smooth. Stigma slightly exserted from the anther lobe. South Indian plants rarely produce seeds.

Distribution: It is widely distributed in Philippines, New Guinea, Malesia and India. In South India it is reported from all districts, but more common along Western Ghats.

Specimen studied: KARNATAKA: Uttar Kannad Dt.: Hirahalli, *Jana Sckornickova 84165*.

Anatomical features

(Fig. 21)

Epidermis: Intercostal cells of the adaxial epidermis are usually polygonal, higher than broad (80-96 x 32-48 μm) *i.e.*, perpendicular to the longitudinal and transeversely stretched. Cells above the veins smaller (16-32 x 48-80 μm) and longitudinally stretched. Intercostal and costal cells are regularly arranged. Abaxial epidermal cells 4-6 sided (48-80 x 32 μm), less transversely stretched, show irregular arrangement. Cells above veins are isodiametric or slightly broader (32 x 32-64 μm). Cells above veins are more evident on the upper epidermis.

Trichomes: Simple unicellular hairs are abundant on the lower surface. They are thin walled, pointed, length ranges between 96-256 μm . Very few hairs can be seen on either side of the veins of upper epidermis also.

Stomata: Tetracytic type and are distributed randomly between the veins on the lower epidermis. The long axis of the pore is parallel to the veins. Length of the guard cells is usually 40 μm long. Stomatal Index is 8.95. Very few stomata can be seen on the upper epidermis (SI = 0 .78).

Sheath: Abaxial surface is wide V-shaped and adaxial surface is wide U-shaped. Epidermal cells are slightly broader than high. Abaxial surface possess numerous hairs of 80 μm long. Hairs towards the tip of the wings are 225 μm long. Bundle arcs I, II and III are present. Metaxylem of the main arc is 40-48 μm wide. Oil cells are seen in the ground tissue. Some cells contain single or few calcium oxalate crystals. Silica sand may be present in the cells surrounding the bundle.

Petiole: Abaxial surface is wide V-shaped and adaxial surface is flat. Petiole is winged, wings are almost equal. 96-102 μm long hairs are seen on both abaxial and adaxial surfaces. Bundle arcs I, II, III and IV are present. Metaxylem of the arc I is 40-56 μm wide. Oil cells are present in the ground tissue and crystals are seen in very few cells.

Midrib: Abaxial surface is wide U-shaped and abaxial surface is wide V-shaped. Bundle arcs I and II are present. Arc II is represented by 2 bundles only, minute hairs of 16-64 μm can be seen on both abaxial and adaxial surface of the midrib. Crystals (1-few) can be seen in the chlorophyllous tissue that surrounds the air cavity.

Lamina: Lamina is 160 μm thick. Adaxial epidermal cells are twice as broad as high (32-40 x 64-96 μm). Cells above bundles are much smaller as compared to other epidermal cells. Abaxial epidermal cells are smaller than upper ones (32-40 x 48-52 μm). Hypodermis is present abaxially. These hypodermal cells contain single large calcium oxalate crystal in it. Hairs are seen on the lower epidermis. Large bundle is connected to both adaxial and

abaxial epidermis by 2-4 layers of sclerenchymatous bundle cap, smaller bundles are connected to abaxial epidermis only. Single layered palisade and 2-layered spongy cells form 64 µm thick mesophyll tissue.

Margin: Tip is tapering and pointed, slightly bent downwards. Epidermal cells as high or slightly broader. Hairs are present on the lower epidermis. Bundle is connected to lower epidermis only. 1-layered palisade and 1 or 2 layered spongy cells constitute the mesophyll. Hypodermis is seen abaxially and the cells contain single large calcium oxalate crystal. Portion beyond last bundle consists of mesophyll tissue. Hyaline portion is biseriate and 80-96 µm wide.

2. *Globba ophioglossa* Wight, Icon. Pl. Indiae Orient. 6: 19. t. 2002. 1853; M. Sabu, Zingiberaceae and Costaceae of S. India 109. 2006. **(Plate 12 D)**

Rhizome conical, light yellow-grey inside. Leaves shortly petiolate or sessile; ligule bipartite. Lamina 5-20 x 2-5 cm, oblong-lanceolate, tip acuminate, lower surface densely pubescent, upper surface sparsely pubescent. Inflorescence 10-20 cm long, bearing few to many branches in the axis of bracts, lower bracts subtends downwardly pointed conical bulbils. Bracts subtend a cincinnus of 2-many flower on a small stalk, deciduous. Calyx yellowish green. Corolla tube orange; lobes unequal, spreading. Labellum much longer than corolla lobes, tip emarginated, orange-yellow. Lateral staminodes, linear, orange. Anther without appendages, connective

slightly projecting to form a hood at the tip. Ovary 2 x 1 mm, smooth. Fruit globose to ovoid, slightly warted, dehiscent, hairy.

Distribution: Endemic to southern Peninsular India. Widely distributed in Kerala, Karnataka and Tamil Nadu.

Specimens studied: **KERALA:** Thiruvananthapuram Dt.: Ponmudi, Prasanth Kumar 86374.

Anatomical features

(Fig. 22)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, higher than broad (64-96 x 16 μm) with their longer axis perpendicular to the longitudinal veins. Cells above veins are smaller and broader than high (16-32 x 32 μm) with their longer axis parallel to the veins. The cell files are regular in both costal and intercostal region. Abaxial epidermal cells are smaller than upper ones, as high as broad (32-48 x 32-48 μm) and shows irregular arrangement. Cells above veins are less evident. Some of the lower epidermal cells contain single large crystal in them.

Trichomes: Simple unicellular hairs are abundant on the lower surface. The hairs are pointed and their length ranges between 128-400 μm . Upper epidermis is glabrous.

Stomata: Tetracytic stomata are distributed randomly between veins on the lower epidermis. The length of the guard cell varies from 36 μm to 48 μm . Stomatal Index is 4.59. Very less stomata are seen on the upper epidermis (SI < 0.78).

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Abaxial surface is ridged and furrowed. Abaxial surface possesses 200 μm long hairs. Bundle arcs I, II and III are present.

Petiole: Abaxial surface is V-shaped and adaxial surface is concave upto 300 μm long hairs are seen on both surfaces. Abaxial surface is wavy in outline. Bundle arcs I, II, III and IV are present.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is wide V-shaped. Bundle arcs I, II and III are present. Arc II is represented by 2 bundles only. Arc II bundles which are very small are seen among the chlorenchyma tissue between the bundle arc I.

Lamina: Lamina is 144 μm thick. Adaxial epidermal cells are twice as wide as high (32 x 64 μm). Cells above bundles are small. Lower epidermal cells are as high as or higher than wide (32-48 x 32 μm). The hypodermis is seen above the abaxial epidermis only. Most of the cells contain single large calcium oxalate crystal in it. Main bundle is connected to the adaxial and abaxial epidermis by 1-3 layered sclerenchymatous caps. Smaller bundles are connected to lower epidermis only. Mesophyll is 48 μm thick and is composed of 1-layered palisade and 2 or 3 layered spongy tissue. Hairs that are 160-192 μm long are present on the lower epidermis.

Margin: Tip is tapering, pointed and slightly bent downwards. Hairs are present on the lower epidermis. 1-layered palisade and 2-layered spongy cells constitute the mesophyll. The portion beyond the last bundle consists of mesophyll cells only. Abaxial hypodermal cells contain single large crystal in them. Very small hairs are seen from the tip also. The hyaline portion is biseriate and 64-90 μm wide.

3. Globba orixensis Roxb., *Asiat. Res.* 11: 358. 1810, *Fl. Indica* 1: 75. 1820; M. Sabu, *Zingiberaceae and Costaceae of S. India* 113. 2006.

(Plate 12

E)

Leafy shoot bending obliquely to one side. Lamina 15-25 x 5-8 cm, oblong to elliptic-lanceolate, lower surface pubescent. Inflorescence 30-40 cm long, with short, rigid, branches. Bracts small, deciduous, lower ones subtend bulbils; upper ones subtend cincinni of 2 or 3 flowers. Calyx greenish-yellow. Corolla lobes unequal. Labellum 1-1.5 cm long, obovate, base auriculate, tip deeply bifid. Lateral staminodes auriculate. Anther without any appendage. Ovary verrucose. Style shorter than filament. Fruit verrucose. Seeds reddish-brown, ovoid.

Distribution: Reported only from India. In India it occurs in Andhra Pradesh, Bihar, Orissa, Tripura and throughout Eastern Himalayas.

Specimen studied: KERALA: Malappuram Dt.: C.U. Botanical Garden, *Jayasree* 86256.

Anatomical features

(Fig. 23)

Epidermis: Adaxial epidermal cells are polygonal, intercostal cells are longer (80-112 x 16-32 μm) and are stretched perpendicular to the longitudinal veins. Costal epidermal cells are much smaller than the intercostal cells (16 x 16 μm). The cell files are very clear in both regions. Intercostal cells of the abaxial epiderms are also polygonal, smaller than upper ones (64-96 x 16-32 μm). Costal cells are smaller and are isodiametric (16-32 x 16-32 μm). Cell files are irregular.

Trichomes: Simple, unicellular trichomes are abundant on the abaxial epidermis. Hairs are upto 720 μm long. Adaxial epidermis is devoid of hairs.

Stomata: Stomata are seen on the abaxial epidermis; very rare on adaxial epidermis. Length of the guard cells range between 44-48 μm . Stomatal Index is 5.42.

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. 20-60 μm long hairs are seen on the abaxial surface of the wings. Bundle arcs I, II and III are present. Oil cells are also seen. Metaxylem of the main arc is 80 μm wide. Almost all cells of the ground tissue and the chlorenchymatous cells possess 1 or 2 large crystals.

Petiole: Abaxial surface is U-shaped and adaxial surface is flat. Petiole is winged and wings are unequal. Abaxial surface bears numerous hairs that are upto 80 μm long. Bundle arcs I, II, III and IV are present. Metaxylem is 88 μm wide. Oil cells are abundant in the ground tissue. All cells of the ground tissue possess either single large or a few crystals in groups.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is concave. Bundle arcs I, II and III are present. Arc III is represented by a single bundle only, which is embedded in the chlorenchymatous tissue. On the abaxial surface 32-40 μm long hairs are seen. 1-few crystals are seen in the ground parenchyma cells and also in the chlorenchymatous cells.

Lamina: Lamina is 224 μm thick. Adaxial epidermal cells are twice as broad as high (40 x 96 μm). Cells above bundle much smaller than the rest. Abaxial epidermal cells are smaller than upper ones (40 x 64 μm). Hypodermis is present abaxially, each cell contains single, large calcium oxalate crystal. Mesophyll is divisible into 1-layered palisade and 3 or 4 layered spongy cells and is 90 μm thick. Main bundle is connected to both abaxial and adaxial epidermis by 1-3 layered sclerenchymatous cap. Small bundle are connected to abaxial epidermis only.

Margin: Tip is straight, gradually tapering and pointed. Upper and lower epidermal cells as high as wide or slightly broader. Hairs are abundant on the lower epidermis. Hair length varies from 48-176 μm . Palisade is 1-layered and spongy is 2 or 3 layered. Lower hypodermis is present. Bundles are connected to the lower epidermis only. Portion beyond last bundles consists of mesophyll tissue alone. Hyaline portion is biseriate and 48-54 μm wide.

4. *Globba schomburgkii* Hook. f., Bot. Mag. 3:33. t. 6298. 1877; M. Sabu, Zingiberaceae and Costaceae of S. India 113. 2006. **(Plate 12**

F)

Leafy shoot 30-60 cm tall, slightly swollen near the rhizome. Leaves shortly petioled; petiole 4 mm long, ligulate; lamina 12-20 x 4-5 cm, oblong-lanceolate, tip acuminate, upper surface glabrous, lower surface minutely pubescent. Inflorescence terminal, peduncle slender, recurved. Bracts many, lax spreading, persistent, lower bracts subtend spherical bulbils, upper

bracts smaller, each subtends a cincinnus of 4-5 flower in two ranks. Bracteoles small, orange. Corolla lobes recurved, orange. Labellum triangular with divergent lobes, orange with a reddish patch at the centre. Lateral staminodes upcurved, tip pointed. Anther with two spreading, narrowly triangular appendages on each side. Ovary rugose. Fruit setting very rare.

Distribution: Throughout India.

Specimen studied: **KERALA:** Malappuram Dt.: C. U. Botanical Garden, *Jayasree 86576*.

Anatomical features

(Fig. 24)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal (64-96 x 16-32 μm) with their longer axis perpendicular to the longitudinal veins. Costal epidermal cells are much smaller and almost rectangular (16-24 x 32-64 μm). They are stretched parallel to the veins. The cell files are very clear on both costal and intercostal region. Cells of the abaxial epidermis are smaller than upper ones (48-80 x 16-48 μm). The cell files are not clear. Cells above veins are distinguishable by their smaller size (32 x 32-48 μm). Some of the abaxial epidermal cells possess single calcium oxalate crystal in them.

Trichomes: Trichomes are absent on both epidermis.

Stomata: Tetracytic stomata are seen on the abaxial epidermis. Long axis of the guard cell is parallel to the veins. Stomata are evenly distributed

between the veins. Length of the guard cell is between 32-36 μm . Stomatal Index is 9.08. A few stomata are seen on the adaxial epidermis also (SI = 1.04).

Sheath: Abaxial surface is V-shaped and adaxial surface is wide U-shaped. Abaxial surface is ridged and furrowed. 0.25 mm long hairs may be present on the abaxial surface. Bundle arcs I, II and III are present. Metaxylem is 40-56 μm wide. Large air canals are seen in between the bundles. Oil cells are present. Some cells contain starch grains in them.

Petiole: Abaxial surface of the petiole is wide U-shaped. Adaxial surface is concave. Bundle arcs I, II, III and IV are present. Adaxial surface possesses 24-36 μm long hairs. Cells of the ground tissue which are surrounding the bundles contain few crystals and some cells contain silica sand.

Midrib: Abaxial surface is U-shaped and adaxial surface is concave. Bundle arcs I, II and III are present in the midrib. Crystals and silica sand are seen in the cells surrounding the bundles and also in chlorenchymatous cells.

Lamina: Lamina is 184 μm thick. Cells of the adaxial epidermis are broader than high (32-40 x 64-80 μm). Abaxial epidermal cells are much smaller (32 x 32-40 μm). Mesophyll is 50-60 μm thick and consists of 1-layered palisade and 2-layered spongy cells. Sclerenchymatous cap of the main bundle is in contact with both epidermis. A hypodermis is present abaxially with single large calcium oxalate crystal in each cell.

Margin: Adaxial epidermal cells are broader than high. Abaxial cells are also broader but smaller than upper ones. Mesophyll is divided into 1-layered palisade and 1 or 2 layered spongy cells. Bundle is in contact with the abaxial epidermis only. Metaxylem is 16 μm wide. The portion beyond the last bundle has mesophyll tissue and 1 or 2 colourless parenchyma cells. Tip is straight and pointed. Hyaline portion is 4-celled at the base and 48 μm wide.

GLOBBA: COMPARATIVE ANATOMY (Fig. 25 & 26)

Intercostal cells of the adaxial epidermal cells are polygonal with their longer axis perpendicular to the longitudinal veins. *G. marantina* and *G. schomburgkii* have broader cells (twice long as broad) than *G. orixensis* and *G. ophioglossa* (3-5 times longer than broad). Costal epidermal cells are much smaller and square in *G. orixensis*, rectangular and stretched parallel to the veins in other three species. Cell files are regular.

Abaxial epidermal cells are smaller than upper ones. Costal cells are indistinguishable in *G. ophioglossa* but can be recognized in all other species. Single crystal is seen in some of the abaxial epidermal cells as observed by Indira (1976).

Simple unicellular trichomes are present on the abaxial epidermis of all species except *G. schomburgkii*. In *G. marantina*, very few hairs can be seen on either side of the veins of adaxial epidermis also. The length of the hairs is upto 400 μm . Very small hairs upto 36 μm long are present on the

adaxial surface and upper part of abaxial surface of petioles of *G. schomburgkii*. According to Tomlinson (1956) trichomes that are interpreted as 'Wiechhaare' occur in *G. marantina*. In our study the hair seen on the leaf surface are thin and delicate and easily detachable, but the length of the hair is much less than what is expected for a 'Weichhaare' type of hair.

Stomata are tetracytic and are distributed abundantly on the abaxial epidermis. The long axis of the guard cell is parallel to the longitudinal veins. Very few stomata can be seen on the adaxial epidermis. There is not much variation in the size of the stomata but stomatal index is maximum in *G. schomburgkii* (9.08) and minimum in *G. ophioglossa* (4.59).

In petiole (absent in all species except *G. schomburgkii*) we can see bundle arcs I, II, III and IV. Crystals (1-few) are seen in the ground parenchyma cells. The parenchymatous cells surrounding the bundle possess silica sand in them. Tomlinson (1956) also reported the presence of silica sand in *Globba* and presence of arc IV bundles in the petiole.

Midribs of all species studied have a uniform structure with I, II and III bundle arcs. Arc III is reported to be absent in *Globba* (Tomlinson, 1956) but in our study bundles of III arc were seen alternating with the Bundle arc I among the chlorenchymatous tissue.

Epidermal cells in T. S. are broader than high in all species studied. All species possess abaxial hypodermis. All cells of the hypodermis contain

single, large calcium oxalate crystal, which is a very distinguishable character.

Margin is gradually tapering pointed straight or slightly bent. Hyaline portion is very narrow and biseriate. Lower epidermal cells possess hairs.

Appearance of midrib, petiole and sheath in T. S. is often somewhat constant and characteristic for the genus *Globba*. The presence of large calcium oxalate crystal in the lower hypodermis may be diagnostic for *Globba* (Tomlinson, 1956). Silica sand is much less abundant in the tribe Globbeae than in Alpinieae.

Key to the species based on anatomical characters

1. Lower epidermis without hairs; petiole prominent, c. 4 mm long 4. **G. schomburgkii**
1. Lower epidermis with hairs; petiole absent or less conspicuous, c. 1 mm long 2
2. Costal cells of the upper epidermis rectangular, stretched parallel to the veins; margin bent downwards3
2. Costal cells of upper epidermis square, not stretched, margins straight 3. **G. orixensis**
3. Adaxial epidermal cells broader (32-46 μ m) with scattered hairs; stomatal index 8.95.....1. **G. marantina**

3. Adaxial epidermal cells longer (64-96 μm), without hairs; stomatal index 4.592. **G. ophioglossa**

Tribe: Zingibereae

1. BOESENBERGIA (Wall.) Kuntze

Boesenbergia (Wall.) Kuntze, Rev. Gen. Pl., 685: 1891; Das & Sikdr., Bull. Bot. Soc. Bengal 36: 39. 1982; M. Sabu, Zingiberaceae and Costaceae of S. India 118. 2006.

Gastrochilus Wall., Pl. Asiat. Rare. 1: 12. 1829, *non*-D. Don, 1825, Baker in Hook. f., Fl. Brit. India 6: 217. 1890.

Rhizome very small. Roots fleshy. Leafy shoot 15-160 cm tall. Axillary bulbils may be present. Leaves 3 or 4 in number petiolate, ligulate; lamina, glabrous or hairy. Inflorescence basal, directly from the rhizome or terminal or from leaf axils. Peduncle bears 2-ranked bracts. Bracts long and narrow, subtends single flower; upper bracts maturing first. Bracteoles as long as the bracts. Clayx short, tubular. Corolla tube slender, longer than the bracts. Labellum longer than corolla lobes, often saccate. Lateral staminodes shorter than or longer than the corolla lobes. Filament as long as the anther; connective sometimes produced into a short crest. Ovary trilocular or incompletely trilocular with a basal group of ovules. Fruit ellipsoid.

Distribution: About 80 species, distributed in India, Thailand, Indo-china, Malay Peninsula, Myanmar, Sumatra, Borneo etc. Das and Sikdar (1982) recorded 6 species from India, of which 2 occur in South India.

Key to the species based on morphological characters

1. Leafy shoot 35-60 cm high; internodes elongated, 3-6 cm long; staminodes longer than the corolla lobes; leaf sheath purple1. **B. pulcherrima**
2. Leafy shoot 15-30 cm high, completely included within leaf sheaths; internodes short, 2-3 cm long; staminodes equal to or shorter than the corolla lobes; leaf sheath green 2. **B. tiliaefolia**

1. Boesenbergia pulcherrima (Wall.) Kuntze., Rev. Gen. Pl. 2: 685. 1891. Manilal, Fl. Silent Valley 310. 1988; M. Sabu, Zingiberaceae and Costaceae of S. India 121. 2006.

Gastrochilus pulcherrima Wall., Pl. Asiat. Rare. 1: 22. t. 24. 1829; Baker in Hook f., Fl. Brit. India 6: 217. 1890. **(Plate 13**

A)

Rhizome aromatic, yellow in the centre, light pinkish towards periphery; root tubers present. Leafy shoot 35-60 cm high. Leaves 3-5, shortly petiolate, sheath greenish or purplish; lamina ovate-elliptic, 6-18 x 5-8 cm, unequal at base, ligulate. Internodes 3-6 cm long. Inflorescence sessile. Bracteoles bilipped. Calyx truncate, shortly 3-lobed. Corolla tube equal to the bract, lobes oblong. Labellum obovate-cuneate, tip entire,

margin wavy, white with pink in the depression. Lateral staminodes slightly longer than corolla lobes. Ovary tricarpeal, unilocular with one or more ovules attached to the lower posterior side of the wall. Capsule dehisces in to 3 valves. Seeds 4 mm long, brown when mature.

Distribution: Myanmar, Borneo and India. In India it is reported from South India, along the Western Ghats in Karnataka and Kerala.

Specimen studied: KERALA: Palakkad Dt.: Kanjirappuzha, *Prasanth Kumar 86363*.

Anatomical features

(Fig. 27)

Epidermis: Intercostal cells of the adaxial epidermis are hexagonal or polygonal (128-144 x 48-80 μm) with their longitudinal axis perpendicular to the longitudinal veins. Costal epidermal cells are also hexagonal, smaller, isodiametric (48 x 48 μm) and arranged in regular cell files whereas intercostal cell files are less regular. Intercostal cells of the abaxial epidermis are polygonal (128 x 48-64 μm) and show very irregular arrangement. Costal epidermal cells are smaller (96 x 80-96 μm) indistinguishable from the rest.

Trichomes: Trichomes are completely absent.

Stomata: Stoma is peculiar in *B. pulcherrima* as it is surrounded by 6-10 subsidiary cells and is called polycytic stomata. The long axis of the guard cell is parallel to the longitudinal vein. The length of the guard cell varies

between 68-80 μm . Stomatal index is 9.96. Very few stomata are present on the upper epidermis and stomatal index is less than 0.74.

Sheath: Abaxial surface is wide U-shaped and adaxial surface is V-shaped. Bundle arcs I, II and III are present. Arcs II and III are represented by 1 bundle each.

Petiole: Abaxial surface is U-shaped and adaxial surface is V-shaped. Petiole wings are broad, gradually tapering and blunt at the tip. They are unequal with one short and one long wing. Bundle arcs I, and III are present. The air canals in between the bundles of arc I are large.

Midrib: Abaxial and adaxial surfaces are wide U-shaped. Bundle arc I alone is present in the midrib.

Lamina: Lamina is 384 μm thick at the bundle and 256 μm at other positions. Adaxial epidermal cells are very large, broader than high (112 x 135-144 μm). Cells above veins smaller and are higher than broad. Abaxial epidermal cells are smaller and as high as or broader than high. The adaxial surface is raised above the veins. Hypodermis is absent. 1-layered palisade and 2 or 3 layered spongy cells constitute the mesophyll tissue which is 110 μm thick. Spongy cells possess one or two big crystals in them. Sclerenchymatous cap of the bundle is not in contact with either of the epidermis.

Margin: Cells of both adaxial and abaxial epidermis are broader than high. Hypodermis is completely absent. Mesophyll tissue consists of 1-layered palisade and 1 or 2 layered spongy cells. Some mesophyll cells contain 1 crystal in it. Some of the adaxial epidermal cells possess single large crystal. Sclerenchymatous cap of last bundle touches the abaxial epidermis.

The portion beyond the last bundle consists of mesophyll only. Tip is straight, gradually tapering and pointed. Hyaline portion is biseriate and 64-80 μm wide.

2. Boesenbergia tiliaefolia (Baker) Kuntze., Rev. Gen. Pl. 685. 1891; M. Sabu, Zingiberaceae and Costaceae of S. India 124. 2006.

Gastrochilus tiliaefolia Baker in Hook. f., Fl. Brit. India 6: 218. 1890.

(Plate 13 B)

Rhizome small; root slender, occasionally tuberous. Leafy shoot 15-30 cm tall; stem short, completely included within leaf sheath, sheath green; some times with axillary bulbils; internodes short, 2-3 cm long. Leaves 3 or 4, petiole 2-4 cm; lamina 8-20 x 6-11 cm, elliptic, tip acute, oblique at base, ligulate. Inflorescence sub sessile, included within the leaf sheath. Calyx truncate. Corolla lobes linear-oblong. Labellum saccate; margin wavy, apex slightly bilobed, white with pink spots in the centre. Lateral staminodes equal to or shorter than corolla lobes. Connective of the anther produced into a small bilobed projection. Ovary unilocular, partially divided by a posterior septum. Capsule with 2-4 seeds, on dehiscence each valve roll outwards. Seeds brown to black.

Distribution: Kerala and Meghalaya.

Specimen studied: **KERALA:** Malappuram Dt.: C. U. Botanical Garden, *Jayasree 86581*.

Anatomical features

(Fig.

28)

Epidermis: Intercostal cells of the adaxial epidermis are as high as or higher than broad (80-100 x 64-88 μm) and they are arranged in regular rows. Costal cells are broader than high (40-48 x 60-88 μm). 3-5 rows of cells are found over the major veins. Abaxial epidermal cells of the intercostal region composed of cells with various size and shape (72-140 x 52-80 μm) and are very irregularly arranged. Oil cells are frequent on the abaxial epidermis. Costal cells are less distinguishable from the rest in size but this region is devoid of stomata.

Trichomes: Very delicate and thin walled hairs which are upto 64 μm long, are rarely seen on the abaxial epidermis.

Stomata: Stomata are polycytic and occur only on abaxial epidermis, in between the veins. Length of the guard cells varies between 76-88 μm . Stomatal Index is 9.44.

Sheath: Abaxial surface is U-shaped and shows some ridges at the base. Adaxial surface is wide U-shaped. Two wings are present which are unequal, and spreading; 0.5 mm long hairs are seen on the abaxial surface towards the distal part of the wing. Tip of the wings are hyaline. Bundle arcs I and II are present. Chlorenchyma is seen lining the air canal. The cells which surround the bundle contain chloroplasts in them.

Petiole: Abaxial surface is U-shaped and ridged. Adaxial surface is grooved. Petiole is winged, wings unequal. Bundle arcs I, II and III are present. Arc III is represented by a single bundle.

Midrib: Abaxial surface is wide V-shaped and adaxial surface is V-shaped. Bundle arc I alone is present. Air canal in between the bundles are not prominent. Very few cells contain solitary crystal in them.

Lamina: Lamina is 432 μm thick at the bundle and 320 μm thick at other portion. Adaxial epidermal cells are longer than broad (128 x 64-80 μm). Abaxial epidermal cells are as high as broad or slightly broader (64-80 x 64-96 μm). Adaxial epidermis is raised above the bundle. Mesophyll is 160 μm thick and is composed of 1-layered palisade and 3-layered spongy. Hypodermis is completely absent. Bundles are never in contact with either epidermis. Metaxylem is 16-32 μm wide. Very few oil cells are seen in the mesophyll.

Margin: Adaxial and abaxial epidermis is as high as broad towards the tip. Mesophyll is composed of 1-layered palisade and 2 or 3 layered spongy cells. A prominent bundle cap is absent, and it is represented by 1 or 2 cells abaxially, which is not in contact with epidermis. Metaxylem is 16-24 μm wide. The portion beyond last bundle is composed of mesophyll and 1 or 2 colourless parenchyma cells. The tip is gradually tapering, very slightly bent downwards and blunt. Hyaline portion is multiseriate (3-celled at the base) and 48-64 μm wide.

BOESENBERGIA: COMPARATIVE ANATOMY (Fig. 29)

Intercostal cells are larger in *B. pulcherrima* (upto 160 x 96 μm) than in *B. tiliaefolia* (80-100 x 64-88 μm). Costal cells of the adaxial epidermis are almost isodiametric in *B. pulcherrima* but broader in *B. tiliaefolia*.

Trichomes are seen on the abaxial surface of leaf, sheath and aerial stem in *B. tiliaefolia* but in *B. pulcherrima* it is absent or rare.

Polycytic stomata are seen in both species studied. Stomata are larger in *B. tiliaefolia* (upto 88 μm).

Petioles have unequal wings in both. Bundle arcs I and III are present in *B. pulcherrima*. *B. tiliaefolia* possess bundle arcs I, II and III. In *B. tiliaefolia*, the abaxial surface of the petiole is ridged and furrowed, whereas in *B. pulcherrima* it is smooth.

In the midrib of both species studied, bundle arc I alone is present.

In Transverse Section of lamina, the adaxial epidermis is raised above the veins. The epidermal cells are as high as or higher than wide in *B. tiliaefolia* and broader than high in *B. pulcherrima*.

Margin is straight and blunt. Hyaline portion is very short (upto 80 μm).

Though Tomlinson (1956) and Indira (1976) have studied the anatomy of Zingiberaceae, their study did not include the genus *Boesenbergia*. Hussin *et al.* (2001) studied the anatomical variations in leaves of 4 *Boesenbergia* species viz., *B. curtisii* (Baker) Schultr., *B.*

prainiana (Baker) Schultr., *B. rotunda* (L.) Mansf. and *B. plicata* (Ridl.) Holttum. Simple Unicellular hairs were observed on the leaf surfaces of *B. curtisii*, *B. rotunda* and *B. plicata*. The stomatal type recorded was polycytic in *B. plicata* and *B. prainiana* which is also found in the species under present study. In lamina Transverse Section, the epidermal cells were as high as wide in *B. plicata* and *B. prainiana*. Similar structure is observed in *B. tiliaefolia*. Hypodermis was completely absent in *B. plicata* and *B. prainiana*. The species included in the present study also lack hypodermis. Margin is straight and blunt in *B. prainiana*, tapering and pointed in other species. The margins of *B. pulcherrima* and *B. tiliaefolia* are straight and blunt.

In many of the characters like the type of stomata, nature of epidermal cells and absence of hypodermis etc., the species under study are more close to *B. plicata* and *B. prainiana* than the other two species studied by Hussin *et al.* (2001).

Key to the species based on anatomical characters

1. Adaxial epidermal cells in the lamina broader than high (112 x 128- 144 μm ; bundle arc II absent in the petiole.....1. **B. pulcherrima**
1. Adaxial epidermal cells in the lamina higher than broad (128 x 64-80 μm); bundle arc II present in the petiole2. **B. tiliaefolia**

2. CURCUMA L.

Curcuma L., Sp. Pl. 2. 1753; M. Sabu, Zingiberaceae and Costaceae of S. India 126. 2006.

Rhizomatous herbs, with or without sessile tubers; roots often bearing root tubers. Leafy shoot 20-180 cm high; leaf sheath ligulate. Leaves 3-9, petiolate; lamina ovate-elliptic to oblanceolate. Inflorescence lateral, central or both, with or without distinct coma. Fertile bracts few-many, each joined to the adjacent ones or to the axis forming pouch. Each bract subtends a single or 2-10 bracteolate flowers. Calyx truncate, shortly 3-lobed. Corolla tube funnel-shaped; lobes unequal, mid-lobe larger. Labellum obscurely 3-lobed. Lateral staminodes linear. Anthers versatile, spurred or not; connective sometimes forms crest. Fruit ellipsoid, thin walled, dehiscent and liberating the seeds into the mucilage in the bract pouch.

Distribution: About 120 species seen mainly in India and South East Asia. In India about 29 species (Karthikeyan *et al.*, 1989) distributed in almost all states. Many are cultivated and naturalised; but the main centre of distribution is South-West India, North East India and Andaman and Nicobar Islands.

Ecology: As undergrowth in tropical and subtropical forests, margins of forest, open grass lands, secondary forests and plantations. Several species are found growing in plains, in coconut and arecanut groves.

Key to the species based on morphological characters

1. Anther lobes ecalcarate 4. **C. aurantiaca**
1. Anther lobes spurred 2
2. Leafy shoot 15-60 cm high..... 3
2. Leafy shoot 65-125 cm high 11
3. Inflorescence with or without inconspicuous coma 4
3. Inflorescence with well developed coma 8
4. Rhizome stoloniferous; flowers shorter than the bracts.
..... 18. **C. vamana**
4. Rhizome ovoid; flowers longer than the bracts5
5. Leaves 0.7-1.5 cm broad; inflorescence only central. 5. **C. bhatii**
5. Leaves 7-14 cm broad; inflorescence both lateral and central. 6
6. Leafy shoot upto 35 cm tall; flowers 5.5-7 cm long15. **C. oligantha**
6. Leafy shoot upto 60 cm tall; flowers 4.5-6 cm long 7
7. Labellum white with a median bright yellow band; anther 4.5 mm long
..... 10. **C. karnatakensis**
7. Labellum yellow or white with yellow center; anther 3.5-4 mm
long. 13. **C. mutabilis**

- 8. Root tubers cylindrical, 10-18 cm long; leaves coriaceous, densely pubescent on both sides 6. **C. coriacea**
- 8. Root tubes small, spherical, ovoid or oblong; leaves not coriaceous, glabrous or sparsely pubescent 9
- 9. Flowers equal to the bracts; lip purple 10
- 9. Flowers longer than bracts; lip yellow 14. **C. neilgherrensis**
- 10. Leaves broadly ovate, subcordate at base; fertile bracts recurved; lip purple towards base 7. **C. decipiens**
- 10. Leaves elliptic, base oblique; fertile bracts not recurved; lip deep purple with a bright yellow band 9. **C. inodora**
- 11. Leaves with purple patch along the midrib12
- 11. Leaves without a purple patch along midrib13
- 12. Rhizome blue within; leaves with a purple patch on the distal half on the upper side only1. **C. aeruginosa**
- 12. Rhizome yellow to deep yellow within; leaves with purple patch on both sides along the whole length of the midrib ...19. **C. zanthorrhiza**
- 13. Lateral staminodes with a patch of glandular hairs at centre 14
- 13. Lateral staminodes without glandular hairs 15

14. Pseudostem reddish purple; leaves spreading, oblong-lanceolate, glabrous below 17. **C. raktakanta**
14. Pseudostem green with a few light pink dots; leaves erect, semiplicate, ovate-elliptic, densely pubescent on the lower surface. 8. **C. haritha**
15. Rhizome with the smell of green mango 2. **C. amada**
15. Rhizome without the smell of green mango 16
16. Rhizome with sessile tubers 17
16. Rhizome without sessile tubers16. **C. pseudomontana**
17. Rhizome deep orange-yellow within; lip light yellow with a median dark yellow band 4. **C. longa**
17. Rhizome yellow or light orange yellow within; lip deep yellow 18
18. Rhizome light orange-yellow within; corolla white; calyx 8 mm long. 12. **C. montana**
18. Rhizome greyish-yellow within; corolla pinkish white; calyx 2 cm long 3. **C. aromatica**

1. **Curcuma aeruginosa** Roxb., *Asiat. Res.* 11: 335. 1310, *Fl. Indica* 1: 27. 1820; M. Sabu, *Zingiberaceae and Costaceae of S. India*: 32. 2006.

(Plate 13 C)

Rhizome large, blue in the centre, verging towards grey, strongly aromatic; sessile tubers branched, condensed; root tubers many. Leafy shoot 70-100 cm tall; pseudostem 30-35 cm. Leaf lamina 30-40 x 10-12 cm, oblong-lanceolate, tip acute, base acuminate, glabrous, purple or reddish brown patch along the sides of the distal half of the midrib on upper side only, groove of the midrib green. Inflorescence lateral; coma bracts large, pink to violet, fertile bract 18-20, each subtends a cincinnus of 8-10 flowers. Bracteoles large. Flower equal to or shorter than the bracts. Corolla tube longer than calyx, pink. Labellum emarginate at tip, yellow with a median deep yellow band. Lateral staminodes yellow. Anther spurred at base, divergent. Stigma bilipped, slightly exerted above the anther lobes. Fruiting not common.

Distribution: Native of Myanmar. Also seen in Java and widely cultivated in Malesia. It is wild in South India.

Specimen studied: **KERALA:** Kozhikode Dt.: Kolathara, *Jana Sckornickova & Jayasree 84130*.

Anatomical features

(Fig. 30)

Epidermis: Adaxial epidermal cells of intercostal region are longer than broad (88-120 x 20-40 μm) with their longer axis perpendicular to the

longitudinal veins and the cell files are regular. Costal epidermal cells are broader than long (20-24 x 32-60 μm). 4 or 5 rows of cells are seen above the major vein. Abaxial epidermal cells are also polygonal and are more or less regular. Costal cells are bigger than adaxial costal cells and are less distinguishable. Rarely oil cells are also seen on the abaxial epidermis.

Trichomes: Completely absent on leaf lamina. Very minute hairs upto 160 μm are seen on the abaxial surface of sheath.

Stomata: Mainly distributed between the veins on abaxial epidermis. Length of the guard cell is 48 μm . Stomatal index is 12.15. Very few stomata are present on the adaxial epidermis nearer to the veins (SI = 1.75).

Sheath: Both abaxial and adaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. Position of xylem and phloem is reversed in bundles of arc III. 9-11 oil cells are seen in the sheath. Metaxylem of the bundle arc I is 88-100 μm wide. Some cells surrounding the bundle contain silica sand.

Petiole: Abaxial surface is U-shaped; adaxial surface is slightly concave. The petiole is winged; wings are narrow and pointed, about 3 mm long. Bundle arcs I, II and III are present. 2-5 oil cells are found in the ground tissue. Some cells contain crystals in clusters. Cells near to the bundle sheath contain silica sand in them. Cells of the bundle sheath also may possess single crystal. Metaxylem of the bundle arc I is 80-92 μm wide.

Midrib: Both abaxial and adaxial surface are V-shaped. Bundle arcs I, II and III are present. Smaller bundles are also seen in arc II. Metaxylem of the arc I bundle is 48-68 μm wide. Few crystals are found in some cells of the ground tissue.

Lamina: Lamina is 352 μm thick. Adaxial epidermal cells are broader than high (32 x 80-96 μm). Cells above bundles are as high as broad. Abaxial epidermal cells are much smaller and broader than high (20-32 x 32-48 μm). Both abaxial and adaxial hypodermis are present. Adaxial hypodermal cells are bigger than the epidermal cells (64-80 x 80-128 μm). Abaxial epidermal cells are much smaller (48 x 64-80 μm). 1 or 2 layered palisade and 4-6 layered spongy tissue constitute the mesophyll, which is 160-176 μm thick. Oil cells are also found in the mesophyll. Some mesophyll cells contain single crystal in them. Bundle cap is 2-layered and it is in contact with the adaxial epidermis only.

Margin: Adaxial epidermal cells are broader and as high as broad towards the tip. Abaxial and adaxial hypodermis continue to be present in the margin also. Mesophyll is composed of 1-layered palisade and 2 or 3 layered spongy. Sclerenchymatous cap of the bundle not in touch with either of the epidermis. The portion beyond last bundle consists of mesophyll and parenchyma cells. The tip is gradually tapering, bent downwards and pointed. Hyaline portion is multiseriate (4-celled at the base) and 268 μm wide.

2. **Curcuma amada** Roxb., *Asiat. Res.* 11: 341. 1810; M. Sabu, *Zingiberaceae and Costaceae of S. India* 138. 2006. **(Plate 13 D)**

Rhizome large, light yellow inside, white towards periphery, with a smell of green mango, sessile tubers thick, cylindrical, branched; root tubers absent. Leafy shoot 65-75 cm high. Pseudostem 30-35 cm tall. Leaves 4-6; petiole 5-10 cm long; lamina 45-60 x 14-15 cm, oblong-lanceolate, without purple patch, lower surface puberulous, upper glabrous. Inflorescence lateral or central. Coma bracts spreading, light violet. Fertile bracts green, subtend 4 or 5 flowers. Flowers longer than bracts. Calyx 3-lobed at the tip. Corolla pale yellow; lobes, white. Labellum elliptic, 3-lobed; mid-lobe emarginate, recurved, pale yellow with median dark yellow band. Lateral staminodes without glandular hairs. Stamen white, spurred. Stigma closely appressed within the anther lobe. Fruits not seen.

Distribution: Native of Bengal. It is now widely cultivated throughout India.

Specimen studied: KERALA: Ernakulam Dt.: Paravur, *Jana Sckornickova 84104*.

Anatomical features

(Fig. 31)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal with their longer axis perpendicular to the longitudinal veins (80-112 x 32-48 μm). The cell files are arranged regularly. Costal epidermal cells are smaller, as high as broad (32 x 32 μm) and show regular arrangement. Intercostal cells of the abaxial epidermis are also polygonal with their longer axis perpendicular to the veins (48-64 x 32-48 μm), but less stretched than adaxial ones; cell files are irregular. Costal epidermal cells are less distinguishable.

Trichomes: Absent.

Stomata: Stomata are abundant on the abaxial epidermis and show even distribution; stomata are seen over the veins also. Stomatal index is 11.67. Very few stomata are present on the adaxial epidermis (SI = 1.08). The guard cells are 36-40 μm long, which differs from the early report (32.6 μm) by Indira (1976).

Sheath: Abaxial surface is U-shaped and shows ridges and furrows. Adaxial surface is wide U-shaped. Abaxial surface possess hairs (60-80 μm long). Bundle arcs I, II and III are present. Metaxylem is 48-60 μm wide. Oil cells are abundant in the ground tissue. Numerous crystals in groups are seen in the ground tissue cells.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Petiole wings are long and curved downwards. Bundle arcs I, II and III are present in the petiole. Few crystals are seen in the chlorenchymatous tissue.

Midrib: Both abaxial and adaxial surface are wide U-shaped. Bundle arcs I, II and III are present. Adaxial epidermis and 1 or 2 layers of cells below it are thick walled. Crystals are seen in the ground parenchyma and chlorophyllous tissue. Oil cells are present in the ground tissue.

Lamina: Lamina is 240 μm thick (304 μm at the bundle region). Adaxial epidermal cells are broader than high (32 x 48-64 μm). Cells above bundles are smaller than the rest. Adaxial epidermis is slightly raised at the position of the bundle. Abaxial epidermal cells are smaller than upper ones (16 x 48

µm). A continuous hypodermis present both abaxially (32 x 48-96 µm) and adaxially (32 x 32 µm). Abaxial hypodermis is sometimes two layered. The hypodermal cells are similar to the epidermal cells in size. Mesophyll consists of 1-layered palisade and 4-6 layered spongy cells and is 96-112 µm thick. Sclerenchymatous bundle cap is in contact with the adaxial epidermis only. Some cells of the hypodermis and some spongy cells contain single crystal in them.

Margin: Adaxial and abaxial epidermal cells are broader. Hypodermis is present above the abaxial epidermis only. 1-layered palisade and 4-layered spongy constitute the mesophyll tissue. The portion beyond last bundle consists of some mesophyll and colourless parenchyma cells. Metaxylem of the last bundle is 10-16 µm thick. The tip is gradually tapering, pointed and bent downwards. The hyaline portion is 3 or 4-seriate and 336-368 µm wide.

3. Curcuma aromatica Salisb., Parad. London t. 96. 1805; M. Sabu, Zingiberaceae and Costaceae of S. India 141. 2006. **(Plate 13 E)**

Rhizome large, greyish yellow within, aromatic; sessile tubers many. Leafy shoot 1 m or more. Leaves 5-7; lamina 50 x 10-14 cm, broadly lanceolate, acuminate, densely pubescent below. Inflorescence lateral. Coma bracts pink. Fertile bracts c. 6 cm long, tip recurved. Calyx c. 2 cm long, sparsely pubescent. Corolla longer than calyx, pinkish white. Labellum orbicular, obscurely 3-lobed, deep yellow. Lateral staminodes oblong, as long as the corolla lobes. Anther spurred. Stigma bilobed with a perforation in the centre.

Distribution: Occurs in India, China and Sri Lanka. It is widely cultivated in South India for its rhizome.

Specimen studied: **KERALA:** Malappuram Dt.: C. U. Botanical Garden, Jayasree 86508.

Anatomical characters

(Fig. 32)

Epidermis: Intercostal cells of the adaxial epidermis polygonal and is stretched perpendicular to the veins (80-112 x 16-32 μm). Costal epidermal cells much smaller, isodiametric or slightly stretched parallel to the veins (16 x 16-32 μm). Cell files are regular. Intercostal cells of the abaxial epidermis are polygonal and less stretched (16-48 x 48-80 μm). Cell files are more or less regular. Costal epidermal cells are isodiametric (16-32 x 16-32 μm) and not stretched.

Trichomes: Simple, unicellular trichomes of 90-244 μm long are present on either side of the veins on the upper epidermis. Numerous hairs can be seen in between the veins on the lower epidermis.

Stomata: Tetracytic stomata are distributed randomly in between the veins. Length of the guard cells varies from 32-36 μm . Stomata are abundant on lower epidermis (SI = 15.03). Very few stomata can be seen on the upper epidermis (0.84).

Sheath: Both abaxial and adaxial surfaces U-shaped. Bundle arcs I, II and III are present. Air canals are larger than the bundle. Oil cells are found in the ground tissue. Crystals in groups are also seen.

Petiole: Abaxial surface is U-shaped and adaxial surface is concave. Bundle arcs I, II and III are present. Smaller bundles are present in arc II. Petiole wings are more than 3 mm long. 1 or 2 crystals are present in the xylem, chlorenchyma cells and ground tissue.

Midrib: Abaxial surface is U-shaped and adaxial surface is grooved. Minute hairs are seen on the abaxial surface of the midrib. Hair length is upto 90 μm . Bundle arcs I, II and III are present. Oil cells are abundant in the ground tissue. Crystals (1-2) are present in the ground tissue and chlorenchyma cells.

Lamina: Lamina is 240 μm thick (288 μm at the bundle region). Upper epidermal cells are twice as broad as high (40 x 80 μm). Cells above veins are much smaller than the rest. Lower epidermal cells are smaller than the upper ones (40 x 48-80 μm). Continuous hypodermis is present above the abaxial epidermis (40 x 64 μm). Upper hypodermis is discontinuous and is represented by 1 or 2 cells on either side of the major veins. Main bundle is connected to the upper epidermis alone by 2 or 3 layers of sclerenchymatous cap. Mesophyll is 150 μm thick. Palisade is 1-layered and spongy tissue form 4 or 5 layered with lot of air space in between. Lower epidermis possesses hairs.

Margin: Margin is gradually tapering and tip is pointed, slightly bent downwards. Upper epidermal cells are broader than high. The portion beyond last bundle consists of mesophyll and parenchyma. Palisade is 1-layered and spongy form 2 layers. Lower hypodermis is present in the margin

also. Crystals (1-2) are seen in the lower hypodermis. Hyaline portion is multiseriate (4-celled) and 448 μ m wide.

4. *Curcuma aurantiaca* Zipp., Recueil Trv. Bot. Neerl. 12. 345. 1915.

Curcuma ecalcarata Sivar. & Indu, Notes Roy. Bot. Gard. Edinburgh 41: 321. 1983; M. Sabu, Zingiberaceae and Costaceae of S. India 150. 2006.

(Plate 13

F)

Rhizome small, conical, yellow inside; sessile tubers absent; root tubers fusiform. Leafy shoot 30-45 cm high. Leaves 6-8, petiolate; petiole 20-25 cm long, minutely pubescent; lamina 20-30 x 10-15 cm, broadly ovate, slightly unequally cordate at base; lower surface densely pubescent. Inflorescence central, with a distinct coma. Coma bracts bright rose or greenish white. Fertile bracts broadly rounded, tip recurved. Flowers longer than the bracts, yellow or orange yellow. Corolla tube longer than calyx, light yellow-orange. Labellum 3-lobed; mid-lobe much exceeding the laterals. Lateral staminode, oblong-obtuse. Stamen yellow, anther ecalcarate; connective forms broad hood at the apex, glandular hairs on back. Fruit obovoid.

Distribution: Common on the Western Ghats and midlands of Kerala.

Specimen studied: **KERALA:** Malappuram Dt.: C. U. Botanical Garden, *Jayasree 103017*.

Anatomical features

(Fig. 33)

Epidermis: Intercostal cells of the adaxial epidermis are longer than broad (100 x 20-40 μm), more or less regularly arranged. Costal cells as long as or slightly broader (20-24 x 20-48 μm). 5 or 6 rows of cells are seen above major veins. Cell files are regular. Abaxial epidermal cells are less distinguishable into costal and intercostal cells based on size difference. Cells are of various size, show very irregular arrangement. Costal cells are distinguishable only by the absence of stomata.

Trichomes: Trichomes are abundant on the abaxial epidermis, base of the hairs are constricted. They have thick walls with narrow lumen. Very few hairs are also seen on the adaxial epidermis on either side of the veins.

Stomata: Stomata are randomly distributed on the abaxial epidermis; sometimes seen above the veins also. Length of the guard cell varies between 40-44 μm . Stomatal Index is 10.01. Few stomata are present on the adaxial epidermis also (SI = 6.75).

Sheath: Abaxial and adaxial surfaces are U-shaped in Transverse Section. Abaxial surface possess 60-100 μm long hairs. Bundle arcs I, II and III are present. 10-12 oil cells are found in the ground tissue. Many cells of the ground tissue possess few crystals in them.

Petiole: Abaxial surface is U-shaped; adaxial surface is wide V-shaped. Both abaxial and adaxial surfaces possess hairs that are upto 80 μm long. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. 6-8

oil cells occur in the ground tissue. Most of the cells of ground tissue contain crystals in groups.

Midrib: Abaxial surface is U-shaped and adaxial surface is grooved. Small, microscopic hairs are seen on the abaxial surface. Oil cells 3-5, content is yellow in colour. Bundle arcs I, II and III are present. Arc II is represented by 2 bundles only.

Lamina: Lamina is 384 μm thick at the bundle, whereas 336 μm at other portions. Cells of the adaxial epidermis are broader than high (38-44 x 80 μm). Cells above vein are much smaller and as high as broad. Abaxial epidermal cells are as high as broad (48-64 x 48-64 μm). A continuous hypodermis is present abaxially. Adaxial hypodermis is seen on either side of the main veins, otherwise absent; hypodermal cells larger than epidermal cells. Mesophyll is 128 μm thick and consists of 1-layered palisade (a second layer also may be seen) and 3 or 4 layered spongy tissue with oil cells are also seen. Bundle cap is in contact with the adaxial epidermis only. Metaxylem is 32 μm wide. Chlorenchyma cells seen below the bundle interrupt the abaxial hypodermis.

Margin: Epidermal cells are as high as or slightly broader. Hypodermis is present abaxially. Mesophyll consists of 1-layered palisade and 2 or 3 layered spongy cells. Bundle cap of the last bundle is not in contact with either epidermis. Metaxylem of the last bundle is 32-40 μm wide. Portion beyond last bundle consists of mesophyll and few parenchyma cells. Tip is gradually tapering, pointed and bent downwards. Hyaline portion is multiseriate (3 or 4 celled at the base) and 160-240 μm wide.

5. **Curcuma bhatii** (R.M. Sm.) Sckornickova & M. Sabu, Gardens Bull. Singapore 57: 37-46. 2005. M. Sabu, Zingiberaceae and Costaceae of S. India 142. 2006.

Paracautleya bhatii R.M. Sm. Notes Roy. Bot. Gard. Edinburgh 35: 368. 1977. **(Plate 14 A)**

Rhizome very small, conical, erect, white inside; root tubers small, many. Leafy shoot upto 18 cm high. Leaves 2-7 in basal tuft; sessile, ligulate. Lamina 4-6 x 0.7-1.5 cm, linear lanceolate, tip acute, glabrous. Inflorescence central, Bracts upto 25, free from each other. Flower longer than bracts, one in each bract, ebracteolate. Calyx companulate. Corolla tube slender, c. 1 cm long. Labellum c. 10 x 8 mm, obovate, deflexed, deeply emarginate. Lateral staminodes petaloid. Anther versatile, spurred; connective prolonged into a minute rounded crest. Ovary imperfectly trilocular, ovules attached to the base of the ovary. Capsule c. 1 cm long, subglobose with persistent calyx.

Distribution: Endemic to South India. Known only from type locality.

Specimen studied: KARNATAKA: South Kanara Dt.: Manipal, *Jana Sckornickova 73446*.

Anatomical features **(Fig. 34)**

Epidermis: Intercostal cells of the adaxial epidermis are of varying size (16-24 x 8-20 μm) and show irregular orientation. Costal cells are smaller (12 x 16-24 μm), very irregularly arranged and indistinguishable. Abaxial

epidermal cells of the intercostal region are polygonal (12 x 8-28 μm) and most of the cells show parallel orientation. Cells of the costal region are polygonal with their longer axis parallel to the veins (8-10 x 20-32 μm). Cell files are more or less regular.

Trichomes: Totally absent.

Stomata: They are evenly distributed in between the veins on abaxial surface. Frequently stomata are arranged in definite rows. Guard cell is 36-40 μm (36 μm common) long and stomatal index is 19.23. Stomata are frequent on adaxial epidermis also (SI = 11.28).

Sheath: Abaxial surface is U-shaped and adaxial surface is V-shaped. Bundle arcs I, II and III are present. Arcs II and III are represented by one bundle each.

Petiole: A distinct petiole is absent, but a section through the junction shows U-shaped abaxial and V-shaped adaxial surfaces. Bundle arcs I and III are found. Arc III is represented by a single bundle. Air canals in between the bundles of arc I are very large.

Midrib: Abaxial surface is U-shaped and adaxial surface is V-shaped. Bundle arc I alone is present in the midrib.

Lamina: Lamina is 240 μm thick at the bundle and 256 μm at other portions. Adaxial epidermal cells are as high as broad or broader than high (64-80 x 64-112 μm). Abaxial epidermal cells are smaller (32-80 x 48-64 μm). Epidermal cells above veins are much smaller and sunken than other

epidermal cells. Mesophyll is 144 μm thick and is divisible into 1-layered palisade and 3 or 4 layered spongy cells. Sclerenchymatous cap of the bundle is in contact with adaxial epidermis only. Smaller bundles are found embedded in the mesophyll.

Margin: Adaxial epidermal cells are as high as or slightly broader than high. Abaxial epidermal cells are smaller than upper ones. Mesophyll is composed of 1-layered palisade and 2 or 3 layered spongy cells. Hypodermis is absent. Margin is abruptly tapering, curved downwards and tip is blunt. The portion beyond last bundle consists of mesophyll only. Hyaline portion is biseriate and 112-128 μm wide.

6. *Curcuma coriacea* Mangaly & M. Sabu, Notes Roy. Bot. Gard. Edinburgh 45: 429. 1989; M. Sabu, Zingiberaceae and costaceae of S. India 145. 2006. **(Plate 14 B)**

Rhizome small, cylindrical to conical, non-aromatic, white inside; sessile tubers absent; root tubers long, 10-18 cm. Leafy shoot 30-45 cm tall, pseudostem 10-15 cm long. Leaves straight; lamina 27-35 x 10-15 cm, elliptic, coriaceous, densely pubescent on both sides. Inflorescence lateral, later central; coma bracts deep pink to violet. Flowers as long as or slightly longer than bracts, yellow, 3-5 in each bract. Corolla bright yellow. Labellum c. 2 x 2 cm, tip deeply split, deep yellow. Anther with small crest, spurred at base. Stigma faintly 4-lobed, bilipped. Seeds ovoid or ellipsoid, smooth.

Distribution: Endemic to Kerala, known only from Idukki, Palakkad and Pathanamthitta Districts.

Specimen studied: KERALA: Idukki Dt.: Kulamavu, *Jana Sckornickova* 84171.

Anatomical features

(Fig. 35)

Epidermis: Intercostal cells of the upper epidermis hexagonal with their longer axis perpendicular to the veins (48-80 x 32-48 μm). Costal cells isodiametric or slightly broader and smaller in size (24 x 16-48 μm) and the cell files are regular. Intercostal cells of the lower epidermis are polygonal (48-60 x 24-48 μm). Costal cells are almost similar in size (48 x 32-48 μm) but can be distinguished by the absence of stomata. Cell files are irregular.

Trichomes: Simple unicellular hairs of 96-192 μm long are seen on both epidermis.

Stomata: Numerous tetracytic stomata are randomly distributed on the lower surface, sometimes on the veins also. Length of the guard cells varies from 36-40 μm . Stomatal index is 14.23. Stomata are rare on upper epidermis (SI = 1.99).

Sheath: Both abaxial and adaxial surfaces are U-shaped. Hairs, upto 96 μm long are seen on the abaxial surface. Bundle arcs I, II and III are present. Air canals are larger than the bundles. Metaxylem is 44-72 μm wide. Groups of calcium oxalate crystals are seen in the ground tissue cells.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide V-shaped. Petiole wings are very short (0.5 mm long), narrow and pointed. Few hairs are seen on the abaxial surface (upto 80 μm long). Bundle arcs I, II and III are present. Calcium oxalate crystals are seen in the ground tissue cells.

Midrib: Abaxial surface of the midrib is V-shaped and adaxial surface is concave. Bundle arcs I, II and III are present. Large parenchyma cells (1-2) form a ring around the main bundle.

Lamina: Lamina is 368 μm thick (352 μm at the bundle). Adaxial epidermal cells are slightly broader than high (40-48 x 48-80 μm). Abaxial epidermal cells are smaller than upper ones (24 x 32-48 μm). Cells above veins are smaller. Hypodermis is present both abaxially (40 x 48 μm) and adaxially (40 x 32 μm). Lower hypodermis may be 2-layered. The main bundle is connected to the upper epidermis only by 2 or 3 layered sclerenchymatous cap. Mesophyll is 176 μm thick and is divisible into 1-layered palisade and 5 or 6 layered spongy tissue.

Margin: Margin is gradually tapering and curved downwards. Upper epidermal cells are as high as broad or slightly broader. Hypodermis is continuous above lower epidermis and discontinuous below upper epidermis. Main bundle is connected to the upper epidermis by 1 or 2 layers of sclerenchymatous cap. Metaxylem of the last bundle is 32 μm wide. Palisade is 1-layered and spongy 3 or 4 layered. The portion beyond last bundle consists of mesophyll and parenchymatous tissue. Hyaline portion is

multiseriate (3 or 4 celled) and 368 μ m wide. Hairs (176 μ m long) are present on both epidermis towards the tip.

7. *Curcuma decipiens* Dalzell, Kew J. Bot. 2: 144. 1850; M. Sabu, Zingiberaceae and Costaceae of S. India 148. 2006. **(Plate 14 C)**

Rhizome small, ovoid, conical; root tubers ovoid. Leafy shoot 30-60 cm high. Leaves 2-4; lamina 10-30 x 5-15 cm, broadly ovate, base slightly cordate, tip deltoid, glabrous. Inflorescence both lateral and central. Coma bracts many, upper deep purple pink. Fertile bracts recurved, green with purple pink tips. Bracteoles 2. Flower equal to the bracts, 1 or 2 in each bract. Calyx white with pink spots. Corolla tube longer than calyx, deep purple. Labellum c. 1.5 x 15 cm, tip slightly 3-lobed; mid-lobe emarginate, purple towards base. Lateral staminodes oblong, yellow. Anther spurs with purple spots. Stigma exerted from the anther. Fruits ovoid. Seeds brown with a white spot at the tip.

Distribution: Endemic to Peninsular India, North Kerala and Karnataka.

Specimen studied: MAHARASHTRA: Sindudurga Dt.: Malwan, *Jana Sckornickova 84179*. (No specimens from South India were available for the present study).

Anatomical features

(Fig.

36)

Epidermis: Intercostal cells of the adaxial epidermis are longer than broad (80-120 x 28-60 μ m) and are arranged in regular files. Costal cells are

broader than long (16 x 52-84 μm) and show regular arrangement. Intercostal cells of the abaxial epidermis show variation in the size (40-100 x 36-48 μm). The cell files are not distinct. Costal epidermal cells are as long as or broader than long (40 x 36-84 μm). Costal region is distinguishable by their small size and absence of stomata.

Stomata: Stomata are evenly distributed between the main veins. They are present over the minor veins also. Stomata of the abaxial epidermis show uniform size of 48 μm . Stomatal index is 14.10. Few stomata are present on the adaxial epidermis also (SI = 4.87). Its size varies between 40-48 μm .

Sheath: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Bundle arcs I, II and III are present. Few crystals in groups are found in most of the ground parenchyma cells. Hairs, 240-320 μm long, are seen arising from abaxial epidermis towards the extreme tip of the sheath. Oil cells are very few (1-2). Metaxylem of the bundle is 72-88 μm wide.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide V-shaped. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. Hyaline wings absent. Very few cells of the ground parenchyma possess crystals. 1 or 2 oil cells are found in the ground tissue. Metaxylem of the bundle is 72-88 μm wide.

Midrib: Abaxial surface is U-shaped; adaxial surface V-shaped. Bundle arcs I, II and III are present. Arc II is represented by 2 bundles only. Cells surrounding the bundles contain some silica granules. Metaxylem is 40-60 μm wide.

Lamina: Lamina is 288 μ m thick at the bundle and 208 μ m thick at other portions. Lamina is raised at the major vein. Adaxial epidermal cells are broader (48-60 x 80 μ m). Cells above the bundle are much smaller. Abaxial epidermal cells are also broader but smaller than adaxial ones (32-40 x 64 μ m). Hypodermis is present abaxially which is interrupted by the mesophyll cells below the major veins only. Mesophyll is 64-80 μ m thick and is composed of 1-layered palisade and 2 or 3 layered spongy cells. Sclerenchymatous cap of the bundle is connected to the adaxial epidermis only. Metaxylem of the bundle is 32-40 μ m wide.

Margin: Both abaxial and adaxial epidermal cells are broader. Mesophyll is divided into 1-layered palisade and 2-layered spongy. The portion beyond last bundle consists of mesophyll and few parenchyma. Metaxylem of the bundle is 32 μ m wide. Tip is gradually tapering, curved and pointed. Hyaline portion is multiseriate (4-celled at the base) and 250 μ m wide.

8. Curcuma haritha Mangaly & M. Sabu, Rheedea 3(2): 152. 1993; M. Sabu, Zingiberaceae and Costaceae of S. India 153. 2006. **(Plate 14 D)**

Rhizome large, yellowish grey inside, non-aromatic; sessile tubers finger-shaped, branched; root tubers present. Leafy shoot 70-100 cm high, pseudostem c. 30 cm long, green with few pink dots. Leaves 4-6; lamina 30-50 x 10-14 cm, ovate elliptic, tip acuminate, base acute, leathery, densely puberulent on lower surface, sparsely hairy above, erect, semiplicate, without purple patch. Inflorescence lateral. Coma bright pink.

Fertile bract, broadly ovate, flowers 3 or 4 in a bract. Corolla tube longer than calyx, white. Labellum c. 2 x 2, shortly 3-lobed, middle lobes shortly emarginate, light yellow with a median dark yellow band. Lateral staminodes with a patch of glandular hairs at the centre. Anther spurred, white. Stigma bilipped, slightly exserted from anther. Fruits not known.

Distribution: Reported only from Kerala.

Specimen studied: **KERALA:** Kozhikode Dt.: Kolathara, *Jana Sckornickova & Jayasree 84129.*

Anatomical features

(Fig. 37)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, longer than broad (72-112 x 24-28 μm). They are arranged in regular files perpendicular to the veins. Costal epidermal cells are broader (20-24 x 40-48 μm) and show regular arrangement. Cells of the abaxial epidermis are also polygonal, but smaller than upper ones and very irregularly arranged (48-80 x 32-56 μm). Costal epidermal cells are also longer than broad and not easily distinguishable (48-80 x 16-48 μm).

Trichomes: Upto 288 μm long hairs are present on either side of the veins on adaxial epidermis and evenly distributed on the abaxial epidermis. Their walls are very thick, lumen is narrow and tip is pointed.

Stomata: Guard cells are 48 μm long and evenly distributed on the abaxial epidermis. Stomatal index is 13.64. Few stomata are distributed on the adaxial epidermis also (SI = 5.51).

Sheath: Both abaxial and adaxial surface are U-shaped. Very smaller hairs (20-32 μm long) are seen on the abaxial surface of the winged portion. 12-15 oil cells can be found in the ground tissue. Most of the cells of ground tissue and some chlorenchymatous cells contain numerous crystals in groups. Bundle arcs I, II and III are present. The position of xylem and phloem is reversed in bundles of arc III. Metaxylem of the arc I bundle is 72-100 μm wide.

Petiole: Both abaxial and adaxial surfaces are U-shaped. Petioles are winged, wings 2.5 mm long. Bundle arcs I, II and III are present. 10-12 oil cells are found in the ground tissue. Almost all cells of the ground tissue contain numerous crystals in groups. Some cells surrounding the bundles contain silica sand in them.

Midrib: Abaxial surface is wide U-shaped; adaxial surface is concave. Bundle arcs I, II and III are seen. 1-3 oil cells are present in the ground tissue. Microscopic hairs of 8-12 μm length are found on the abaxial surface.

Lamina: Lamina is 352 μm thick at the bundle (288 μm at other portions). Adaxial epidermal cells are broader than high (48 x 64-80 μm); cells above bundle much smaller, as high as broad. Abaxial epidermal cells are much smaller (32 x 48 μm). Hypodermis is present both abaxially and adaxially. Adaxial hypodermal cells are bigger than the epidermal cells (64-80 x 80-112 μm). Abaxial hypodermal cells are smaller (32 x 48-64 μm). Mesophyll is 80 μm thick, composed of 1-layered palisade and 3 or 4 layered spongy

tissue. The sclerenchymatous bundle caps abut on the abaxial epidermis only. Oil cells are seen in the mesophyll.

Margin: Adaxial epidermal cells are broader than high; abaxial epidermal cells as high as broad or slightly broader. Hypodermis is present only above the abaxial epidermis. 1-layered palisade and 2 or 3 layered spongy cells constitute the mesophyll. Tip is gradually tapering, straight and pointed. The portion beyond last bundle is composed of mesophyll and parenchyma cells. Hyaline portion is multiseriate (4-celled at the base) and 304-336 μm wide.

9. Curcuma inodora Blatter J. Proc. Asiat. Soc. Bengal 26: 357. 1930; M. Sabu, Zingiberaceae and Costaceae of S. India 155. 2006. **(Plate 14 E)**

Rhizome conical; root tubers ovoid. Leafy shoot 30-60 cm tall. Leaves 3-5; petiole 20-25 cm long; lamina 15-30 x 7-12 cm, elliptic, base oblique, tip acuminate, upper side minutely hairy along the prominent veins, lower surface glabrous. Inflorescence both lateral and central; with violet coma. Fertile bracts pale green with purple patch at the tip, not recurved, each subtends 3 or 4 flowers. Bracteoles small, purple. Flowers equal to the bracts. Calyx white. Corolla tube longer than calyx, deep purple. Labellum obovate, obscurely 3-lobed, tip emarginate, purple with a median bright yellow band. Lateral staminodes purple. Anther spurs bent inwards. Style pink, stigma bilobed. Fruit globose to ovoid with persistent calyx. Seeds brown.

Distribution: Endemic to peninsular India, extending from Maharashtra upto North Karnataka.

Specimen studied: MAHARASHTRA: Vajeswari Dt.: Ganeshpuram, *Jana Sckornickova 73403*. (No specimens from South India were available for the present study).

Anatomical features

(Fig. 38)

Epidermis: Intercostal cells of the upper epidermis are polygonal with their longer axis perpendicular to the veins (80-112 x 16-32 μm). Costal cells are much smaller (16-24 x 16-32 μm). Cell files are regular. Intercostal cells of the lower epidermis are polygonal (48-64 x 24-48 μm) and less stretched. Costal cells are as high as or slightly broader (32-40 x 32-64 μm) and less distinguishable from the rest.

Trichomes: Simple unicellular hairs are seen on upper epidermis, on either side of the veins. Their length varies from 230-350 μm .

Stomata: Tetracytic stomata are abundant and randomly distributed on the lower epidermis. Length of the guard cells ranges from 36-40 μm . Stomatal index is 11.29. Few stomata are present on the upper epidermis also (SI = 3.52).

Sheath: Abaxial surface is U-shaped and adaxial surface is wide V-shaped. Abaxial surface possess 96-112 μm long hairs towards the tip of the wings. 3-5 oil cells are seen in the ground tissue.

Petiole: Abaxial surface is U-shaped, adaxial surface is wide V-shaped. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. 1-many crystals are seen in the ground tissue and chlorenchyma.

Midrib: Abaxial surface is U-shaped; adaxial surface is grooved. Bundle arcs I, II and III are present.

Lamina: Lamina is 224 μm thick, (256 μm at the bundle). Adaxial epidermal cells twice as broad as high (40 x 64-80 μm). Cells above veins are much smaller than the rest. Abaxial epidermal cells are smaller than upper ones (32 x 32-64 μm). A continuous hypodermis is seen on the abaxial epidermis (48 x 64-80 μm). Upper hypodermis is discontinuous. The main bundle is connected to the upper epidermis by 2-layered sclerenchymatous cap. 1-layered palisade and 3-layered spongy constitute the mesophyll which is 60-70 μm thick.

Margin: Margin is gradually tapering. Tip is pointed and slightly bent downwards. Upper epidermal cells are broader than long. A continuous hypodermis is seen abaxially. Palisade is 1-layered and spongy form 2 or 3 layers. Bundle is connected to the upper epidermis only. Portion beyond the last bundle consists of mesophyll and parenchyma cells. Hyaline portion is 352-354 μm wide and 4-cells thick. Hairs are seen on the upper epidermis.

10. *Curcuma karnatakensis* Amalraj, Velayudhan & V.K. Murali, J. Econ. Tax. Bot. 15(2): 490. 1991; M. Sabu, Zingiberaceae and Costaceae of S.

India 156. 2006.

(Plate 14

F)

Rhizome small, ovoid, cream colour with slight mango ginger flavour; root tubers fusiform or conical. Leafy shoot c. 40 cm high. Leaves upto c. 26 x 7-14 cm, broadly ovate elliptic, spreading, base unequal and slightly cordate; petiole c. 6 cm long, petiole and sheath green or purple tinged. Inflorescence lateral or central, coma absent. Flowers longer than bracts, c. 5.6 cm long. Calyx c. 2 cm long, pale transparent green. Corolla tube longer than calyx. Labellum c. 1.9 x 2 cm, white, three lobed, mid-lobe larger, deeply bifid, bright yellow band in the middle. Lateral staminodes multicoloured. Anther white, c. 4.5 mm long, spurs rose coloured; filament pale yellow.

Distribution: Endemic to Karnataka State, South India.

Specimen studied: KARNATAKA: Uttar Kannada Dt.: Hirahalli, *Jana Sckornickova 84164*.

Anatomical features

(Fig. 39)

Epidermis: Intercostal cells of the adaxial epidermis are 4-6 sided, higher than broad (72-88 x 32-40 μm) with their longer axis perpendicular to the longitudinal veins. The cell files are regular. Costal cells are much smaller than intercostal cells, as high as or usually broader than high (20 x 20-40 μm) and arranged in regular rows. Inter costal cells of the abaxial epidermis

are polygonal, as high as broad and arranged in somewhat regular tiles. Costal cells are of varying size and not easily distinguishable from the rest.

Trichomes: Trichomes are distributed on adaxial epidermis, on either side of the main vein. They are 192-400 μm long, with bulbous base and pointed tip. Their walls are highly thickened and the lumen is very narrow. Very rarely hairs are seen on the abaxial epidermis.

Stomata: Stomata are evenly distributed between the veins on the abaxial epidermis; sometimes above the veins also. Length of the guard cell is 36-40 μm . Stomatal Index is 14.20. Few stomata are seen on the adaxial epidermis also with stomatal index 5.95.

Sheath: Both abaxial and adaxial surfaces are U-shaped. Few hairs upto 0.5 mm long are seen at the tip of the wings. Bundle arcs I, II and III are present. Large air canals are seen in between the bundles of arc I which possess trabeculae like elongated cells across it. 1-5 oil cells are seen in the cross section.

Petiole: Both abaxial and adaxial surfaces are U-shaped. Hyaline wings are absent. Bundle arcs I, II and III are present. Usually smaller bundles are absent in between the bundles of arc II. About 5 oil cells are seen in Transverse Section. Some cells contain few crystals in groups. Parenchyma cells surrounding the bundle contain silica sand in them.

Midrib: Abaxial and adaxial surface are V-shaped in outline. Bundle arcs I, II and III are present in the petiole. The chlorenchymatous as well as the cells of ground tissue contain few crystals in them.

Lamina: Lamina is 272 μm thick at the bundle (280 μm at other portions). Adaxial epidermal cells are larger, broader than high (48-64 x 64-80 μm); cells above veins much smaller and as high as broad. Abaxial epidermal cells are broader than high but smaller than upper ones (32-40 x 48-72 μm). A continuous hypodermis present abaxially (48 x 48-56 μm); adaxial hypodermis is discontinuous and composed of a few cells on either side of the main vein only. Metaxylem of the bundle is 32-40 μm wide. 1-layered palisade and 4-layered spongy cells constitute the mesophyll, which is 128 μm thick. Bundle cap is in contact with the adaxial epidermis only. In some cells 1 or 2 crystals are seen.

Margin: Adaxial and abaxial epidermal cells are broader, adaxial epidermal cells become higher than broad towards the extreme tip. Abaxial hypodermis is present in the margin also. Mesophyll is composed of 1-layered palisade and 2 or 3 layered spongy cells. The portion beyond last bundle consists of mesophyll and parenchymatous cells. The tip is gradually tapering, bent downwards and pointed. Hyaline portion is multiseriate (3-celled at the base) and 224 μm wide.

11. Curcuma longa L., Sp. Pl. 1: 2. 1753; M. Sabu, Zingiberaceae and Costaceae of S. India 160. 2006. **(Plate 15**

A)

Rhizome medium sized, conical, deep orange-yellow inside, strongly aromatic; sessile tubers many, branched. Leafy shoot 80-120 cm high. Leaves 4-6; lamina 45-60 x 15-20 cm, oblong-lanceolate, tapering at both ends, glabrous, without purple patch. Inflorescence central, with distinct white coma. Fertile bracts many, tip recurved, subtends 1 or 2 flowers. Flowers equal to the bracts. Bracteoles 2. Calyx c. 1 cm long, white. Corolla longer than calyx, white. Labellum c. 2.2 x 2.5 cm, trilobed; mid-lobe emarginate, light yellow with a broad median dark yellow band. Lateral staminode without glandular hairs. Anther spurred. Stigma bilipped. Fruits not seen.

Distribution: The plant is cultivated throughout the tropics.

Specimen studied: **KERALA:** Malappuram Dt.: C. U. Botanical Garden, *Jayasree 86536.*

Anatomical features

(Fig. 40)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal and longer than broad (60-144 x 36-56 μm). Costal cells are always broader than long (112-16 x 40-88 μm). Cell files are regular in both regions. 4 or 5 rows of cells are seen above the main vein. Abaxial epidermal cells of the intercostal region are of varying size, but usually longer than broad (60-120 x 24-48 μm). Costal cells are much smaller and as high as broad (40-48 x 40-48 μm). Cell files are less distinguishable than adaxial epidermis. Oil cells are frequent on abaxial epidermis.

Trichomes: Trichomes are completely absent.

Stomata: Stomata are evenly distributed in between the veins on abaxial epidermis. Length of the guard cells varies from 48-56 μm . Stomatal index is 15.19. Few stomata are seen on the adaxial epidermis also (SI = 3.97).

Sheath: Abaxial surface is U-shaped and adaxial surface is slightly concave. Bundle arcs I, II and III are present. Arc II contain 3 systems of bundle of various sizes. Cells of ground tissue contain numerous crystals in groups. Metaxylem is 64-76 μm wide. Bundles of arc III show inverted xylem and phloem groups. Oil cells are present in the ground tissue.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Petiole wings are narrow, short and pointed, not hyaline. Bundle arcs I, II and III present. Arc II contain bundles of 3 different sizes. Ground tissue

contains oil cells (1-3). Some cells of ground tissue possess few crystals in groups. Metaxylem of the bundle is 60-72 μm wide.

Midrib: Abaxial surface is U-shaped and adaxial surface is concave. Bundle arcs I, II and III are present. Bundle arc II consists of 2 systems of bundles. Very few crystals in groups are found in the cells of ground tissue. Metaxylem of the bundle is 40-60 μm wide. Oil cells are also seen.

Lamina: Lamina is 368 μm thick at the bundle and 336 μm thick at other portions. Lamina is raised at the major veins. Epidermal cells are broader than high (60 x 112 μm). Cells above veins are much smaller. Abaxial epidermal cells are also broader (32 x 60 μm). A continuous hypodermis is present both adaxially and abaxially (adaxial 80 x 104 μm ; abaxial 48 x 88 μm). Hypodermal cells are larger than epidermal cells. Mesophyll is 144 μm thick and is composed of 1-layered palisade and 3 or 4 layered spongy cells. Oil cells are found in the mesophyll. Some spongy cells contain 1-3 crystals in them. Sclerenchymatous cap of the major vein is in contact with the adaxial epidermis only. Metaxylem of the bundle is 32 μm wide.

Margin: Adaxial epidermal cells are as high as or slightly broader. Mesophyll is composed of 1-layered palisade and 3 or 4 layered spongy cells. Abaxial hypodermis continues to be present in the margin also. The tip is gradually tapering, pointed and bent downwards. Hyaline portion is multiseriate (4-celled at the base) and 352 μm wide.

12. *Curcuma montana* Roxb., Pl. Corom. 2: 28. t. 151. 1802; M. Sabu, Zingiberaceae and Costaceae of S. India 163. 2006. **(Plate 15 B)**

Rhizome ovate-conical, uniform light orange-yellow within; sessile tubers branched; root tubers fusiform. Leafy short 80-100 cm tall. Leaves 15-17 cm long, oblanceolate, lower surface puberulent. Inflorescence central, with distinct coma. Coma white with pink in the distal half. Fertile bracts many, green with pink patch. Flowers as long as or smaller than bracts. Calyx c. 8 mm long. Corolla much longer than calyx, white. Labellum 1.8-1.6 cm long; mid-lobe with an apical notch, deep yellow. Lateral staminodes included within corolla lobe, without glandular hairs. Anther spurred; connective prolonged into a hood. Stigma bilipped included within the hood. Fruits not seen.

Distribution: South India.

Specimen studied: **ORISSA:** Jeypore Dt.: Koraput, *Jana Sckornickova* 73425. (No specimens from South India were available for the present study).

Anatomical features **(Fig. 41)**

Epidermis: Intercostal cells of the adaxial epidermis are polygonal with their longer axis perpendicular to the veins. The average cell size is 100-120 x 20-28 μm . The cell files are less regularly arranged. Costal epidermal cells are broader than high (12-16 x 24-40 μm) and are arranged in regular files. 5 or 6 rows of cells are seen above the major veins. Intercostal cells of the

abaxial epidermis are also polygonal but show very irregular arrangement. Costal epidermal cells are smaller and their walls are much thickened than the rest.

Trichomes: Numerous hairs (160-188 μm long) are evenly distributed on the adaxial epidermis. Their bases and walls are much thickened and lumen is very narrow.

Stomata: Stomata are abundant on the abaxial surface. The length of the guard cell is 36-40 μm . Stomatal index is 11.14. Stomata are evenly distributed between the veins. Adaxial surface also shows the presence of stomata with stomatal index 3.12.

Sheath: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Hairs upto 0.5 mm are seen at the tip of the wings. Bundle arcs I, II and III are present. Arrangement of xylem and phloem is reversed in bundles of arc III. The ground tissue contains crystals in groups. Oil cells are also seen. Cells adjoining the bundle sheath contain silica sand in them.

Petiole: Abaxial surface is U-shaped; adaxial surface is wide U-shaped or almost straight. Petiole wings are present which are very narrow, gradually tapering and pointed. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. 5-8 oil cells are present in the ground tissue. Cells of the ground tissue contain crystals in groups. Cells surrounding the bundle sheath possess silica sand in them.

Midrib: Abaxial and adaxial surface are wide U-shaped. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. Microscopic hairs of 36 μm length are seen on the abaxial epidermis. 1-few crystals are seen in the ground tissue and sclerenchymatous tissue. 4-6 oil cells are also seen in the ground tissue.

Lamina: Lamina is 352 μm thick at the bundle (288 μm at other portions). Both adaxial (6-32 x 80-96 μm) and abaxial (32-64 x 80-96 μm) epidermis cells are broader than high. Cells of the adaxial epidermis just above the bundle are much smaller. A continuous hypodermis is seen both abaxially (32-48 x 80-112 μm) and adaxially (32-64 x 80-96 μm); abaxial hypodermis is 2-layered near the major vein. Mesophyll is 96-100 μm thick and consists of 1-layered palisade and 3 or 4 layered spongy cells. 1-3 crystals are present in the spongy tissue as well as hypodermis. Oil cells are also seen in the mesophyll. The bundle cap of the main bundle is in contact with the adaxial epidermis only.

Margin: Epidermal cells are as high as broad or slightly broader; abaxial epidermal cells are smaller than the adaxial ones. Hypodermis is continuous on abaxial surface; but the adaxial hypodermis is discontinuous and mesophyll is composed of 1-layered palisade and 3 or 4 layers of spongy cells. Crystals (1 or 2) are seen in the mesophyll cells, hypodermis or even in the abaxial epidermal cells. Sclerenchyma cap of the bundle is in contact with the adaxial epidermis only. The portion beyond last bundle consists of mesophyll and parenchyma cells. The tip is gradually tapering, pointed and

straight. Hyaline portion is multiseriate (4-celled at the base) and 272-290 μm wide.

13. *Curcuma mutabilis* Sckornickova, M. Sabu & Prasanth Kumar, Gard. Bull. Singapore. 56: 43-54. 2004; M. Sabu, Zingiberaceae and Costaceae S. India 164. 2006. **(Plate 15 C)**

Rhizome, conical or cylindrical, light brown externally, faintly aromatic; root tubers ovoid. Leafy shoot 15-60 cm long. Leaves 7; petiole upto 20 cm long, green or with red tinge; lamina 14-35 x 7-11, ovate elliptical, hairy on prominent raised margin on upper surface of leaf, lower surface glabrous. Inflorescence both lateral and terminal. Bracts many, light green or with red tinge, tip rounded with a patch of deep violet colour; coma insignificant. Each bract subtends a cincinnus of 2-4 flowers. Flowers exserted from bracts, 4.5-6 cm. Calyx c. 1 cm long, white or tinged with pink or violet. Corolla longer than calyx, yellowish; lobes tinged with pink or violet. Labellum 1.4-1.6 x 1.5-1.9 cm, emarginate yellow with deep yellow in the centre. Lateral staminodes yellow with reddish base. Anther 3.5-4 mm long; spur pointing upwards. Stigma exserted. Fruit dehiscent capsule, spherical. Seeds brown, shiny glabrous.

Distribution: Reported only from Nilambur (Type locality).

Specimen studied: **KERALA:** Malappuram Dt.: Nilambur, *Jana Sckornickova 84138*.

Anatomical features

(Fig. 42)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal (60-120 x 24-40 μm) with their longer axis perpendicular to the longitudinal vein. Cell files are regular. Costal cells are rectangular (36-64 x 12 μm) with their longer axis parallel to the longitudinal veins. 5-7 rows of cells are seen above the veins and they are regularly arranged. Abaxial epidermal cells of the intercostal region are polygonal (60-80 x 24-48 μm) with longer axis of the cells perpendicular to the longitudinal vein. Cells of this region show more or less regular arrangement. Costal cells are isodiametric or rectangular (40-72 x 40-48 μm) and are not easily distinguishable.

Trichomes: 144-224 μm long hairs occur on adaxial surface of the leaf on either side of the main vein. The hairs are thick walled and have a very narrow lumen. Base of the hair is bulbous and tip is pointed.

Stomata: Evenly distributed in between the veins on the abaxial leaf surface usually in definite rows. Guard cells are 36-40 μm long. Stomatal index is 14.85, whereas adaxial surface possess very few stomata and stomatal index is 5.22.

Sheath: Both abaxial and adaxial surface are U-shaped. Bundle arcs I, II and III are present. Smaller bundles are also seen in between the bundles of arc II. Various shaped crystals are seen in groups in the cells of the ground tissue towards the adaxial epidermis. Silica sand can be seen in few cells near the bundle. Metaxylem is 60-72 μm wide.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Hyaline wings are absent. Bundle arcs I, II and III are seen in the petiole. Smaller bundles are present in arc II. 1-3 oil cells can be seen in the ground tissue. Metaxylem is 64-72 μm wide.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is slightly grooved. Bundle arcs I and II (represented by 2 bundles) are prominent. Bundles of arc III are found embedded in the sclerenchymatous tissue. Almost all cells of the ground tissue and chlorenchymatous cell possess crystals in groups. Metaxylem is 40-60 μm wide.

Lamina: Lamina is 240 μm thick. Adaxial epidermal cells are broader than high (100 x 40 μm). Abaxial epidermal cells are also broader than high but smaller than upper ones (48-60 x 32-40 μm). Hypodermis is present abaxially and it is single layered. Mesophyll can be divided into 1-layered palisade and 3-layered spongy cells. Mesophyll is 100 μm thick. Sclerenchymatous cap of the main bundle is connected to adaxial epidermis only. Hairs are found on abaxial epidermis on either side of the main vein.

Margin: Adaxial epidermal cells are broader than high; abaxial cells are also broader, but smaller than upper ones. Hypodermis is absent. 1-layered palisade and 2 or 3 layered spongy cells constitute mesophyll. The portion beyond last bundle consists of mesophyll cells. The tip is gradually tapering, slightly bent and pointed. Hyaline portion is biseriate except for 1 cell at the base and 144 μm wide.

14. Curcuma neilgherrensis Wight, Pl. Ind. Orient. t. 2006. 1853; M. Sabu, Zingiberaceae and Costaceae of S. India 169. 2006. **(Plate 15 D)**

Rhizome small, conical, white inside; sessile tubers absent; root tuber few. Leafy shoot 20-30 cm high. Leaves 6-9; petiole 10-15 cm long; lamina 12-18 x 6-9 cm, ovate-elliptic, base subequal, lower surface sparsely pubescent. Inflorescence both lateral and central, with a distinct coma. Coma bracts light to dark pink or violet. Fertile bracts green or with a pink or violet spot at the tip, slightly recurved. Bracteoles 2 or 3, triangular. Flowers longer than bracts, 3 or 4 in each bract, light yellow. Calyx 3-lobed at apex, violet spotted. Corolla tube light yellow. Labellum c. 2 x 2 cm, with a median cleft, yellow with deep yellow median band. Anther hooded; spurs downwardly pointing. Stigma bilipped appressed within the anther thecae. Fruit yellowish green, with persistent calyx. Seeds obovate.

Distribution: Endemic to South India.

Specimen studied: KERALA: Wayanad Dt.: Perya, *Jana Sckornickova* 84157.

Anatomical features **(Fig. 43)**

Epidermis: Adaxial epidermal cells are polygonal with their longer axis perpendicular to the veins (80-128 x 32-48 μm). Cells above veins are isodiametric or slightly broader (16-24 x 32-48 μm). Cell files are more or less regular. Cells of the lower epidermis mostly isodiametric and less

stretched (64-80 x 32-48 μm). Cells above veins are smaller than the intercostal cells (40-48 x 48-64 μm) and are distinguishable by the absence of stomata. Cell files are irregular.

Trichomes: Simple unicellular trichomes of 144-288 μm long are found on either side of the major veins on the upper epidermis. Trichomes of the lower epidermis is smaller than upper ones (80-112 μm) and seen in between the veins.

Stomata: Tetracytic stomata with about 36-40 μm long guard cells are distributed randomly in between the veins. Stomatal Index is 12.45. Stomata are abundant on lower epidermis. Few stomata are seen on the upper epidermis (SI= 4.76).

Sheath: Abaxial and adaxial surface are U-shaped. Abaxial surface is slightly ridged and furrowed. Bundle arcs I, II and III are present. 1 or 2 smaller bundles are present in arc II.

Petiole: Abaxial surface is U-shaped and adaxial surface is V-shaped. Bundle arcs I, II and III are present. Sometimes smaller bundles are seen in arc II. 1-numerous crystals are seen in the ground tissue and chlorenchymatous cells.

Midrib: Abaxial surface is V-shaped and adaxial surface is U-shaped. Bundle arcs I, II and III are present. Few hairs can be seen on the adaxial surface. Air canal in between the bundles of arc I are bigger. Bundle arc III

is represented by a single median bundle. 1-numerous crystals are seen in the ground tissue also.

Lamina: Lamina is 304 μm thick (368 μm at the bundle). Adaxial epidermal cells are broader than high (48 x 64-96 μm). Cells above veins are much smaller than the rest of the cells. Abaxial epidermal cells are smaller than upper ones (32 x 48 μm). Hypodermis is seen below abaxial (48 x 48-64) and adaxial epidermis (48 x 32-48 μm). Bundles are connected to the upper epidermis only by 2 or 3 layered bundle caps. Mesophyll is 128 μm thick and consists of 1-layered palisade and 4 or 5 layered spongy tissue. Crystals can be seen in cells flanking the bundle. Unicellular trichomes are seen on both upper and lower epidermis.

Margin: Margin is gradually tapering and pointed, tip is curved downwards. Upper epidermal cells are slightly broader than the lower epidermis. Hypodermis is present above the abaxial epidermis. Portion beyond last bundle consists of chlorenchyma and parenchyma cells. Hyaline portion is 192 μm wide and 4-cells thick.

15. ***Curcuma oligantha*** Trimen, J. Bot. 23. 245. 1885; M. Sabu, Zingiberaceae and Costaceae of S. India 170. 2006.

Rhizome small, 1-1.2 cm, conical, non-aromatic; sessile tubers absent; root tubers large, c. 4 cm long, ovate or fusiform. Leafy shoots 15-35 cm high. Leaves petiolate; petiole 7-10 cm long; lamina 10-20 x 7-14 cm, ovate elliptic, base oblique, glabrous or minutely pubescent.

Inflorescence lateral or central, without distinct coma. Fertile bracts 5-10, recurved at apex; green or with pinkish tinge. Flowers longer than bracts, 5.5-7 cm long. Corolla equal to or longer than bracts, light yellow. Labellum obovate, shortly 3-lobed, white or orange yellow. Anther spurred; connective prolonged in to a small crest, crest orange yellow. Stigma bilipped, appressed within the thecae and crest. Fruit subglobose, with persistent calyx. Seeds obovate with a basal depression.

Two varieties have been described under this species

Key to the varieties

1. Flowers white; labellum c. 2.3 x 1.5 cm, lobe pointed var. **oligantha**

1. Flowers yellow; labellum c. 1.5 x 1.5 cm, lobes rounded var. **lutea**

15. *Curcuma oligantha* Trimen var. ***oligantha*** K.G. Bhat, Indian J. For. 10: 68. 1957; M. Sabu, Zingiberaceae and Costaceae of S. India 174. 2006.

(Plate 15 E)

Flowers c. 5.5 cm long. Corolla tube light yellow. Dorsal lobe c. 2.2 x 1.9 cm, ovate elliptic; lateral lobes c. 1.8 x 1 cm, greenish white. Labellum c. 2.3 x 1.8 cm, obovate, white, deeply split at tip, lobes acute. Lateral staminodes c. 2.6 x 1.5 cm tip rounded, white.

Distribution: Sri Lanka and South India. In South India it occurs in North Kerala and Southern parts of Karnataka, along the west coast.

Specimen studied: KERALA: Kannur Dt.: Karimbam, *Jana Sckornickova* 84144.

Anatomical features

(Fig. 44)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal (80-100 x 40-52 μm) with their longer axis perpendicular to the longitudinal veins and are arranged in regular files. Costal cells are smaller and broader than high (20 x 32-52 μm). The cell files are regular; 3 or 4 rows of cells are seen above the major vein. Intercostal cells of the abaxial epidermis are polygonal but smaller than upper ones and show irregular arrangement. Costal epidermal cells are broader and larger than the costal cells of adaxial epidermis and are irregularly arranged.

Trichomes: Completely absent.

Stomata: Stomata are seen mainly on the abaxial epidermis in between the veins, sometimes above the veins also. Length of the guard cell varies from 36-40 μm . Stomatal Index is 15.11. Stomata are frequent on the adaxial epidermis also (SI = 7.5). Most of the guard cells are 40 μm long.

Sheath: Abaxial surface is V-shaped and adaxial surface is wide U-shaped. Bundle arcs I, II and III are present. 2-5 oil cells are seen in the ground tissue. Crystals are absent in the cells of ground tissue. Metaxylem is 44-52 μm wide.

Petiole: Abaxial surface is U-shaped; adaxial surface is V-shaped. Bundle arcs I, II and III are present. Wings are absent. Ground tissue contains 1-3 oil cells. Metaxylem is 40-44 μm wide.

Midrib: Abaxial surface is wide V-shaped and adaxial surface is grooved. Bundle arc I alone is present. Some cells of the ground tissue contain few crystals in groups. 1 or 2 oil cells are also seen. Metaxylem is 28-32 μm wide.

Lamina: Lamina is 208 μm thick at the bundle (176 μm at other portions). Adaxial epidermal cells are larger, broader than high (48-64 x 64-96 μm). Abaxial epidermal cells are smaller (32-48 x 48-80 μm). Hypodermis is totally absent. 1-layered palisade and 2 or 3 layered spongy cells constitute the mesophyll which is 96 μm thick. Sclerenchymatous cap of the bundle is connected to the adaxial epidermis only.

Margin: Adaxial epidermal cells are broader than high. Abaxial epidermal cells are smaller. Mesophyll is composed of 1-layered palisade and 2-layered spongy cells. The portion beyond last bundle consists of mesophyll. The tip is gradually tapering and blunt. The hyaline portion is biseriate except for a single parenchyma cell at the base and 64-80 μm wide.

16. *Curcuma oligantha* Trimen var. ***lutea*** (Ansari, V.J. Nair & N.C. Nair) Bhat, Indian J. For. 10: 68. 1987; M. Sabu, Zingiberaceae and Costaceae of S. India 175. 2006.

Curcuma cannanorensis var. *lutea* Ansari, V.J. Nair & N.C. Nair, Curr. Sci. 51: 294. 1982. **(Plate 15**

F)

Flowers less than c. 5.5 cm. Corolla tube yellow. Dorsal lobe c. 1.8 x 1.5 cm, ovate; lateral lobes c. 1.5 x 1 cm, yellow. Labellum c. 1.8-2 x 1.8 cm, shortly 3-lobed, middle lobe deeply split, lobes rounded, orange-yellow. Lateral staminodes 2.5 x 1.2 cm, tip acute, orange-yellow.

Distribution: Reported only from North Kerala and Karnataka.

Specimens studied: KERALA: Kannur Dt.: Karimbam, *Jana Sckornickova* 84173.

Anatomical features

(Fig. 45)

Epidermis: Adaxial epidermal cells of the intercostal region are polygonal, longer than wide (80-100 x 32-36 μm) with their longer axis perpendicular to the veins. The cell files are more or less regular. Costal epidermal cells as high as broad or slightly broader (20 x 20-32 μm). 5-7 rows of cells are seen above the veins and are arranged in distinct rows. Intercostal cells of the abaxial epidermis also polygonal but the cell files are irregular. Costal epidermal cells are larger than upper one and less distinguishable from the rest. Few oil cells are also found on the abaxial epidermis.

Trichomes: Unicellular trichomes of 60-168 μm long are seen on either side of the major vein on the adaxial epidermis. Hairs are abundant on the abaxial epidermis, they are randomly distributed and are 200-280 μm long.

Stomata: Stomata are evenly distributed in between the veins on abaxial epidermis; sometimes above the veins also. Length of the guard cells varies between 36-40 μm . Stomatal index is 12.89. Few stomata are found on the adaxial epidermis also (SI= 6.85).

Sheath: Abaxial surface is U-shaped; adaxial surface is straight or slightly concave. Bundle arcs I, II and III are present. Metaxylem is 72-80 μm wide. Abaxial surface possess unicellular hairs which are upto 180 μm long towards the winged portion. Almost all cells of the ground tissue contain numerous crystals in groups. 10-15 oil cells are also found in the ground tissue.

Petiole: Abaxial surface is U-shaped; adaxial surface is V-shaped. Few hairs which are upto 192 μm long are born on the adaxial surface. Bundle arcs I, II and III are present. Metaxylem is 60-100 μm wide. The position of xylem and phloem are reversed in some bundles of arc III. Some cells of the ground tissue possess 2-few crystals in them. 5-7 oil cells are also found in the ground tissue.

Midrib: Abaxial surface is U-shaped; adaxial surface is concave. Bundle arc I alone is present. Few oil cells are seen in the ground tissue.

Lamina: Lamina is 208 μm thick (240 μm at the bundle). Adaxial epidermal cells are broader than high (32-48 x 64-96 μm); cells above veins as high as broad. Abaxial epidermal cells are smaller than upper ones (32-48 x 64-80 μm). Hypodermis is present abaxially. 1-5 cells are sometimes present just

below the adaxial epidermis, on either side of the bundle. Mesophyll is 80 μm thick and is divided into 1-layered palisade and 3 or 4 layered spongy tissue. Sclerenchymatous cap of the bundle is connected to the adaxial epidermis only. Mesophyll is seen below the bundle also.

Margin: Adaxial and abaxial epidermal cells are broader than high. Hypodermis is absent from both the epidermis. Mesophyll is composed of 1-layered palisade and 2-layered spongy tissue. The portion beyond last bundle is made up of mesophyll and parenchyma cells. The tip is gradually tapering, slightly bent downwards, tip is blunt. Sometimes 36 μm long hairs arise from the margin. Hyaline portion is multiseriate (4-celled at the base) and 128-144 μm wide.

17. *Curcuma pseudomontana* J. Graham, Cat. Pl. Bombay 210. 1839; M. Sabu, Zingiberaceae and Costaceae of S. India 175. 2006. **(Plate 16 A)**

Rhizome small, conical, yellow in centre, white towards periphery, aromatic; sessile tubers absent; root tubers 2-10 cm long. Leafy shoot 80-125 cm. Leaves 6-7; petiole 60-70 cm long; lamina 40-50 x 6-9 cm, oblong-lanceolate, base tapering, margins and terminal half of upper surface pubescent. Inflorescence both lateral and central, with bright pink coma. Fertile bracts green with purple tinge or purple. Bracteoles pink. Flowers longer than bracts. Calyx membranous, white or pale yellow. Labellum c. 1.5-1.8 x 1.7 cm, clearly 3-lobed, mid-lobe deeply cleft, bright yellow. Lateral staminodes bright yellow, without glandular hairs. Anther spurs

divergent and pointed forward, connective prolonged into small crest. Stigma slightly exerted above anther lobes. Fruits trigonous.

Distribution: Endemic to Peninsular India. In South India, it occurs in Andhra Pradesh, Karnataka & Kerala.

Specimen studied: MAHARASHTRA: Khandala Dt.: St. Xavier's villa, *Jana Sckornickova 73402*. (No specimens from South India were available for the present study).

Anatomical features

(Fig. 46)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal with their longer axis perpendicular to the longitudinal veins (80-112 x 16-48 μm). Cell files are almost regular. Costal epidermal cells are as high as or slightly broader (24 x 32 μm). 6 or 7 rows of cells are seen above the veins. The cell files are regular. Intercostal cells of the abaxial epidermis are higher than broad (48-64 x 32-48 μm), but the cell files are not clear. Costal epidermal cells are indistinguishable.

Trichomes: Hairs of 144-288 μm long are seen on the adaxial epidermis nearer to the veins. Hairs on the abaxial epidermis are much shorter, 64-144 μm long and show random distribution.

Sheath: Abaxial and adaxial surfaces are U-shaped. Bundle arcs I, II and III are present.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide U-shaped. Petiole wings are short, 1-2 mm long, gradually tapering and pointed. Bundle arcs I, II and III are present.

Midrib: Abaxial and adaxial surfaces are wide V-shaped. Bundle arcs I, II and III are present.

Stomata: Length of the guard cell varies between 32-36 μm . Stomata show a random distribution on abaxial epidermis. Stomatal index is 11.67. Very few stomata are seen on the adaxial epidermis (SI = 0.44).

Lamina: Lamina is 288 μm thick. Adaxial epidermal cells are broader than high (48 x 64-80 μm). Cells above the veins are smaller. Abaxial epidermal cells are also broader, but smaller than upper ones (32 x 48 μm). Hypodermis is present both abaxially and adaxially. Adaxial hypodermal cells are of comparable size to the epidermal cells. Abaxial hypodermal cells are much smaller (32 x 32 μm). 1-layered palisade and 4 or 5 layered spongy cells constitute the mesophyll tissue which is 112 μm thick. Trichomes are seen on both abaxial and adaxial epidermis. Bundle cap is in contact with the adaxial epidermis only.

Margin: Adaxial and abaxial epidermal cells are broader than high. Hypodermis is present above the abaxial epidermis only. Palisade is 1-layered and spongy consists of 3 or 4 layers. The portion beyond last bundle consists of mesophyll and colourless parenchyma. The tip is gradually tapering and pointed and slightly curved downwards. Hyaline

portion is 288-320 μm wide. Hairs are seen on both adaxial and abaxial epidermis.

18. *Curcuma raktakanta* Mangaly & M. Sabu, J. Econ. Tax. Bot. 12: 475. 1988, Rheedea 3(2): 168. 1993; M. Sabu, Zingiberaceae and Costaceae of S. India 179. 2006. **(Plate 16 B)**

Rhizome medium sized, conical, aromatic; sessile tubers finger-shaped, branched; root tubers fusiform. Leafy shoot 65-75 cm high; pseudostem reddish purple. Leaves 4-6, spreading; lamina 35-45 x 10-12 cm, oblong-lanceolate, base and tip acuminate, glabrous. Inflorescence lateral with distinct coma, coma deep pink. Fertile bracts green with pink tip. Bracteoles many. Flowers as long as or slightly smaller than the bracts, 3-4 in each bract. Calyx white. Corolla light pink. Labellum c. 2 x 2.2 cm, with median cleft, light yellow with a median dark yellow band. Lateral staminodes included within dorsal corolla lobe, with a patch of glandular hairs. Anther spurs divergent. Stigma exserted from the anther. Fruits not seen.

Distribution: Endemic to Kerala. Known to occur in Ernakulam and Trissur districts only.

Specimen studied: KERALA: Ernakulam Dt.: North Paravur, *Jana Sckornickova 86519*.

Anatomical features

(Fig. 47)

Epidermis: Adaxial epidermal cells of the intercostal region are polygonal with their longer (100-120 x 20-40 μm) axis perpendicular to the longitudinal vein. Costal epidermal cells are rectangular and are stretched parallel to the veins (36-80 x 20 μm). 5 rows of cells are seen above the main veins. Cell files are regular in both these regions. Intercostal cells of the abaxial epidermis are polygonal with varying size and show very irregular arrangement. Costal cells are also polygonal (40-92 x 32-36 μm), irregularly arranged and are distinguishable from the intercostal cells by the absence of stomata.

Trichomes: Completely absent.

Stomata: They are randomly distributed in between the major veins on the abaxial epidermis. Guard cells are 60-64 μm long. Stomatal index is 13.17. Few stomata are seen on the adaxial epidermis also (SI = 6.46).

Sheath: Abaxial surface is U-shaped; adaxial surface flat or slightly concave. Bundle arcs I, II and III are present. Oil cells are abundant in the ground tissue. Smaller bundles occur in arc II. Metaxylem is 24-64 μm wide.

Petiole: Abaxial surface is U-shaped; adaxial surface is V-shaped, sometimes slightly concave. Petiole is winged and wings are long, narrow and recurved. Bundle arcs I, II and III are present. Oil cells are abundant in the ground tissue. Cells of the ground tissue contain crystals in groups.

Midrib: Abaxial surface U-shaped and adaxial surface is V-shaped or straight. Bundle arcs I, II and III are found. Usually single crystal or few in groups are seen in the cells of ground tissue. 5-8 oil cells are also present in the ground tissue. Metaxylem is 72-84 μm wide.

Lamina: Lamina is 384 μm thick. Adaxial epidermis is broader than high (40-48 x 96 μm). Abaxial epidermal cells are also slightly broader than high but smaller in size (32 x 48-64 μm). Cells of the adaxial epidermis that are seen above bundles are much smaller and isodiametric (16 x 16 μm). Epidermal cells are slightly sunken at the region of main bundles. Hypodermis is present both abaxially and adaxially; adaxial hypodermis is single layered (48-64 x 96-112 μm) whereas abaxial hypodermis (48-64 x 80 μm) is 2-layered in between the bundles. Hypodermal cells are larger than epidermal cells. Mesophyll is divisible into 1-layered palisade and 4 or 5 layered spongy tissue and is 160 μm wide. Sclerenchymatous cap of the main bundle is in contact with the adaxial epidermis only. Smaller bundles are found embedded in the mesophyll. Oil cells are abundant in the mesophyll.

Margin: Adaxial epidermal cells are as high as broad towards the margin. Hypodermis is single layered both abaxially and adaxially. 1-layered palisade and 3-layered spongy constitute the mesophyll. Sclerenchymatous cap of the main bundle is not connected to either of the epidermis. Portion beyond last bundle is composed of mesophyll and colourless parenchyma cells. Margin is gradually tapering, incurved and tip is pointed. Hyaline

portion is multiseriate (5-celled at the base, biseriate towards tip) and 256 μm wide.

19. Curcuma vama M. Sabu & Mangaly. J. Econ. Tax. Bot. 10. 307. 1988; M. Sabu, Zingiberaceae and Costaceae of S. India 181. 2006.

(Plate 16 C)

Rhizome small, conical; orange within, stoloniferous; sessile tubers absent; root tubers few, spherical or ellipsoid. Leafy shoot upto 50 cm tall. Leaves 4 or 5; petiole 20-30 cm long; lamina 20-25 x 6-8 cm, oblong, base subequal. Inflorescence central, distinct coma absent. Bracts 4-8, loosely arranged, slightly recurved, subtends 2-4 flowers. Flower shorter than the bracts, 1.8-2 cm long. Calyx persistent. Corolla tube c. 8 mm long; lobes almost equal, yellowish white. Labellum c. 8 x 7 mm, tip notched, margin crisped, golden yellow. Anther thecae convergent at base to form a beak-like spur. Epigynous glands absent. Stigma exserted from the anther. Fruit obovoid with persistent calyx. Seeds brown when mature.

Distribution: Endemic to Kerala.

Specimen studied: **KERALA:** Thrissur Dt.: KFRI Campus, *Prasanth Kumar* 86368.

Anatomical features

(Fig. 48)

Epidermis: Intercostal cells of the upper epidermis polygonal with their longer axis perpendicular to the veins (80-128 x 32-48 μm). The cell files are

regular. 4 rows of cells are found above the veins. Costal cells are isodiametric or slightly broader (16-24 x 24-32 μm). Intercostal cells of the lower epidermis are polygonal with their longer axis perpendicular to the veins (64-96 x 32-72 μm), but smaller than upper ones. Cell files are irregular. Costal epidermal cells are slightly smaller than the intercostal cells (48-64 x 48-64 μm), but not distinguishable.

Trichomes: Absent.

Stomata: Tetracytic stomata are randomly distributed in between the veins. Length of the guard cells vary from 32-40 μm (usually 36 μm long). Stomatal Index is 13.56. Very few stomata are seen on the adaxial surface.

Sheath: Abaxial surface is U-shaped and adaxial surface is wide V-shaped. Epidermal cells are as high as broad. Bundle arcs I, II and III are present. Air canal is larger than the bundle. Metaxylem is 40-52 μm wide. Numerous crystals in groups are seen in the ground tissue cells.

Petiole: Abaxial surface is U-shaped and adaxial surface is wide V-shaped. Bundle arcs I, II and III are present. Air canal in between the bundles of arc I is larger than the size of the bundle.

Midrib: Abaxial side is wide U-shaped, adaxial surface is U-shaped. Bundle arc I alone is seen in the midrib.

Lamina: Lamina is 240 μm thick (256 μm at the bundle). Adaxial epidermal cells are large, broader than high (64 x 96 μm). Cells above veins are much smaller than the rest. Abaxial epidermal cells are slightly smaller (64 x 80-96

µm). Mesophyll consists of 1-layered palisade and 3-layered spongy tissue and is 112 µm thick. The main bundle is connected to upper epidermis only. Sclerenchymatous cap of the bundle is 1-2 layered.

Margin: Margin is gradually tapering and slightly bent downwards. Upper and lower epidermal cells are broader than high. Palisade is 1-layered and spongy is 3-layered. Bundle is connected to upper epidermis only. Metaxylem of the last bundle is 10-12 µm wide. The portion beyond last bundle consists of mesophyll. Hyaline portion is biseriate and 128 µm wide.

20. *Curcuma zanthorrhiza* Roxb., Fl. India 1: 25. 1820; Sckornickova & M. Sabu, Garden's Bull. Singapore 57: 200. 2005; M. Sabu, Zingiberaceae and Costaceae of S. India 183. 2006. **(Plate 16**

D)

Rhizome large, 5-8 x 7-9 cm, broadly ovoid, with smell of camphor, yellow to deep yellow inside; sessile tubers branched; root tubers present. Leafy shoot 80-100 cm high. Leaves 4-6; lamina 40-60 x 15-20 cm, oblong-lanceolate, purple coloured patch on the upper side along the whole length of the midrib, glabrous. Inflorescence lateral, with dark pink coma. Fertile bracts 20-25, tip recurved, green with pink margin. Flowers almost equal to the bracts, 4 or 5 in each bract. Calyx greenish white. Corolla longer than calyx, white with pinkish tinge. Labellum 1.5-2 cm wide, shortly 3-lobed; mid-lobe emarginate, pale yellow with deep yellow band. Anther connective not produced into crest. Stigma bilipped. Fruit ovoid, smooth.

Distribution: Cultivated and naturalised throughout India and S.E. Asia.

Specimen studied: KERALA: Malappuram Dt.: C. U. Botanical Garden, Jayasree 86532.

Anatomical features

(Fig. 49)

Epidermis: Adaxial epidermal cells are polygonal, longer than broad (104-128 x 20-36 μm) with their longer axis perpendicular to the longitudinal veins. Costal cells are rectangular, broader than high (40-64 x 20-24 μm). About 6 layers of cells are present above the main veins. Abaxial epidermal cells are irregular in size and shape. Costal cells are distinguishable by their thicker walls and absence of stomata. The cell files are indistinguishable. Very rarely oil cells are seen in the abaxial epidermis.

Trichomes: Completely absent.

Stomata: Are evenly distributed in between the veins on abaxial epidermis. Length of the guard cell is 48 μm . Stomatal index is 14.19. Few stomata are seen on the adaxial epidermis also (SI = 4.17).

Sheath: Both adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. The arrangement of xylem and phloem are reversed in the III arc bundles. Oil cells are abundant in the ground tissue. Bundle arc II shows the presence of smaller bundle.

Petiole: Abaxial surface is U-shaped; adaxial surface is somewhat flat or slightly concave at the middle. Petiole wings are narrow, gradually tapering

and pointed. Bundle arcs I, II and III are present. Smaller bundles are in between the bundles of arc II. Numerous oil cells are seen in the ground tissue.

Midrib: Both abaxial and adaxial surfaces are wide V-shaped. Bundle arcs I, II and III are present. Arc II is represented by 2 bundles. Cells surrounding the bundles contain few crystals in them. Cells of the ground tissue contain very few crystals (1-3). A single layer of cells of the ground tissue are elongated radially.

Lamina: Lamina is 288 μm thick (320 μm at the bundle). Adaxial (32 x 64-96 μm) and abaxial (48 x 48-64 μm) epidermal cells are broader than high. Cells above the veins are much smaller and as high as broad. A continuous and single layered hypodermis is present both abaxially (40-48 x 56 μm) and adaxially (32-48 x 64-80 μm). Mesophyll is composed of 1-layered palisade and 3 or 4 layered spongy and is 178 μm thick. 1 or 2 small crystals are found in some mesophyll cells. Oil cells are also seen in the mesophyll. Sclerenchymatous bundle cap is in contact with the adaxial epidermis only. Metaxylem is 24 μm wide.

Margin: Epidermal cells are slightly broader than high, cells towards the tip as high as broad. Single hypodermis is seen both abaxially and adaxially. 1-layered palisade and 3-layered spongy cells constitute the mesophyll. Oil cells are abundant in the mesophyll. The portion beyond last bundle consists of mesophyll and colourless parenchyma cells. The tip is gradually tapering,

pointed and curved downwards. The hyaline portion is multiseriate (4-celled at the base) and 240 μm wide.

CURCUMA: COMPARATIVE ANATOMY

(Fig. 50, 51, 52, 53, 54, 55 & 56)

Intercostal cells of the adaxial epidermis are polygonal, longer than broad with their longer axis perpendicular to the longitudinal veins and are arranged in definite rows in all species studied except *C. bhatii*, where the cells are of different shapes and size and they do not show the particular arrangement seen in other *Curcuma* spp. The costal epidermal cells are as high as broad in *C. amada* and *C. inodora*, broader than long in all other species examined. In *C. bhatii* cells above the veins are not distinguishable by their size because they are almost similar in size to the intercostals cells. Indira (1976) studied 5 species of *Curcuma* viz., *C. longa*, *C. montana*, *C. aromatica*, *C. amada* and *C. zedoaria* and found that, in *C. montana* and *C. aromatica* intercostal cells are arranged in definite transverse rows. In *C. longa* and *C. amada* the cells are very broad and in *C. zedoaria* cells over the vein are much smaller.

Oil cells are found on the abaxial epidermis of species such as *C. longa*, *C. aeruginosa*, *C. haritha*, *C. amada*, *C. raktakanta* and *C. montana*. This observation agrees with that of Solereder and Meyer (1930) and Tomlinson (1956).

Indira (1976) recorded presence of oil cell on the epidermis without specifying its position. Abaxial epidermal cells are of different size and shape so an arrangement into definite rows is not observed. But in *C. bhatii* the cell files are very distinct in the abaxial epidermis.

According to Meyer (1881) the number of oil cells varies considerably in different species or in individuals belonging to a single species and also in different parts of the same plant. Present study also agrees with this.

Trichomes are simple, unicellular, 'Borste' type of hair (Staudermann, 1924). It is thick walled with narrow lumen.

Indira (1976) reported the occurrence of trichomes only on the lower epidermis of leaves of all species studied. Present study shows that, trichomes are completely absent in *C. bhatii*, *C. amada*, *C. oligantha* var. *oligantha*. They are seen only on adaxial surface in *C. inodora*, *C. karnatakensis*, *C. mutabilis*, *C. vamana* and *C. montana* and on both surfaces of *C. aurantiaca*, *C. aromatica*, *C. haritha*, *C. coriacea*, *C. pseudomontana*, *C. oligantha* var. *lutea* and *C. neilgherrensis* but pubescence is more on abaxial epidermis.

Stomata are distributed more on abaxial epidermis of all species studied. Stomatal index is maximum in *C. bhatii* (19.23) and minimum in *C. aurantiaca* (10.06). Guard cell is shortest in *C. aromatica* (32-36 μ m) and longest in *C. raktakanta* (64 μ m). Few stomata are found on the adaxial epidermis also and stomatal index is maximum for *C. bhatii* (11.24) and minimum in *C. amada* (1.08). Stomatal index and length of the guard cells show deviation from the earlier report (Indira, 1976).

The abaxial surface of the sheaths of *C. oligantha* var. *lutea*, *C. montana* and *C. karnatakensis* possess hairs. The abaxial surface is U-shaped in all species examined except *C. oligantha* var. *oligantha* and *C. vamana* where it is V-shaped.

Petiole wings are long and narrow in *C. amada*, *C. aromatica*, *C. haritha*, *C. aeruginosa*, *C. longa*, *C. montana*, *C. pseudomontana*, *C. raktakanta* and *C. zanthorrhiza*. Wings are broad in *C. aurantiaca*, *C. coriacea*, *C. decipiens*, *C. inodora*, *C. bhatii*, *C. karnatakensis*, *C. oligantha* var. *oligantha*, *C. oligantha* var. *lutea*, *C. neilgherrensis*, *C. mutabilis* and *C. vamana*. Petioles of all species show the presence of bundle arcs I, II and III. In *C. bhatii*, a distinct petiole is absent and the junction between the base of lamina and ligule is studied, and it shows bundle arc I with large air canals in between. Bundle arc III is represented by a single bundle. Silica sand is observed in the cells near to the bundles in *C. aeruginosa*, *C. decipiens*, *C. haritha*, *C. montana*, *C. oligantha* var. *oligantha* and *C. karnatakensis*. Similar observation was made by Tomlinson

(1956) in some *Curcuma* spp., but was absent in *C. longa*. Solereder and Meyer (1970) have not observed silica sand in *Curcuma*.

Calcium oxalate crystals of various shapes are seen in the ground tissue of the sheath, petiole and midribs of *C. inodora*, *C. mutabilis*, *C. aeruginosa*, *C. montana*, *C. haritha*, *C. neilgherrensis*, *C. karnatakensis*, *C. oligantha* var. *lutea* etc. Lamina is thickest in *C. coriacea* (368 μ m) and thinnest in *C. oligantha* var. *oligantha* (176 μ m). Both abaxial and adaxial hypodermis are seen in *C. coriacea*, *C. haritha*, *C. pseudomontana*, *C. neilgherrensis*, *C. longa* and *C. montana*. An adaxial hypodermis is seen only on either side of the major veins, in *C. karnatakensis*, *C. aurantiaca* and *C. aromatica*, otherwise abaxial hypodermis alone present. Hypodermis is present only at the abaxial side in *C. oligantha* var. *lutea* and *C. mutabilis*. Hypodermis is totally absent in *C. bhatii*, *C. vamana* and *C. oligantha* var. *oligantha*. In these 3 species, the epidermal cells are bigger than those having hypodermis. Lamina is raised at the bundle in all species, except *C. coriacea* and *C. raktakanta*.

Margin is usually gradually tapering, pointed or blunt in all species studied except *C. bhatii*, where it is abruptly tapering and blunt. Margin is straight in *C. haritha*, *C. montana* and *C. oligantha* var. *oligantha*. It is bent downwards in *C. decipiens*, *C. amada*, *C. karnatakensis*, *C. aurantiaca*, *C. longa*, *C. vamana*, *C. oligantha* var. *lutea* and *C. mutabilis*. Tip is curved in *C. coriacea*, *C. pseudomontana* and *C. neilgherrensis* and incurved in *C. raktakanta* and *C. zanthorrhiza*. Hyaline portion is multiseriate in all

species except *C. bhatii* and *C. oligantha* var. *oligantha*. Hyaline portion is longest in *C. inodora* and *C. aromatica* (368 μ m) and shortest in *C. oligantha* var. *oligantha* (64-80 μ m).

The subgeneric classification into *Eucurcuma* and *Hitcheniopsis* based on the presence or absence of anther spur does not coincide with the occurrence of any particular anatomical characters. Out of the 20 taxa studied *C. bhatii* shows some variations from all other species under study. *Curcuma bhatii* was originally described under another genus *Paracautleya* in 1977 by R.M. Smith based on specimens collected by K.G. Bhat. However, the characters were not sufficient to keep it under another genus, hence Sckornickova & Sabu (2005) merged *Paracautleya* with *Curcuma*. As well as similarity in habit, they found that the generic diagnostic characters including floral morphology described for *Paracautleya* can be observed in at least some members of the genus *Curcuma*.

However, this species shows some differences from other South Indian species of *Curcuma* in anatomy. The leaves of *C. bhatii* are linear and almost sessile. The junction between the base of the leaf and ligule is studied and it shows bundle arc I and III (represented by single bundle). In all other species of *Curcuma*, bundle arcs I, II and III are present; bundle arc II and III are well developed in the petioles.

In *C. bhatii*, costal cells are large and indistinguishable, and show irregular arrangement, whereas in other species, they are much smaller and arranged in definite rows. The intercostal cells of the former are broader and

longer axis parallel to the longitudinal veins. Whereas in the latter, intercostal cells are longer than broad with their longer axis perpendicular to longitudinal veins.

Key to the species based on anatomical characters

1. Petiole wings long, narrow, hyaline or not2
1. Petiole wings broad, never hyaline.10
2. Trichomes absent on leaves.....3
2. Trichomes present on leaves. 7
3. Leaves with purple patch along the midrib.....4
3. Leaves without purple patch along the midrib.....5
4. Purple patch seen towards the distal end; rhizome pale blue, leaf margin bent downwards.....1. **C. aeruginosa**
4. Purple patch seen throughout the midrib; rhizome bright yellow; leaf margin incurved.....20. **C. zanthorrhiza**
5. Pseudostem reddish; leaf margin incurved; guard cells 64 μ m long.....
.....18. **C. raktakanta**
5. Pseudostem green; leaf margin bent downwards; guard cells 48 μ m long.....6

6. Rhizome light yellow inside, with smell of mango; petiole wings 3 mm long.....2. **C. amada**
6. Rhizome orange yellow inside, without the smell of mango; petiole wings 2 mm long, 11. **C. longa**
7. Lamina ovate-elliptic.....8
7. Lamina oblong or oblanceolate.....9
8. Leaf margin straight, leaves; numerous crystals in groups in the cells of petiole; guard cells 48 μ m long.....8. **C. haritha**
8. Leaf margin slightly bent downwards; crystals 1-few in the cells of petiole; guards cells 36 μ m long.....3.**C. aromatica**
9. Lamina 15 cm long; upper surface puberulent; margin straight, pointed.....12. **C. montana**
9. Lamina 40-50 cm long, both surfaces hairy; margin curved downward.....17. **C. pseudomontana**
10. Leaves 4-6 cm long, linear-lanceolate; petiole absent; intercostal cells of the adaxial epidermis irregularly arranged.....5. **C. bhatii**
10. Leaves more than 20 cm long, ovate, elliptic or oblong, petiolate; intercostal cells of the adaxial epidermis arranged in definite rows.....11
11. Epidermal hairs present.....12
11. Epidermal hairs absent.....7. **C. decipiens**

12. Epidermal hairs on both adaxial and abaxial surface.....13
12. Epidermal hairs only on adaxial surface.....16
13. Hairs on adaxial surface upto 204 μ m long; lamina not raised at the major veins6. **C. coriacea**
13. Hairs on adaxial surface upto 288 μ m long; lamina raised at the major veins 14
14. Hypodermis throughout abaxial and adaxial surface or restricted to either side of the veins.....15
14. Hypodermis only on abaxial surface10. **C. karnatakensis**
15. Leaf margin incurved; hypodermis throughout abaxial and adaxial surface.....14. **C. neilgherrensis**
15. Leaf margin bent downwards; adaxial hypodermis restricted to either side of the major veins4. **C. aurantiaca**
16. Hypodermis absent17
16. Hypodermis present on abaxial surface.....18
17. Sheath V-shaped; leaf margin straight; hyaline portion 64-80 μ m wide....
.....15. **C. oligantha** var. **oligantha**
17. Sheath U-shaped; leaf margin bent downwards; hyaline portion 128 μ m wide.....19. **C. vamana**

18. Hairs upto 224 μ m long.....13. **C. mutabilis**
18. Hairs upto 672 μ m long.....19
19. Stomatal index of the adaxial epidermis 6.8; crystals in ground tissue rod shaped; hyaline portion 128-144 μ m wide 16.**C.oligantha** var. **lutea**
19. Stomatal index of adaxial epidermis 3.52; crystals in ground tissue plate like; hyaline portion 352 μ m wide9. **C. inodora**

3. HEDYCHIUM Koenig

Hedychium Koenig in Retz., Obs. Bot. 3: 73. 1783; M. Sabu, Zingiberaceae and Costaceae of S. India 192. 2006.

Terrestrial or epiphytic. Rhizome creeping, fleshy. Leafy stem 1-3 m high. Leaves sessile or shortly petiolate. Ligule closely adhering to the stem. Spike terminal, bracts imbricating or lax. Flowers showy and large. Calyx tubular, 3-toothed. Corolla tube much longer than the calyx; lobes 3. Labellum broad, more or less bilobed. Lateral staminodes petaloid. Filament usually long and slender; anther neither crested nor spurred. Ovary glabrous or hairy. Capsule globose, oblong or trigonous, loculicidal.

Distribution: About 80 species, mostly Indian; also reported from Malesia, Borneo, Philippines, Myanmar and Nepal. The centre of distribution is the eastern Himalayas, a few species are reported from South India.

Ecology: Grow in the edges of tropical and sub-tropical forests forming patches in marshy areas, on grassy slopes and along banks of streams. All

species are grown in bright sunlight. Some species (*H. villosum*, *H. longicornutum* & *H. lineare*) are epiphytic.

Key to the species based on morphological characters

1. Bracts more than 2.5 cm broad, closely imbricating; labellum broad, white or yellow, without red blotch, shortly bifid; inflorescence ovate-elliptic, upto 15 cm long; filament white or yellow..... **2**
1. Bracts narrow, less than 2.5 cm broad; loosely arranged; labellum narrow, yellow with red blotch, deeply bifid; inflorescence elongated, 16-25 cm long; filament red**3. H. spicatum** var. **acuminatum**
2. Calyx shorter than the bract; labellum white to pale yellow; stamen shorter than the lip**1. H. coronarium**
2. Calyx equal to or slightly longer than the bract; labellum sulphur yellow; stamen longer than the lip **2. H. flavescens**

1. Hedychium coronarium Koenig in Retz., Obs. Bot. 3: 73. 1783; M. Sabu, Zingiberaceae and Costaceae of S. India 196. 2006. **(Plate 16 E)**

Rhizome fleshy, yellow inside. Leafy shoots 2-3 m high. Leaves sessile, 30-60 x 6-10 cm, oblong-lanceolate, tip acuminate, base attenuate, lower surface densely pubescent, upper glabrous. Ligule 2 or 3 cm long, densely pubescent, brown. Inflorescence 15-20 cm long, elliptic. Flower c. 15 cm long. Bracts at the base of the inflorescence c. 5 x 3 cm, oblong, rounded with a pointed tip, green, subtends 4 or 5 flowers, becoming smaller

towards the tip. Bracteoles triangular. Calyx shorter than the bracts. Corolla tube longer than the calyx; lobes equal, white. Labellum orbicular-obcordate, 5-5.5 x 5-5.5 cm, shortly bilobed, abruptly narrowed at base, white with central greenish yellow tinge. Lateral staminodes oblong-lanceolate, petaloid. Stamen shorter than the lip; filament white; thecae c. 1.2 mm long. Capsule oblong, 3 celled, 3-valved, opening from the apex.

Distribution: Common throughout India, Malesia, Widely grown as ornamentals in tropical countries.

Specimen studied: **KERALA:** Thiruvananthapuram Dt.: Nadukanipara, Sanoj 86184.

Anatomical features

(Fig. 57)

Epidermis: Intercostal cells of the adaxial epidermis are longer than broad (52-80 x 20-40 μm) and are arranged in definite rows. Costal cells are broader (16-24 x 36 μm) and show regular arrangement. Cells of the abaxial epidermis have different size and shapes and are very irregularly arranged. Costal cells are broader and are somewhat regular. Oil cells are frequent on abaxial epidermis.

Trichomes: Hairs upto 2-2.5 mm length are present on the abaxial leaf surface, midrib, petiole etc. Hair type is described as 'Weichhaare' type (Staudermann, 1924). Each hair is surrounded by 5-7 cells.

Stomata: Stomata are evenly distributed between the veins on abaxial epidermis. Length of the guard cells varies from 36-48 μm . 40-44 μm long

guard cells are common. Stomatal index is 15.52. Few stomata are seen on the adaxial epidermis also (SI = 1.63).

Sheath: Abaxial surface is wide V-shaped and adaxial surface is wide U-shaped. Bundle arcs I, II, III and IV are present. Smaller bundles are seen in arc II.

Petiole: A distinct petiole is absent, but a section through the junction between the base of the lamina and ligule shows the following features. Both abaxial and adaxial surfaces are wide U-shaped. Bundle arcs I, II, III and IV are present. Smaller bundles are seen in arc II. The wings are broad and blunt. The blunt ends possess upto 1 mm long hairs. Hairs are also present on abaxial surface. Large air canals are seen in between the bundles of arc I.

Midrib: Abaxial surface is V-shaped; adaxial surface is slightly concave. Bundle arcs I, II, III and IV are present. Arc IV is represented by a single bundle.

Lamina: Lamina is 320 μm thick. Adaxial epidermal cells are broader than high (16 x 64 μm). Cells above bundles are smaller and as high as broad. Abaxial epidermal cells are smaller and slightly broader than high. Hypodermis is single layered and is made up of larger cells, broader than high (48 x 90 μm). Abaxial hypodermis is 2-layered and the cells are as high as broad (48-64 x 48-64 μm). Mesophyll is 144-160 μm thick and is composed of 2-layered palisade and 2-4 layered spongy cells. In the mesophyll, oil cells and crystals are present. Sclerenchymatous cap of the bundle is in contact with both abaxial and adaxial epidermis. Metaxylem of the bundle is 32 μm wide.

Margin: Adaxial epidermal cells are slightly broader than high; as high as broad towards the tip. A single layered hypodermis is present both abaxially and adaxially. Mesophyll is divisible into 1-layered palisade and 3 or 4 layered spongy tissue. Sclerenchymatous cap is in contact with the abaxial epidermis only. The portion beyond last bundle consists of mesophyll and few parenchyma cells. Metaxylem of last bundle is 32 μm thick. The tip is gradually tapering and curved downwards. The hyaline portion is multiseriate (4-celled at the base) and 240 μm wide.

2. *Hedychium flavescens* Carey ex Roscoe, Monandr. t. 50. 1825; M. Sabu, Zingiberaceae and Costaceae of S. India 199. 2006. **(Plate 16 F)**

Rhizome thick, light greyish yellow inside. Leafy shoot 2 or 3 m high. Leaves sessile or shortly petiolate, hairy. Lamina 30-50 x 6-8 cm, lanceolate acuminate, tapering towards the base, glabrous above, densely pubescent below. Ligule 2 or 3 cm, pubescent; leaf sheath sparsely pubescent. Spike ovate, 10-15 cm long. Bracts broadly ovate, 4.5-5 x 3-3.5 cm, ciliate, subtend 3 or 4 flowers. Bracteoles slightly keeled, obtuse. Calyx equal to or slightly longer than bract. Corolla twice as long as the calyx tube; lobes unequal. Labellum yellow, broadly obcordate, 4-5 x 3.5 cm, bilobed, narrowed into a distinct claw at the base. Lateral staminodes spatulate. Stamen slightly longer than the labellum, 5-6 cm long; filament yellow, thecae c. 1.2 cm long. Ovary densely pubescent. Fruiting not common.

Distribution: India, Sri Lanka. In India, it is distributed in N.E. India and S. India. In South India it occurs along the Western Ghats and Bison hill in Andhra Pradesh.

Specimen studied: **TAMIL NADU:** Dindigul Dt.: Kodaikanal, *Sanoj 95663*.

Anatomical features

(Fig. 58)

Epidermis: Intercostal cells of adaxial epidermis are longer than broad (48-64 x 20-28 μm) and are arranged in definite rows. Costal cells are as high as broad or broader (20 x 16-36 μm) and arranged in more or less regular rows. 4 to 5 rows of cells are seen above the veins. Abaxial epidermal cells of the intercostal region are of different size and shapes and are very irregularly arranged. Very few oil cells are seen on the abaxial epidermis.

Costal cells are usually broader (16-20 x 32-80 μm). Oil cells are frequent on the abaxial epidermis.

Trichomes: Hairs upto 2.5 mm long are present on the abaxial surface of leaf midrib and petiole. Hairs are of 'Weichhaare' type (Staudermann, 1924).

Stomata: Stomata are abundant on the abaxial epidermis. They are randomly distributed between the veins, sometimes above the veins also. Guard cells are 48 μm long. Stomatal index is 13.05. Very few stomata are seen on the adaxial epidermis also (SI = 0.82). Guard cells are slightly smaller than the abaxial ones, and its length varies between 40-44 μm .

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Abaxial surface possess 1.5 mm long hairs. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. 1-few crystals are present in the cells of ground tissue. Metaxylem of the bundle is 64 μm wide.

Petiole: A section through the junction between base of the lamina and ligule is studied. Abaxial surface is wide U-shaped. Adaxial surface is wide V-shaped. Wings are broad, gradually tapering and blunt. Hairs upto 2 mm long are present through out the surface, forms tufts at the ends of wings. Bundle arcs I, II, III and IV are present. Smaller bundles are seen in the arc II. Cells surrounding the bundles and cells of ground tissue contain 1-few large calcium oxalate crystals. Oil cells are abundant. Metaxylem of the bundle is upto 88 μm wide.

Midrib: Abaxial surface is wide V-shaped; adaxial surface concave. Bundle arcs I, II and III are present. Abaxial surface possess 1.5 mm long hairs. Metaxylem of the bundle is 48 μm wide. Oil cells are abundant.

Lamina: Lamina is 336 μm thick at the bundle and 352 μm thick at other portions. Adaxial epidermal cells are broader than high (28 x 44-69 μm). Cells above the veins are as high as broad and very small. Abaxial epidermal cells are as high as broad or slightly broader. Hypodermis is present both abaxially and adaxially. Adaxial hypodermal cells are larger than the epidermal cells and form a single layer; cells are broader than high (40-44 x 72 μm). Abaxial hypodermis is 2-layered. Here also the hypodermal cells are larger than the abaxial epidermis. Mesophyll is 146-160 μm thick and composed of 2-layered palisade and 4-layered spongy cells, which are very compactly arranged. The second layer is smaller in size. Abaxial sclerenchymatous cap of the main bundle abut on the adaxial epidermis only. Metaxylem of the bundle is 44 μm wide.

Margin: Adaxial epidermal cells are broader than long, but become as high as broad towards the tip. The hypodermis continues to be present in the margin also; both hypodermis are single layered. Sclerenchymatous cap of the bundle abut on the abaxial epidermis only. Metaxylem of last bundle is 32 μm wide. Mesophyll is composed of 1-layered palisade and 4-layered spongy tissue. The portion beyond last bundle consists of mesophyll and parenchyma cells. The margin is gradually tapering, curved downwards and

pointed. The hyaline portion is multiseriate (5-celled at the base) and 256 μ m wide.

3. *Hedychium spicatum* Hamilton ex Smith var. ***acuminatum*** (Roscoe) Wall. in Hook. f., Kew J. Bot. 5: 328. 1853; M. Sabu, Zingiberaceae and Costaceae of S. India 202. 2006.

Hedychium acuminatum Roscoe, Monandr. Pl. t. 47. 1828. **(Plate 17 A)**

Rhizome thick, light yellow inside. Leafy shoot less than 1 m long. Leaves subsessile or sessile, oblong lanceolate, tip acuminate, 20-25 x 4-6 cm, lower surface densely pubescent; upper surface glabrous. Ligule small, 0.8-1.5 cm long. Spike straight, elongated, 16-25 cm. Bracts coriaceous, 10-13, loosely arranged, c. 2.5 x 1.5 cm ovate oblong, lower bracts subtend 2 or 3 flowers, upper bracts with single flower. Flowers longer than bracts. Corolla tube 6 cm long, lobes equal. Labellum 3.5-4 x 2 cm, deeply bilobed, lobes yellow with a red blotch at the mouth. Lateral staminodes linear, tip shortly bifid. Stamen shorter than labellum, curved; filament c. 2 cm long, red; anther thecae c. 1.2 cm long, red. Stigma protruding from the middle of the anther thecae, cup-shaped. Fruit globose to subglobose,

Distribution: Earlier it was reported only from NE India; recently this has been collected and reported from the Western Ghats in Kerala and Tamil Nadu (Sabu, 2000).

Specimen studied: **KERALA:** Thiruvananthapuram Dt.: Ponmudi, *Sanoj* 95651.

Anatomical Features

(Fig. 59)

Epidermis: Intercostal cells of the adaxial surface are longer than broad (40-64 x 16-24 μm) and are arranged in regular rows. Costal cells are broader (12-16 x 20-44 μm) and are arranged in definite rows. Intercostal cells of the abaxial epidermis are of varying size and shapes and are irregularly oriented. Costal cells are broader and somewhat regular compared to the intercostal cells. Oil cells can be seen on the abaxial epidermis.

Trichomes: Trichomes are upto 1.25 mm long, distributed on the abaxial, epidermis of leaves, petiole and midrib. Hairs are of 'Wiechhaare' type (Staudermann, 1924). Each hair is surrounded by 4-5 cells.

Stomata: Stomata are abundant on the abaxial epidermis, distributed evenly between the veins, sometimes above the veins also. Guard cells are 36-44 μm long. Stomatal index is 11.08. Very few stomata are seen on the adaxial epidermis also (SI = 0.89).

Sheath: Abaxial and adaxial surface are wide U-shaped. Bundle arcs I, II and III are present. Smaller bundles are seen in arc II. Metaxylem of the bundle is upto 88 μm wide. Oil cells are present in large numbers.

Petiole: A distinct petiole is absent; section through the junction between the base of the lamina and ligule is studied. Abaxial surface is U-shaped; adaxial surface is wide U-shaped. Bundle arcs I, II and III are present. Wings are broad and blunt. The blunt end possesses about 1 mm long hairs. Oil cells are abundant in the petiole.

Midrib: Abaxial surface is wide V-shaped; adaxial surface is concave. Bundle arcs I, II and III are present, 1-few large crystals are found in the ground parenchyma cells, chlorenchyma cells, sclerenchymatous sheaths of bundles etc. Metaxylem of the bundles is 60 μm wide. Few oil cells are also seen.

Lamina: Lamina is 256-272 μm thick. The adaxial epidermal cells are broader than high (16 x 48 μm); abaxial epidermal cells are as high as or slightly broader (24 x 28 μm). Continuous hypodermis is present abaxially and adaxially. Adaxial hypodermis single layered, cells broader than high (40-44 x 88 μm); abaxial hypodermis sometimes 2-layered. Mesophyll is 100 μm thick and consists of 2-layered palisade and 3 or 4 layered spongy cells. Sclerenchymatous cap of the bundle about on both abaxial and adaxial epidermis. Metaxylem is 36 μm wide.

Margin: Adaxial epidermal cells are twice broad as high, cells above the veins much smaller. Abaxial epidermal cells are also broader than high. Both hypodermal layers are seen in the margin also. Mesophyll is composed of 2-layered palisade and 1-layered spongy. Oil cells are abundant in the mesophyll. Bundle cap is in contact with the abaxial epidermis only. Metaxylem of the last bundle is 32 μm wide. The portion beyond last bundle consists of mesophyll and few parenchyma cells. The tip is gradually tapering, pointed and curved downwards or incurved. The hyaline portion is multi layered (4-celled at the base) and 272 μm wide.

Intercostal cells of the adaxial epidermis are polygonal with longer axis perpendicular to the longitudinal veins in all species studied. Among the three species from S. India, epidermal cells are largest in *H. coronarium*. Cells on the abaxial epidermis are of varying sizes and shapes and show very irregular arrangement. Costal cells of the abaxial epidermis are broader in all species and maximum width (44 μm) is noticed in *H. spicatum* var. *acuminatum*. The presence of oil cells on the abaxial epidermis agrees with the observations by Solereder and Meyer (1930) and Tomlinson (1956). Indira (1976) also reported the presence of oil cells in the epidermis without specifying their location.

Trichomes are present on the abaxial epidermis of all species studied. *H. flavescens* possesses 2.5 mm long hairs, which densely covers the abaxial surface, petiole, midrib and sheath. *H. spicatum* has 1-1.25 mm long hairs. Hairs are of 'Weichhaare' type (Staudermann, 1924), and easily detachable. Adaxial surface is glabrous.

Length of the guard cell (40-44 μm long) is almost same in all species studied. Stomatal Index is maximum for *H. coronarium* (15.52) and minimum for *H. flavescens* (10.9).

Abaxial surface of the sheath shows the presence of hairs in *H. flavescens* whereas in other two species the abaxial surface is glabrous. Calcium oxalate crystals are seen in the chlorenchymatous and ground parenchyma cells of *H. flavescens* and *H. spicatum*. Chlorenchyma cells of

H. spicatum contain starch grains, but starch grains are absent in other two species. Bundle arcs I, II, and III are present.

A distinct petiole is absent. Section through the junction between leaf base and ligule shows four bundle arcs I, II, III and IV (except *H. spicatum*).

Midrib of *H. flavescens* possesses 1.5 mm long hairs on abaxial surface. Bundle arcs I, II and III are present.

In the lamina a continuous hypodermis is present both abaxially and adaxially in all three species. Abaxial hypodermis is 2-layered in *H. coronarium* and *H. flavescens* (Indira, 1976). In *H. spicatum*, hypodermis is 2-layered nature is not consistent. Palisade layer is 2-layered in all species studied.

Margin is gradually tapering, pointed and curved downwards. In *H. spicatum* it is sometimes incurved.

Key to the species based on anatomical characters

1. Hairs on lamina more than 2 mm long; lamina more than 320 μm thick. ..
.....2
1. Hairs on lamina upto 1.5 mm long; lamina is upto 300 μm thick
.....3. **H. spicatum** var. **acuminatum**
2. Abaxial surface of midrib hairy; stomatal index 11
.....2. **H. flavescens**

2. Abaxial surface of midrib glabrous; stomatal index 15..1. **H. coronarium**

4. KAEMPFERIA L.

Kaempferia L., Sp. pl. 1: 2. 1753; M. Sabu, Zingiberaceae and Costaceae of S. India 208. 2006.

Rhizome highly aromatic; roots ending in fleshy tubers. Leafy stem short or absent. Leaves erect or spreading. Inflorescence terminal on the leaf shoot or on separate short peduncle. Flowers few to many, spirally arranged, bracteolate. Calyx tubular, unilaterally split. Corolla tube longer than the calyx. Labellum nearly flat, wider than long. Lateral staminodes petaloid, spreading. Anther sessile or with small filament; connective prolonged into a crest. Fruit an oblong capsule. Seeds sub-globose.

Distribution: The genus *Kaempferia* comprises approximately 60 species, distributed from tropical Africa to India, and throughout South East Asia. In South India 3 species are recognised.

Ecology: Commonly occur in swampy areas, in grass lands, teak forests and natural forest as undergrowth.

Key to the species based on morphological characters

1. Leaves oblong-lanceolate, erect; corolla tube 6.5-11 cm long.....2
1. Leaves ovate, spreading; corolla tube 4.5-5.5 cm long
..... 1. **K. galanga**

2. Inflorescence terminal; leaves green; labellum white; flowers opens at night 3. **K. scaposa**

2. Inflorescence separate from leaf shoot; leaves variegated with dark brown and green; labellum lilac with deep violet at the centre; flowers open during day 2. **K. rotunda**

1. Kaempferia galanga L., Sp. Pl. 1: 2. 1753; M. Sabu, Zingiberaceae and Costaceae of S. India 213. 2006. **(Plate 17 B)**

Rhizome crowded. Leafy shoot stemless. Leaves 2 or 3; lamina 10-15 x 6-10 cm, broadly ovate or orbicular, base rounded, tip broadly pointed, upper surface dark green, glabrous, lower surface pale green, densely hairy. Inflorescence terminal, sessile. Bracts bifarious. Bracteoles split to base. Corolla tube 4.5-5 cm long. Labellum broader than long, white with violet bands in basal half. Lateral staminodes white. Anther connective prolonged into a bilobed crest. Stigma globular.

Distribution: Native of India. Cultivated throughout India, Malesia, Africa, China and Sri Lanka. It is very rare and endangered in wild.

Specimen studied: **KERALA:** Malappuram Dt.: C. U. Botanical Garden, Jayasree 86567.

Anatomical features **(Fig. 61)**

Epidermis: Cells are large and polygonal in shape (80-96 x 48-64 μm). Cells of the adaxial epidermis are arranged more or less in definite rows but in the

abaxial epidermis cells are irregularly arranged. The epidermal cells of costal and intercostal regions are indistinguishable on both surfaces. The epidermis is covered by thick cuticle. The cuticle is characterised by striations radiating from the centre of each cell on the lower epidermis (Indira, 1976). On the upper epidermis the striations are parallel to each other.

Trichomes: Unicellular, wavy or twisted, long hairs are seen only on the lower epidermis. They are upto 1 mm long. The hairs are surrounded by 3 or 4 cells at the base. Hairs with biforcated tips are also present.

Stomata: Stomata are tetracytic with long axis of the guard cells parallel to the veins. Length of the guard cells varies from 44-56 μm . Stomata are abundant on the abaxial epidermis and very few on the adaxial epidermis (SI = 0.75). Stomatal Index for the abaxial epidermis is 12.91 which differ from the observations of Indira (1976) and Das *et al.* (2004), as they reported it to be 8.9 and 15.05 respectively.

Sheath: Both abaxial and adaxial surfaces are U-shaped. Hairs (upto 1.25 mm long) are present on the abaxial surface. Bundle arcs I, II and III are present. Air canals in between the bundles are very large. Oil cells are abundant. In the ground tissue cells numerous crystals are seen in groups.

Petiole: Abaxial surface is U-shaped in Transverse Section and adaxial surface is V-shaped. Bundle arcs I, II and III are present. Bundle arc I has

large air cavities between the bundles and cells bordering the air cavities contain chloroplasts.

Midrib: Abaxial surface is wide V-shaped to almost straight and adaxial surface is concave. Bundle arc I alone is present. Hairs on the abaxial surface are easily detachable. Very small air canals can be seen on either side of the median bundle.

Lamina: Lamina is 624 μm thick. Epidermal cells are broader than high (32 x 96 μm). They are much smaller than the hypodermal cells. 2 or 3 layers of hypodermis can be seen below the upper epidermis. Hypodermal cells are as high as or higher than broad (128-144 x 156-192 μm). Mesophyll tissue is 160 μm thick and consists of 1 layer of palisade and 2-4 layers of spongy cells. The vascular bundle has an upper and lower sclerenchymatous cap which is not connected to either of the epidermis. 2 or 3 layers of hypodermis is present abaxially, the cells of which are broader than high (64 x 128-160 μm) and some cells contain small and single crystal in it. The lower epidermal cells are smaller and broader than the upper ones. The thick cuticle and striations are visible in Transverse section and cuticle is slightly raised in the middle of the cell (papillae).

Margin: A single layered hypodermis is present both abaxially and adaxially. The portion beyond the last bundle consists of mesophyll cells and some colourless parenchyma cells. The tip is gradually tapering and almost straight. The hyaline portion is multiseriate (4-celled at the base) and 288 μm wide.

2. Kaempferia rotunda L., Sp. Pl. 1: 3. 1753; M. Sabu, Zingiberaceae and Costaceae of S. India 215. 2006. **(Plate 17 C)**

Rhizome short, stout. Leafy shoot 50-65 cm high. Leaves few, radical, erect; lamina 15-30 x 5-12 cm, oblong-lanceolate, base acute, apex gradually acuminate, purple beneath, mottled green above, lower surface densely covered with hairs; petiole 6-8 cm long. Inflorescence appears before leaves, shortly peduncled. Calyx light violetish. Corolla tube 6 or 7 cm long. Labellum broadly ovate, deeply divided into 2 lobes, lilac with deep violet in the centre. Lateral staminodes white with violet tinge towards margin. Filament short; crest broadly ovate, divided half way down into 2. Stigma slightly flattened, cupular.

Distribution: Wild in teak forests, grass lands and in swampy areas in natural forests in India, Malesia and Thailand. Commonly cultivated throughout India. In South India it is endangered.

Specimen studied: KERALA: Pathanamthitta Dt.: Kakkathode, *Prasanth Kumar* 86422.

Anatomical features **(Fig. 62)**

Epidermis: Intercostal cells of the adaxial epidermis are polygonal and broader than long (64-80 x 64-128 μm). Cells above the veins are small, rectangular, with their longer axis parallel to the veins (64-96 x 16-32 μm). Abaxial epidermal cells are polygonal (64-80 x 80-112 μm) and irregularly arranged. Cells above veins are rectangular and elongated, parallel to the

veins (48 x 80-176 μm); but they are not prominent as in upper epidermis.

Cuticular striations are seen on both upper and lower epidermis.

Trichomes: Long, wavy, unicellular hairs with pointed or blunt tip, which varies from 0.6-1.5 mm, are seen on the lower epidermis.

Stomata: Tetracytic and mainly seen on the abaxial epidermis, with stomatal index 11.12. [SI= 9.7 (Indira, 1976)]. Length of the guard cells varies from 52-60 μm [43 μm (Indira, 1976)]. Very few stomata are seen on the upper epidermis (SI = 0.31).

Sheath: Both abaxial and adaxial surfaces are U-shaped. On the abaxial surface 1.25 mm long hairs are seen. Bundle arcs I, II and III are present. Air canal is very large and it contains vascular tissue. 3 or 4 oil cells are found in the ground tissue, epidermis also possess oil cells. Metaxylem is 64-88 μm wide. Cells surrounding the bundles possess silica bodies.

Petiole: Abaxial surface is U-shaped in outline and adaxial surface wide V-shaped. Petiole wings narrow and pointed. Vascular systems I and III are present. Large air cavities are seen in between bundles of arc I and a few chlorenchymatous cells surround them. Oil cells and crystals (1/cell) are seen in the ground tissue and epidermis.

Midrib: Abaxial and adaxial surfaces are U-shaped. Easily detaching hairs are present on the abaxial surface. Two bundles of arc III are present above bundle arc I.

Lamina: Lamina is 320 µm thick. Adaxial epidermal cells are large and as high as broad or broader (48-80 x 64-96 µm). Cells above veins are much smaller. Abaxial epidermal cells are broader than high (32 x 64-80 µm). Both abaxial and adaxial hypodermis are present. Adaxial hypodermal cells are larger than epidermal cells (96-112 x 80-96 µm) and abaxial hypodermal cells (64 x 80 µm). Mesophyll tissue consists of 1-layered palisade and 2 or 3 layered spongy cells and is 112-144 µm thick. Adaxial cap is in contact with the upper epidermis. 1-few crystals are seen in the mesophyll cells.

Margin: Adaxial epidermal cells are much larger and as high as wide. Abaxial epidermal cells are smaller than upper ones. Cells above bundle are much smaller. Mesophyll is divided into 1-layered palisade and 2-layered spongy cells. Bundles are connected to the lower epidermis by 1 or 2 layered sclerenchyma cap. The tip of the margin is slightly pointed downwards. The portion beyond last bundle consists of mesophyll cells only. The hyaline portion is biseriate and 144 µm wide.

3. Kaempferia scaposa (Nimmo.) Benth. & Hook. f., Gen. Pl. 3: 642. 1884; M. Sabu, Zingiberaceae and Costaceae of S. India 219. 2006.

Hedychium scaposum Nimmo. in J. Graham, Cat. Bombay Pl. 205. 1839.

Monolophus scaposus Dalzell, Kew J. Bot. 2: 143. 1850. **(Plate 17**

D)

Leafy shoot erect, 60-70 cm high. Leaves 4-6, erect; lamina 20-25 x 5-8 cm, oblong-lanceolate, glabrous, green above, pale green beneath.

Inflorescence central; peduncle 40-45 cm long; spike 15-20 cm long. Bracts persistent, subtends a pair of flowers; flowers open during night. Calyx 3-toothed. Corolla tube 10-10.5 cm long, white. Labellum broad, bilobed, ovate, white. Lateral staminodes white. Filament short; anther spurred, connective prolonged into a sub-trapezoidal ciliated crest. Stigma turbinate.

Distribution: Karnataka, Goa and Maharashtra.

Specimen studied: **GOA:** North Goa Dt.: Desai Nagar, behind Govt. College, Sanqueilim, *Sabu 86407*.

Anatomical features

(Fig. 63)

Epidermis: Intercostal cells of the adaxial epidermis are polygonal, longer than broad (80-128 x 48-64 μm), with their longer axis perpendicular to the veins. Cells are irregularly arranged. Cells above veins are rectangular (16 x 64-96 μm) with their longer axis parallel to the veins. Cells of the abaxial epidermis are usually polygonal (48-80 x 32 μm) and irregularly arranged. Cells above veins are small and isodiametric and distinguishable from the rest.

Trichomes: Unicellular hairs of about 250 μm long are present on the upper epidermis.

Stomata: Tetracytic, with the longer axis of the guard cells parallel to the veins. They are abundant (stomatal index 14.27) on the abaxial epidermis in between the veins. Stomata are seen on the upper epidermis also, but the

number is less with stomatal index 5.43. Size of the guard cells ranges from 32-40 μm with an average of 36 μm .

Sheath: Abaxial surface is V-shaped and wavy in outline. Adaxial surface is U-shaped. Bundle arcs I, II and III are present. Air canals are large. Cells of the ground tissue possess numerous crystals in groups.

Petiole: Abaxial surface is U-shaped and adaxial surface is V-shaped in outline. Wings are narrow and pointed. Bundle arcs I, II and III are present. Large air canals are seen in between the bundles of arc I. Cells of the ground tissue contain numerous crystals.

Midrib: Abaxial surface is V-shaped in outline, adaxial surface is slightly grooved. Bundle arcs I and III are present. Cells of the ground tissue contain numerous crystals in them.

Lamina: Lamina is 208-224 μm thick (240 μm at the bundle). Cells of the adaxial epidermis are broader than high (32 x 80 μm). Abaxial epidermal cells are smaller than upper ones (16-30 x 32-64 μm). Hypodermis is completely absent. Cells above and below bundles are smaller than the rest. Mesophyll tissue is divided into 1-layered palisade and 3 or 4 layered spongy tissue and is 170 μm thick. Large bundles have 1 or 2 layered sclerenchymatous bundle caps which are in contact with both upper and lower epidermis. Smaller bundles are surrounded by thick walled cells and are embedded in the mesophyll tissue.

Margin: Upper epidermal cells are broader than high. Tip is almost straight or slightly bent downwards. The portion beyond last bundle consists of mesophyll cells and a few colourless parenchyma cells. Metaxylem of the last bundle is 16 μm wide. Mesophyll tissue is composed of 1-layered palisade and 2 or 3 layered spongy cells. Hyaline portion is mutiseriate (4-celled at the base) and 96-112 μm wide.

KAEMPFERIA: COMPARATIVE ANATOMY (Fig. 64)

Adaxial epidermal cells are hexagonal and transversely stretched in most of the species of Zingiberaceae but they are longitudinally stretched in *Kaempferia* spp. (Tomlinson, 1956). Out of the 3 taxa studied *K. rotunda* shows longitudinally stretched epidermal cells. The presence of cuticular striations on the epidermis of *K. galanga* is reported earlier (Indira, 1976; Sabu, 1991). Achra and Lakoet (2002) emphasized the role of cuticular architecture on leaf surface and papillose epidermis should be useful for identification of *Kaempferia* spp. Oil cells in the upper epidermis have been seen only in *Kaempferia* spp. (Tomlinson, 1956). This was recorded by Solereeder and Mayer (1930) also. In the present study upper epidermis of *K. rotunda* showed the presence of oil cell.

The type of hair in *Kaempferia* is 'Weichhaare' (Soft or delicate hair) which is defined as unicellular, simple, blunt or pointed hair (Staudermann, 1924). The distinctive feature of this type of hair is that they get easily detached at the slight constriction of wall and lumen at the surface of leaf.

They are thin walled and the lumen of the hair extends upto the tip. This type of hair is seen in *K. rotunda* and *K. galanga* and the hair may be upto 2 mm long. But in *K. scaposa*, 'Borste' (Bristle) type of hair is seen on the adaxial surface of the leaf. They are 1-celled, cylindrical, pointed, stout hairs. This type of hair is usually seen in other genera like *Curcuma*, *Cautleya*, *Elettaria*, *Alpinia*, *Roscoea* etc. The wall is much thicker and uneven, reducing the lumen considerably.

Usually *Kaempferia* is characterised by the presence of upper and lower hypodermis but in *K. scaposa* hypodermis is completely absent which is similar to *K. kirkii* (Tomlinson, 1956). Bundles in the lamina are generally buttressed to the abaxial epidermis in most species of Zingiberaceae, but bundle is buttressed to adaxial epidermis only (*K. rotunda*) or to both epidermis as in *K. scaposa*.

Anatomical studies of *Kaempferia* by Hussin *et al.* (2001) suggest that the unthickened midrib of *K. galanga* can be easily distinguished from other two species studied, whose midrib is wide V-shaped abaxially.

Petioles of all the three species studied have similar shape and structure. Studies by Hussin *et al.* (2001) differentiate *Kaempferia* from *Boesenbergia* by the presence of arc II bundles in the petioles of the latter. In *K. rotunda*, arc II is absent but in *K. galanga* arc II is represented by 2 bundles and in *K. scaposa* by 6 or 7 bundles.

The 3 taxa studied belong to the 3 different sections of the genus. Section *Kaempferia* Benth. includes *K. galanga*, section Protanthium (Horan.) Benth. includes *K. rotunda*, while section *Stachyanthesis* Benth. is typified by *K. scaposa*. The first two sections share some common characters like type of hair and presence of hypodermis; but the third section is entirely different in having 'Bristle' type hair and absence of hypodermis.

K. scaposa was originally described as a species of *Hedychium* by Nimmon in 1839 and subsequently it was transferred to *Monolophus* by Dalzell in 1850. Bentham and Hooker (1884) again transferred to *Kaempferia*. Present anatomical studies have proved that it shows similarities to *Curcuma* than any of the former genera.

This species differs from the genus *Kaempferia* in having distinct costal and intercostal cells on epidermis and their regular arrangement. Presence of hypodermis and cuticular striations, characteristic for the genus are absent in this species. Vascular bundles of the leaf are in contact with both upper and lower epidermis, whereas they are not in contact with either of the epidermis in other two species studied.

It shows some similarities with *Hedychium* in floral characters. Anatomically it is similar to *Hedychium* in the nature and arrangement of epidermal cells (distinct costal and intercostals cells). The differences between the two are as follows.

In *K. scaposa*, costal cells of the adaxial epidermis are broader and regularly arranged, whereas in *Hedychium*, costal cells are very small, usually as high as broad and irregularly arranged. Bristle type of hair is seen on the adaxial leaf epidermis of *K. scaposa*, while in *Hedychium*, soft and delicate hairs present on the abaxial leaf surface. Intercostal cells of the abaxial leaf epidermis are more or less regularly arranged in *K. scaposa*, whereas *Hedychium* shows irregular arrangement of the intercostals cells.

K. scaposa is more closer to *Curcuma* than other genera. The similarities include:

- The arrangement of epidermal cells into definite, smaller costal cells and longer intercostal cells.
- 'Bristle' type of hair having thick walls and narrow lumen.
- Absence of hypodermis as in some species like *C. vamana* and *C. oligantha* var. *oligantha*.

Key to the species based on anatomical characters

1. Abaxial surface hairy, hairs 0.5-2 mm long; adaxial surface glabrous; hypodermis present in the lamina 2
1. Abaxial surface glabrous; adaxial surface hairy, hairs less than 0.5 mm long; hypodermis absent in the lamina. 3. **K. scaposa**

2. Leaves oblong-lanceolate; arc II bundles absent in the petiole; leaf margin without adaxial and abaxial hypodermis; hyaline portion biseriate; 144 μm wide 2. **K. rotunda**
2. Leaves ovate-orbicular; arc II bundle present in the petiole; leaf margin with adaxial and abaxial hypodermis; hyaline portion multiseriate, 288 μm wide1. **K. galanga**

5. ZINGIBER Boehm.

Zingiber Boehm. in Ludwig, Defin. Gen. Pl. 89. 1760; Roxb., Fl. Indica 1: 46. 1820; M. Sabu, Zingiberaceae and Costaceae of S. India 225. 2006.

Rhizome fleshy, highly aromatic, coloured. Leaves sessile or shortly petiolate, ligulate; lamina oblong-lanceolate. Inflorescence borne on separate leafless shoot or rarely terminal; spike ovoid or cylindrical. Bracts large, imbricating, persistent, each subtends a single flower. Bracteoles one for each flower, persistent. Calyx tubular, 3-lobed. Corolla tube cylindrical, as long as the bract, 3-lobed; dorsal lobe broader, erect. Labellum deeply 3-lobed, apex emarginate. Filament short; connective prolonged into a slender, beak-like structure. Stigma projecting just below the apex of the crest. Fruit enclosed within persistent bract and bracteole, dehiscing loculicidally. Seeds many.

Distribution: About 141 species, widely distributed throughout India, Malesia, Queensland, Japan, East Indies, Java, New Guinea, Thailand, China *etc.*

Ecology: Majority of the species are seen in the dense forests and grass lands of tropical areas, at high altitude. Some species grow in plains also.

Notes: *Zingiber* is easily distinguishable by the presence of pulvinus at the base of petiole. Anatomically bundle sheaths of this region is collenchymatous (Tomlinson, 1956) where as in other Zingiberaceous genera the bundle sheath are sclerenchymatous.

Key to the species based on morphological characters

- 1. Spike terminal on leafy stem.....1. **Z. captatum** var. **elatum**
- 1. Spike lateral, from the base of the leafy stem.....2
- 2. Peduncle short, 1-8 cm long or absent.....3
- 2. Peduncle long, 10-50 cm.4
- 3. Leaves linear, 5-6 cm wide; peduncle 4-8 cm long; labellum yellow orange, heavily marked deep purple-red6. **Z. wightianum**
- 3. Leaves broader, 8-15 cm wide wide; peduncle 0.5-3 cm, long; labellum yellow with purple spots.....4. **Z. nimmonii**
- 4. Ligule 2.5-3.5 cm long; labellum pale yellow, unspotted.....7. **Z. zerumbet**
- 4. Ligule 2-4 mm long; labellum yellowish white or dark purple spotted.....5
- 5. Lamina broad, 5-7 cm wide; labellum 3 lobed, yellowish white.....
.....2. **Z. montanum**

5. Lamina narrower, 1.5-3.5 cm wide; labellum purple spotted.....6

6. Spike 4-7 x 2-3 cm, ovoid.5. **Z. officinale**

6. Spike 8-20 x 1-1.5 cm, cylindrical.....3. **Z. neesatum**

1. Zingiber capitatum Roxb. var. **elatum** (Roxb.) Baker in Hook. f., Fl. Brit.

India 6: 249. 1692; M. Sabu, Zingiberaceae and Costaceae of S. India 229. 2006.

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

(Plate 17

E)

Rhizome thick, yellow inside, aromatic, root tubers oblong. Plants 1.5-2 m high. Leaves 30-45 × 2-3.5 cm, linear, glabrous above, minutely hairy on lower side. Spike terminal. Bracts green with red margins. Bracteoles 2-keeled. Flowers pale yellow. Calyx white. Corolla tube deep yellow. Labellum deep yellow, tip bilobed. Anther yellow; beak equal to the anther lobes. Stigma funnel-shaped with ciliate margin. Capsule 3-sided, smooth, bright red. Seeds black, aril white.

Distribution: This taxon is so far reported only from Bihar and Bengal (Jha & Varma, 1995) and Sikkim (Kumar, 2001). Sabu (2006) recorded this for the first time from South India.

Specimen studied: JHARKHAND: Sahibganj Dt.: Paharpur forest, Jana *Sckornickova* 73466. (No specimens from South India were available for the present study).

Anatomical features

(Fig. 65)

Epidermis: Cells of the adaxial epidermis polygonal (80 x 32-64 μm), with their longer axis perpendicular to the longitudinal veins. Cells above the veins are smaller (16-32 x 64-80 μm) and their longer axis is parallel to the longitudinal veins. Cells of both the costal and intercostal region are arranged in regular files. Some of the epidermal cells contain a single, large crystal. Cells of the abaxial epidermis are polygonal and smaller than upper ones (32-64 x 32-64 μm). Cell files are indistinguishable. Cells above veins are regularly arranged with their longer axis parallel to the longitudinal veins (32 x 48-80 μm). Cells of the abaxial epidermis also contain single large crystal in them.

Trichomes: Simple unicellular hairs are seen on the abaxial epidermis; adaxial surface is glabrous. Length of the hair is 500-880 μm . Tip of the hair is pointed.

Stomata: Tetracytic stomata are abundant on the abaxial epidermis, they are distributed randomly in between the veins. The longer axis of the guard cell is parallel to the longitudinal veins. Length of the guard cell may vary from 56-60 μm . Stomatal Index for abaxial epidermis is 15.80 and that of adaxial epidermis is 1.31.

Sheath: Abaxial surface is wide V-shaped and adaxial surface is wide U-shaped. Epidermal cells are as high as or slightly broader. Bundle arcs I, II and III (2 bundles) are present. Metaxylem is 80 μm wide. Oil cells are rare.

Petiole: Both abaxial and adaxial surfaces are wide V-shaped. Abaxial surface is densely hairy (0.25 mm long). Epidermal cells are broader than high. Bundle arcs I, II and III are present. Oil cells are abundant. 1-few crystals are also seen.

Midrib: Abaxial surface is wide V-shaped; adaxial surface wide U-shaped. Bundle arcs I and III are present. Hairs are seen on the abaxial epidermis. One small crystal is seen in the cells of ground tissue.

Lamina: Lamina is 320 μm thick. Cells of the adaxial epidermis are broader than high (32-48 x 64-80 μm). Cells above the veins are much smaller. Cells of the abaxial epidermis are much smaller than upper ones (32-48 x 16-32 μm). Mesophyll is 60 μm thick, divisible into 2 or 3 layered palisade and 3-layered spongy. Sclerenchymatous cap of main bundle is in contact with both adaxial and abaxial epidermis. Sclerenchyma of the smaller bundle is attached to the abaxial epidermis only. But a few sclerenchyma cells can be seen just below the adaxial epidermis opposite to these bundles. Hypodermis is completely absent.

Margin: Cells of the adaxial epidermis broader than high. Cells of abaxial epidermis smaller are than upper ones. Hypodermis like layer may be seen towards the tip. Mesophyll consists of 2 or 3 layered palisade and 3-layered spongy. Portion beyond the last bundle consists of mesophyll and few parenchymatous cells. The tip is gradually tapering, blunt and slightly curved. Hyaline portion is multiseriate (4-celled at the base) and 256 μm wide.

2. Zingiber montanum (K.D. Koenig) Link ex Dietr., Sp. Pl. 1: 52. 1831; M. Sabu, Zingiberaceae and Costaceae of S. India 231. 2006.

Amomum montanum K.D. Koenig in Retz. Observ. 3: 51. 1783. **(Plate 17 F)**

Rhizome yellow inside. Leafy shoot 1-1.5 m high. Leaves subsessile; ligule membranous, c. 2 mm long. Lamina 20-40 x 5-7 cm, oblong-lanceolate, tip acute, base slightly rounded, upper surface glabrous, lower surface pubescent. Inflorescence borne separately from the leafy shoot; peduncle 10-25 cm. Spike 6-8 x 4 cm, ovate, purple. Bracts broadly ovate, purplish brown, pubescent. Calyx truncate. Corolla tube pale yellow, lobes lanceolate; dorsal lobe cymbiform. Labellum sub-orbicular, 3-lobed, apex emarginate with crisp margins, yellowish white, lateral lobes erect. Ovary pubescent. Capsule c. 1.5 cm long, ovoid. Seeds very small, purple.

Distribution: Native of India, seen throughout in India, Malay Peninsula and Java. Cultivated widely in tropical Asia. In South India, it is reported from all four states.

Specimen studied: ORISSA: Rayagarh, 20 km towards Koraput, *Jana Sckornickova* 73429. (No specimens from South India were available for the present study).

Anatomical features

(Fig. 66)

Epidermis: Cells of the adaxial epidermis polygonal (48-64 x 32-64 μm) and as high as broad or slightly higher. Cells above the veins are smaller (16-32 x 32-64 μm) with their longer axis parallel to the longitudinal veins. The cell

files are regular. Intercostal cells of the abaxial epidermis are similar to the upper ones in their size and the cell files are indistinguishable. Cells above the veins are arranged in regular files with their longer axis parallel to the longitudinal veins (16-32 x 48-80 μm).

Trichomes: Simple unicellular hairs are seen on the abaxial epidermis, whose length varies from 800 μm -1.25 mm.

Stomata: Tetracytic stomata are abundant on the abaxial epidermis; the longer axis of the guard cell is parallel to the longitudinal vein. The average length of the guard cell is 44 μm . Stomatal index is 11.44. Few stomata are seen on the adaxial epidermis also (SI = 2.3).

Sheath: Abaxial and adaxial surfaces are wide U-shaped. Abaxial surface towards the tip possess 320-640 μm long hair. Epidermal cells are as high as broad. Bundle arcs I, II and III are present. Oil cells are abundant in the ground tissue. 1-4 crystals are seen in the chlorenchyma cells.

Petiole: Abaxial surface is wide U-shaped and adaxial surface is wide V-shaped. Hairs upto 1 mm long, are present on both surfaces. Bundle arcs I, III and IV are present. Bundle sheath is collenchymatous. Numerous oil cells are seen in the ground tissue. Some cells of the ground tissue and chlorenchymatous cells contain 1-few crystals.

Midrib: Abaxial surface is wide V-shaped and adaxial surface is concave. Bundle arcs I and III are present. Oil cells are seen in the ground tissue of the midrib.

Lamina: Lamina is 160 μm thick. Cells of the adaxial epidermis are broader than high (32 x 48-64 μm). Cells above the veins are much smaller. Cells of abaxial epidermis are smaller than upper ones (16-24 x 32 μm). Mesophyll consists of 1-layered palisade and 2 or 3 layered spongy and is 64 μm thick. A continuous hypodermis is absent, but a few colourless hypodermis like cells can be seen on either side of the bundle. The sclerenchymatous cap of the bundle is in contact with both upper and lower epidermis. Some of the lowest mesophyll cells contain 1 large or small crystals.

Margin: Cells of the adaxial hypodermis broader than high; abaxial epidermal cells much smaller than upper ones. 1-layered palisade and 2 or 3 layered spongy cells constitute the mesophyll tissue. Hypodermis is absent on both surfaces. Bundles towards tip are connected to the abaxial epidermis only. The portion beyond last bundle consists of mesophyll and a few parenchymatous cells. The tip is gradually tapering and bent downwards. Hyaline portion is multiseriate (4-celled at the base) and 208 μm long.

3. Zingiber neesatum (J. Graham) Ramamoorthy in Saldanha & Nicolson, Fl. Hassan Dist., 769. 1976; M. Sabu, Zingiberaceae and Costaceae of India 235. 2006.

Alpinia neesana J. Graham, Cat. Pl. Bombay 207. 1839. **(Plate 18 A)**

Rhizome creeping just below the soil surface, yellow inside; root tubers fusiform. Leafy shoot 60-120 cm tall, enclosed within reddish-green

vegetative bracts. Leaves shortly petiolate; ligule short, 2-3 mm long; lamina 15-25 x 2.3-3.5 cm, linear, oblong-lanceolate, base equal. Inflorescence separate from leafy shoot; peduncle 15-30 cm; spike 8-20 x 1-1.5 cm, cylindrical, tapering to a narrow apex. Bracts reddish green. Calyx tubular, split on one side. Corolla tube slender. Labellum equal to or slightly shorter than lateral corolla lobes, obovate, white with pink or purple spotted and striped. Filament short, connective has violet stripes on upper surface. Stigma with an apical circular aperture. Fruit ellipsoid or sub-globose, 3-valved. Seed deep purple to black.

Distribution: Endemic to peninsular India. It is reported from Maharashtra, Karnataka and Kerala.

Specimen studied: KERALA: Idukki Dt.: Munnar, *Vasantha* 103205.

Anatomical features

(Fig. 67)

Epidermis: Cells of the adaxial epidermis polygonal (48-80 x 32-48 μm) with their longer axis perpendicular to the longitudinal veins. Cells above the veins are smaller than the intercostal cells (32 x 32 μm). Both intercostal and costal epidermal cells are arranged in regular cell files. Cells of the abaxial epidermis polygonal, smaller and less stretched than the upper ones (32-64 x 16-48 μm). Cells above the veins are smaller than the rest of the cells. Some cells contain crystal inside them.

Trichomes: Unicellular hairs upto 1 mm long are present on the abaxial and adaxial surface of petiole.

Stomata: Tetracytic stomata are seen on the abaxial epidermis, which are evenly distributed between the veins. Average length of the guard cell is 40 μm . Stomatal index is 8.82. Very few stomata are seen on the adaxial epidermis also (SI = 1.36).

Sheath: Abaxial surface is wide V-shaped and adaxial surface is wide U-shaped. Bundle arcs I, II and III are present, arc III is represented by a single bundle. Metaxylem is 60 μm wide. Very few cells of the ground tissue possess 1-few crystals in groups.

Petiole: Abaxial surface of the petiole is wide U-shaped, adaxial surface is V-shaped. Unicellular trichomes which may be upto 1 mm long are seen mainly on the abaxial surface. Few hairs can be seen on the adaxial surface also. Bundle arcs I, III and IV are present in the petiole.

Midrib: Abaxial and adaxial surfaces are wide U-shaped. Bundle arcs I and III are present.

Lamina: Lamina is 176 μm thick. Cells of the adaxial epidermis are slightly broader than high (32 x 32-48 μm). Cells above the veins are much smaller. Cells of the lower epidermis are smaller than upper ones (16-32 x 16-32 μm). Mesophyll is 80 μm thick and consists of 1-layered palisade and 2 or 3 layered spongy tissue. Bundle cap is in contact with both abaxial and adaxial epidermis. Hypodermis is completely absent.

Margin: Cells of the upper epidermis are as high as broad. Upper palisade is 1-layered and lower spongy is 2 or 3 layered. The portion beyond the last bundle consists of mesophyll only. The tip is gradually tapering, pointed and bent downwards. Hyaline portion is biseriate and 128-144 μm wide.

4. Zingiber nimmonii (J. Graham) Dalzell in Hook., Kew J. Bot. 4: 341. 1852; M. Sabu, Zingiberaceae and Costaceae of S. India 237. 2006.

Alpinia nimmonii J. Graham, Cat. Pl. Bombay 206. 1839. **(Plate 18 B)**

Rhizome small, purplish lilac inside, strongly aromatic; root tubers present. Leafy shoot 60-90 cm high, clothed by greenish or reddish bracts. Leaves almost sessile or shortly petiolate; ligule bilobed, coriaceous; lamina 20-25 x 8-10 cm, oblong-lanceolate, tip acuminate, base oblique, upper surface dark green, lower surface densely pubescent. Inflorescence produced directly from the rhizome; peduncle very short (0.5-3 cm) or absent; spike ovate or sub-globose. Bracteoles small, shortly trilobed.

Flowers c. 5.5 cm long. Calyx unilaterally split. Corolla tube slender. Labellum shorter than corolla lobes, light yellow with purple spots. Lateral staminodes half as long as mid-lobe, deep yellow with purple red spots. Anther sessile. Fruit trigonous, exceeding bracts, whitish when young, turning deep red at maturity; seeds, 7-8 mm long, dark red, striate.

Distribution: Endemic to peninsular India; reported to occur in Karnataka, Kerala, Maharashtra and Tamil Nadu.

Specimen studied: KERALA: Idukki Dt.: Munnar, *Vasantha 103203*.

Anatomical characters

(Fig. 68)

Epidermis: Cells of the upper epidermis are polygonal (64-96 x 32-48 μm) with their longer axis stretched perpendicular to the longitudinal veins. Cells above the veins are much smaller (16-32 x 16-32 μm). Both costal and inter costal cells are arranged in regular files. Cells of the lower epidermis are polygonal, smaller than upper ones and less stretched (48-64 x 16-48 μm). Cells above the veins are indistinguishable. Cell files are not clear.

Trichomes: Unicellular trichomes are seen on the lower epidermis, whose length may vary from 800 μm -1.5 mm.

Stomata: Tetracytic stomata are randomly distributed on the abaxial epidermis. Average length of the guard cell is 40 μm . Stomatal index is 6.83. Stomata are very rare on the upper epidermis (SI < 1).

Sheath: Abaxial and adaxial surfaces are wide U-shaped. Bundle arcs I, II and III are present. Cells of the ground tissue possess either a single large crystal or few crystals in groups. Metaxylem is 80 μm wide.

Petiole: Both abaxial and adaxial surfaces are wide U-shaped. Petiole wings are broad and blunt. Bundle arcs I, III and IV are present in the petiole.

Midrib: Both abaxial and adaxial surfaces are wide U-shaped. Bundle arcs I and III are present.

Lamina: Lamina is 160-176 μm . Cells of the adaxial epidermis are broader than high (32 x 48-64 μm). Cells above veins are much smaller and as high as broad. Abaxial epidermal cells are smaller than upper ones (16-32 x 32 μm). Mesophyll consists of 1-layered palisade and 3-layered spongy cells and is about 80 μm thick. Hypodermis is absent. Sclerenchymatous bundle cap is in contact with both abaxial and adaxial epidermis.

Margin: Cells of the upper epidermis are broader than high. 1-layered palisade and 2 or 3 layered spongy cells constitute the mesophyll tissue. The portion beyond last bundle consists of mesophyll cell and very few parenchyma. The tip is gradually tapering, pointed and curved downwards. Hyaline portion is biseriate and 128-144 μm wide.

5. Zingiber officinale Roscoe, Trans. Linn. Soc. London 8: 348. 1807; M. Sabu, Zingiberaceae and Costaceae of S. India 241. 2006. **(Plate 18**

C)

Rhizome thick, palmately lobed, greyish-yellow within, smell pungent. Leafy shoot c. 1 m high. Leaves sessile; pulvinus prominent, ligulate; ligule 2-4 mm; lamina 25-30 x 1.5-2 cm, narrowly lanceolate, acuminate, base attenuate, lower surface hairy, upper glabrous. Inflorescence lateral; peduncle 15-25 cm long; spike 4-8 x 2-3 cm long, ovoid. Bracts green with pale margin, lower ones mucronate, turning red at maturity. Flowers longer than the bracts. Corolla tube included within the bract, lobes equal. Labellum more or less round; dark purple spotted. Lateral staminodes smaller. Anther connective yellow, prolonged into a 5-8 mm long, dark purple crest. Stigma white.

Distribution: Cultivated in tropical countries throughout the world. In South India it is widely cultivated in all districts. Some wild forms occur in evergreen forests of Kerala.

Specimen studied: **KERALA:** Malappuram Dt.: C. U. Botanical Garden, *Jayasree 103016*.

Anatomical characters

(Fig. 69)

Epidermis: Epidermal cells of the adaxial surface are polygonal (48-64 x 32-48 μm) with their longer axis perpendicular to the longitudinal veins. Cells above the veins are rectangular (16 x 32-64 μm) and are stretched parallel to the veins. Cells of both costal and intercostal regions are arranged in regular files. Cells of the abaxial epidermis are polygonal and less stretched than upper ones (32 x 32 μm). Cells above the vein are rectangular and

stretched parallel to the veins (16 x 32-96 μm). Costal and intercostal region are very clear on both surfaces. Single large crystal can be seen in the epidermal cells.

Trichomes: Simple, unicellular, long, soft hairs are seen on the lower epidermis. The hairs are upto 0.75 mm long.

Stomata: Tetracytic stomata are abundant on the lower epidermis. Stomata are evenly distributed between the veins. The average length of guard cell is 36 μm . Stomatal index is 6.40. A few stomata can be seen on the upper epidermis also (SI = 1.60).

Sheath: Abaxial surface is wide V-shaped and slightly wavy in outline. Bundle arcs I, II and III are present. Arc III is represented by 1 or 2 bundles which are often fused with the bundles of arc I. Metaxylem of arc I is 40-60 μm wide. Oil cells are abundant in the ground tissue, epidermis also bear oil cells. Cells surrounding the bundles and the chlorenchyma cells possess either single or few crystals in groups.

Petiole: Abaxial surface of the petiole is U-shaped and adaxial surface is concave. Few hairs, upto 1 mm are present on both adaxial and abaxial surfaces. Bundle arcs I, II, III and IV are present. Oil cells are abundant in the ground tissue. 1-many crystals can also be seen in the ground parenchyma and chlorenchymatous cells. Bundle sheath is made up of collenchyma cells, which is a very unique feature.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is wide V-shaped. Bundle arcs I and III are present. 1-few crystals can be seen in the ground parenchyma and chlorenchymatous tissue.

Lamina: Lamina is 160 μm thick. Adaxial epidermal cell are broader than long (20-32 x 32-48 μm). Abaxial epidermal cells are smaller than upper ones (16-20 x 32 μm). Mesophyll is 64 μm thick and is composed of 1-layered palisade and 2 or 3 layered spongy. Hypodermis is present abaxially. Bundle cap of large bundle is in contact with both abaxial and adaxial epidermis whereas smaller bundles are connected to the abaxial epidermis only.

Margin: Adaxial epidermal cells are as high as broad or slightly broader than high. Abaxial epidermis is as high as broad. Crystals can be seen in the hypodermis. Palisade is 1-layered and spongy cells consist of 3 layers. Portion beyond last bundle consists of mesophyll cells only. Tip is tapering and bent downwards. Hyaline portion is biseriate and 96-128 μm wide.

6. Zingiber wightianum Thwaites, Enum. Pl. Zey. 315. 1861; M. Sabu, Zingiberaceae and Costaceae of S. India 245. 2006. **(Plate 18 D)**

Rhizome fleshy. Leafy shoot c. 1.2 m high. Leaves sessile; ligule 5-6 mm long, membranous, bifid; lamina 15-35 x 5-6 cm, oblong-lanceolate, tip acuminate, lower surface pubescent, upper surface glabrous. Inflorescence radical, peduncle 4-8 cm long; spike c. 9 x 6 cm, ovate or oblong. Bracts greenish red, pubescent. Calyx green with red markings. Corolla tube longer

than calyx, yellowish green, pubescent. Corolla lobes equal, acuminate, yellow orange. Labellum c. 3 cm long, cuneate, obovate, emarginate, yellow-orange, heavily marked deep purple red. Lateral staminodes c. 1 cm long. Stamen shorter than the lip, connective prolonged into dark purple-red beak. Ovary c. 5 mm long, slightly pubescent. Fruit c. 2.5 cm long, oblong, red. Seeds black with white aril.

Distribution: Occurs in Southern Peninsular India and Sri Lanka.

Specimen studied: **TAMIL NADU:** Coimbatore Dt.: Anamalai, *Sanoj & Jayasree 95656*.

Anatomical features

(Fig. 70)

Epidermis: Cells of the adaxial epidermis are polygonal (96-128 x 16-48 μm) with their longer axis stretched perpendicular to the longitudinal veins. Cells above the veins are much smaller and almost square. Both intercostal and coastal cells are arranged in regular files. Cells of the abaxial epidermis are polygonal (48-64 x 32 μm) with their longer axis perpendicular to the longitudinal vein but less stretched than the upper ones. The cell files are less regular. Cells above the veins are smaller with their longer axis parallel to the longitudinal veins (16 x 32-48 μm). Single large crystals can be seen in the abaxial epidermal cells.

Trichomes: Unicellular, simple, trichomes that are 640 μm -1.2 mm long are seen on the abaxial epidermis. Adaxial epidermis is glabrous.

Stomata: Tetracytic stomata are present on the lower epidermis. The longer axis of the guard cell is parallel to the longitudinal veins. The average length of the guard cell is 44 μm . Stomatal index is 8.72. Very few stomata can be seen on the adaxial epidermis also (SI = 1.53).

Sheath: Both abaxial and adaxial surfaces are wide U-shaped. Abaxial surface possess 0.5 mm long hairs. Bundle arcs I, II and III are present. Metaxylem is 52-80 μm wide. Oil cells are seen in the ground tissue. Some cells of the ground tissue contain 1 or 2 crystals.

Petiole: Abaxial surface is wide U-shaped and adaxial surface is concave, edges round. 800-960 μm long hairs can be seen on the abaxial surface. Bundle arcs I, III and IV are present. 1 or 2 crystals can be seen in most cells of the ground tissue. 6-8 oil cells are seen in the petiole.

Midrib: Both abaxial and adaxial surfaces are U-shaped. 0.7 mm long hairs can be seen on the abaxial surface. Bundle arcs I and III are present.

Lamina: Lamina is 256 μm thick. Cells of the adaxial epidermis are broader than high (64 x 80-112 μm). Cells above the veins are much smaller. Cells of the abaxial epidermis are smaller than the upper ones (32-48 x 48-64 μm). Hypodermis is present above the abaxial epidermis only. 1 large crystal is seen in the hypodermal cells. Mesophyll is 128 μm thick and is composed of single layered palisade and 3 or 4 layered spongy tissue. 1 or 2 small crystals can be seen in the spongy cells. Sclerenchymatous cap of the

bundle is in contact with the adaxial and abaxial epidermis, while smaller bundles are connected to the abaxial epidermis only.

Margin: Cells of the adaxial epidermis are broader than high. Cells of the abaxial epidermis are smaller than upper ones. 1-layered palisade and 3-layered spongy constitute the mesophyll tissue. Bundle is connected to the abaxial epidermis only. Hypodermis is present abaxially. The portion beyond the last bundle consists of few parenchymatous and chlorenchymatous cells. The tip is gradually tapering, pointed and bent. Hyaline portion is biseriate (except for the three cells at the beginning) and 288-304 μm wide.

7. Zingiber zerumbet (L.) Smith, Exot. Bot. 2: 105, t. 112. 1806; M. Sabu, Zingiberaceae and Costaceae of S. India 247. 2006.

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

(Plate 18

E)

Rhizome large, 10-15 x 4 cm, light yellow inside. Leafy shoot 1-2 m high. Leaves shortly petiolate; petiole 4-5 mm long; ligule 2.5-3.5 cm long, membranous, entire; lamina 10-35 x 5-10 cm, oblong-lanceolate, tip acuminate, upper surface glabrous, lower surface pubescent. Inflorescence lateral; peduncle 20-25 cm long; globose or oblong. Bracts c. 3 x 5 cm, ovate-obovate, green. Flowers larger than bracts, c. 5 cm long. yellow. Corolla as long as the bracts, white; dorsal lobe large. Labellum pale yellow, dark yellow towards the centre, margin highly crumpled, unspotted; mid-lobe

emarginate. Fruit c. 1.5 cm long, white with persistent calyx. Seeds many, black, glabrous.

Distribution: Widely distributed throughout India, Malay Peninsula and Java, Grown extensively in Sri Lanka and other countries. This species is supposed to be native of India (Holttum, 1950).

Specimen studied: KERALA: Malappuram Dt.: C. U. Botanical Garden, *Jayasree 86145*.

Anatomical features

(Fig. 71)

Epidermis: Cells of the adaxial epidermis are polygonal (64-96 x 32-48 μm) with their longer axis perpendicular to the longitudinal veins. Cells above the veins are much smaller, not stretched (16-32 x 16-32 μm). Both costal and intercostal cells are arranged in regular files. Cells of the abaxial epidermis are polygonal, less stretched (32-48 x 32 μm) and cell files are not clear. Cells above the veins smaller and slightly stretched parallel to the veins. Some of the epidermal cells contain single large crystals.

Trichomes: Simple, unicellular hairs upto 800 μm long are seen on the abaxial epidermis of leaf.

Stomata: Tetracytic stomata are distributed randomly in between the veins of the abaxial epidermis. Average length of the guard cell is 36 μm . Stomatal index is 10.17. Stomata are frequent on the adaxial epidermis also (SI = 1.52).

Sheath: Both abaxial and adaxial surfaces are wide V-shaped. Numerous hairs (0.5 mm long) are seen on the abaxial surface. Bundle arcs I and II are present.

Petiole: Adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II, III and IV are present. Upto 0.5 mm long hairs are seen on both abaxial and adaxial surfaces.

Midrib: Abaxial surface is wide U-shaped and adaxial surface is grooved. Bundle arcs I, II and III are present.

Lamina: Lamina is 256 μm thick. Cells of the adaxial epidermis are twice broader than high (32 x 80-96 μm). Cells above the veins are much smaller. Abaxial epidermal cells are much smaller than upper ones (32 x 48-64 μm). Mesophyll consists of 1 or 2 layered palisade and 3-5 layered spongy cells and is 144 μm thick. Hypodermis is present only above the abaxial epidermis. Sclerenchymatous cap of the main bundle is in contact with both adaxial and abaxial epidermis. Sclerenchymatous cap of the smaller bundle is in contact with lower hypodermis only. One large crystal can be seen in the lower spongy cells.

Margin: Cells of the adaxial epidermis are as high as or broader than high. Abaxial epidermal cells are smaller than upper ones. 1-layered palisade tissue and 2 or 3 layered spongy cells constitute the mesophyll. Abaxial hypodermis is present. Crystals are seen in the lower hypodermal and lower

epidermal cells. Tip is gradually tapering, pointed and bent downwards. Hyaline portion is biseriate and 288 μm wide.

ZINGIBER: COMPARATIVE ANATOMY

(Fig. 72, 73 & 74)

Intercostal cells of the adaxial epidermis are polygonal and the longer axis is perpendicular to the longitudinal veins in all species. The cell files are distinguishable in the adaxial epidermis. The costal epidermal cells are stretched parallel to the veins in *Z. capitatum* var. *elatum*, *Z. montanum* and *Z. officinale*. In all other species they are much smaller, not stretched and the cell files are very clear.

Intercostal cells of the lower epidermal cells are smaller and less stretched than the upper ones and the cell files are not recognizable. Costal epidermal cells are indistinguishable on the abaxial epidermis. Presence of single, large crystal in the abaxial epidermis is a common feature seen in all species studied. It agrees with the observations made by Indira (1976).

Sometimes the epidermal cells harbour various microorganisms. Similar observation was made by Indira (1976). The presence of such organism was noticed even in the guard cells of *Z. neesatum* and *Z. zerumbet*.

Oil cells are distributed mainly on the lower epidermal cells of all species studied but was abundant in *Z. officinale*. This agrees with the observations of Tomlinson (1956) and Indira (1976).

Simple unicellular trichomes (upto 1.5 mm long) are present on the abaxial epidermis in all species except *Z. neesatum*. Hairs upto 1 mm long are seen on the midrib, petiole, sheath and sometimes on the leaf margins of all species studied except in *Z. nimmonii*. The type of hair seen is 'Borste' (Bristle) type. 'Weichhaarre' (soft and delicate hair) type of hairs having greater length and are easily detached are seen on the abaxial leaf surface of *Zingiber officinale* (Tomlinson, 1956), *Z. nimmonii*, *Z. zerumbet* and *Z. wightianum*.

Leaves are amphistomatic with more stomata present on the abaxial surface in all species studied. Stomata are rare on the adaxial epidermis, but never completely absent. This is in contrary to the earlier reports (Indira, 1976) where *Z. neesatum* is recorded as having stomata only on the abaxial surface. Stomata are tetracytic with longer axis of the guard cell parallel to the longitudinal veins. The length of the guard cell varies from a minimum size of 36 μm seen in *Z. officinale* and *Z. zerumbet* to a maximum average size of 56 μm in *Z. capitatum* var. *elatum*. Stomatal index is minimum for *Z. officinale* (6.4) and maximum for *Z. capitatum* var. *elatum* (15.8).

Petiole is absent in *Z. montanum* and *Z. capitatum* var. *elatum*, whereas a prominent petiole is present in all other species. Petiole wing is absent in *Z. officinale* but they are short, broad and blunt in *Z. nimmonii* and *Z. zerumbet*. Their surface is long hairy especially the adaxial surface, in *Z. zerumbet* and abaxial surface in *Z. wightianum*. In *Z. neesatum* the petiole wings are triangular and pointed. Silica sand can be seen in the ground

tissue of the petioles of *Z. officinale*. It was also reported by Tomlinson (1956).

Pulvinus: The pulvinus region of *Z. officinale* is characterised by the collenchymatous bundle sheath. But in all other parts of the plant the bundle sheath is sclerenchymatous. Tomlinson (1956) noted the absence of air canals and assimilating tissue, hypertrophied nature of the groundparenchyma and abundant deposition of tannin in the pulvinus. But in the present study, the pulvinus region also showed the presence of air canals and assimilatory tissue, though the air canals were not well developed as in *Curcuma*. Sections below and above the pulvinus region showed the presence of sclerenchymatous thickenings of the bundle sheath in the median bundle of arc I.

Bundle arc II is present in the petiole of *Z. zerumbet* and is absent in all other species studied. Chlorenchymatous as well as the cells of the ground tissue contain 1-few crystals in them.

In the Transverse section of lamina, the epidermal cells are always broader than high in all species. Abaxial hypodermis alone is seen in *Z. officinale*, *Z. zerumbet* and *Z. wightianum* and is completely absent in all other species. Indira (1976) has reported the presence of both abaxial and adaxial hypodermis in *Z. officinale*. But in the present study, only abaxial hypodermis was found in *Z. officinale*. Lower spongy cells, hypodermal cells and abaxial epidermal cells contain single large crystal in them. Palisade is usually 1-layered in all species except in *Z. zerumbet* and *Z. capitatum* var.

elatum. In *Z. zerumbet*, the palisade is 2-layered and the second layer is composed of shorter cells. In *Z. capitatum* palisade is 2 or 3 layered, which is unique for the species. A centric leaf structure was reported in *Z. capitatum* by Solereder and Meyer (1930) but according to Tomlinson (1956) leaves show a dorsiventral structure and our study also support this observation.

Leaf margin is always gradually tapering, pointed (*Z. neesatum*, *Z. nimmonii*, *Z. officinale* and *Z. zerumbet*) or blunt (*Z. capitatum* var. *elatum* and *Z. montanum*) and bent or curved downwards (*Z. capitatum* var. *elatum* and *Z. montanum*). Tip ends in short or long hyaline portion which is almost biseriate except for 1 or 2 additional cells near the beginning. In *Z. capitatum* the hyaline portion is multiseriate. The hyaline portion is broadest (286 μm) in *Z. wightianum* and *Z. zerumbet* and shortest (120-148 μm) in *Z. neesatum*, *Z. officinale* and *Z. nimmonii*.

Key to the species based on anatomical characters

1. Costal cells of both epidermis as high as or higher than broad 2
1. Costal cell of both epidermis broader than high 3
2. Bundle arc II present in the petiole 4
2. Bundle arc II absent in the petiole 5
3. Palisade 2 or 3 layered in the lamina and margin; lamina 320 μm thick
..... 1. **Z. capitatum** var. **elatum**

3. Palisade 1-layered in the lamina and margin; lamina 160-176 μm thick 2. **Z. montanum**
4. Petiole wings absent; bundle arc II absent in the midrib; hyaline portion of the margin 96-128 μm wide; leaves narrow (1.5-2 cm) 5. **Z. officinale**
4. Petiole wings short and blunt, bundle arc II present in the midrib; hyaline portion of the margin 288 μm wide; leaves broad (5-10 cm) 7. **Z. zerumbet**
5. Abaxial surface of the leaves glabrous; leaves narrow (2.5-3.5 cm) 3. **Z. neesatum**
5. Abaxial surface of the leaves hairy; leaves broad (5-10 cm) 6
6. Hypodermis abaxial in the lamina; hyaline portion of the leaf margin 288-304 μm wide 6. **Z. wightianum**
6. Hypodermis absent in the lamina; hyaline portion of the leaf margin upto 144 μm wide 4. **Z. nimmonii**

II. AERIAL STEM

Among the 9 genera studied, only 7 of them possess aerial stem, whereas *Curcuma* and *Kaempferia* have a pseudostem formed by the association of leaf bases. Transverse section of stem is circular in outline. Ridges and furrows may be present. Epidermal cells may be as high as broad or broader.

Fibrous cylinder

A cylinder of fibre-like cells separates cortex from the central cylinder. It may be 2-4 layered, continuous or discontinuous. The cells may be thick as the cells of bundle sheath (*A. galanga*) or thinner. In *Globba* and *Boesenbergia*, the fibrous cylinder is absent.

Cortex

The width of the cortex is narrow, about $1/4^{\text{th}}$ or $1/5^{\text{th}}$ of the width of the central cylinder. The assimilatory tissue and air canals of the sheath may be seen in the cortex also (*Hedychium* spp. and *Elettaria* spp.). The termination of assimilatory tissue is often represented in the cortex of the stem by a cylinder of round cells with chloroplast or starch grains and with large intercellular spaces. Sometimes the parenchyma adjacent to the bundles and the fibrous cylinder is collenchymatous.

In Zingiberaceae, the bundle system of the cortex form 1-4 rings, which are not easily distinguishable. The outermost bundles abut on the epidermis.

Individual bundle of the cortex resemble arc II of sheath. They are circular in section with complete fibre sheath. Sheath is widest at the xylem region. Bundles consist of single large metaxylem or several smaller ones and small phloem group; extended protoxylem is absent. In some, irregular alternation of small and large bundles occurs in the rings. Bundles of arc I (petiole or sheath) are also seen in the section of internode as they pass the cortex into the central cylinder.

Central cylinder

Numerous bundles are scattered irregularly in the ground parenchyma. The bundles are characterised by the weak development of mechanical tissue of bundle sheath. Protoxylem is more frequent in the bundles of central cylinder.

Alpinia galanga

Epidermal cells are broader than high. The stem is divided into 2 regions by the presence of a 2-4 layered, thick-walled and continuous fibrous cylinder. Outer region possesses two rings of bundles. Outer most ring comprises of small circular bundles. Bundles of the inner ring are larger than outer ones. Bundles of both these rings are circular and possess well developed bundle sheath. Ground parenchyma cells next to the bundle

sheath contain silica granules. Bundles have 1 large metaxylem (80 μ m wide), 1-4 angular xylem and phloem. Bundles of the inner zone are also well developed; bundle cap is mainly seen abaxially. Adaxial cap is either absent or very poorly developed. Many oil cells are found in this region and they have very thick walls. Almost all cells of the ground parenchyma of both inner and outer zone contain either single or a few crystals in group, which are of various size and shapes.

Amomum masticatorium

Transverse section is elliptic in outline (*Plate 19 A-E*). Epidermal cells are as high as broad. Stem is divided into a central cylinder and an outer cortex by a fibrous cylinder. Fibrous cylinder is 2-layered, sclerenchymatous and continuous. Bundles of the outer cortical region contain a ring of vascular bundles towards the fibrous cylinder. Outer to this a few bundles are seen which is rarely organised into a ring. The bundles may be fused. The bundle sheath is sclerenchymatous and completely covers the bundle. Bundle is made up of 1 metaxylem, 5 angular xylem and phloem. Cells near to the bundle possess silica sand. A few ground parenchyma cells possess starch grains in them. Central cylinder contain randomly scattered numerous bundles. Bundles contain 1 metaxylem element and phloem. Sheath is very poorly developed, sometimes adaxial only. Cells of the ground tissue possess acicular crystals (1-few) in them. Oil cells are seen both in central cylinder and outer cortical region.

Elettaria cardamomum

Stem in Transverse section is rounded with ridges and furrows. Epidermal cells are higher than broad. The cells in the furrow region are larger than those in ridged portion. In the ridges, just below the epidermis, small or medium sized bundles are present depending on the size of ridge. Alternating with this is the next ring of large sized bundle. Alternating with this there may be 1 or 2 more rings in the outer zone. The rings of bundles are not clearly distinguishable. Xylem of the bundle is very prominent, 88 μm wide. The sclerenchymatous sheath is incomplete. Mercy *et al.* (1977) have recorded the presence of complete sclerenchymatous sheath. The fibrous layer is 2 or 3 layered, slightly thick walled and composed of cells smaller than the cells of ground tissue. It forms a slightly wavy and discontinuous layer. Inner region contain numerous bundles that are scattered. They are smaller than outer ones. The ground parenchyma cells are loosely arranged and enclose lots of air spaces in between the cells. Metaxylem of the inner bundles is 40 μm wide.

Globba schomburgkii

Stem is ovate or elliptic in outline (*Plate 20 D-G*). Epidermal cells are small, broader than high, outer wall is straight. Fibrous cylinder between the 2 regions is absent. Outer region possess 1 ring of bundle just below epidermis. The bundles are of various sizes. The bundle is completely surrounded by sclerenchymatous bundle sheath. The bundle consists of large metaxylem and few phloem. So the bundle is broader at the xylem

region. The inner region consists of large number of bundles without any regular arrangement. Ground tissue possesses few oil cells (with yellow content). Very few starch grains (1 or 2) are seen in some cells.

Boesenbergia tiliaefolia

Stem in Transverse section is circular (*Plate 21 A & B*) and it possesses hairs upto 0.5 mm long. Epidermis is single layered. Epidermal cells are large and with convex outer wall, as high as broad. Ground tissue is made up of larger cells. It is divided into 2 regions. The fibrous cylinder separating these two regions is absent. In the outer region a ring of roughly alternating big and small bundles are present. Bundles consist of 1-4 xylem elements and phloem. The bundle sheath is collenchymatous in nature. Alternating with these bundles, there is another ring of medium sized bundles. Between these bundles, chlorenchymatous cells are present which are very loosely arranged and enclose small air cavities. Bundles of the inner zone are very small. They consists of 1 or 2 xylem and very few phloem elements. They are not surrounded by collenchymatous sheath. Few oil cells are seen in the ground tissue.

Hedychium coronarium

The aerial stem in Transverse section is broadly elliptic in outline (*Plate 20 A-C*). Ground tissue is differentiated in to 2 regions by a 2-layered, sclerenchymatous fibrous cylinder. Epidermal cells are as high as broad or slightly higher. Just below the epidermis, 1st ring of vascular bundles are

seen. They are very small, completely surrounded by well developed sclerenchymatous bundle sheath and xylem alone is present in these bundles. The 2nd ring is made up of larger, rounded bundles alternating with the bundles of first ring. Sclerenchymatous sheath is well developed around the bundle. In between these bundles, 2 or 3 layered chlorenchyma is present which is loosely arranged and air cavities are seen in it. In the inner region numerous bundles are present. Just inner to the fibrous cylinder is a ring of bundles. Between the bundles, few chlorenchyma cells are seen. Air cavities are present in this region also. Bundles are very few in the central portion. Almost all cells of the ground tissue possess large, 1-5 plate-like crystals. The chlorenchyma cells and a few outer cells of the ground tissue contain upto 8 starch grains in them. Oil cells are also present in the ground tissue.

Zingiber officinale

Aerial stem in Transverse section is broadly elliptic in outline (*Plate 21 C-G*). Epidermal cells are slightly broader than high; outer wall is straight or slightly convex. Just below the epidermis is a vascular ring made up of alternating small and large bundles. Smaller bundles are rounded in shape; larger bundles are obovate, sclerenchymatous sheath is well developed and wall is very thick. In the larger bundles the bundle sheath is interrupted by parenchyma cells. Bundle consists of 1-4 metaxylem, 1-4 angular xylem and phloem.

AERIAL STEM: COMPARATIVE ANATOMY

Aerial stem in Transverse section is rounded, elliptic or broadly elliptic. Stem of *Boesenbergia tiliaefolia* possess 0.5 mm long hairs. Aerial stem is divisible into an outer cortex and inner central cylinder. The bundles of the outer cortex are arranged in roughly distinguishable rings. The bundles are rounded and the bundle sheath completely surrounds the vascular elements (except in *Elettaria*). The rings may be 1 (*Globba schomburgkii*, *Amomum masticatorium*, *Boesenbergia tiliaefolia*) or 2 (*Hedychium coronarium*, *Alpinia galanga* or 4 (*Elettaria cardamomum*). The outline is smooth in all species except *Elettaria cardamomum*, where it is wavy. The fibrous cylinder separating the two regions is thick walled and continuous in *Alpinia galanga*, *Hedychium coronarium* and *Amomum masticatorium*; discontinuous in *Zingiber officinale*, discontinuous and slightly wavy in *Elettaria cardamomum* and absent in *Globba* and *Boesenbergia*. Bundles of the central cylinder are small and their bundle sheaths are very poorly developed and they show scattered arrangement. Oil cells are seen in the ground tissue of all species studied. Air canals and chlorenchyma cells are present in the outer cortex of *Boesenbergia tiliaefolia*, *Hedychium coronarium* and *Zingiber officinale*. In *Hedychium coronarium*, chlorenchyma cells and air cavities are seen in the central cylinder also. In *Elettaria*, the cells of ground tissue are loosely arranged and enclose air cavities. In *Alpinia galanga*, almost all cells of ground tissue possess 1-few crystals (plate-like). In *Amomum masticatorium* ground tissue of the central cylinder possesses 1-few acicular crystals, which is a very prominent distinguishable feature; the cells of outer cortex are devoid of

such crystals. Starch grains are present in some cells of outer cortex in *Amomum masticatorium*. In *Hedychium coronarium*, the chlorenchymatous cells of both central cylinder and cortical region possess starch grains.

III. RHIZOME

A well developed rhizome shows sympodial branching. It is morphologically equivalent to aerial stem. Accurate transverse sectioning is almost impossible because of its irregular shape.

The outermost region is sometimes suberised. If it is accompanied by cell division a periderm is formed which shows storied appearance. Sometimes periderm is absent. Development of periderm is associated with habitat conditions and it does not possess any diagnostic value.

The rhizome is separated into cortex and central cylinder by an endodermis. The cortex contains numerous scattered vascular bundles. Immediately below the endodermis is a narrow cylinder of vascular tissue, which is very conspicuous. The individual vascular bundle of this cylinder is not recognizable. Structure of the bundle is similar to those in aerial stem. In the central cylinder the bundles are closely arranged.

Starch grains

Starch is usually abundant in the rhizome. They are also seen in root tubers. The starch grains are often flattened (*Globba schomburgkii* and

Kaempferia). The flattened grains, in face view, are circular, oval or elliptical. The hilum is often situated in a projecting beak which may or may not lie in the plane in which the grain is flattened. The grains which are not flattened may be spherical, cylindrical or ellipsoidal. Striations around the hilum are sometimes visible.

Starch grains are often concentrated around the endodermis, in the inner cortex and outer layers of the central cylinder. Endodermis is always devoid of starch grains. Starch grains can be seen in the root cortex, pith or both (*Hedychium coronarium* and *Globba schomburgkii*). It may be seen in the aerial stem or leaf sheath of some species (*Amomum masticatorium*, *Hedychium coronarium* and *Alpinia calcarata*).

Although flattened starch grains are said to be the characteristic of Scitamineae, they are not universal. The shape of the grains appears to be constant and characteristic for certain genera eg. *Alpinia*, *Hedychium* and *Kaempferia*.

Alpinia, Amomum, Elettaria

In the cortical region, bundles are completely surrounded by sclerenchymatous sheaths, which are 2-7 layers thick. The bundles of the central cylinder also possess sheath but they are thinner. This was noted by Datta and Mukerji (1950) in *Alpinia galanga*. In *Elettaria cardamomum*, upto 7 xylem elements are seen in a bundle of cortical region whereas in central bundles 3 or 4 xylem elements are seen.

In *Alpinia*, the starch grains are ovate, elliptic or circular in outline. Size varies from 4-28 x 4-24 μm . Datta & Mukerji (1950) reported the size of starch grains as 11-25 x 25-40 μm .

In *Amomum masticatorium* (Plate 22 G), the shape of starch grains may be ovate, elliptic or cylindrical and their size varies from 18-40 x 14-20 μm . *Elettaria cardamomum* possess elliptic or cylindrical starch grains with an average size of 20 x 12 μm .

Globba schomburgkii

A multilayered prominent periderm is present in *G. schomburgkii*. Endodermal layers are very prominent. Very few bundles are seen in the cortical region (Plate 22 A & B). The bundle sheath is sclerenchymatous with very thick wall and narrow lumen. Bundles of the cortical region possess complete sheath, whereas the bundles of central cylinder have an abaxial bundle cap. Starch grains are circular and their size varies from 22-48 x 20-48 μm (Plate 22 I).

Boesenbergia

Mechanical tissue is very poorly developed. Bundles of both regions do not possess bundle sheath. Starch grains are oval in shape. Size varies from 12-20 x 8-12 μm (Plate 26 H).

Curcuma

Periderm is prominent. Large number of curcumin cells are present in both regions. Mechanical tissue around the bundle is very poorly developed in both regions (*Plate 22 C & D*). Starch grains in *Curcuma longa* are ovate to elliptic and their size varies from 8-16 x 12-16 μm . In *C. aeruginosa* and *C. amada*, the starch grains are elliptic to cylindrical. In *C. aeruginosa*, starch grains are very large up to 84 x 34 μm , whereas in *C. amada* they are smaller, upto 68 x 24 μm . Endodermis is continuous and made up of barrel-shaped cells. This was also noted by Datta and Mukerji (1950), Sherlija *et al.* (1998) and Remashree and Indira (2006). Tomlinson (1956 & 1969) and Sherlija (1998) observed 2-celled hairs on the rhizome. But in the present study, trichomes were absent on the rhizome. This agrees with the observation by Remashree and Indira (2006).

Starch grains were of 4-15 μm diameter in *C. longa* (Datta and Mukerji, 1950). According to Remashree and Indira (2006), starch grains are $10.3 + 2.86 \mu\text{m}$ in *C. longa* and $16.32 + 3.2 \mu\text{m}$ in *C. amada*. Vessels with spiral, reticulate and annular thickening were observed by Datta and Mukerji (1950). According to Remashree and Indira (2006), spiral and helical thickenings are found in the vessels. But in the present study vessels are absent in the rhizome.

Hedychium

The outer cortical region possesses very few bundles. Bundle sheaths are sclerenchymatous. In the case of larger bundles, the sclerenchymatous cap is 3 or 4 layered on abaxial side and single layered on adaxial side. Some bundles possess abaxial cap only. Bundles of the central region have 2-layered abaxial cap. Numerous air canals are seen in the cortex and central cylinder. Oil cells are abundant in both regions. In *Hedychium coronarium*, the starch grains are flattened, cylindrical or flake-like and size varies from 48-64 x 20-24 μm (Plate 22 F).

Kaempferia

Mechanical tissue is poorly developed. Bundles are very few in cortical region. In *K. galanga* the starch grains are flattened and oval in shape. Size varies from 16-52 x 12-36 μm (Plate 22 E). Tomlinson (1956) reported the absence of starch grains in the rhizomes of *K. rotunda* and the present study also supports his observation.

Zingiber

Oil cells are abundant in both regions. Endodermis is thick walled and consists of broad cells. Bundles of the outer cortical region possess 2-layered, incomplete sclerenchymatous sheath on the abaxial side. This agrees with the observation of Datta and Mukerji (1950). Bundle sheath of the central cylinder is poorly developed. In *Zingiber officinale* the starch grains are ovate, cylindrical, triangular or rarely rod-shaped. Size varies from

20 x 16 μm (ovate), or 32 x 8-12 μm (cylindric or rod-shaped). According to Datta and Mukerji (1950), starch grains are 50-60 μm long. Remashree *et al.* (1997) observed vessels in the rhizome of *Z. officinale* with scalariform perforation plates. In the present study vessels were found to be absent.

RHIZOME: COMPARATIVE ANATOMY

Rhizome is hard in *Alpinia galanga*, *Amomum masticatorium* and *Elettaria cardamomum*. In *Boesenbergia tiliaefolia*, *Curcuma longa*, *Globba schomburgkii*, *Hedychium coronarium* and *Kaempferia galanga* it is fleshy. An endodermis separates the outer cortical region with fewer vascular bundles and central cylinder. Vascular bundles are completely surrounded by sclerenchymatous sheath in *Alpinia galanga*, *Amomum masticatorium* and *Elettaria cardamomum*. Incomplete sheath is present in *Hedychium coronarium* and *Zingiber officinale*. Mechanical tissue around bundle is poorly developed in *Kaempferia galanga* and almost absent in *Boesenbergia tiliaefolia* and *Curcuma longa*. Cortical region and central cylinder are aerenchymatous in *Hedychium coronarium*.

Starch grains are usually flattened; they are rounded, elliptic or ovate in *Globba schomburgkii*, *Kaempferia galanga* and *Boesenbergia tiliaefolia* triangular shaped in *Zingiber officinale* and flake-like in *Hedychium coronarium*.

IV. ROOT

The formation of periderm is rare in root. However, certain cells of the outer cortical layers get differentiated and appear to be highly compact and radially arranged cells, which possess suberised walls. This is termed as exodermis by Solereder and Meyer (1930). Aerenchyma is seen in the cortex of *Curcuma*, *Kaempferia*, *Alpinia*, *Hedychium* etc. The boundary between cortex and the stele is represented by an endodermis which shows characteristic casparian thickening of typical monocotyledons. A single layered pericycle is seen inner to endodermis.

Roots are polyarch and the protoxylem points abut on the pericycle. Phloem group in between the xylem show limited radial extension. Conspicuous pith composed of thin walled, round parenchyma cells are present in all roots.

The anatomical studies of roots of Zingiberaceae have revealed that it provides considerable character differences for generic delimitation. However, the species delimitation is not possible as the anatomical characters show little infrageneric variation.

Alpinia galanga

Outer walls of the epidermis are convex and possess root hairs (*Plate 23 A-D*). A hypodermal layer, made up of radially elongated cells is seen below it. Inner to this is a 2-layered region, composed of slightly thick walled cells, smaller in size and are compactly arranged. Next is the aerenchymatous zone, composed of rounded, loosely arranged cells. Air

cavities are radially elongated. The partition is made up of a single row of rounded cells; thus appearing as beaded string. Very rarely 2 or 3 rows make up the partition. Cells just outer to the endodermis is made up of 3 layers of concentrically arranged cells. Endodermis is thick walled. Upto 30 xylem groups are seen. Oil cells are present in the cortical region. Upto 5 layers of thick walled cells are present below the xylem. Pith is highly reduced and composed of small compactly arranged cells.

Amomum masticatorium

Epidermal cells are higher than broad. Exodermis is absent. Two layers below the epidermis are compactly arranged. The cortex is uniform and composed of rounded, loosely arranged cells enclosing small air cavities (*Plate 23 E & F, 24 A*). 3 or 4 layers of cells outer to the endodermis show concentric arrangement. Endodermis is single layered and possess very thick casparian strip. Pericycle cells are large and inner to it upto 19 xylem groups are seen. Metaxylem is of 100 x 72 μm size. Upto 5 layers of cells below the xylem are sclerenchymatous. Pith is highly reduced and consists of few cells which are also thick walled. These cells are rounded and intercellular spaces are seen in between them. Oil cells are seen in the ground tissue.

Elettaria cardamomum

A layer with radially elongated cells is seen below the epidermis (*Plate 24 B-G*). The cortex is divisible into 3 regions. Inner to the radially

elongated cells, 2 or 3 layers of cells are seen which are smaller and compactly arranged. Broad cortical region is 20-24 layered. It is composed of larger cells and is with many intercellular spaces. Air spaces are not prominent as in *Hedychium*. Inner region is made up of 6 layers of radially arranged cells. Within the exodermis a narrow cylinder of fibres were observed by Tomlinson (1956). In the present study, such narrow cylinder is absent, but some cells of the outer cortical region are very thick walled. Endodermis shows casparian thickenings (moderate). Pericycle is seen below it. About 46 xylem groups with 6-8 xylem vessels in each bundle are seen in a row. 2 or 3 layers of cells below this xylem are thick walled. Pith is reduced and is made up of rounded, loosely arranged cells. Oil cells are seen in the cortex and pith.

Globba schomburgkii

Outermost periderm is composed of 6-8 layers of cells. Cortical region is divided into 2 zones. Outer zone is composed of comparatively thin walled cells, which are almost isodiametric and they contain very few or no starch grains (*Plate 25 A-C*). Oil cells can be seen in this region. Inner region consists of thick walled and radially elongated cells with numerous starch grains. Thin walled endodermis is followed by pericycle. Upto 18 xylem groups are seen. Below the xylem, 2-4 layers of sclerenchyma cells are seen. Central pith is small and its cells also contain numerous starch grains. They are flat and of various size and shapes

Boesenbergia siphonantha

Epidermal cells are higher than broad (*Plate 25 D & E*). Root hairs are present. Exodermis is absent. Cortical cells are larger, with intercellular spaces. Endodermis is thin walled, next to this pericycle is seen. Some cortical cells near the endodermis harbour some microorganisms. Xylem groups are about 8 in number. Metaxylem is rounded and 44 μm wide. All cells seen within stelar region are thick walled.

Curcuma longa

Epidermal cells are higher than broad, which is followed by 10-layered exodermis. The outer cortex is composed of thin walled and radially elongated cells. This is followed by 3 layers of rounded, loosely arranged cells enclosing rounded or elliptic air canals (*Plate 25 F*). Again a periderm like layer is seen, which is 5-layered. Inner to this, rounded cells are concentrically arranged. Cortex is limited by endodermis. Endodermis shows casparian thickening. This is followed by a single layer of pericycle. Upto 14 xylem groups are seen. Metaxylem is elliptic (72 x 64 μm) in cross section. 5 layers of cells below this metaxylem are thick walled with reduced pith. Pith cells are thin walled, loosely arranged with intercellular spaces. Oil cells are abundant in the inner cortical region.

Hedychium coronarium

The cortex is divided into 3 zones. Outer zone is composed of small compactly arranged cells of about 4 layers. The cortical region is aerenchymatous (*Plate 26 A-G*) with large circular air spaces in the outer

part and gradually become smaller towards the inner side. The cells of cortical region possess starch grains. Inner to the aerenchymatous region concentric rings of rounded cells are seen. Endodermis possesses very thick casparian strip, which is followed by 1-layered pericycle. About 30 xylem groups are seen. Upto 5 layers of cells below the xylem are thick walled. Pith is reduced and is aerenchymatous. Isolated xylem groups are seen in the pith. Such isolated phloem groups were observed by Tomlinson (1956) which is unique for *Hedychium*. The pith cells also possess starch grains.

Kaempferia galanga

Epidermal cells are higher than broad and possess root hairs. The exodermis is 5-layered. Outer cortical cells are large, thin walled and radially elongated. Oil cells and tannin cells are abundant in this region. Inner cortical cells can be divided into 2 regions. About 3 layers of cells just below the outer cortical region is rounded and loosely arranged and they enclose radially elongated air canals. Inner to this is 3 or 4 layers of rounded cells that are concentrically arranged. Cortex is limited by single layered endodermis, which is followed by pericycle. Upto 16 xylem groups are present. Metaxylem is 60 μm wide. 1-3 layers of pith cells below the xylem are thick walled and those towards the centre are thin walled, with intercellular spaces.

Zingiber officinale

Epidermis is made up of rounded cells. Epidermis and 2 layers of cells next to it possess some chemical constituent and appear brown in colour. This is followed by 6-8 layers of regularly arranged periderm cells. The cortex is divisible into 2 regions. Outer zone consists of compactly arranged cells without intercellular spaces and they show slight radial elongation in the outer region. Inner cortex is composed of very regularly and radially arranged cells. A prominent endodermis and pericycle are seen. Upto 25 xylem groups are present. Metaxylem is 40-48 μm wide. Pith is very large and the inner region is composed of large cells. As in other genera, the cells below the xylem are not sclerenchymatous. Many of the cells of periderm region, outer cortex, inner cortex and central pith possess 1 or 2 starch grains.

ROOT: COMPARATIVE ANATOMY

An exodermis or periderm is present in *Curcuma longa*, *Globba schomburgkii*, *Kaempferia galanga* and *Zingiber officinale*. Cortical region is aerenchymatous in *Alpinia galanga*, *C. longa*, *K. galanga* and *Hedychium coronarium*. In *A. galanga*, air canals are radially elongated and almost traverse the cortex. In *C. longa*, and *K. galanga*, air canals are radially elongated, but they are smaller than that of *A. galanga*. In *H. coronarium*, the air canals are circular. Cortical cells are usually thin walled, but groups of thick walled cells are seen in *Elettaria cardamomum*. Cells of cortical region and pith of *G. schomburgkii* and *H. coronarium* possess upto 12 starch grains whereas in *Z. officinale*, 1 or 2 starch grains are seen. Roots show

the typical exarch and polyarch condition as in other monocotyledons. Xylem shows radial elongation and it is maximum in *E. cardamomum*. A few layers just below the vascular tissue are sclerenchymatous in all taxa studied except *Boesenbergia siphonantha*, and *Z. officinale*. In *H. coronarium*, isolated vascular tissues are seen in the pith region which is unique to this genus only (Tomlinson, 1956). Pith is thick walled in *Amomum masticatorium* and *B. siphonantha*.

V. XYLEM ELEMENTS

The occurrence and distribution of tracheids and vessels are of considerable phylogenetic interest (Tomlinson, 1956). The xylem elements were studied by maceration method.

Usually the vessels are confined to the roots whereas in other parts tracheids are common. Vessels are recognized by the narrow bars of scalariform perforation plates which are not bordered. In imperforate walls the bars are wider and slightly bordered. Perforated walls can be recognized because of the absence of primary membrane; the bars are supported only at their ends and consequently tend to be evenly spaced in the center. Description of end walls follows Cheadle (1943 a). End wall is transverse, when it lies at right angles to the length of the xylem element; slightly oblique when it is not more than twice as long as the diameter of the element; oblique when two to five times the diameter and very oblique when

more than 5 times longer than the diameter. In root, where fibres of the ground tissue abut on the lateral walls of the tracheids and vessels, the area of contact is unpitted. Perforation plates of vessels may be oblique or transverse. Perforation plates are scalariform with few to many bars. They are often convex and encroach into the lumen of the adjacent vessel, whose walls are concave correspondingly. The perforation plate of two ends may vary.

End walls of tracheids vary from oblique to very oblique or even unrecognizable. The first formed xylem elements are very long, narrow tracheids with very oblique, imperforate end walls. Inner most xylem elements which are largest and last formed are generally vessel members.

Various parts like root, rhizome, aerial stem and petioles of different species were macerated to study the xylem elements. Roots alone showed the presence of vessels. Vessels were absent in all other parts, instead tracheids were seen. The length, width, nature of end wall and perforation plate showed variation in the roots of different species studied. However the nature of xylem tissue is of little diagnostic value in species delimitation. Vessels with transverse, simple perforation plates were observed in *Alpinia galanga*, *Amomum masticatorium* (Plate 27 A-H), *A. pterocarpum* and *Elettaria cardamomum*. Slightly oblique end walls with simple perforation plate were also present. Solereder and Meyer (1930) reported the presence of simple perforation plates in *Alpinia* but the perforation plates were scalariform according to Tomlinson (1969). The present study confirmed the

occurrence of simple perforation plates in the roots of *Alpinia*. In the above mentioned species, most of the vessels are with simple perforation plate, but scalariform plates having few bars, with oblique walls are present. In *Amomum hypoleucum* slightly oblique walls with simple perforation plates are present. In *Curcuma longa*, *C. aeruginosa*, *C. zanthorrhiza* and *Hedychium flavescens*, slightly oblique to oblique end walls with scalariform perforation plates are present. In *Globba orixensis* and *Amomum* spp. very oblique end walls with scalariform perforation plates having 28-50 bars are seen. From a phylogenetic point of view scalariform perforation with many bars are primitive and with few bars are advanced (Cheadle & Tucker, 1961). Such scalariform plates are also seen in families like Haemodoraceae, Hypoxidaceae, Velloziaceae, Philydraceae, Apostasiaceae, Taccaceae (Cheadle, 1968) Amaryllidaceae and Tecophilaeaceae (Cheadle, 1969) and Iridaceae (Cheadle, 1963) where vessels are seen in roots only with very few exceptions.

Cheadle (1942) and Solereder and Meyer (1930) claimed that *Hedychium* is completely devoid of vessels. But Tomlinson (1956) has reported the presence of scalariform perforated vessels in the roots of *Hedychium*. Present study confirms this report as in the roots of *Hedychium flavescens* and *H. coronarium*, scalariform perforated vessels are present (Plate 27 I & J).

Aerial stem of *H. coronarium* showed tracheids with annular thickening and spiral thickening (having deep turns). Petioles of *Alpinia*

zerumbet also show tracheids with spiral thickening (*Plate 27 K*). Remashree *et al.* (1998, 2006) reported the occurrence of vessels in the rhizome of *Curcuma longa*, but we were not able to find vessels in the rhizome of *C. longa* or any other species under study.

According to Cheadle (1943 a, 1953) the vessels originated in the roots, stem and leaves in succession and specialized in the same sequence. He classified the monocotyledonous families based on the presence of vessels in different organs and the family Zingiberaceae was included in families having some species with vessels in roots only and other with vessels elsewhere (Cheadle, 1953). This was confirmed by Tomlinson (1956) and Dahlgren and Clifford (1982). The vessel types in the roots of Zingiberaceae were considered as more advanced type than those found in the other families of Zingiberales (Wagner, 1977). Based on vessel characters Cheadle & Tucker (1961) refuted the possible origin of Zingiberales from Commelinaceae, because in Commelinaceae, the vessels are highly specialized than Zingiberaceae.

Leaf anatomy has proven to be the most valuable in systematic botany. The useful characters include the type of stomata, hair, vascular bundles, presence of silica bodies *etc.* Metcalfe (1950) has commented that the petiole is of considerable taxonomic value. Such reliable characters help in the identification of plant specimens even in sterile condition. It is also helpful in identifying the incomplete and doubtful herbarium specimens. So

based on leaf anatomical characters, keys to the subfamilies, tribes and genera are prepared separately.

Key to the Subfamilies

1. Epidermal silica inclusions present

Alpinioideae

1. Epidermal silica inclusions absent **Zingiberoideae**

Key to the tribes in Zingiberoideae

1. Hypodermal cells with single, large calcium oxalate crystals

.....**Globbeae**

1. Hypodermal cells without calcium oxalate crystals **Zingibereae**

Key to the genera of Alpinieae

1. Silica bodies 1 or 2 per costal cell2

1. Silica sand present in the costal cells (except *A. hypoleucum* & *A. pterocarpum*)

Amomum

2. Costal cells as high as broad or slightly broader; silica body 1 per cell

..... ***Alpinia***

2. Costal cells thrice or more broader than high; silica bodies 1 or 2 (1 big and 1 small) per cell ***Elettaria***

Key to the genera of Zingibereae

- 1. Bundle arc IV present in the petiole 2
- 1. Bundle arc IV absent in the petiole 3
- 2. Pulvinus present in the leaf, bundle sheath of the petiole collenchymatous
..... **Zingiber**
- 2. Pulvinus absent in the leaf, bundle sheath of the petiole sclerenchymatous
..... **Hedychium**
- 3. Stomata tetracytic; bundle arc III well developed ((represented by more
than 8 bundles) in sheath and petiole..... 4
- 3. Stomata polycytic; bundle arc III poorly developed (represented by 1 or 2
bundles) in sheath and petiole..... **Boesensergia**
- 4. Cuticular striations present; hairs 'Weichhaare' type
Kaempferia
- 4. Cuticular striations absent; hairs 'Borste' type
Curcuma

SUMMARY

The family Zingiberaceae are perennial rhizomatous herbs growing in shady habitats. They are considered as one of the most difficult families of monocotyledons. The identification and species delimitation are often difficult because of close resemblance of the vegetative characters, short flowering period associated with rainy season and perishable nature of the flower.

Anatomy has been of much importance in taxonomy from the time of Linnaeus. The use of leaf anatomy for taxonomic purpose is more reliable because it possesses those anatomical characters which are most essential in systematics (Solereder & Meyer, 1998; Carlquist, 1961.)

This study was aimed to analyze the use of vegetative anatomy in identification and delimitation of different species of Zingiberaceae in South India. A detailed study of the anatomy of 51 species and 2 varieties belonging to 9 genera from South India were carried out. They belong to 3 tribes viz., Alpinieae, Zingibereae and Globbeae under 2 subfamilies Alpinioideae and Zingiberoideae (Kress *et al.*, 2002) The role of anatomy in supporting or providing additional data to this classification is also checked.

The leaf anatomical characters include the nature of abaxial and adaxial epidermis, type of trichomes, stomata, shape and structure of sheath, Transverse section of petiole, midrib, lamina and margin. The anatomy of other vegetative parts like aerial stem, rhizome and root were studied on selected species of each genus since they did not show much variation among species. To study the xylem elements, various parts like root, rhizome, aerial stem and petiole were macerated. A comparative

anatomy of different species of each genus is provided. An artificial key based on anatomical characters for the genera of the family and species under each genus are also provided.

Though the members of the family Zingiberaceae exhibit lots of similarity in their basic structure, there are some characters which are useful in tribal level or generic level classification. The characters common to all species studied include: a) Nature of epidermal cells (wall is always straight and never sinuous) and b) Structure of bundle ('Musa' type- typical for Scitamineae).

The taxonomically significant characters used in the present study can be classified broadly under 2 sub headings.

1. Dermal morphology

- a) Presence of cuticular striations.
- b) Nature of trichomes.
- c) Nature and arrangement of costal and intercostal cells.
- d) Type of stomata.
- e) Stomatal index.
- f) Silica inclusions.
- g) Presence of oil cells.

2. Anatomical Characters.

- a) Anatomy of leaf sheath.
- b) Shape and structure of petiole.
- c) Structure of midrib.
- d) Number of bundle arcs.
- e) Bundle Sheath characters.
- f) Shape of epidermal cells in Transverse section.
- g) Presence or absence of hypodermis.
- h) Nature of bundle sheath in lamina.
- i) Presence of hypodermal fibers.
- j) Presence of calcium oxalate crystals in hypodermis.
- k) Nature of leaf margin.

The anatomical and morphological features characteristic of the subfamilies, tribes and genera from South India are as follows.

1. Subfamily : Alpinioideae

This includes 2 tribes viz., Alpinieae and Ridelleae, of which only the former is represented in South India.

1.1. Tribe: Alpinieae

This tribe includes perennial plants upto 5 m high. Distichy of leaves is transverse to the rhizome. Rhizome is usually hard and woody. Three genera viz., *Alpinia*, *Amomum* and *Elettaria* come under this tribe. Tribe Alpinieae is characterized by the presence of epidermal silica inclusions and 'Bristle' type of hair. It also shows the presence of bundle arc IV in the petiole and the bundle of the lamina is in contact with both upper and lower epidermis.

The most striking feature of this tribe is the presence of silica inclusions in the costal epidermal cells on both surfaces.

i) *Alpinia*

Seven species of *Alpinia* from South India viz., *A. abundiflora*, *A. calcarata*, *A. fax*, *A. galanga*, *A. malaccensis*, *A. nigra*, and *A. zerumbet* were studied. The genus is characterized by the presence of single, large silica body of varying size in the costal epidermal cells. Costal cells are as high as broad in all species except *A. abundiflora* and *A. fax*.

ii) Amomum

The species included for the present study are *A. cannicarpum*, *A. ghaticum*, *A. hypoleucum*, *A. masticatorium*, *A. muricatum* and *A. pterocarpum*.

Amomum is peculiar in having silica sand in costal epidermal cells with the exception of *A. pterocarpum* and *A. hypoleucum* which possess single, large silica body in their costal cells.

In *A. hypoleucum*, silica sand is seen in epidermal cells close to the costal cells. The presence of silica body is associated with the occurrence of hypodermal fibers either singly or in groups. In all other species which contain silica sand do not possess hypodermal fibers.

iii) Elettaria

Elettaria is different from other two genera of the tribe Alpinieae in having costal cells which are twice or thrice broader than high and they contain 1 or 2 silica bodies (1 big and 1 small) in them.

2. Subfamily: Zingiberoideae

The two tribes viz., Zingibereae and Globbeae are represented in South India. This includes plants with distichy of leaves parallel to the rhizome. The members of this tribe lack silica inclusions in their costal cells.

2.1. Tribe: Globbeae

This tribe includes four genera, viz., *Gagnepainia* K. Schum, *Globba* L., *Hemiorchis* Kurz. and *Mantisia* Sims., of which, only *Globba* is represented in South India.

i) *Globba*

The species studied include *G. marantina*, *G. ophioglossa*, *G. orixensis* and *G. schomburgkii*.

The genus *Globba* is unique with the presence of large, solitary calcium oxalate crystals in all cells of the abaxial hypodermis. The hairs are soft and delicate. Length of the hair is much less when compared to the typical 'Weichhaare' type of hairs seen in other genera like *Kaempferia*, *Hedychium* and *Zingiber*. The petiole possesses bundle arc IV. Silica sand is found in the parenchymatous bundle sheath cells of petiole and midrib.

2.2. Tribe : Zingibereae

Five genera viz., *Boesenbergia* (Wall.) Kuntz, *Curcuma* L., *Hedychium* Koenig, *Kaempferia* L. and *Zingiber* Boehm. are present in South India. This tribe is heterogenous, in having genera with pseudostem (*Kaempferia* & *Curcuma*) and with true aerial stem (*Boesenbergia*, *Hedychium* & *Zingiber*). They differ anatomically in the type of stomata, nature of hair, structure of epidermal cells, presence of hypodermis etc.

i) Boesenbergia

Two species, *B. pulcherrima* and *B. tiliaefolia* were studied. The genus is characterized by the presence of polycytic stomata, whereas in all other genera they are tetracytic. Stomata are almost absent on the adaxial epidermis. The adaxial epidermis is raised at the major veins and the epidermal cells are twice or thrice higher than broad in those regions.

ii) Curcuma

A total of 19 species and 1 variety were studied. They show variation in size, shape, texture and vestiture of leaves. Leaves are petiolate except in *C. bhatii*. The taxa included for the present study are *C. aeruginosa*, *C. amada*, *C. aromatica*, *C. aurantiaca*, *C. bhatii*, *C. coriacea*, *C. decipiens*, *C. haritha*, *C. inodora*, *C. karnatakensis*, *C. longa*, *C. montana*, *C. mutabilis*, *C. neilgherrensis*, *C. oligantha* var. *oligantha*, *C. oligantha* var. *lutea*, *C. pseudomontana*, *C. raktakanta*, *C. vamana* and *C. zanthorrhiza*.

Anatomically they are grouped on the basis of nature of wings of the petiole. Bundle arc IV is absent in the petiole. Large air canals are present in between the bundles of arc I. Trabeculae are well developed. The leaf margin is always gradually tapering and pointed. Most of the species possess oils cells on the abaxial epidermis.

iii) Hedychium

Aerial stem is 1-2 m high. Petiole is absent. Upper surface of the leaf glabrous and lower side is densely pubescent with hairs upto 3 mm long.

Inflorescence is always terminal. Taxa included in the present study are *H. coronarium*, *H. flavescens* and *H. spicatum* var. *acuminatum*.

Epidermis is distinguishable into costal and intercostal regions. Oil cells are abundant on abaxial epidermis. Hairs are of the 'Weichhaare' type. Section through the junction between leaf base and ligule shows the presence of arc IV. The identification of different species is very difficult because of the close resemblances in their anatomy.

iv) Kaempferia

The species studied include *K. galanga*, *K. rotunda* and *K. scaposa*.

Epidermis is less distinguishable into costal and intercostal cells and they are arranged irregularly. Cuticular striations are present on both epidermis. Hairs are abundant on the abaxial epidermis. Air canal is prominent as in *Curcuma*, transverse bundles are present in the diaphragm of the air canal. The bundle sheath cells or the cell near to the bundle sheath possess single large silica body. Presence of 1-3 layered hypodermis is another character – upto 3 layers may be seen (*K. galanga*). *K. scaposa* shows difference in morphology and anatomy. As it is more closer to *Curcuma*, the transfer of the genus is proposed.

v) Zingiber

Seven taxa viz., *Z. capitatum* var. *elatum*, *Z. montanum*, *Z. neesatum*, *Z. nimmonii*, *Z. officinale*, *Z. wightianum* and *Z. zerumbet* were studied.

Presence of pulvinus at the petiole is a unique feature of this genus. Costal and intercostal cells are distinct on the epidermis. Hairs are of 'Weichhaare' type. A section through the pulvinus shows bundle arc IV. The most remarkable feature of *Zingiber* is the collenchymatous bundle sheath in petiole. A few layers of ground tissue cells below the abaxial epidermis show collenchymatous thickening. Hyaline portion of the margin is usually biseriolate.

Present studies have shown that some genera can be identified by the possession of some unique characters. The genus *Globba* can be easily recognised by the presence of single, large calcium oxalate crystal in hypodermal cells, *Boesenbergia* having polycytic stomata and *Zingiber* with collenchymatous bundle sheath in the petiole. Whereas characters common for a particular tribe is rare. Excepting a few, the anatomical characters are very much helpful in delimitation of species.

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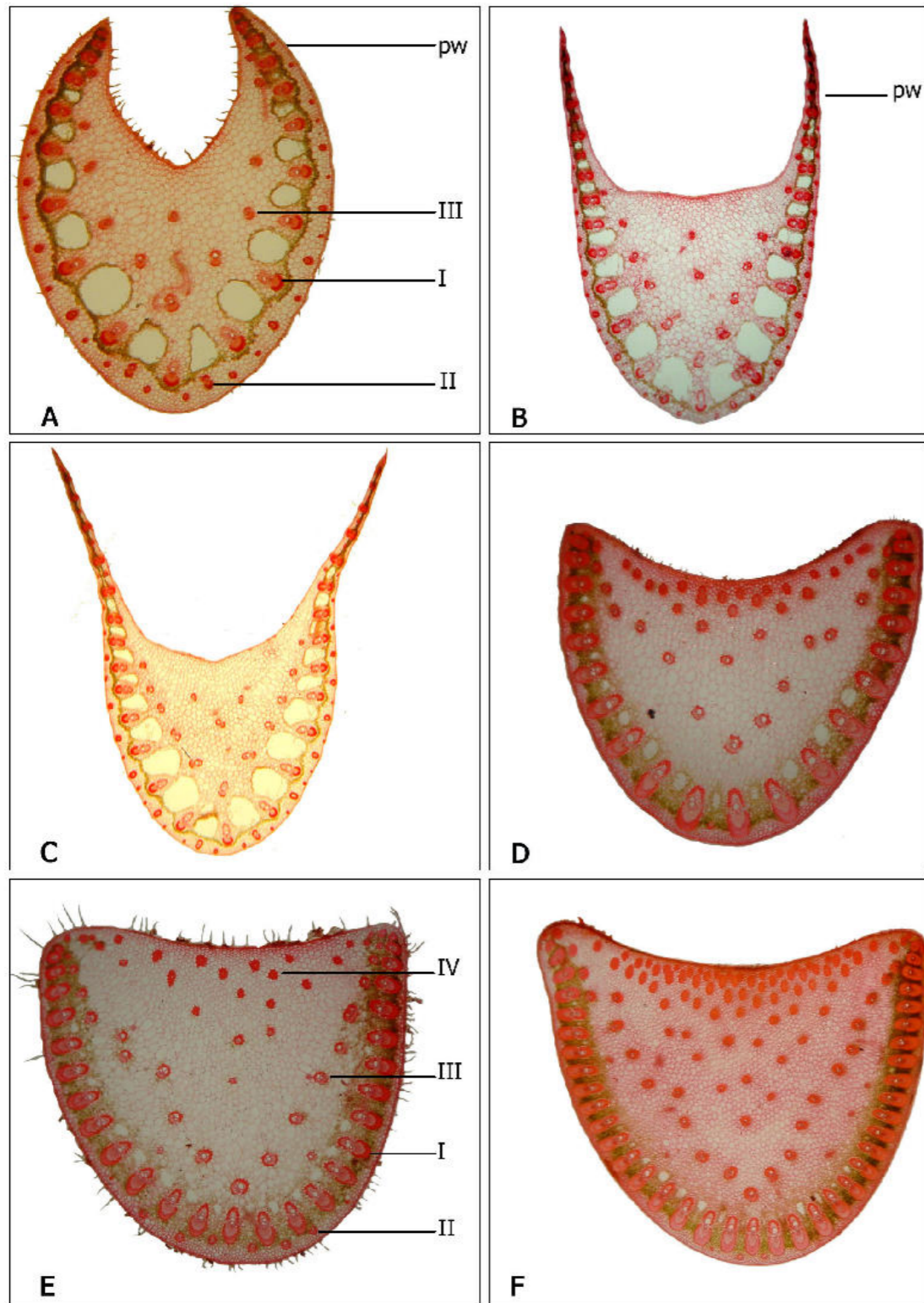


Plate 05. Comparison of T. S. of petioles of various taxa : **A.** *Curcuma aurantiaca* with short and broad wings; **B.** *Curcuma aeruginosa* with long and narrow wings; **C.** *Curcuma zanthorrhiza* (A-C, Arcs I, II and III present); **D.** *Alpinia calcarata* with short and broad wings on both sides; **E.** *Alpinia malaccensis* with blunt edges ; **F.** *Alpinia zerumbet* with one wing on one side (D-F. Arcs I, II, III and IV present). * pw- petiole wings.

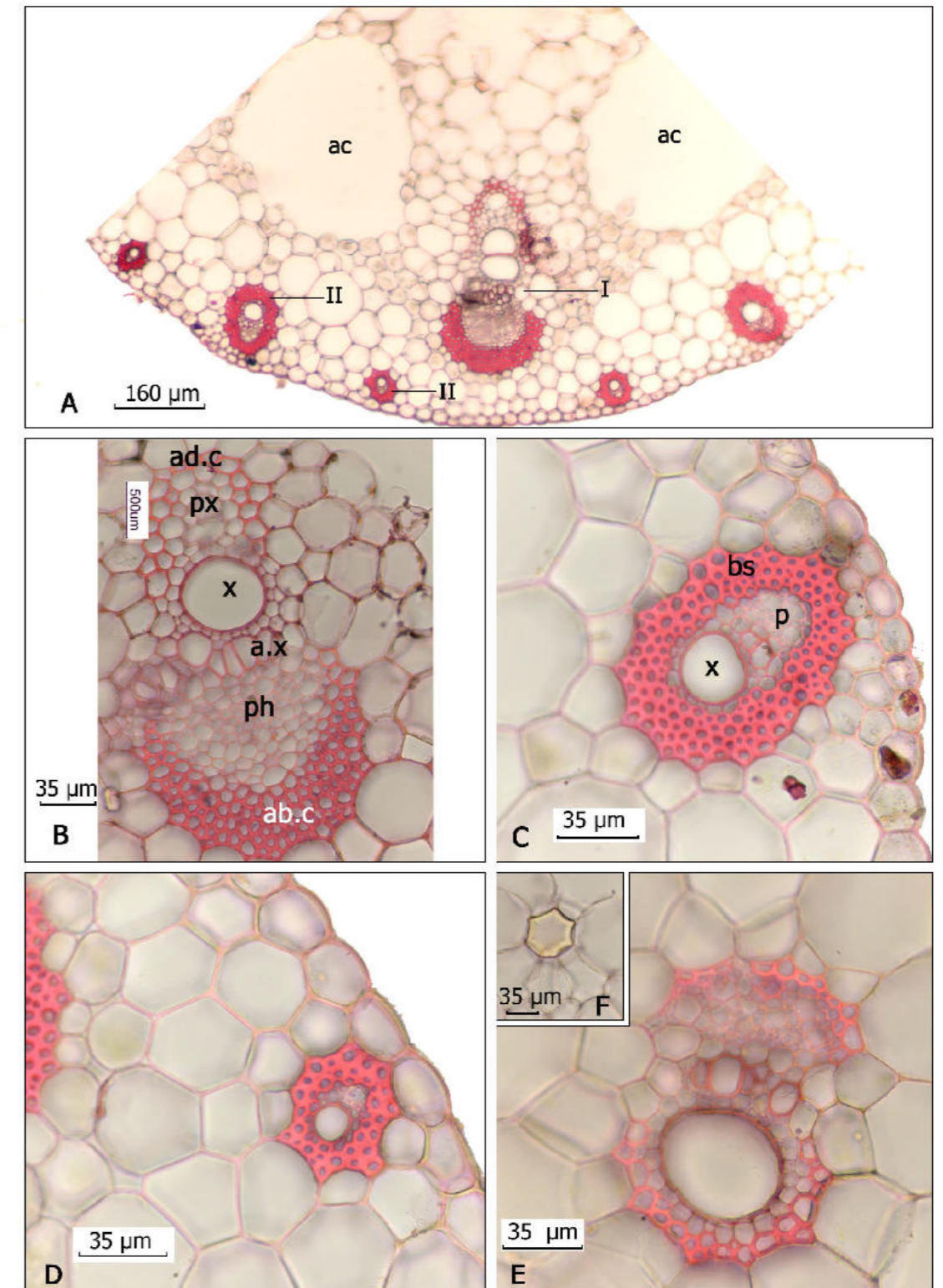


Plate 06. Vascular bundles of Petioles I: **A.** Enlarged view of petiole of *Curcuma decipiens* showing arc I, II and air canal; **B.** Magnified view of arc I bundle (Musa- Type); **C.** Larger bundle of arc II showing complete sheath; **D.** Smaller bundle of arc II; **E.** Bundle of arc III with poorly developed bundle caps and showing reverse orientation of xylem and phloem; **F.** Oil cell in the ground tissue. * ac- air canal, I- arc I bundle. II- arc II bundle, ad.c- adaxial cap, px- protoxylem, x- xylem, a.x- angular xylem, ph- phloem, ab.c- abaxial cap, bs- bundle sheath.



Plate 11. Habit: a. *A. zerumbet*; b. *Amomum cannicarpum*; c. *A. ghaticum*; d. *A. hypoleucum*; e. *A. masticatorium*; f. *A. muricatum*.



Plate 12. Habit: a. *A. pterocarpum*; b. *Elettaria cardamomum*; c. *Globba marantina*; d. *G. ophioglosa*; e. *G. orixensis*; f. *G. schomburgkii*.

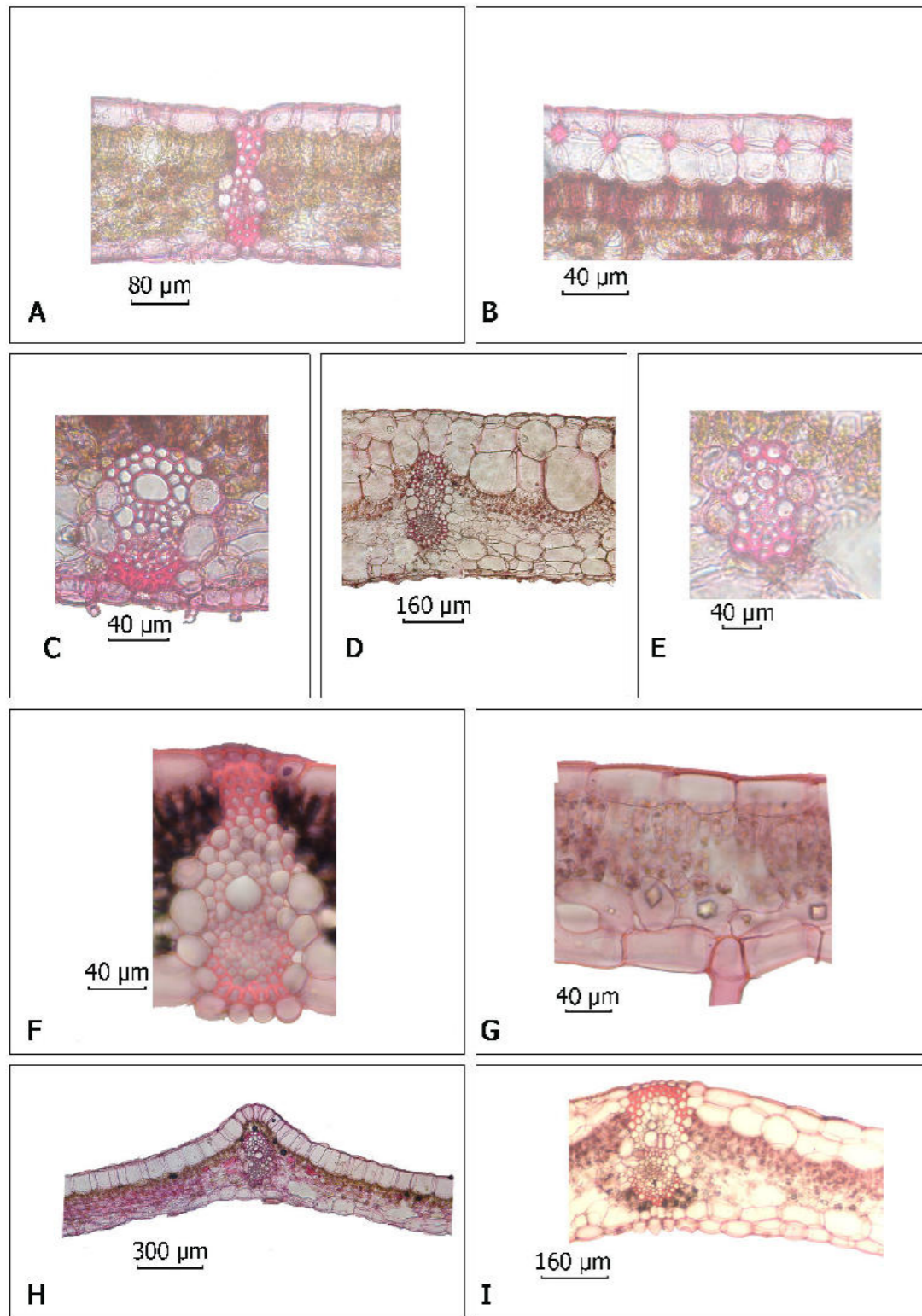


Plate 09: Comparison of T. S. of Lamina of various taxa: **A.** *Alpinia galanga*; **B & C.** *Amomum hypoleucum*. **B.** Hypodermal fibers; **C.** Bundles connected to abaxial epidermis ; **D.** *Kaempferia galanga* with 2 or 3 layers of hypodermis below both epidermis; **E.** Bundles embedded in the mesophyll tissue; **F & G.** *Globba orixensis*. **F.** Largest bundle connected to both epidermis; **G.** Calcium oxalate crystals in the hypodermal cells; **H.** *Boesenbergia tiliaefolia* with raised adaxial epidermis; **I.** *Curcuma zanthorrhiza*- largest bundle connected to adaxial epidermis.



Plate 10. Habit: **a.** *Alpinia abundiflora*; **b.** *A. calcarata*; **c.** *A. fax*; **d.** *A. galanga*; **e.** *A. nigra*; **f.** *A. malaccensis*.

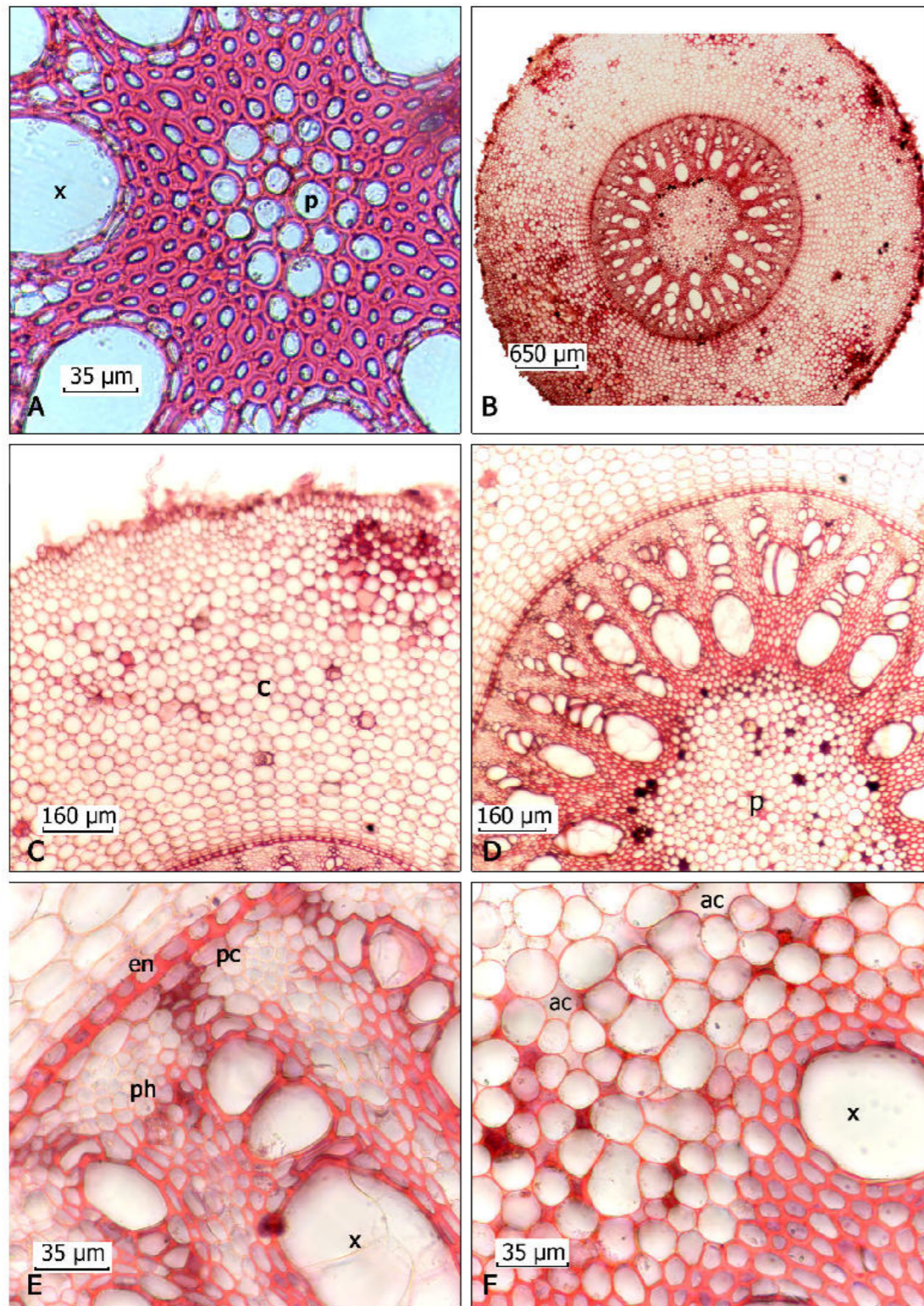


Plate 24. T. S. of Root II: A. Pith of *Amomum masticatorium*; B-F. *Elettaria cardamomum*. B. Root; C. Cortex. D. Stele; E. Enlarged view of stele; F. Pith showing air canals. * c- cortex, p- pith, en- endodermis, pc- pericycle, ph- phloem, x- xylem, ac- air canal.

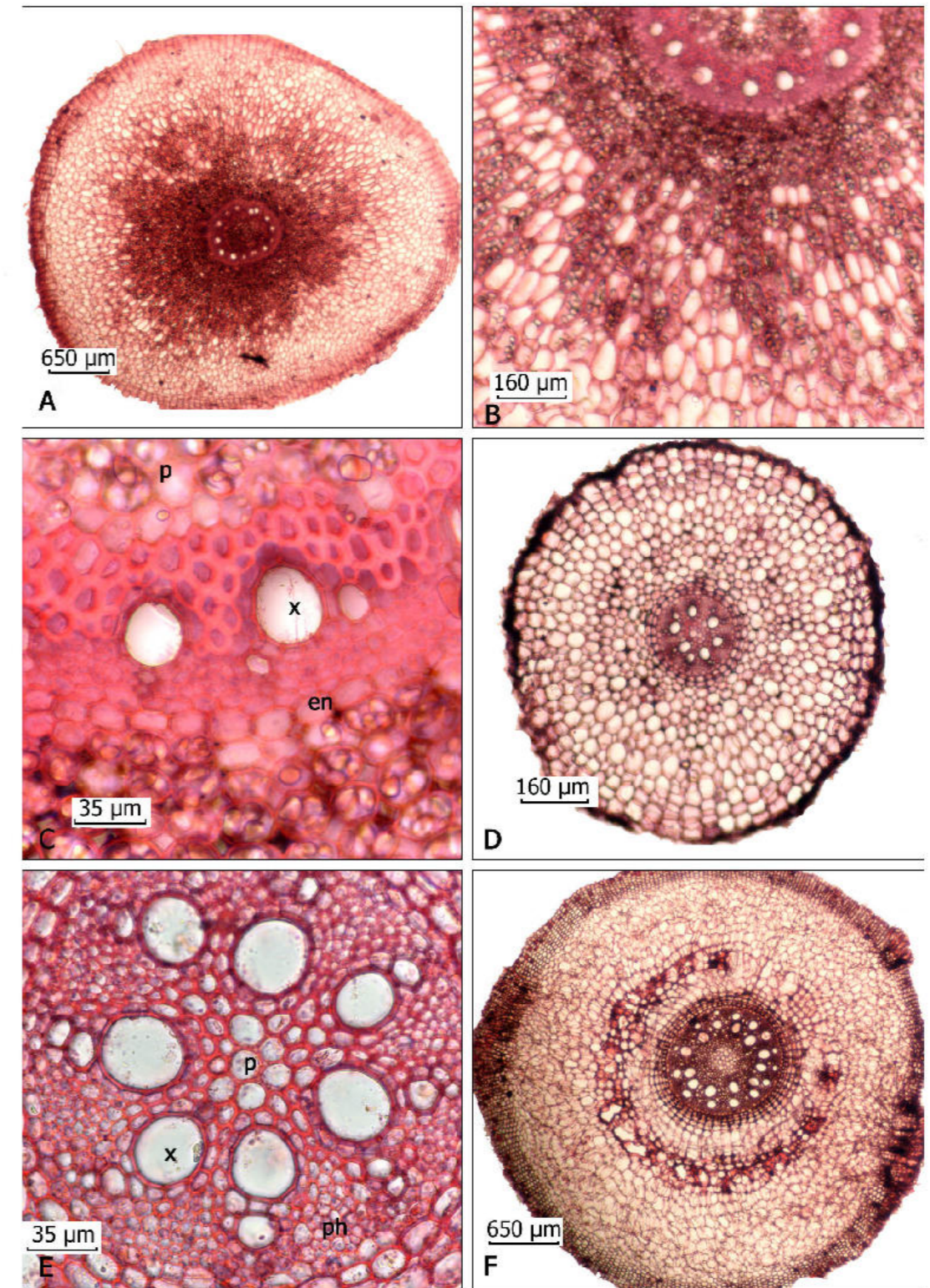


Plate 25. T. S. of Root III: A-C. *Globba schomburgkii*. A. Root; B. Inner cortical cells filled with starch grains; C. Enlarged view of stele; D & E. *Boesenbergia siphonantha*. D. Root; E. Stele; F. *Curcuma longa*. * en- endodermis, p- pith, x- xylem, ph- phloem.

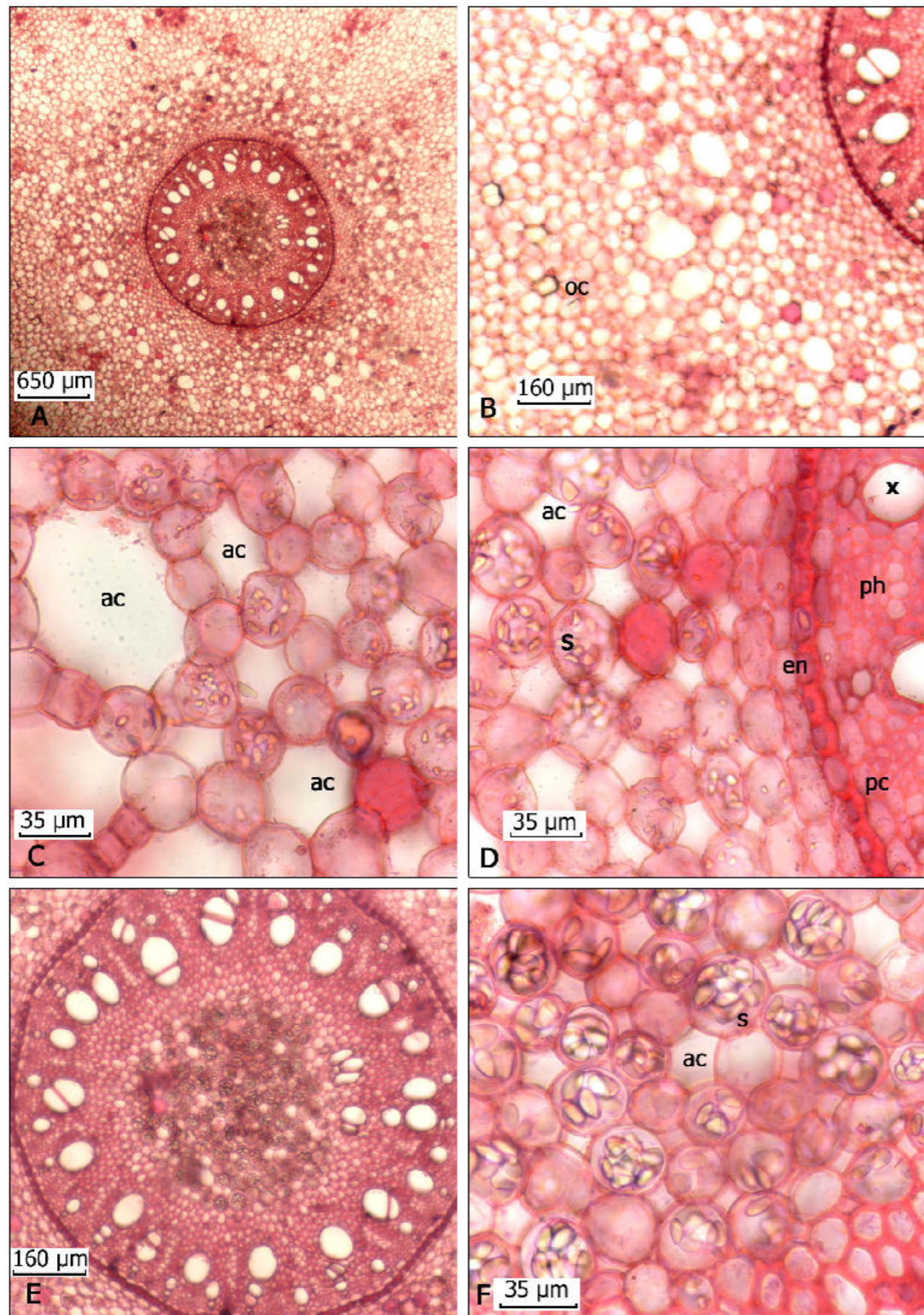


Plate 26. T. S. of Root IV: **A-F.** *Hedychium coronarium*. **A.** Root; **B.** Cortical region; **C.** Air canals in the cortical region; **D.** Inner cortical region and endodermis; **E.** Stele; **F.** Pith region containing starch grains and air canals. * **oc**- oil cell, **ac**- air canal, **s**- starch grains, **en**- endodermis, **pc**- pericycle, **x**- xylem, **ph**- phloem.

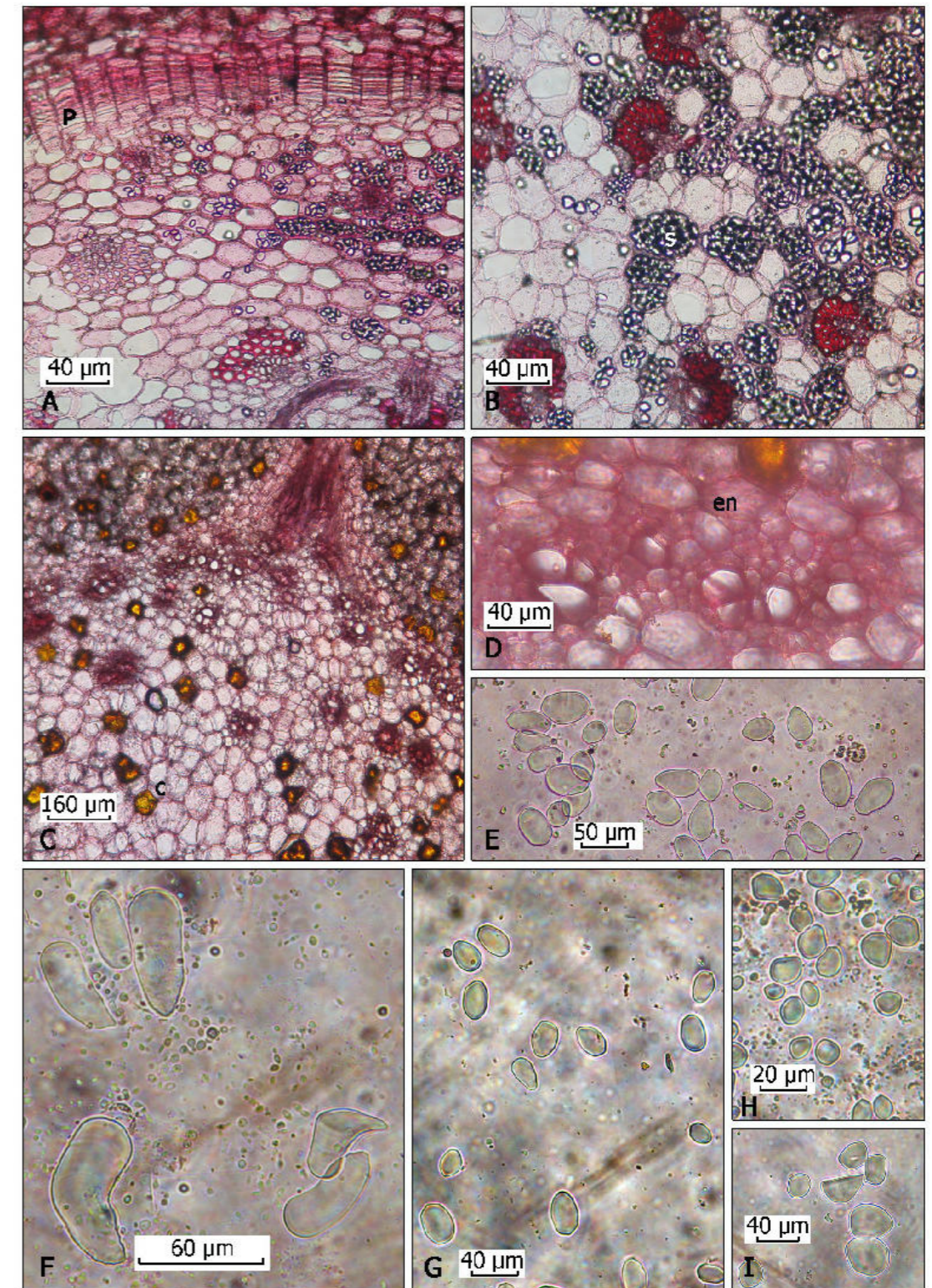


Plate 22. Comparison of Rhizome of various taxa: **A & B.** *Globba schomburgkii*. **A.** Periderm and cortical bundles; **B.** Central region showing bundles and cells containing starch grains; **C & D.** *Curcuma longa*. **C.** T. S. of rhizome with numerous curcumin cells; **D.** Bundles of the central cylinder- bundle sheath poorly developed; **E-I.** Starch grains. **E.** *Kaempferia galanga*; **F.** *Hedychium coronarium*; **G.** *Amomum masticatorium*; **H.** *Boesenbergia tiliaefolia*; **I.** *Globba schomburgkii*. * **p**- periderm, **s**- starch grains, **en**- endodermis, **c**- curcumin cells.

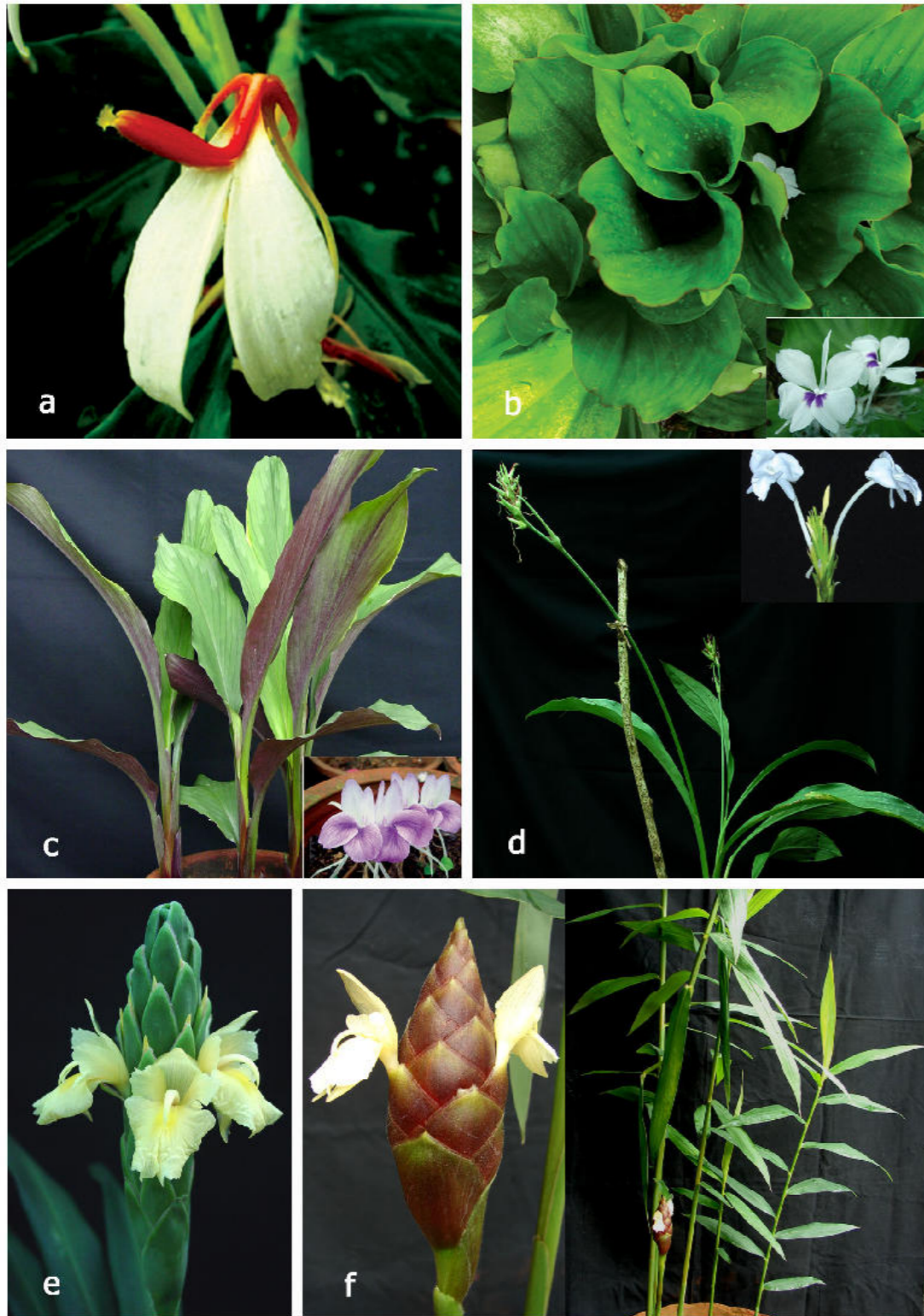


Plate 17. Habit: a. *H. spicatum* var. *acuminatum*; b. *Kaempferia galanga*; c. *K. rotunda*; d. *K. scaposa*; e. *Zingiber capitatum* var. *elatum*; f. *Z. montanum*.

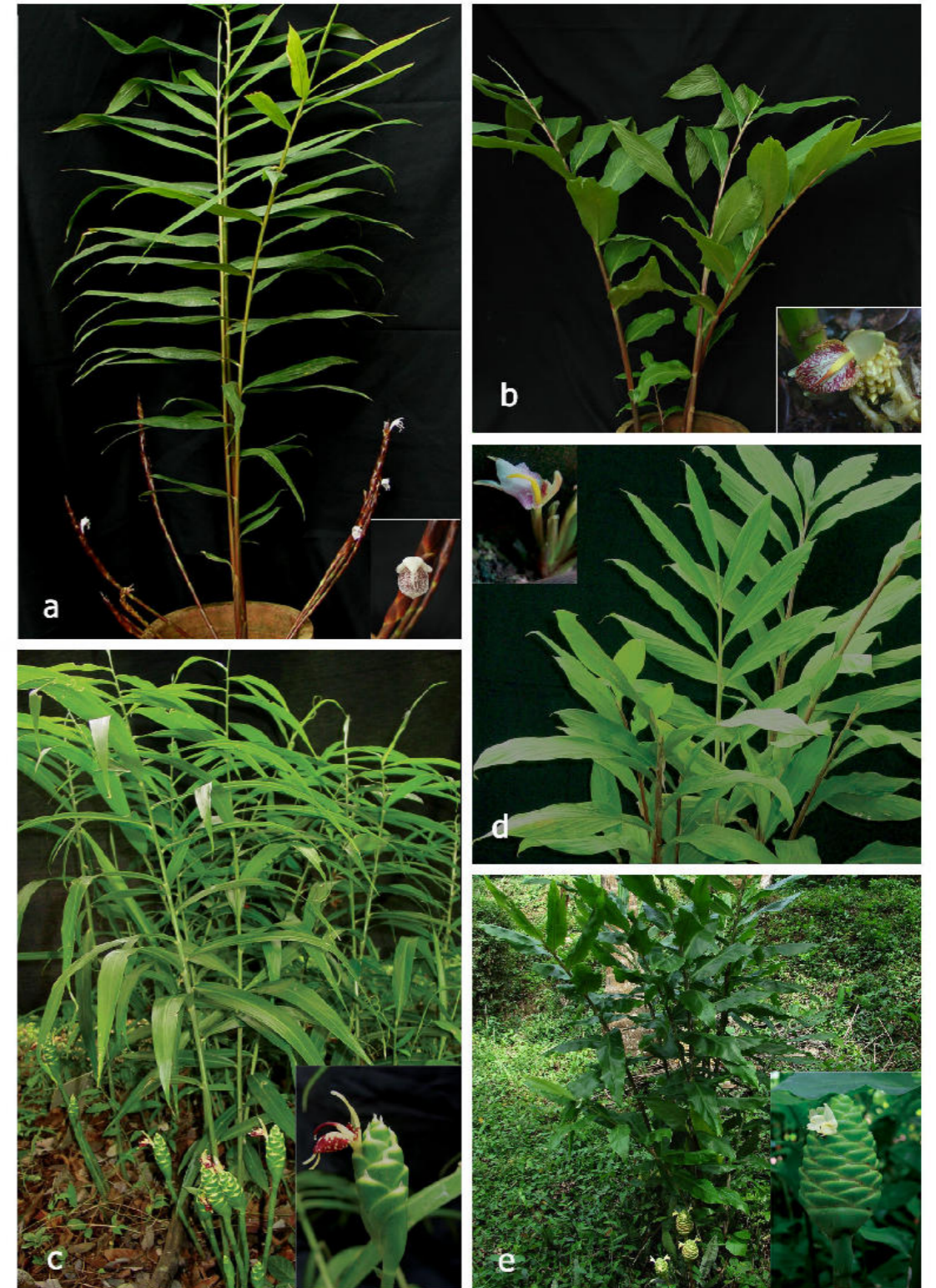


Plate 18. Habit: a. *Z. neesatum*; b. *Z. nimmonii*; c. *Z. officinale*; d. *Z. whightianum*; e. *Z. zerumbet*.



Plate 13. Habit: a. *Boesenbrgia pulcherrima*; b. *B. tiliaefolia*; c. *Curcuma aeruginosa*; d. *C. amada*; e. *C. aromatica*; f. *C. aurantiaca*.



Plate 14. Habit: a. *C. bhatii*; b. *C. coriacea*; c. *C. decipiens*; d. *C. haritha*; e. *C. inodora*; f. *C. karnatakensis*.

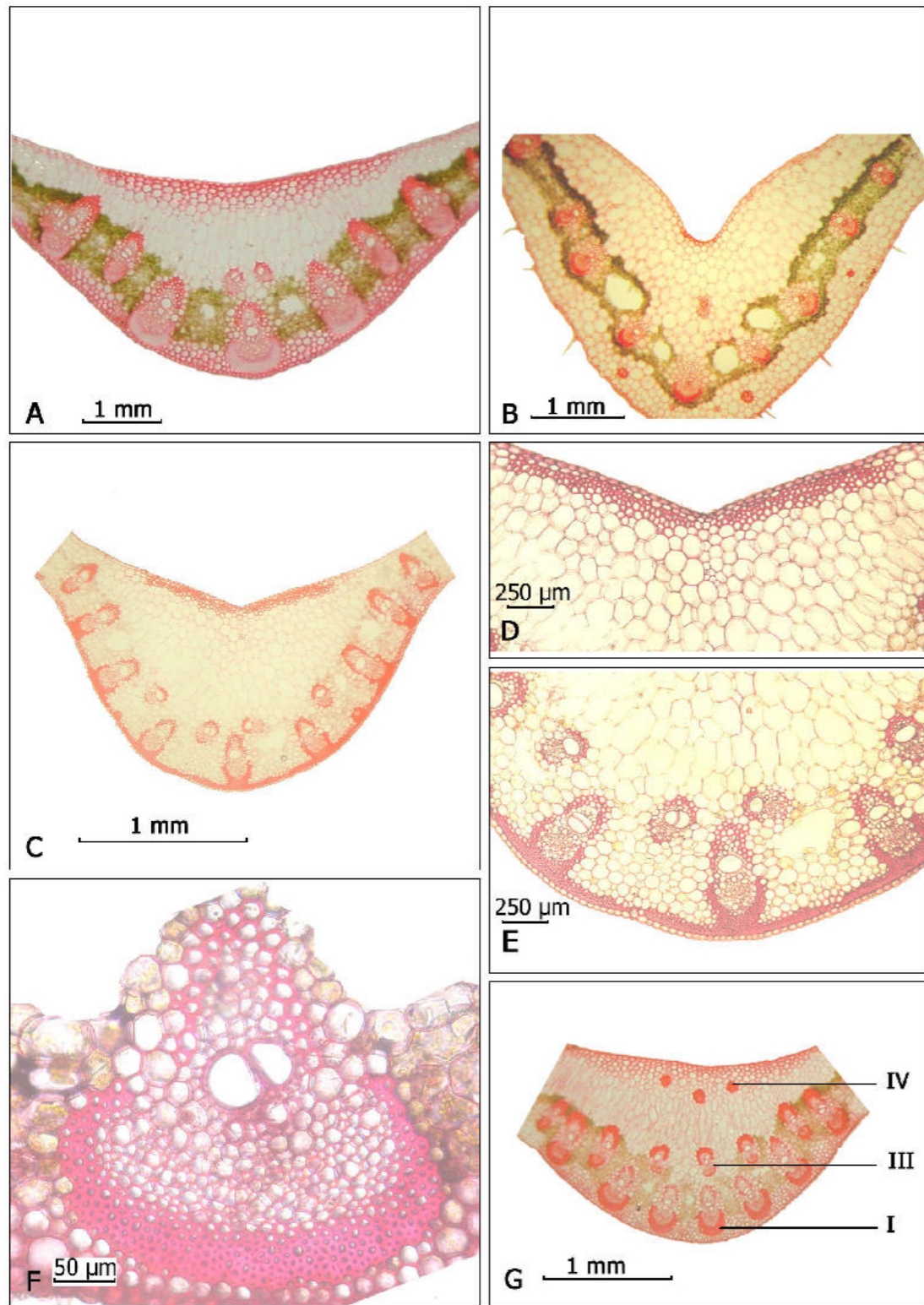


Plate 08. Comparison of T. S. of Midribs of various taxa: **A.** *Alpinia calcarata* showing thick walled cells below the adaxial epidermis; **B.** *Curcuma* spp. with arcs I, II and III; **C.** Midrib of *Alpinia galanga* with bundle arcs I and III; **D.** Thick walled cells below the adaxial epidermis; **E.** Fibrous band below the arc I; **F.** Arc I bundle of *Amomum muricatum*; **G.** *Alpinia zerumbet* with bundle arcs I, III & IV.

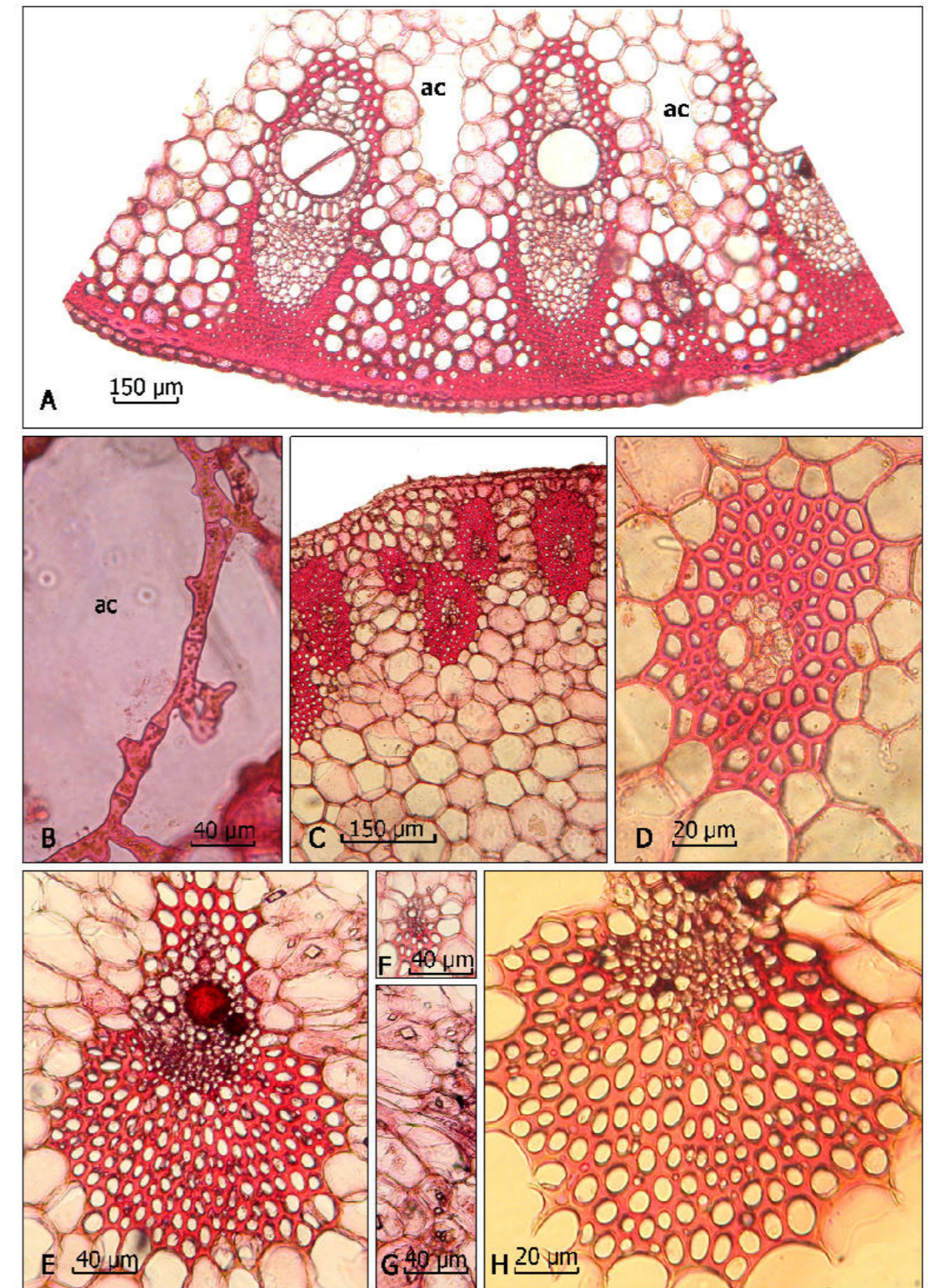


Plate 07. Vascular bundles of Petioles II: **A.** Fibrous band below the arc I bundles of *Alpinia galanga*; **B.** Assimilatory tissue or diaphragm seen in the air canals of *Curcuma aromatica*; **C.** Bundles of arc IV in *Alpinia galanga*; **D.** A bundle enlarged; **E-H.** *Z. officinale*. **E.** Arc I bundle in the petiole; **F.** Arc II bundle; **G.** Calcium oxalate crystals in the assimilatory tissue; **H.** Collenchymatous bundle sheath. * ac- air canal.

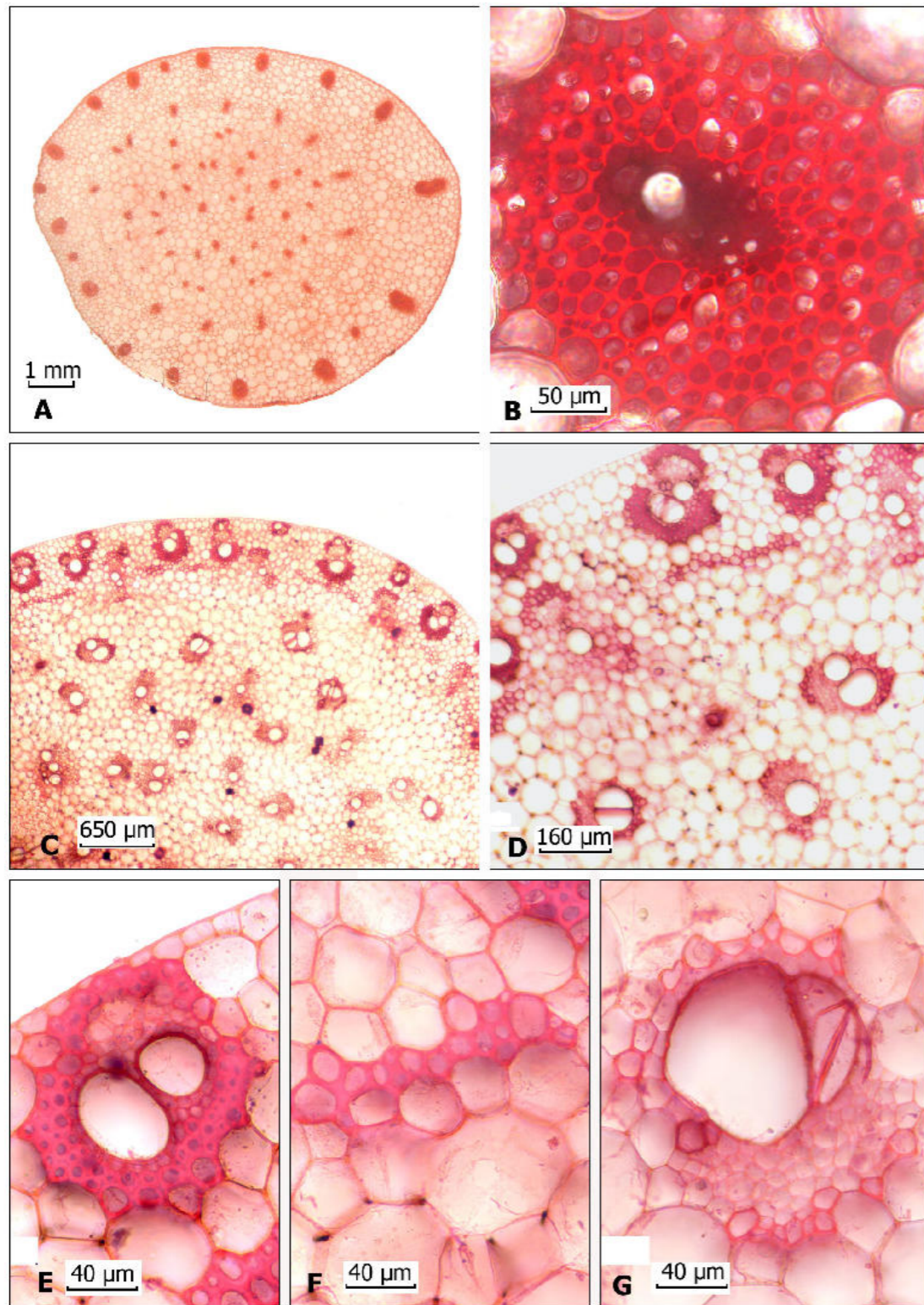


Plate 21. T. S. of Aerial stem III: **A & B.** *Boesenbergia tiliaefolia*. **A.** Stem without fibrous band; **B.** Cortical bundle with collenchymatous bundle sheath; **C-G.** *Zingiber officinale*. **C.** A portion of stem; **D.** Enlarged view showing the discontinuous fibrous band; **E.** Bundle seen in the central region; **F.** Fibrous cylinder; **G.** Central bundle with very poorly developed sheath.

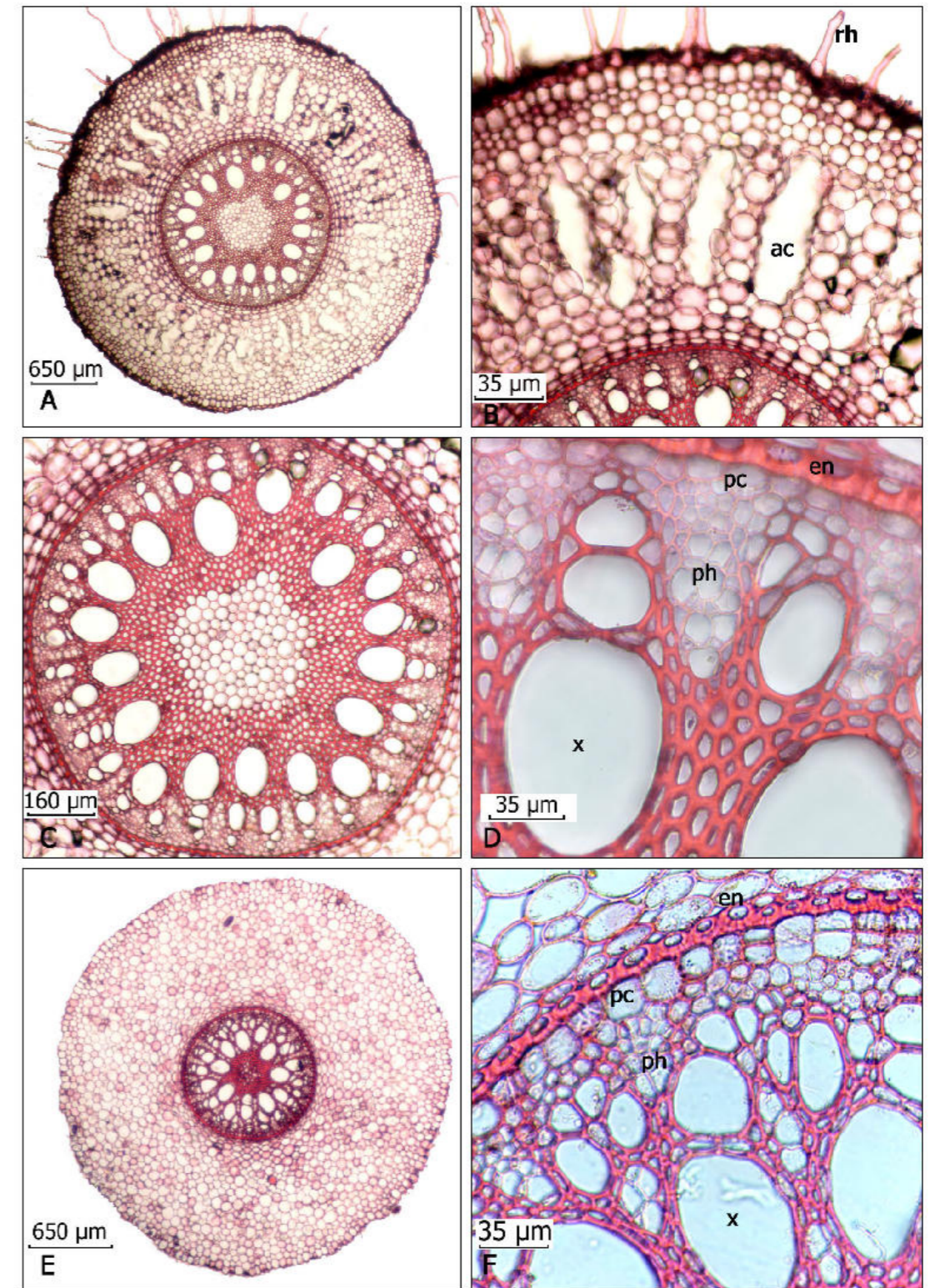


Plate 23. T. S. of Root I: **A-D.** *Alpinea galanga*. **A.** Root; **B.** Cortex showing air canals and root hairs on the epidermis; **C.** Stele; **D.** Enlarged view of stele. **E & F.** *Amomum masticatorium*. **E.** Root; **F.** Enlarged view of a portion of stele. * **rh-** root hair, **ac-** air canal, **en-** endodermis, **pc-** pericycle, **ph-** phloem, **x-** xylem.

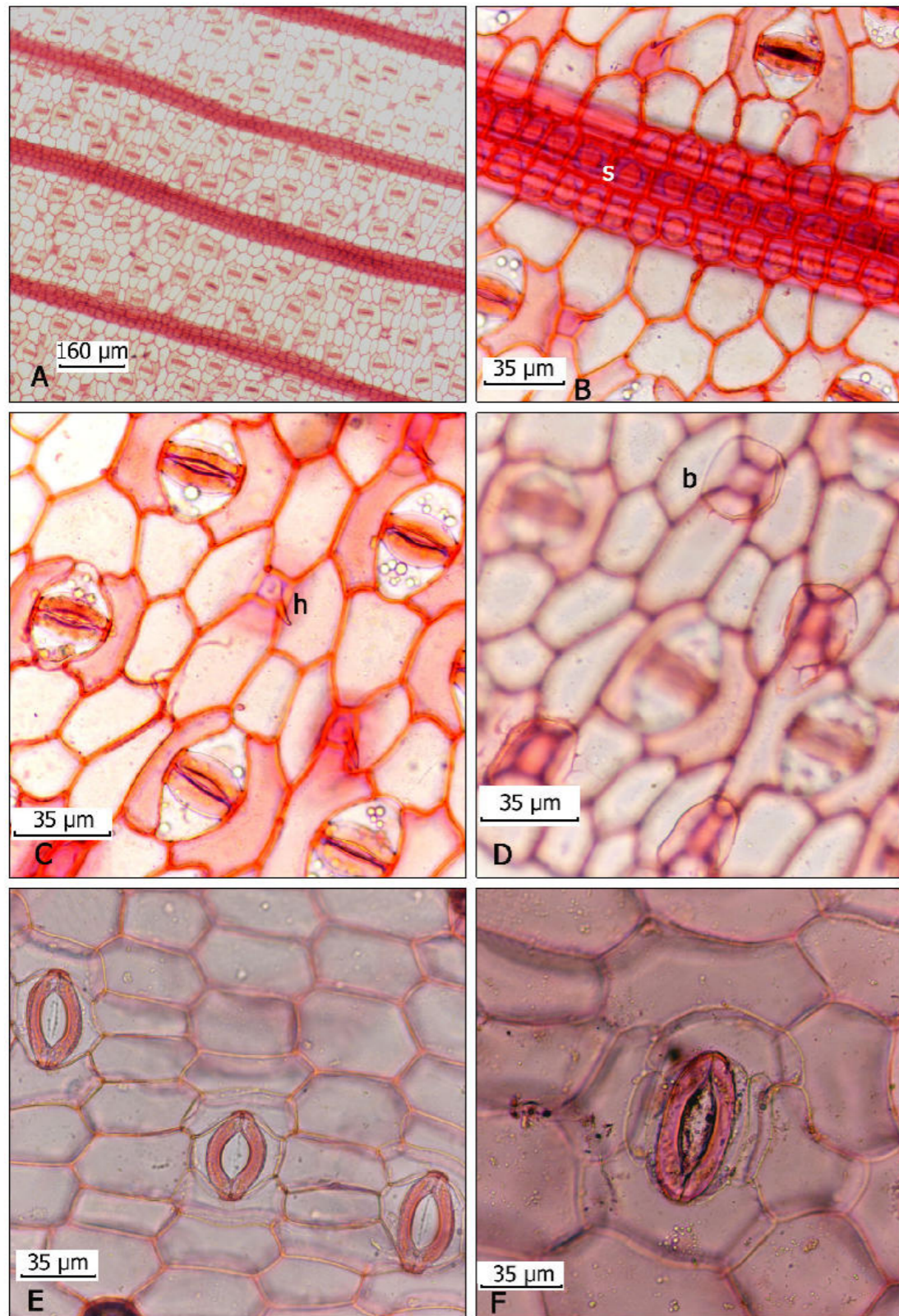


Plate 03. Epidermal features of various taxa II: **A.** Abaxial epidermis of *Alpinia galanga* showing distinct costal and intercostal regions; **B.** Costal cells containing single large silica body; **C.** Prickle type of hair on abaxial epidermis of *A. galanga*; **D.** Bulbous base of hair; **E.** Tetracytic stomata of *Globba orixensis*; **F.** Polycytic stomata of *Boesenbergia*. * s- silica body, h- hair, b- base of hair.

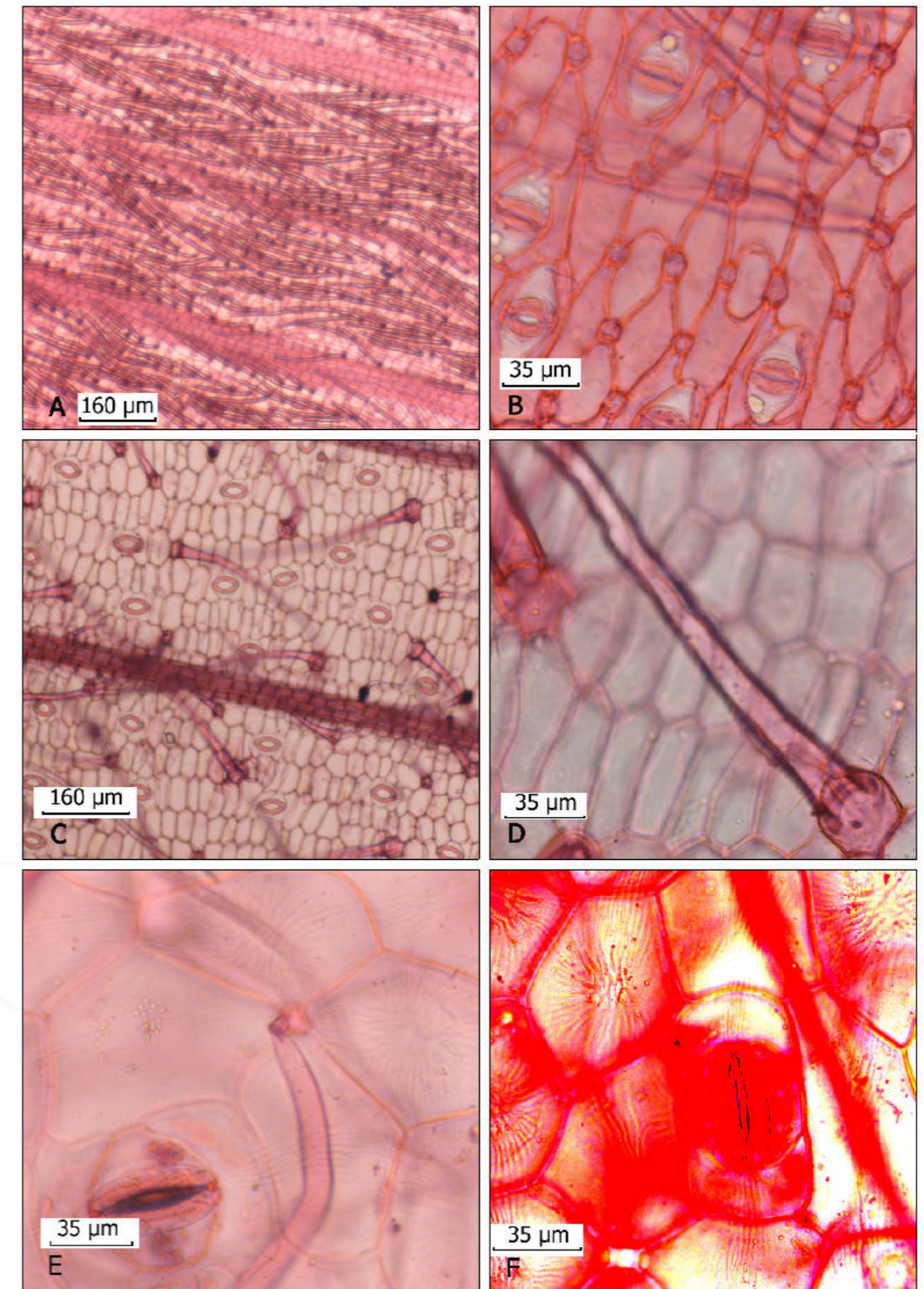


Plate 04. Epidermal features of various taxa III: **A.** Abaxial surface of *Amomum hypoleucum* showing hairs; **B.** Appearance of the abaxial surface after the removal of hairs; **C & D.** *Globba orixensis*. **C.** Abaxial surface with hairs; **D.** Basal part of the hair; **E & F.** *Kaempferia galanga*. **E.** Abaxial surface showing the base of the hair; **F.** Cuticular striations on the abaxial surface.

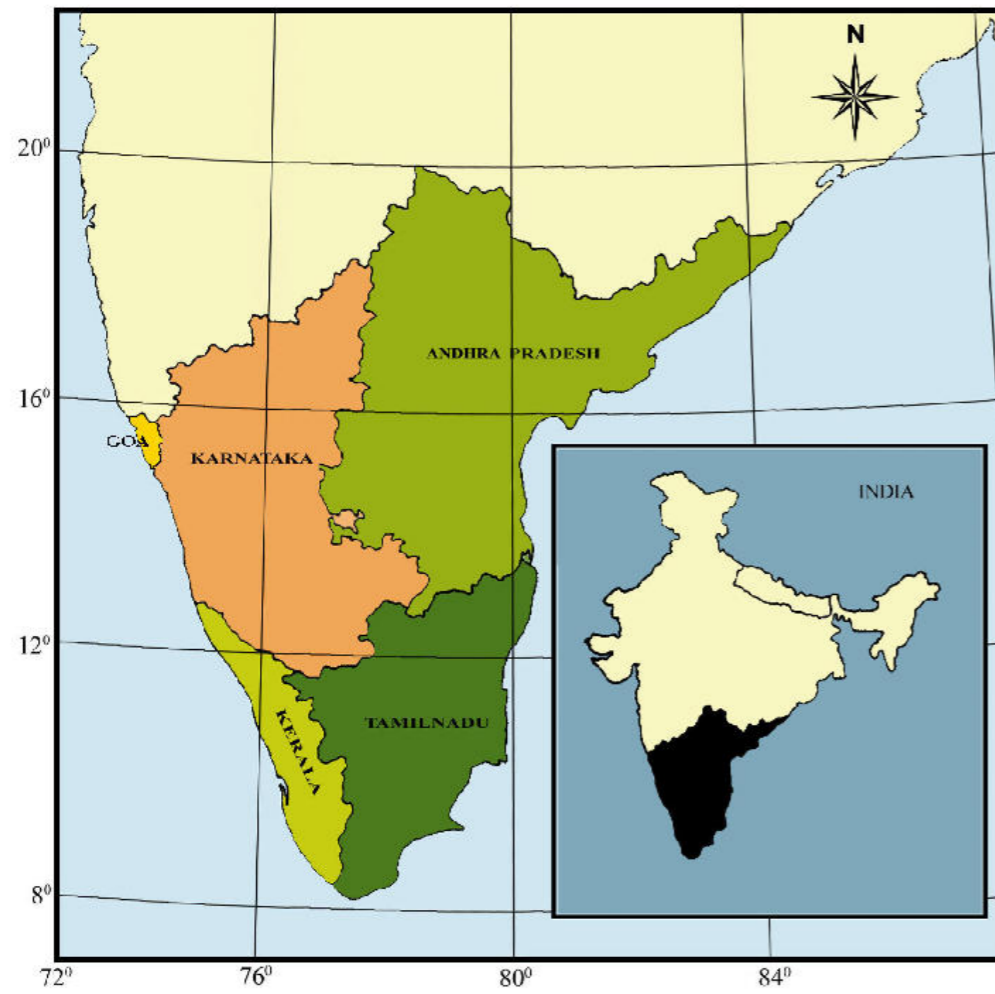


Plate 01. Map of South India

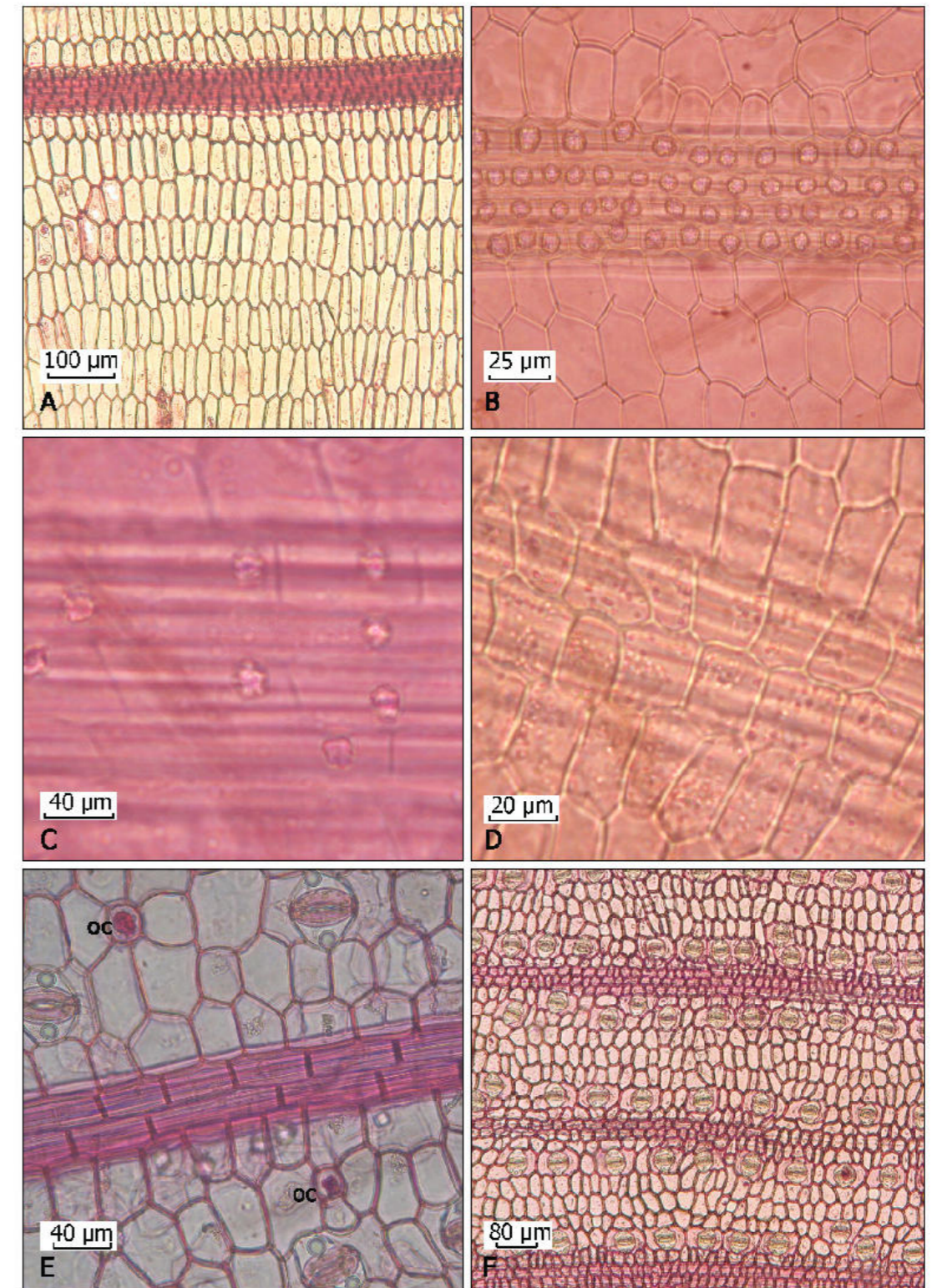


Plate 02. Epidermal features of various taxa I: A. Adaxial epidermis of *Globba orixensis*; B. Silica bodies in the costal cells of *Alpinia galanga*; C. Silica bodies of *Elettaria cardamomum*; D. Silica sand in *Amomum muricatum*; E. Abaxial epidermis of *Zingiber officinale* with oil cells; F. Abaxial epidermis of *Alpinia zerumbet* - stomata seen on either side of the vein. * oc- oil cells.



Plate 15. Habit: a. *C. longa*; b. *C. montana*; c. *C. mutabilis*; d. *C. oligantha* var. *oligantha*; e. *C. oligantha* var. *lutea*; f. *C. neilgherrensis*.



Plate 16. Habit: a. *C. pseudomontana*; b. *C. raktakanta*; c. *C. vamaana*; d. *C. zanthorrhiza*; e. *Hedychium coronarium*; f. *H. flavescens*.

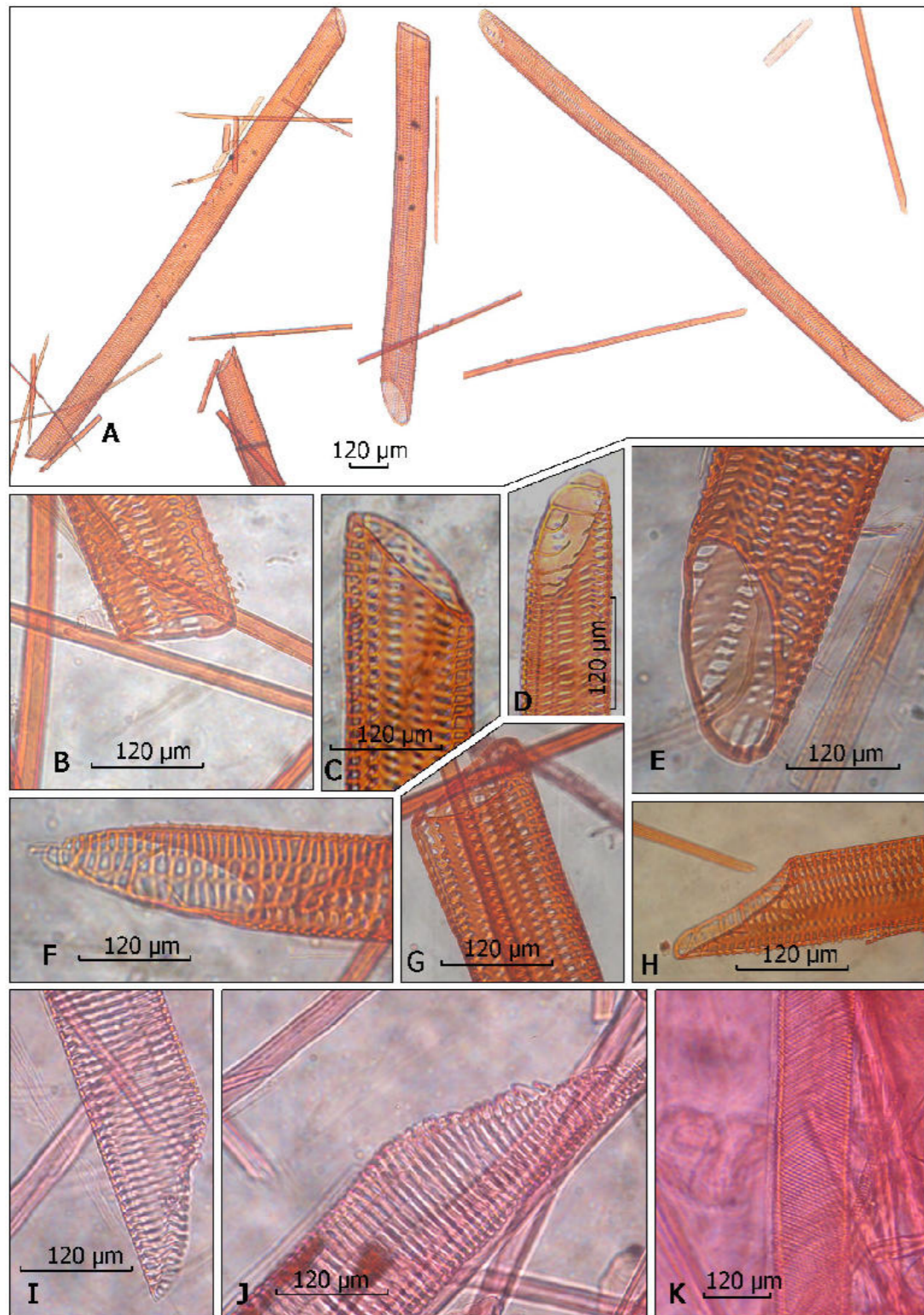


Plate 27. Xylem elements of various parts: **A-H.** Vessels of *Amomum masticatorium* with simple and scalariform perforation plates. **A.** Entire view; **B.** Simple, transverse perforation plate; **C & G.** Slightly oblique end wall of simple perforation plate; **D & F.** Oblique end walls with scalariform perforation plate; **E & G.** Oblique end walls with simple perforation plate; **I & J.** *Hedychium flavescens*- Vessels with scalariform perforation plate; **K.** Tracheids of the petiole of *Alpinia zerumbet* showing spiral thickening.

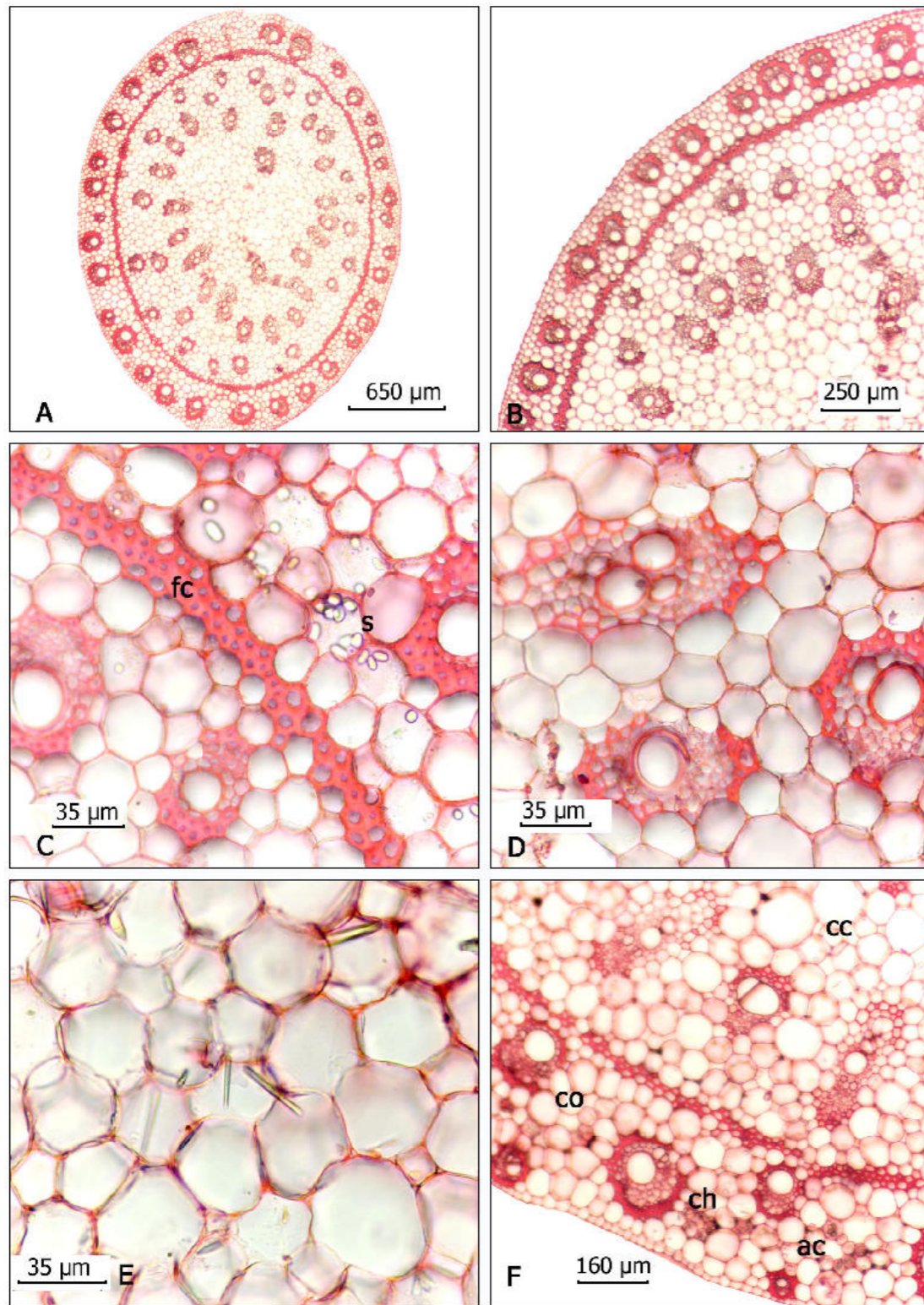


Plate 19. T. S. of Aerial stem I: **A-E.** *Amomum masticatorium*. **A.** Stem; **B.** A portion enlarged; **C.** Fibrous cylinder separating the two regions and starch grains in the cells of outer cortical region; **D.** Bundles of the central cylinder; **E.** Acicular crystals in the cells of central cylinder; **F.** *Hedychium coronarium* - Enlarged view of the stem showing fibrous cylinder, outer cortical region with 2 bundle rings, air cavities and chlorenchyma. * **fc**- fibrous cylinder, **s**- starch grains, **ch**- chlorenchyma cells, **ac**- air canal, **co**- cortical region, **cc**- central cylinder.

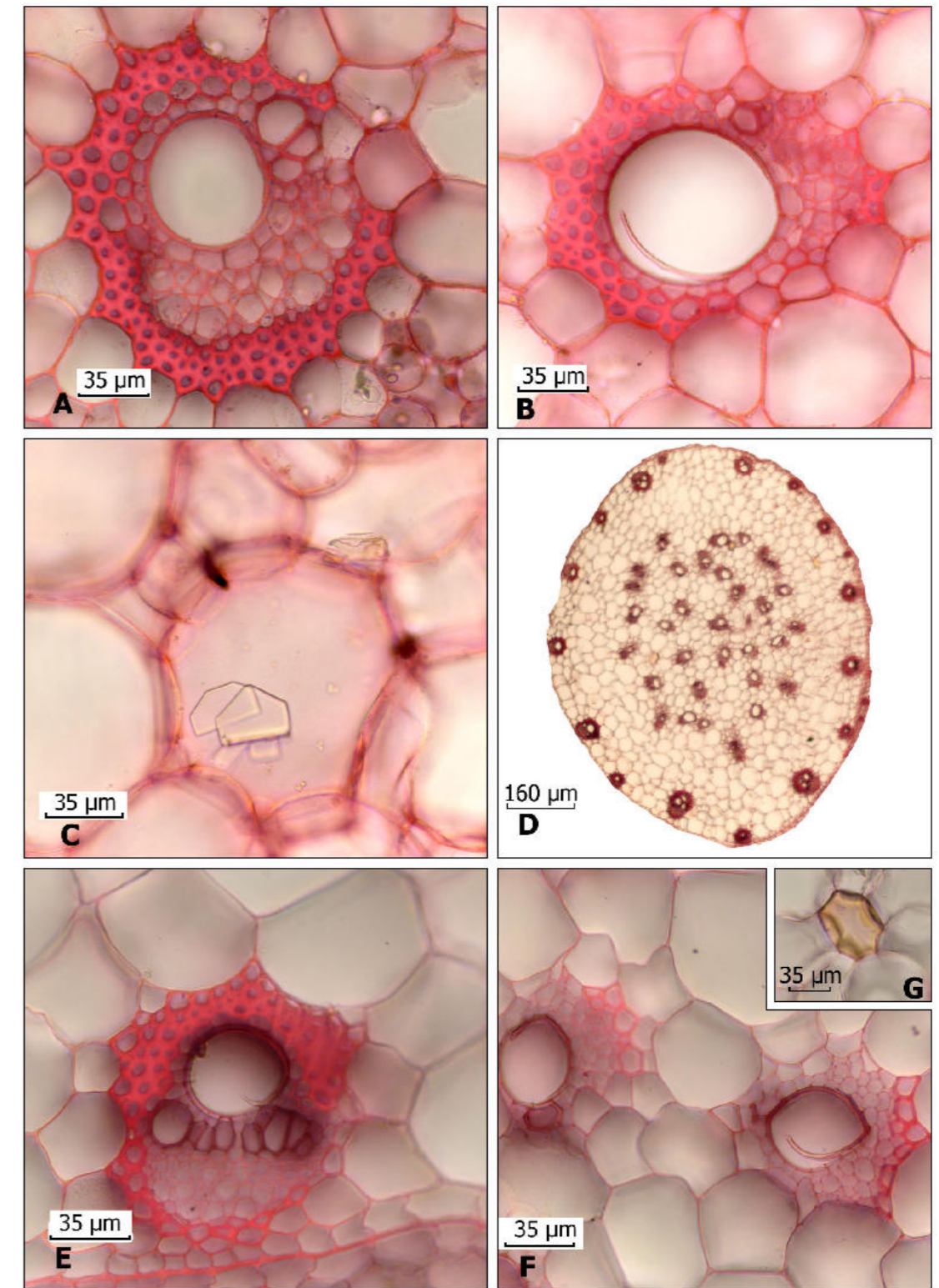


Plate 20. T. S. of Aerial stem II: **A-C.** *Hedychium coronarium*. **A.** Large bundle of the outer cortical region; **B.** Bundle of the central region; **C.** Crystals in the cells of ground tissue; **D-G.** *Globba schomburgkii*. **D.** Stem without fibrous cylinder; **E.** Larger bundle of cortical region; **F.** Bundles of central cylinder; **G.** Oil cells in the ground tissue.

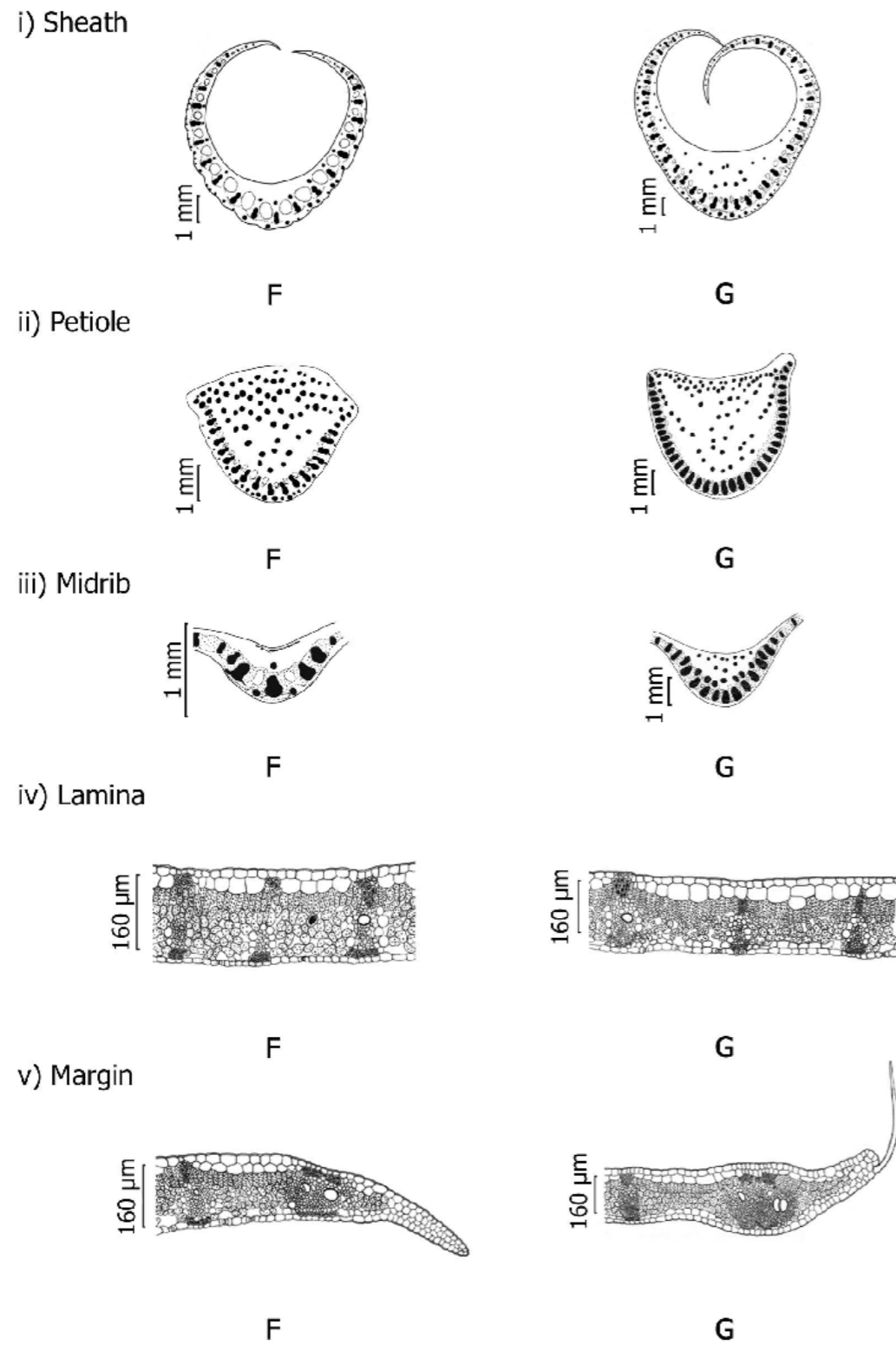


Fig. 11. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Alpinia* spp. III: F. *A. nigra*; G. *A. zerumbet*.

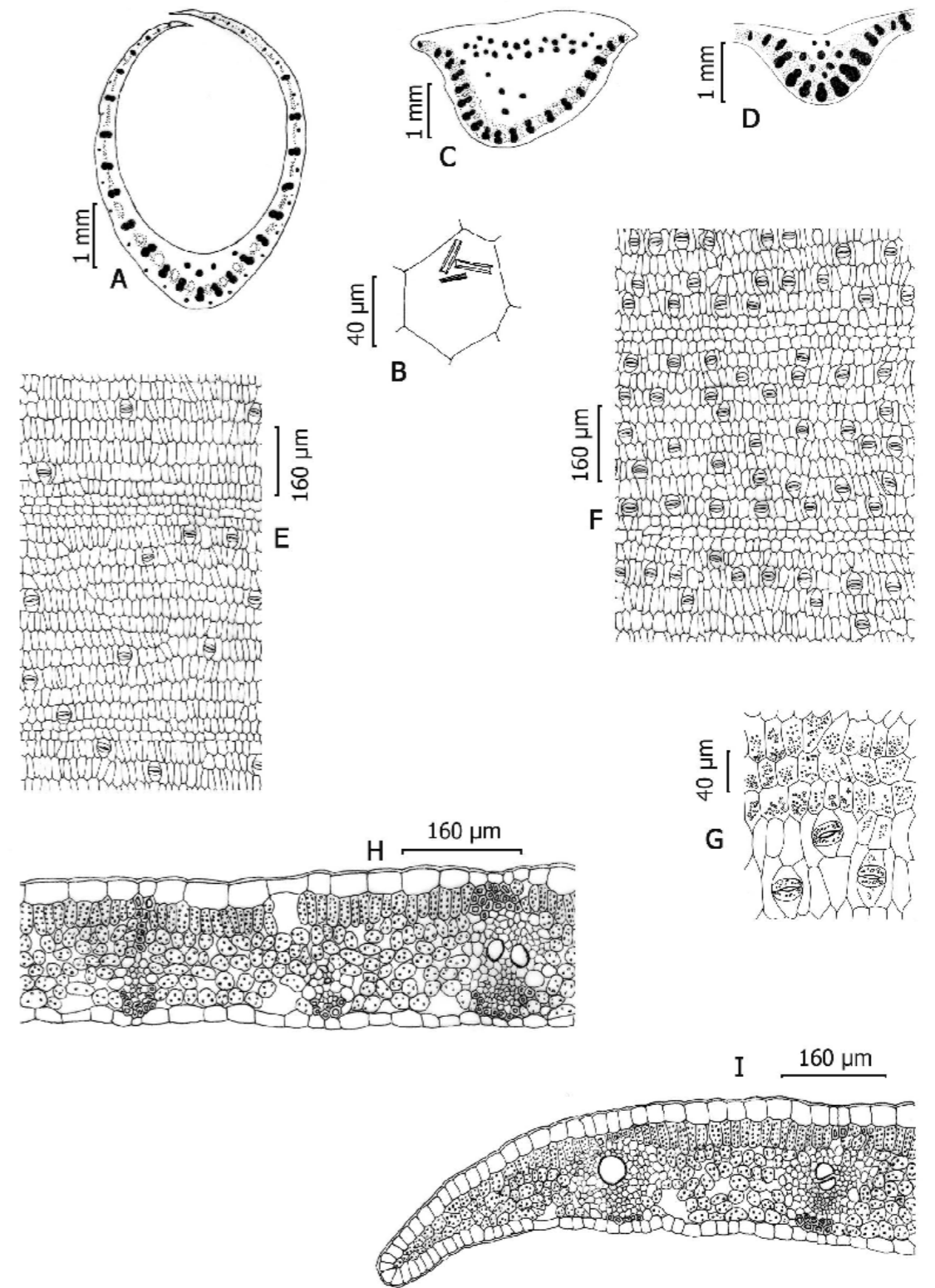


Fig. 12. *Amomum cannicarpum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Acicular crystals seen in the ground tissue; C. Petiole; D. Midrib; E. Adaxial epidermis; F. Abaxial epidermis; G. Costal cells containing silica sand; H. Lamina; I. Margin.

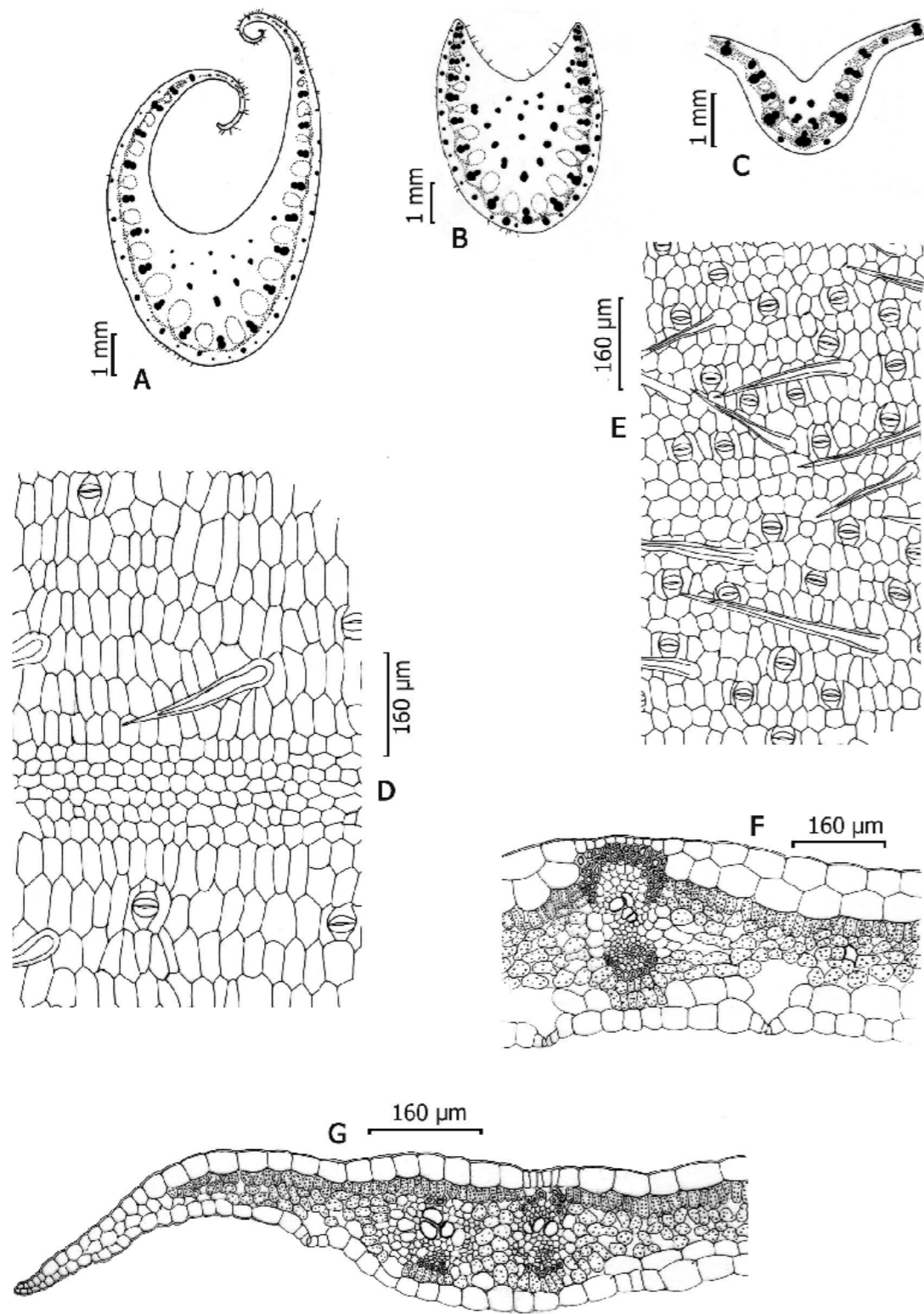


Fig. 33. *Curcuma aurantiaca* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

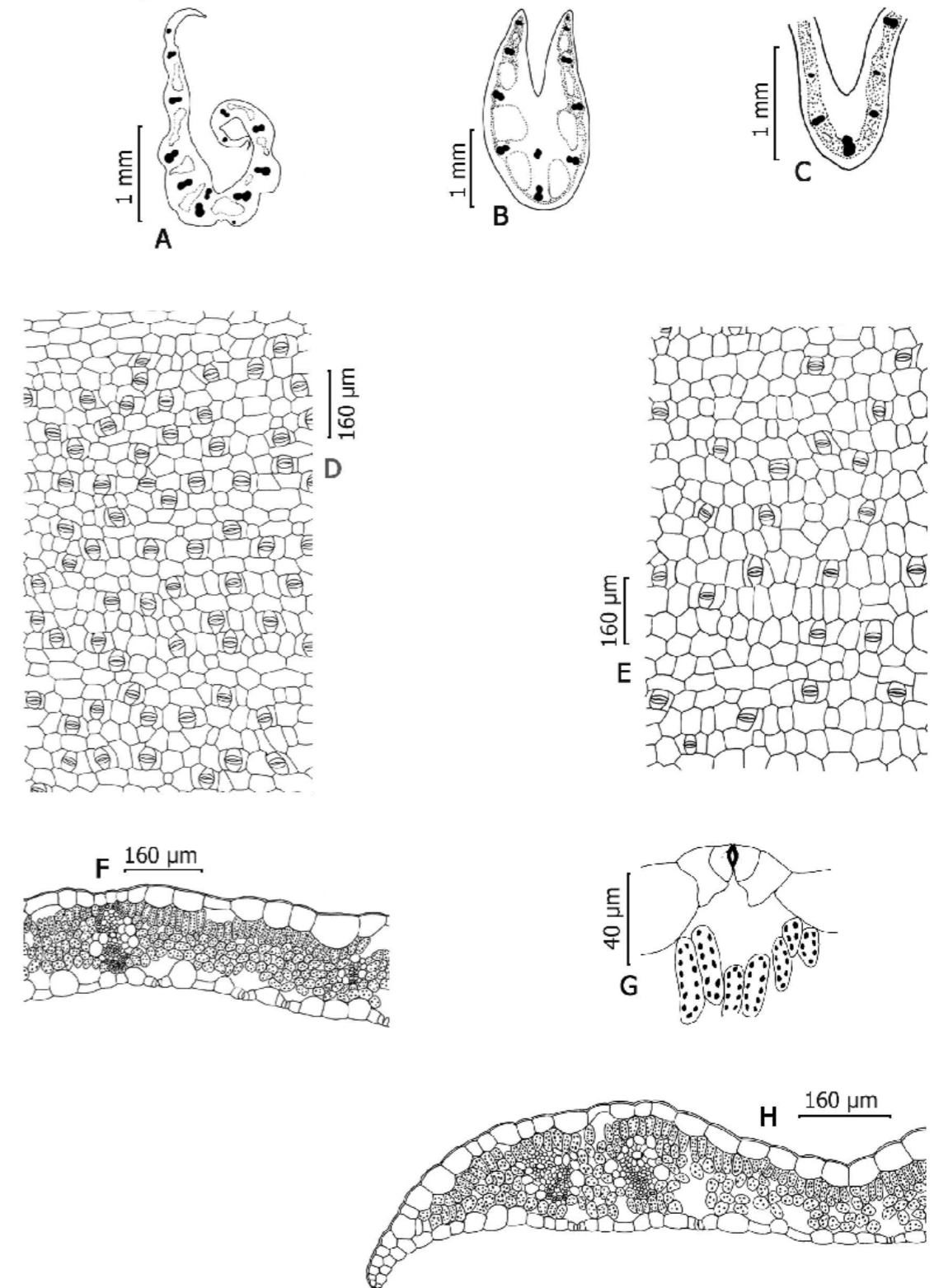


Fig. 34. *Curcuma bhatii* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Stomata; H. Margin.

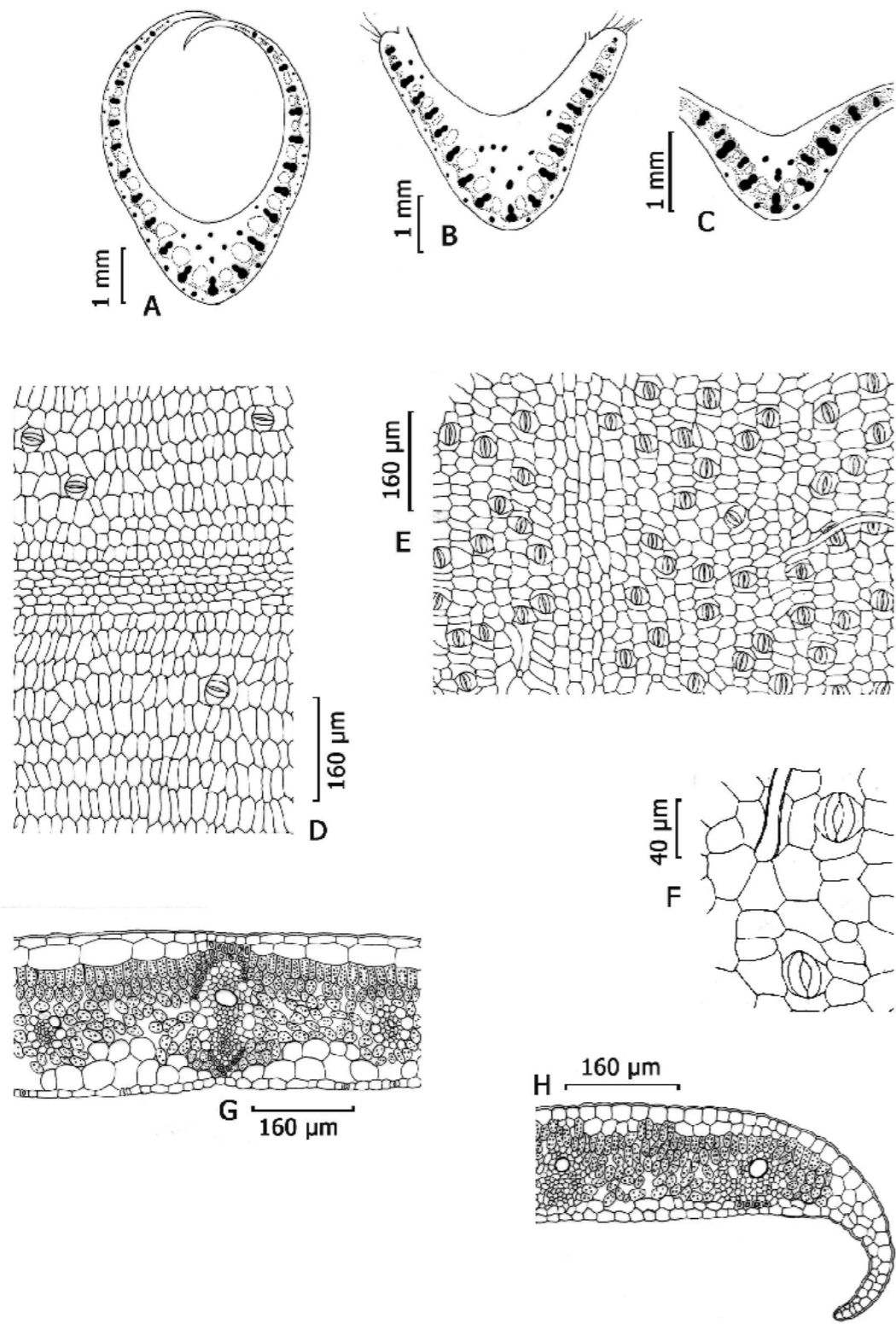


Fig. 59. *Hedychium spicatum* var. *acuminatum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Abaxial epidermis showing base of hair and oil cell; G. Lamina; H. Margin.

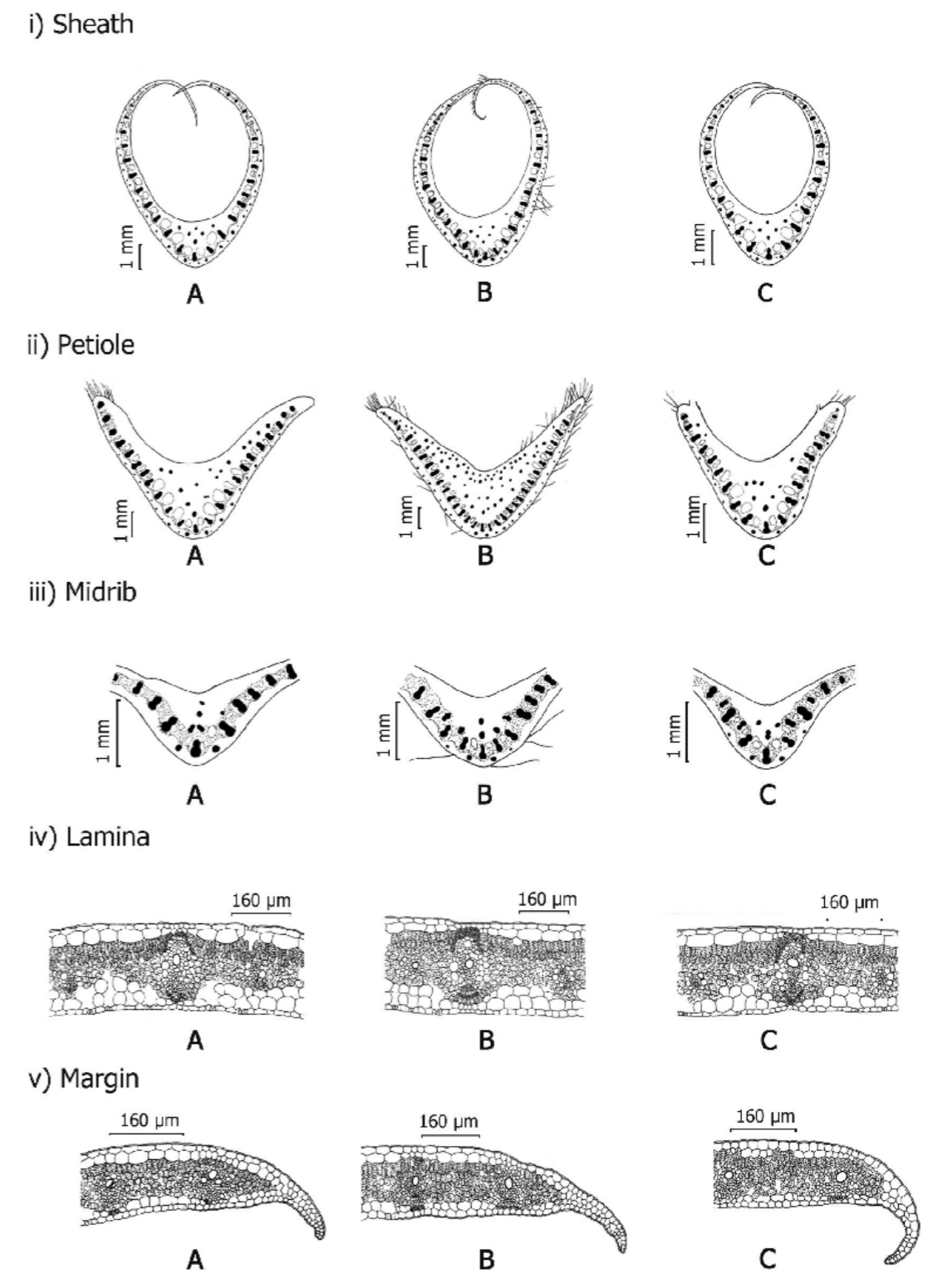


Fig. 60. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Hedychium* spp.: A. *H. coronarium*; B. *H. flavescens*; C. *H. spicatum* var. *acuminatum*.

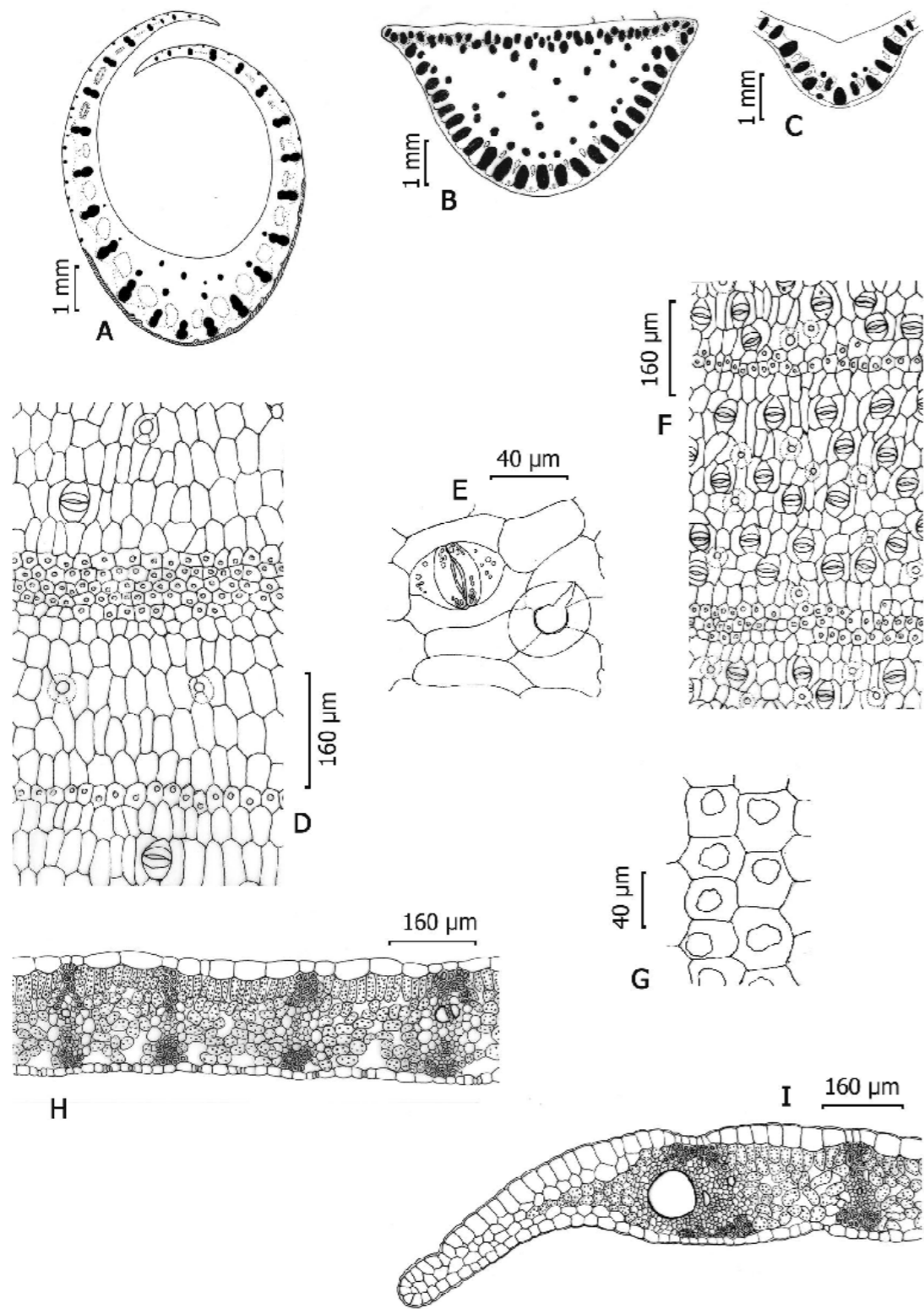


Fig. 05. *Alpinia galanga* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Hair; F. Abaxial epidermis; G. Costal cells containing silica body; H. Lamina; I. Margin.

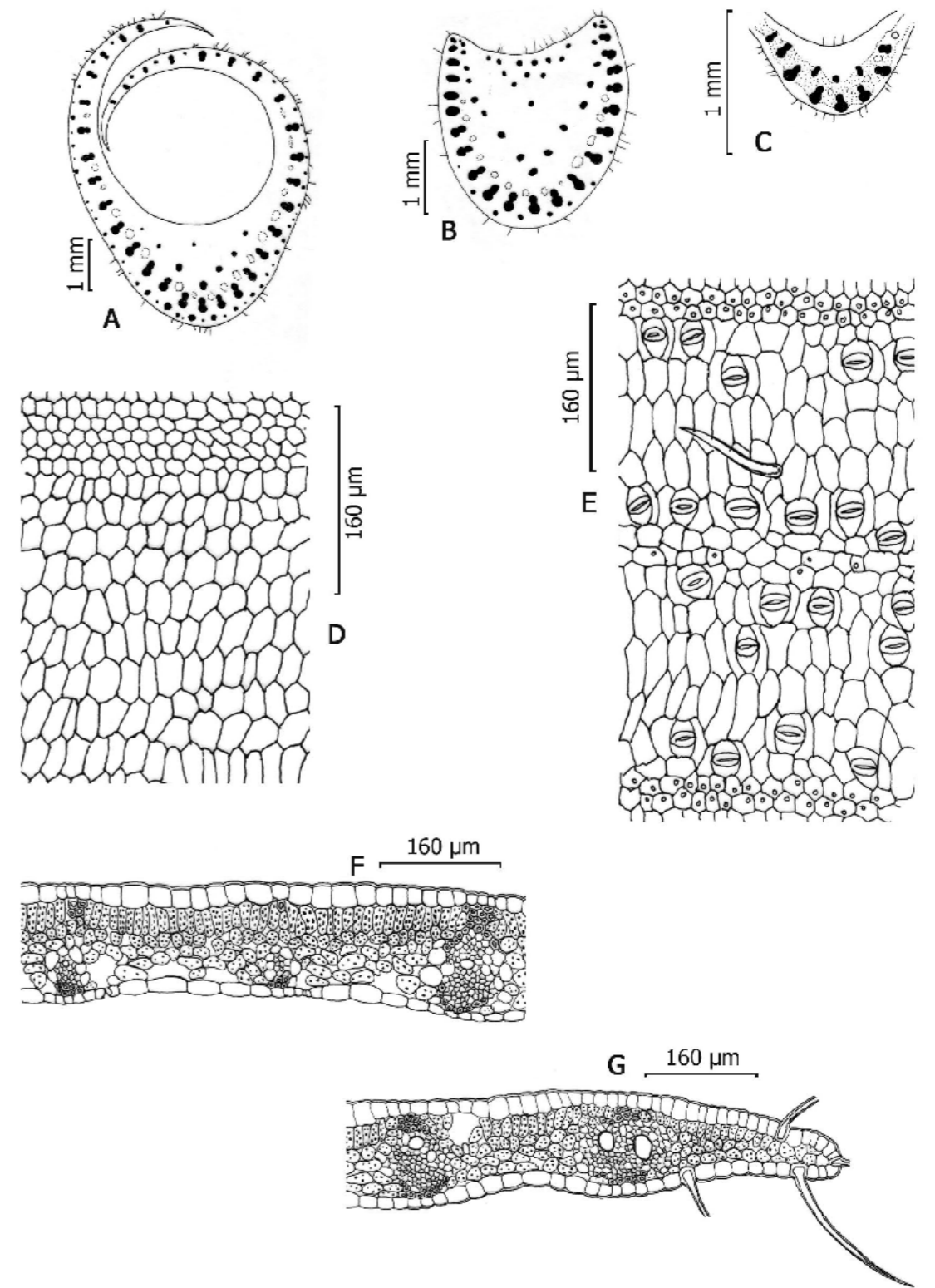
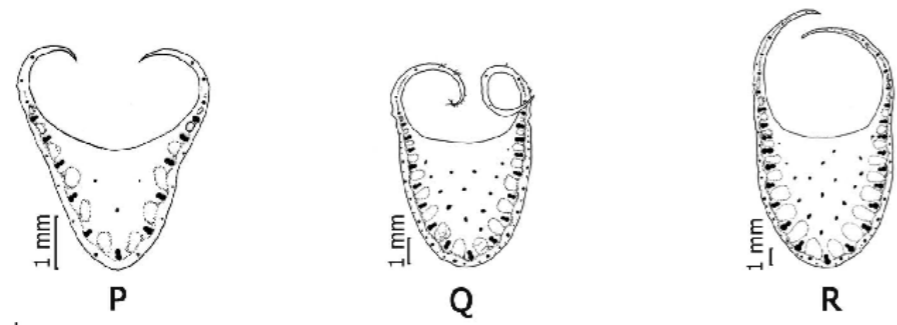
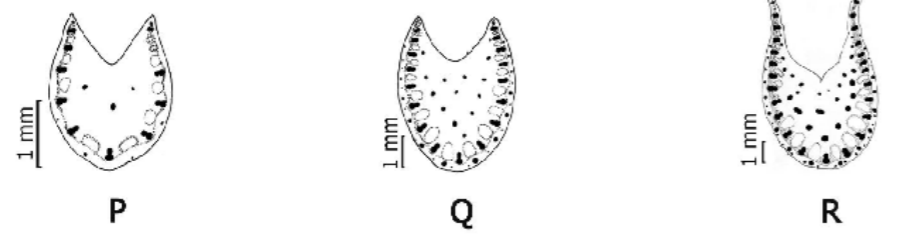


Fig. 06. *Alpinia malaccensis* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

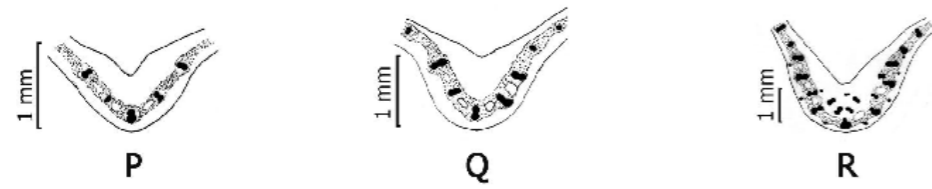
i) Sheath



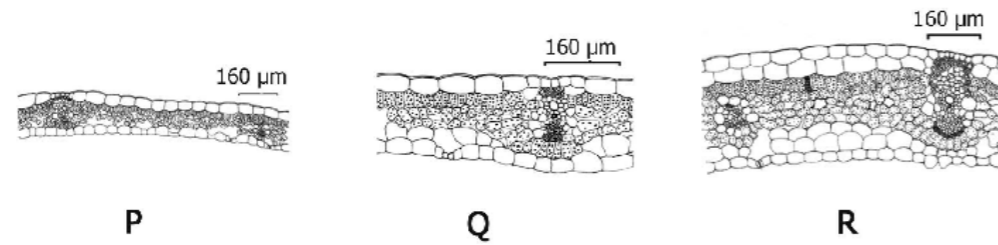
ii) Petiole



iii) Midrib



iv) Lamina



v) Margin

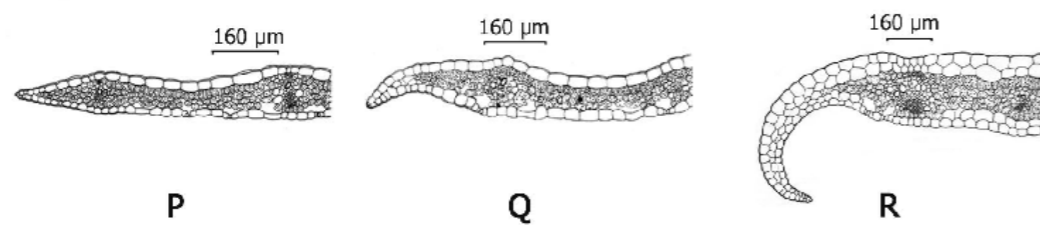


Fig. 55. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Curcuma* spp. VI: P. *C. oligantha* var. *oligantha*; Q. *C. oligantha* var. *lutea*; R. *C. raktakanta*.

i) Sheath



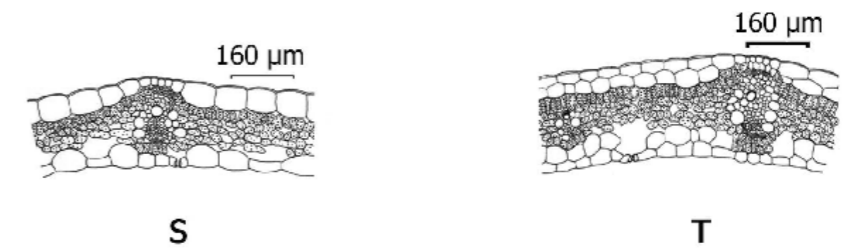
ii) Petiole



iii) Midrib



iv) Lamina



v) Margin

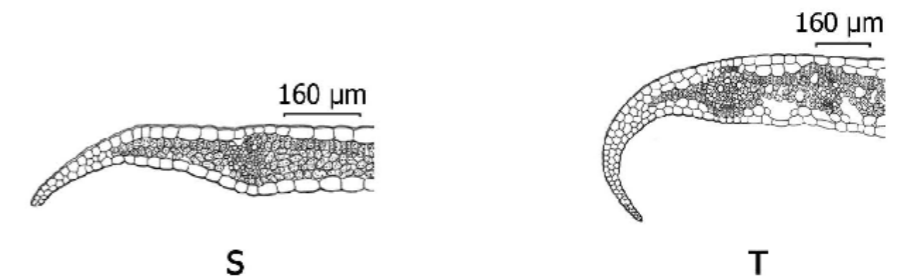


Fig. 56. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Curcuma* spp. VII: S. *C. vamana*; T. *C. zanthorrhiza*.

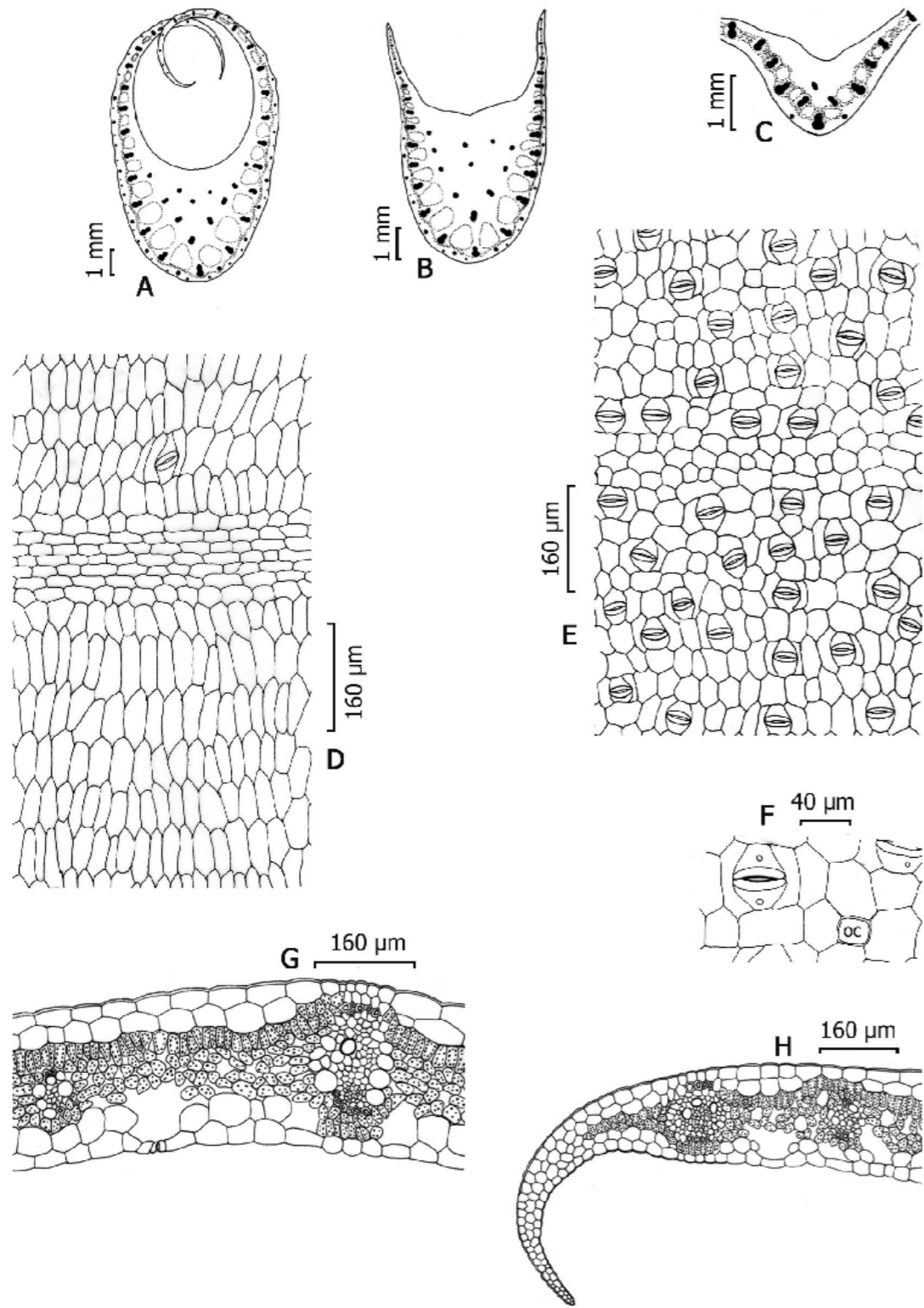


Fig. 49. *Curcuma zanthorrhiza* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Oil cell on the abaxial epidermis; G. Lamina; H. Margin.

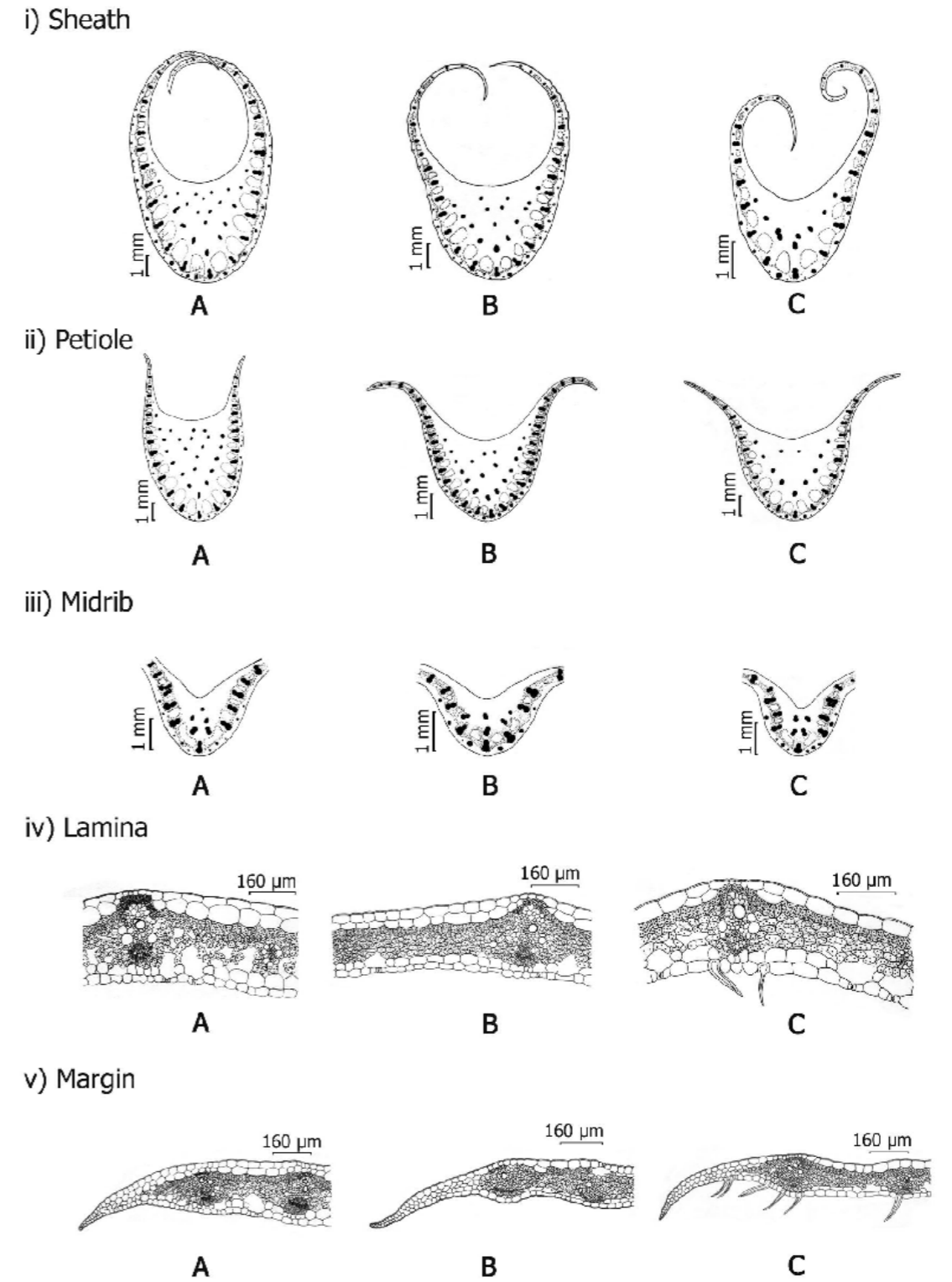


Fig. 50. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Curcuma* spp. I: A. *C. aeruginosa*; B. *C. amada*; C. *C. aromatica*.

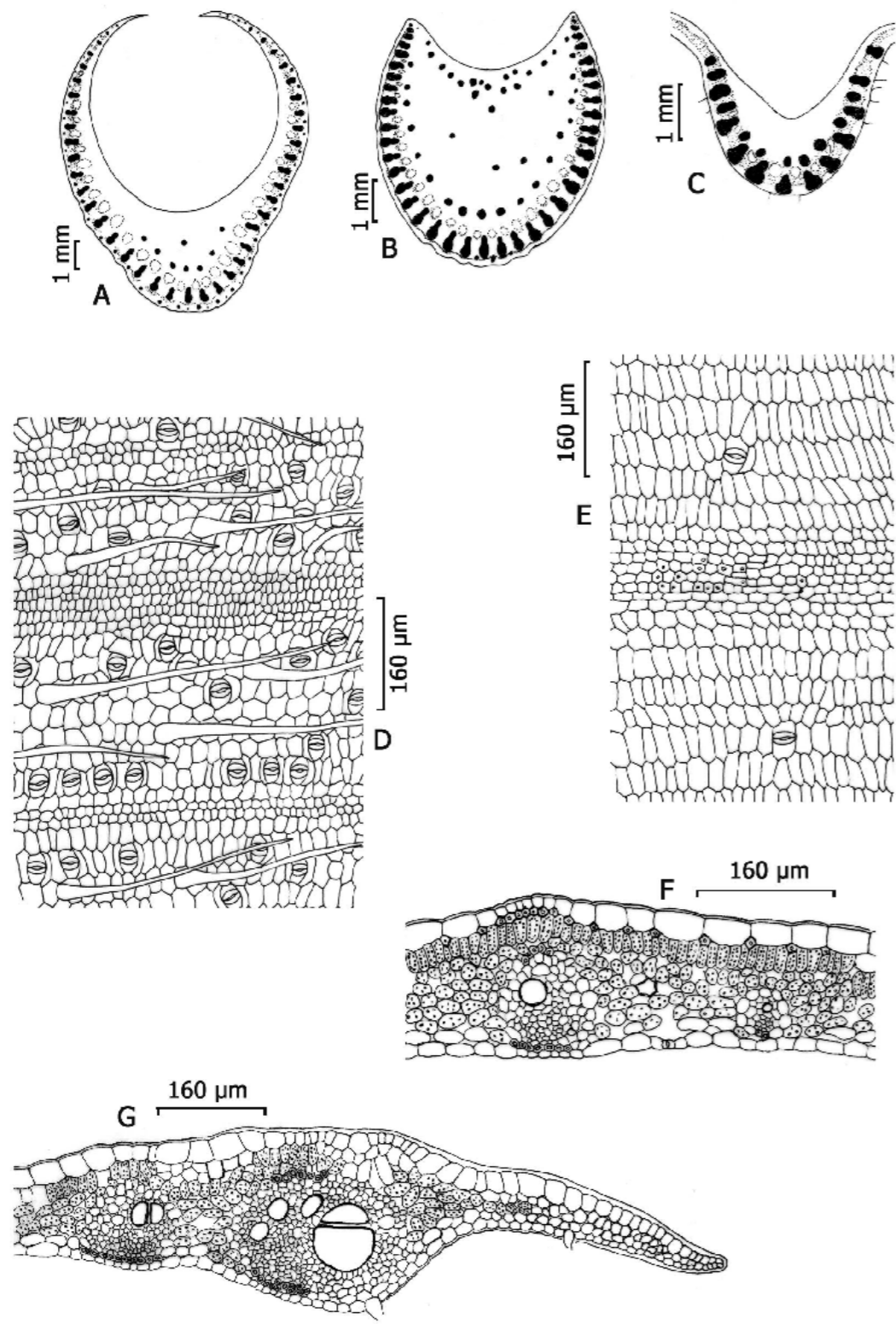


Fig. 17. *Amomum pterocarpum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

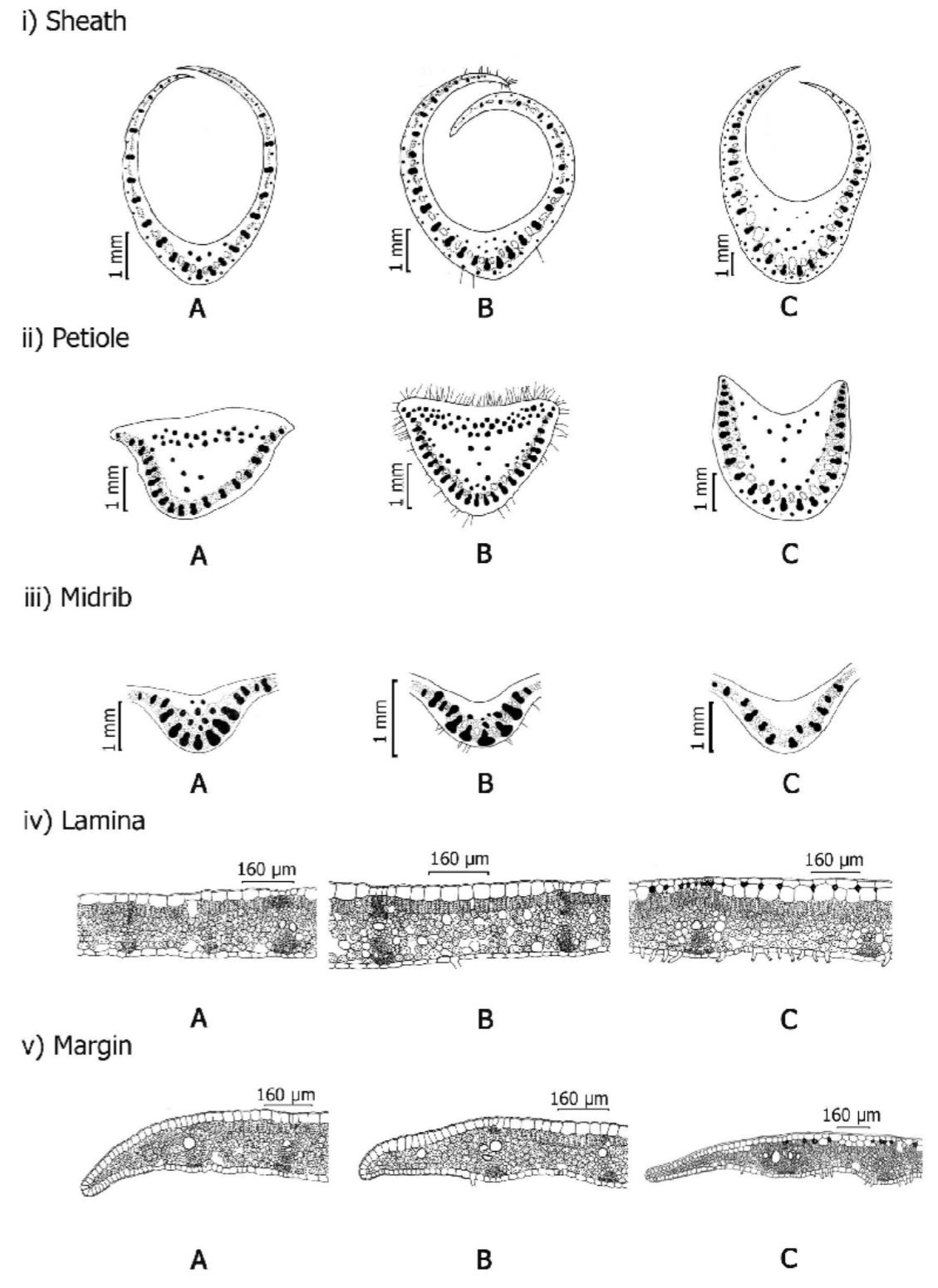


Fig. 18. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Amomum* spp. I: A. *A. cannicarpum*; B. *A. ghaticum*; C. *A. hypoleucum*.

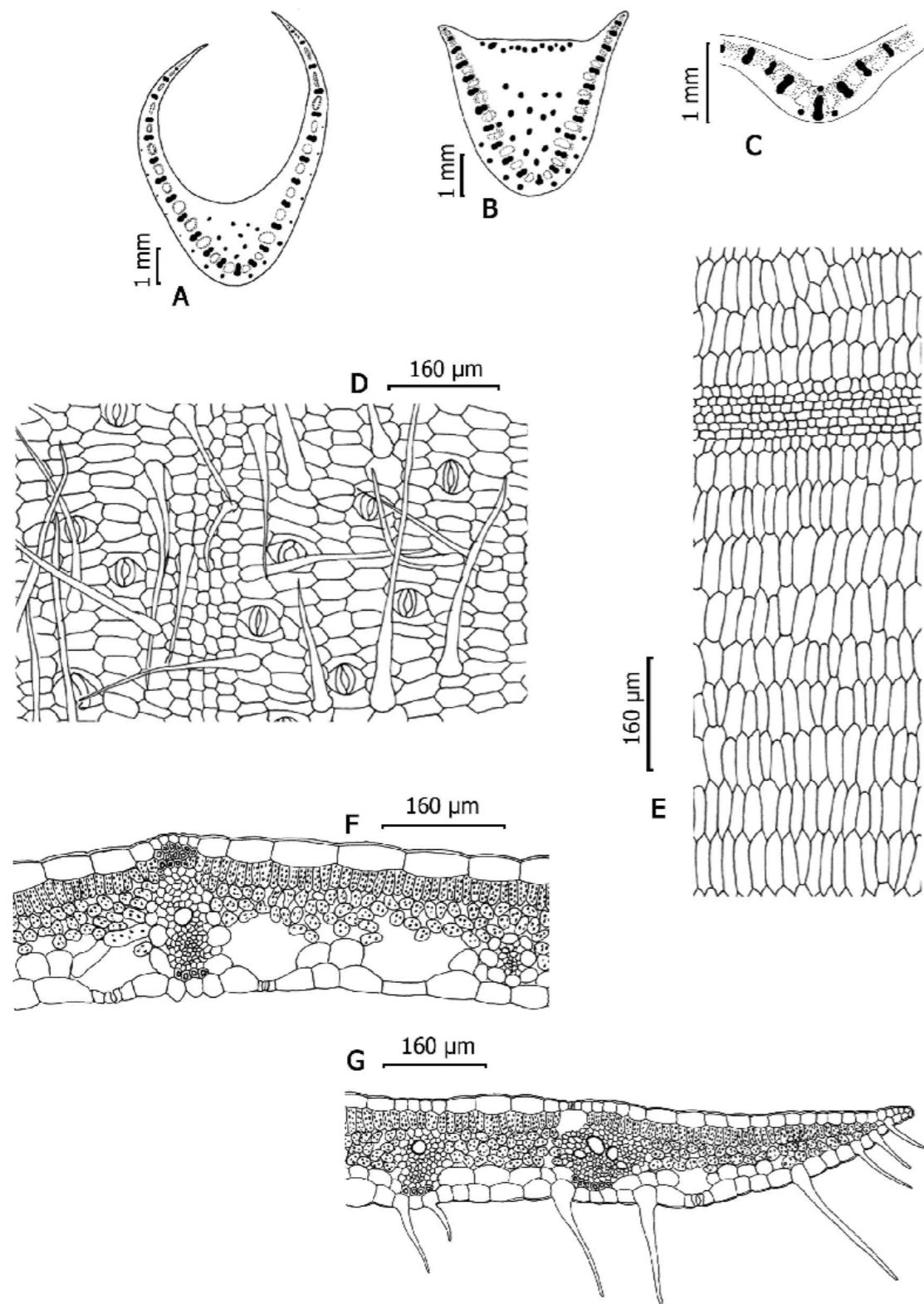


Fig. 23. *Globba orixensis* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

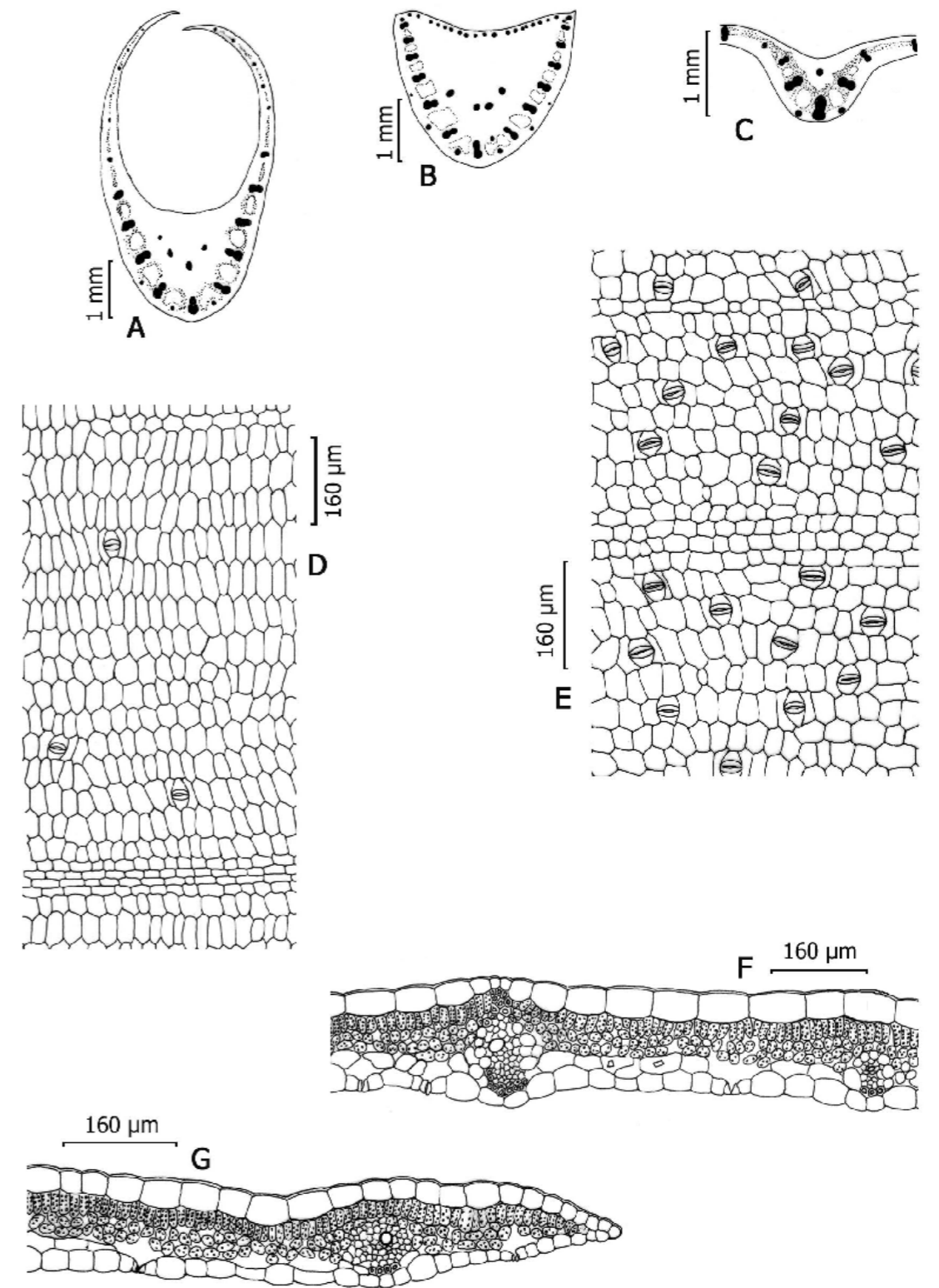


Fig. 24. *Globba schomburgkii* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

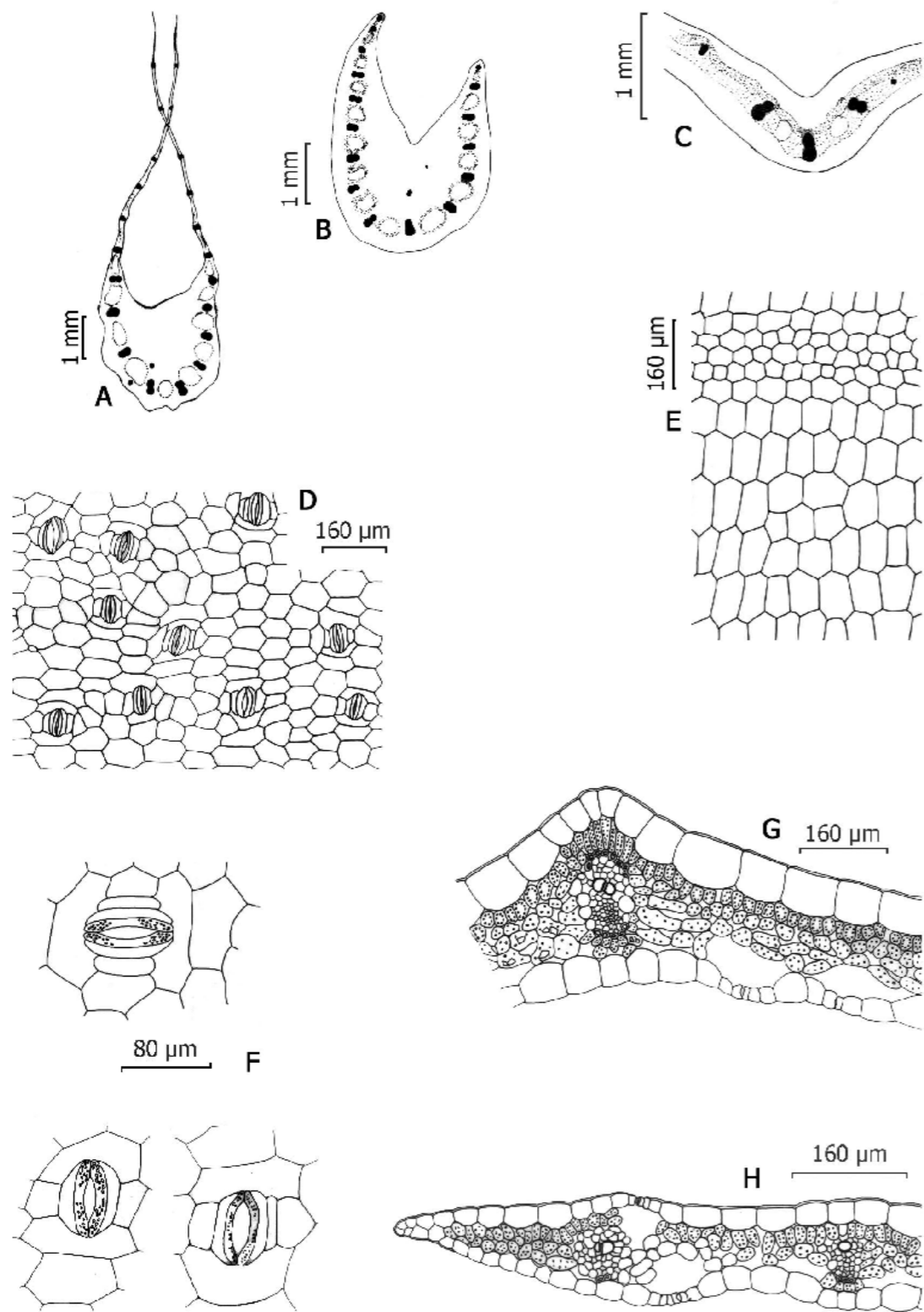


Fig. 27. *Boesenbergia pulcherrima* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Polycytic stomata; G. Lamina; H. Margin.

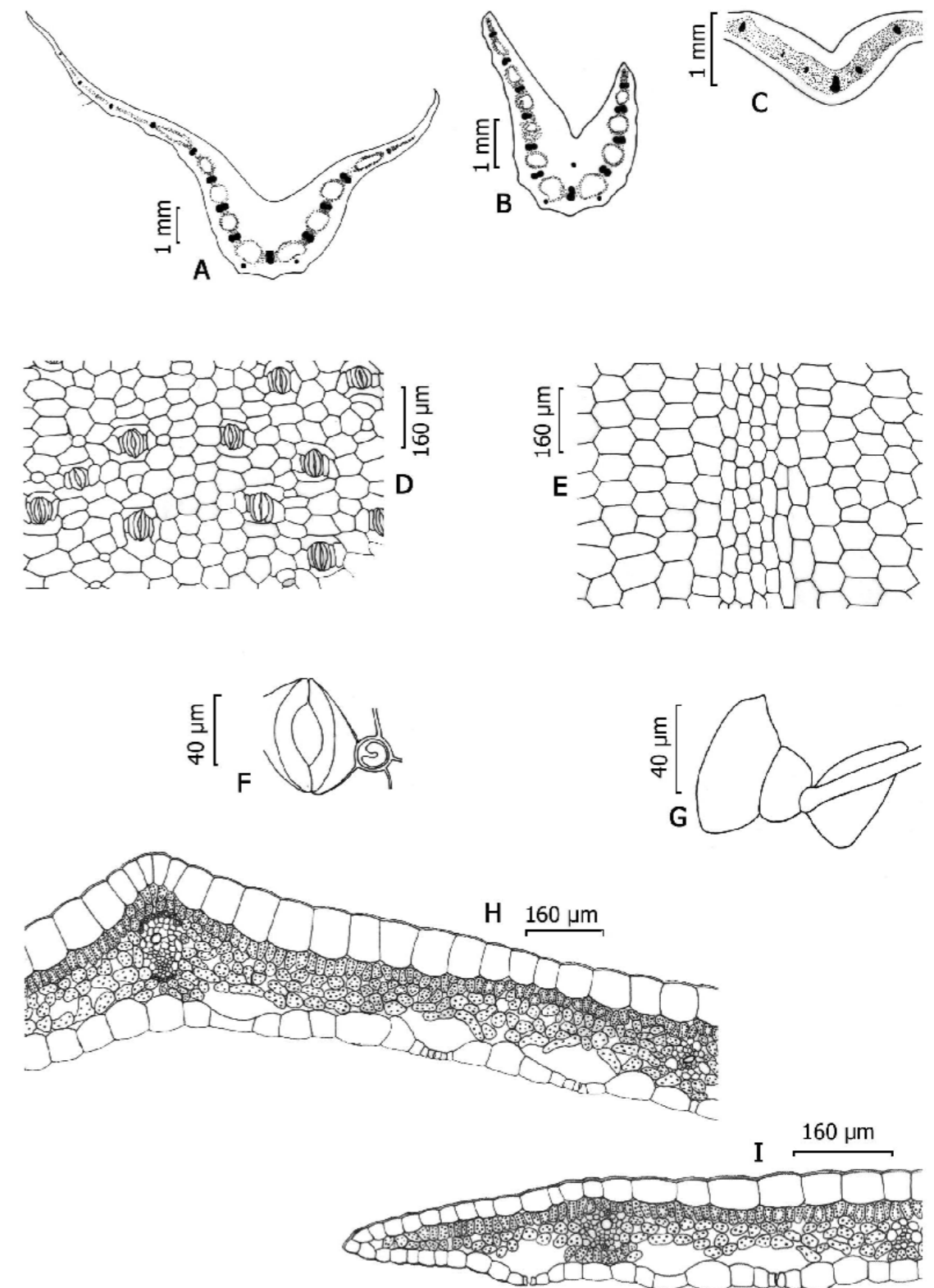


Fig. 28. *Boesenbergia tiliaefolia* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Oil cell; G. Base of hair; H. Lamina; I. Margin.

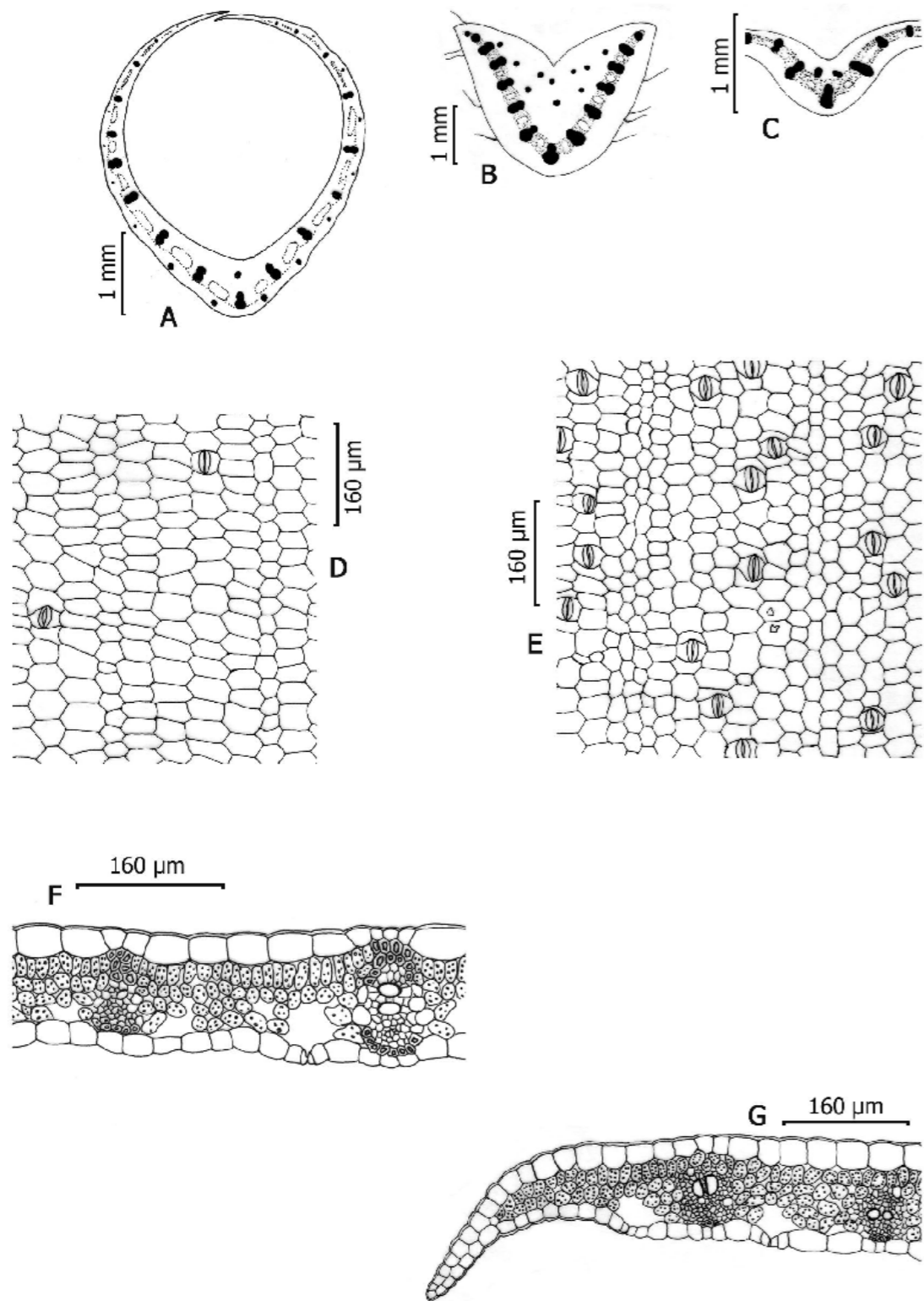


Fig. 67. *Zingiber neesatum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

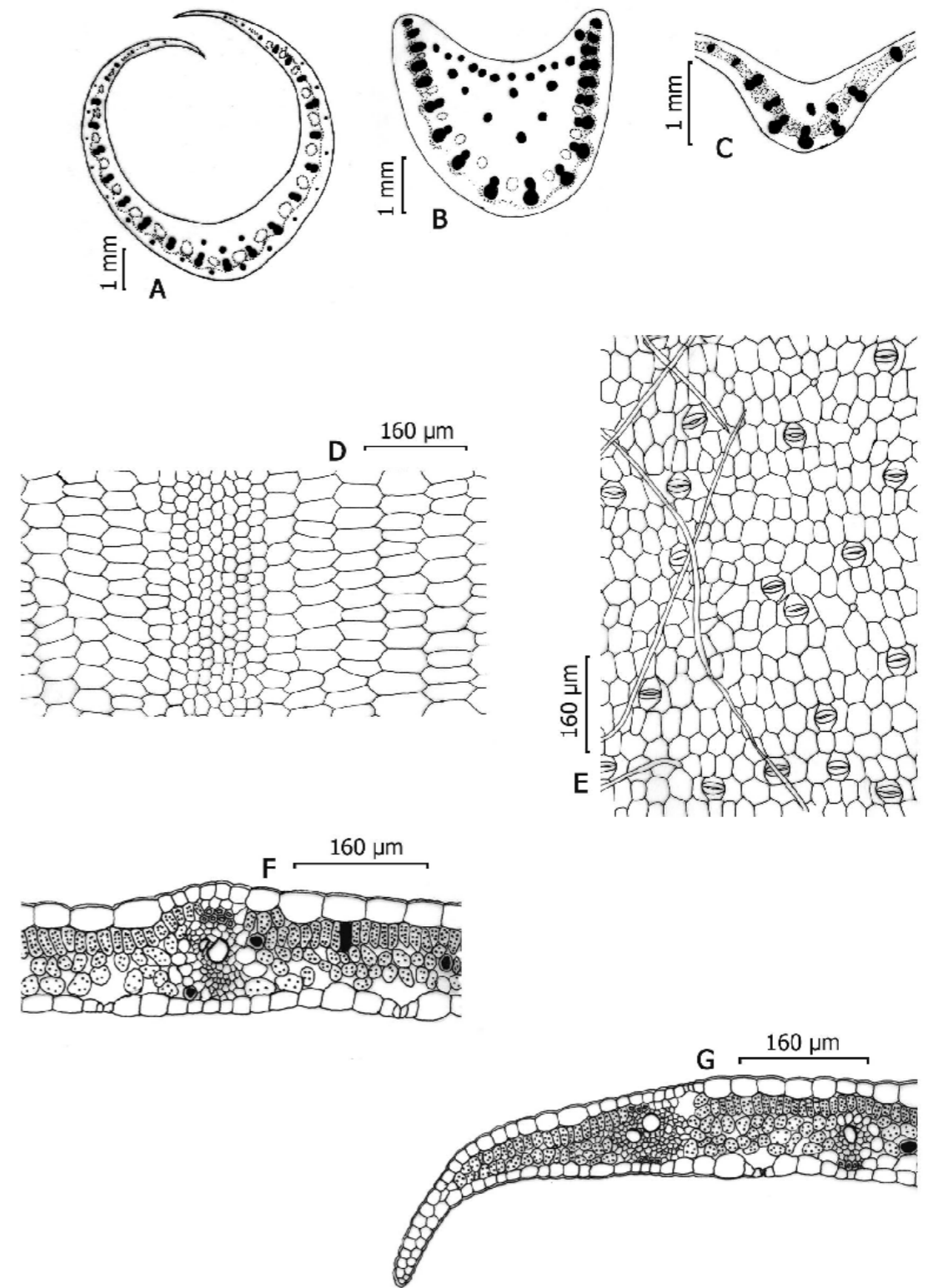


Fig. 68. *Zingiber nimmonii* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

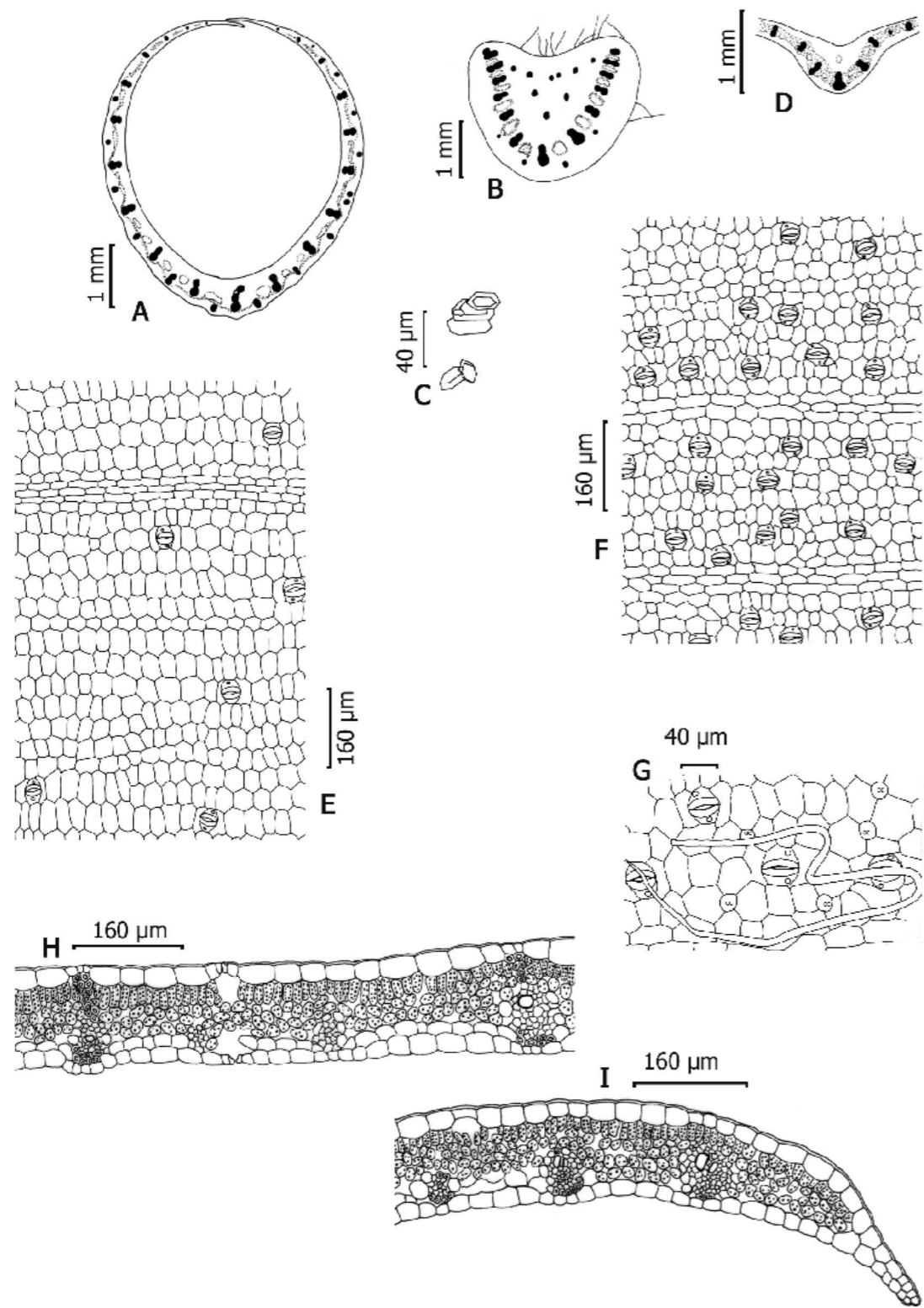


Fig. 69. *Zingiber officinale* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Crystals in the ground tissue of petiole; D. Midrib; E. Adaxial epidermis; F. Abaxial epidermis; G. Abaxial epidermis showing hair and oil cells; H. Lamina; I. Margin.

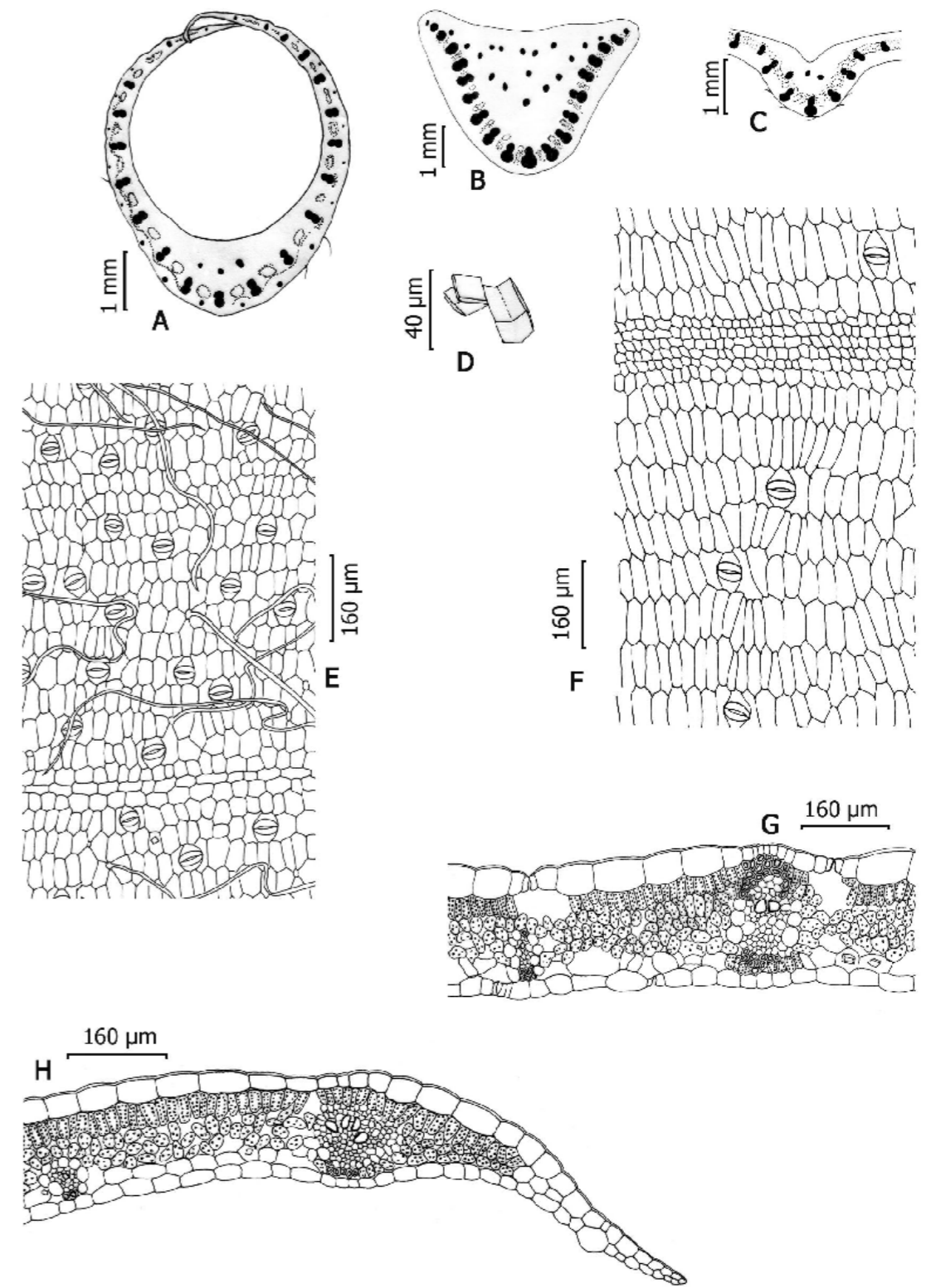


Fig. 70. *Zingiber wightianum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Crystals in the ground tissue of sheath; E. Abaxial epidermis; F. Adaxial epidermis; G. Lamina; H. Margin.

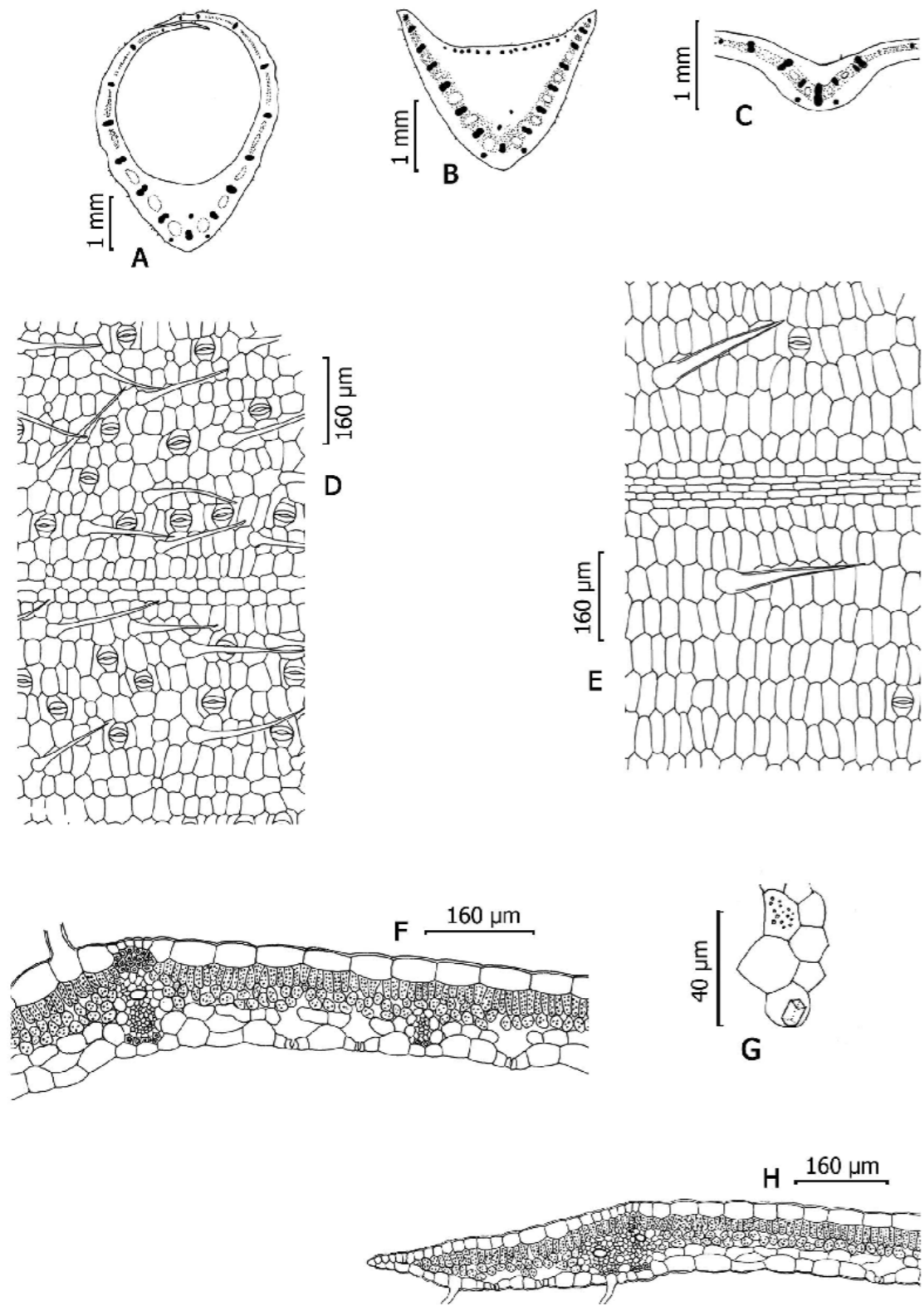


Fig. 21. *Globba marantina* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Cells near bundle containing silica sand and crystals; H. Margin.

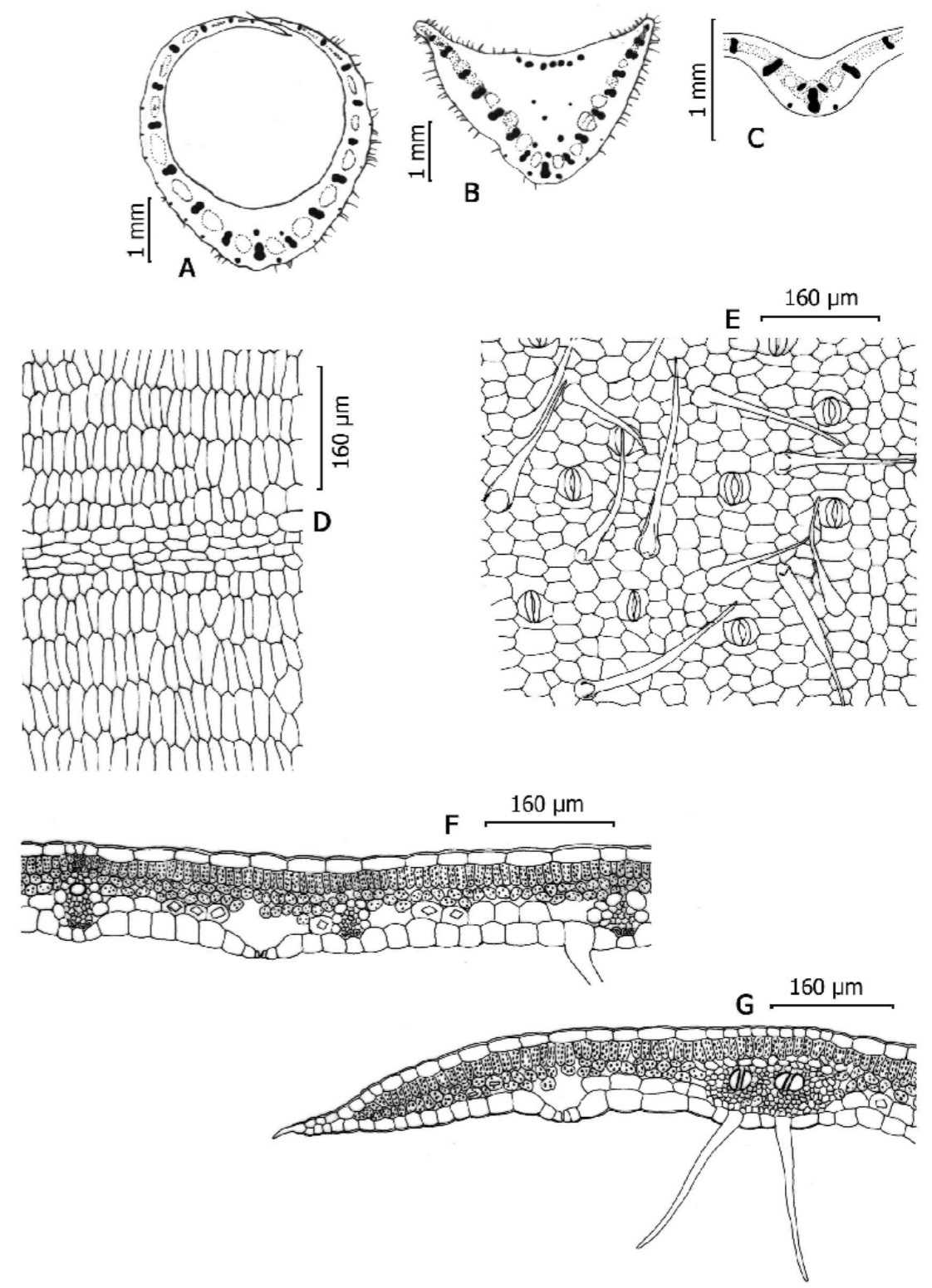


Fig. 22. *Globba ophioglossa* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

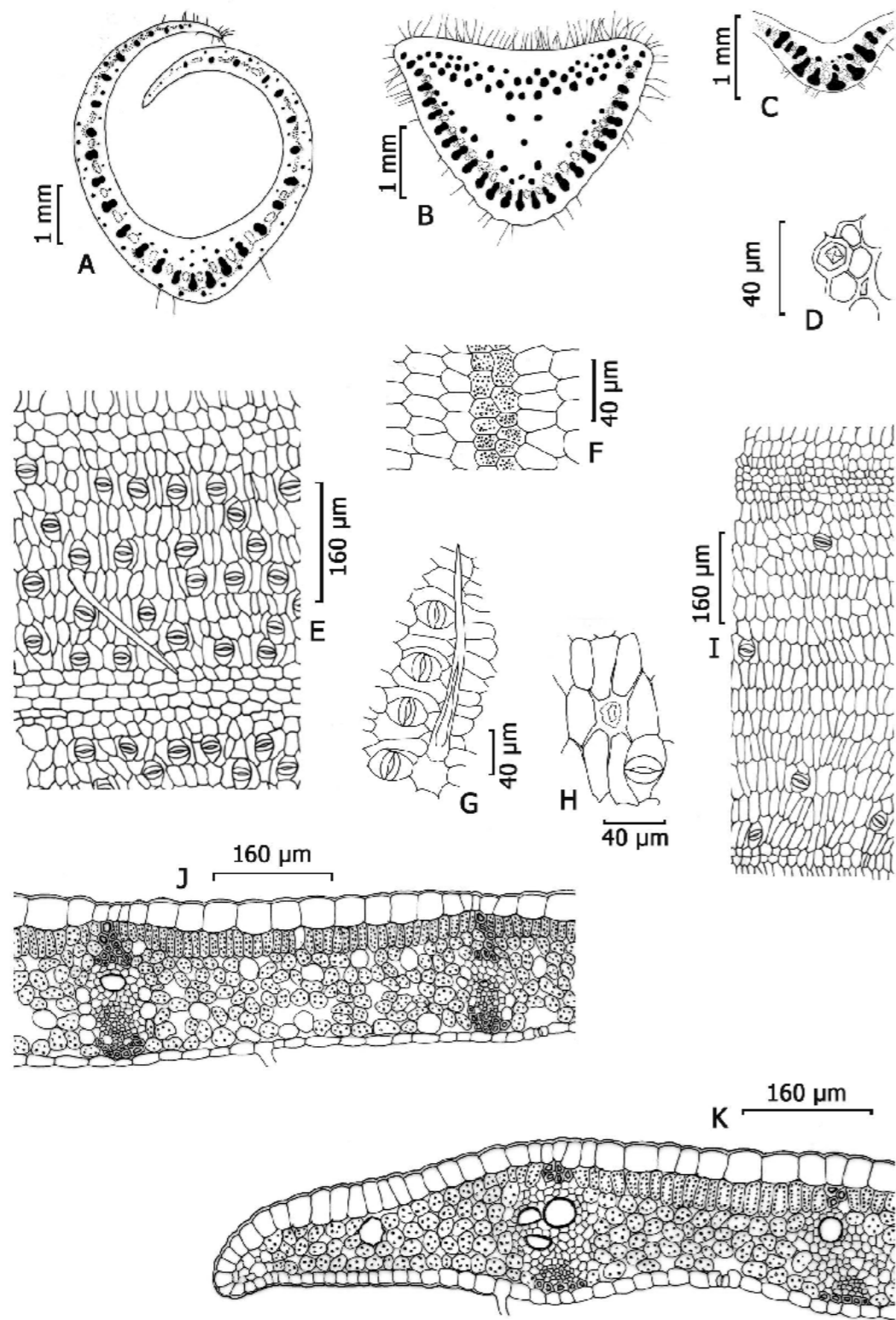


Fig. 13. *Amomum ghaticum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Crystals in the bundle sheath cells; E. Abaxial epidermis; F. Costal cells containing silica sand; G. Hair; H. Appearance of the leaf surface after the removal of hair; I. Adaxial epidermis; J. Lamina; K. Margin.

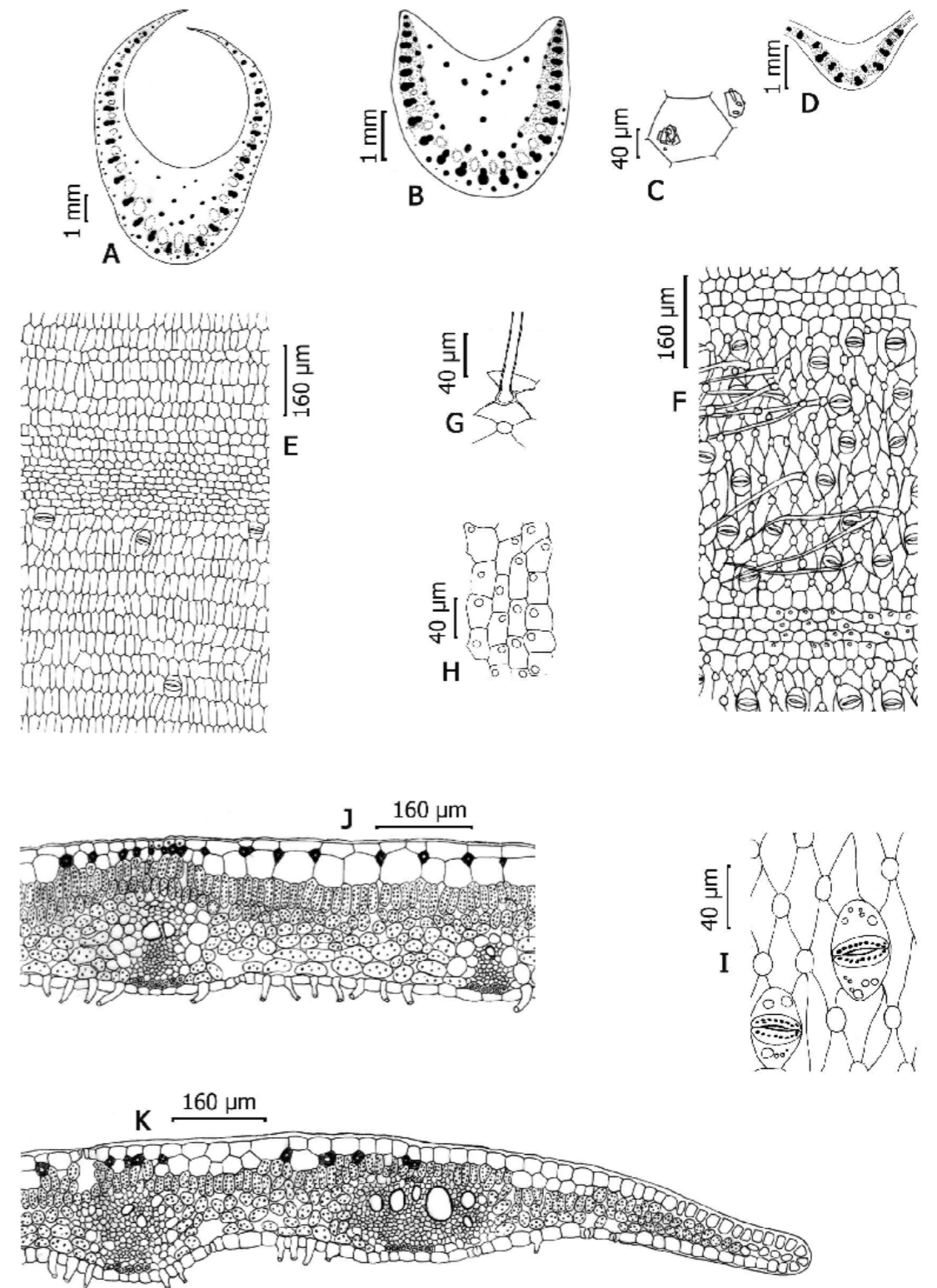


Fig. 14. *Amomum hypoleucum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Crystals in the ground tissue of petiole; D. Midrib; E. Adaxial epidermis; F. Abaxial epidermis; G. Base of the hair; H. Costal cells containing silica bodies; I. Abaxial epidermis after the removal of hairs; J. Lamina; K. Margin.

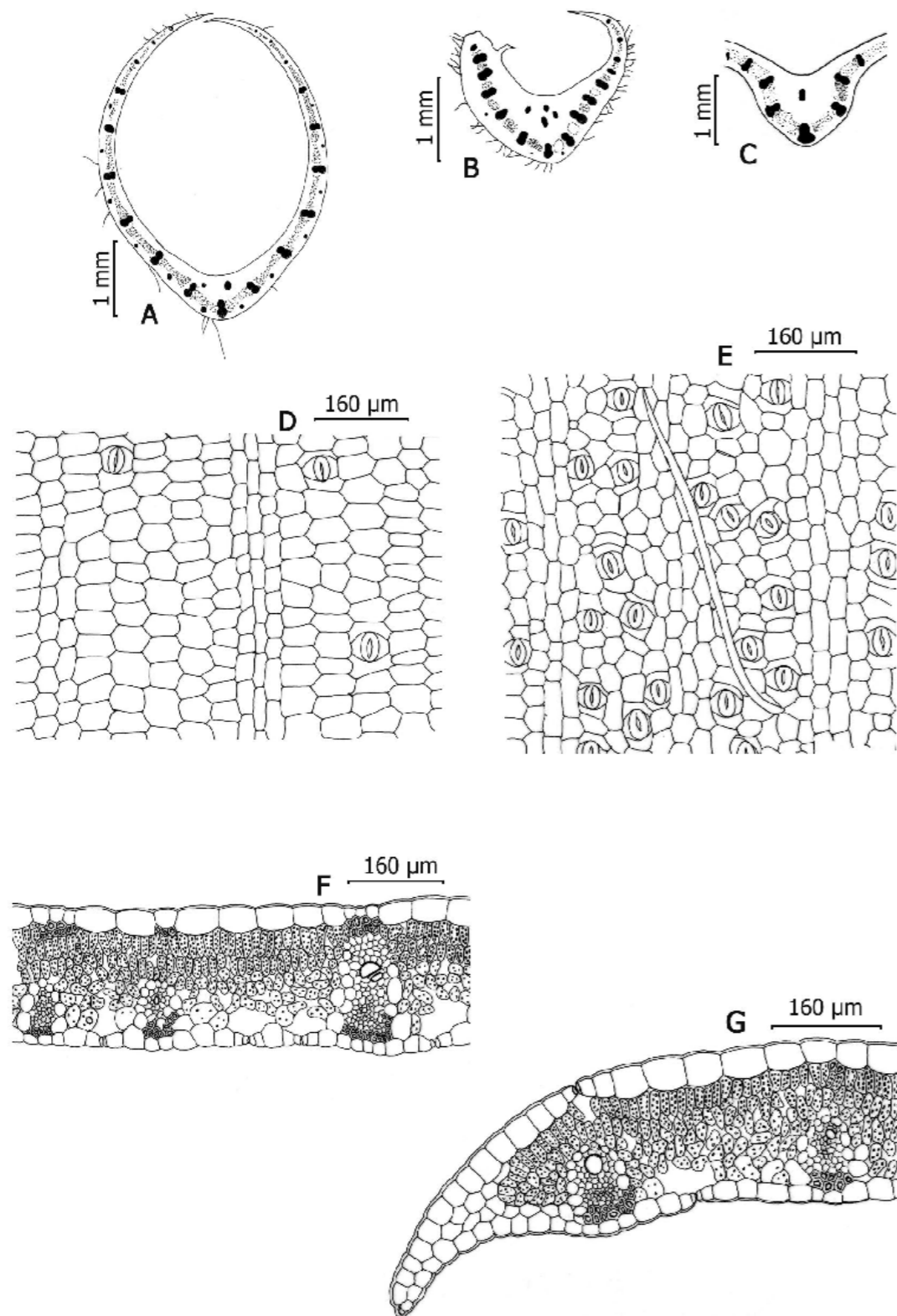


Fig. 65. *Zingiber capitatum* var. *elatum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

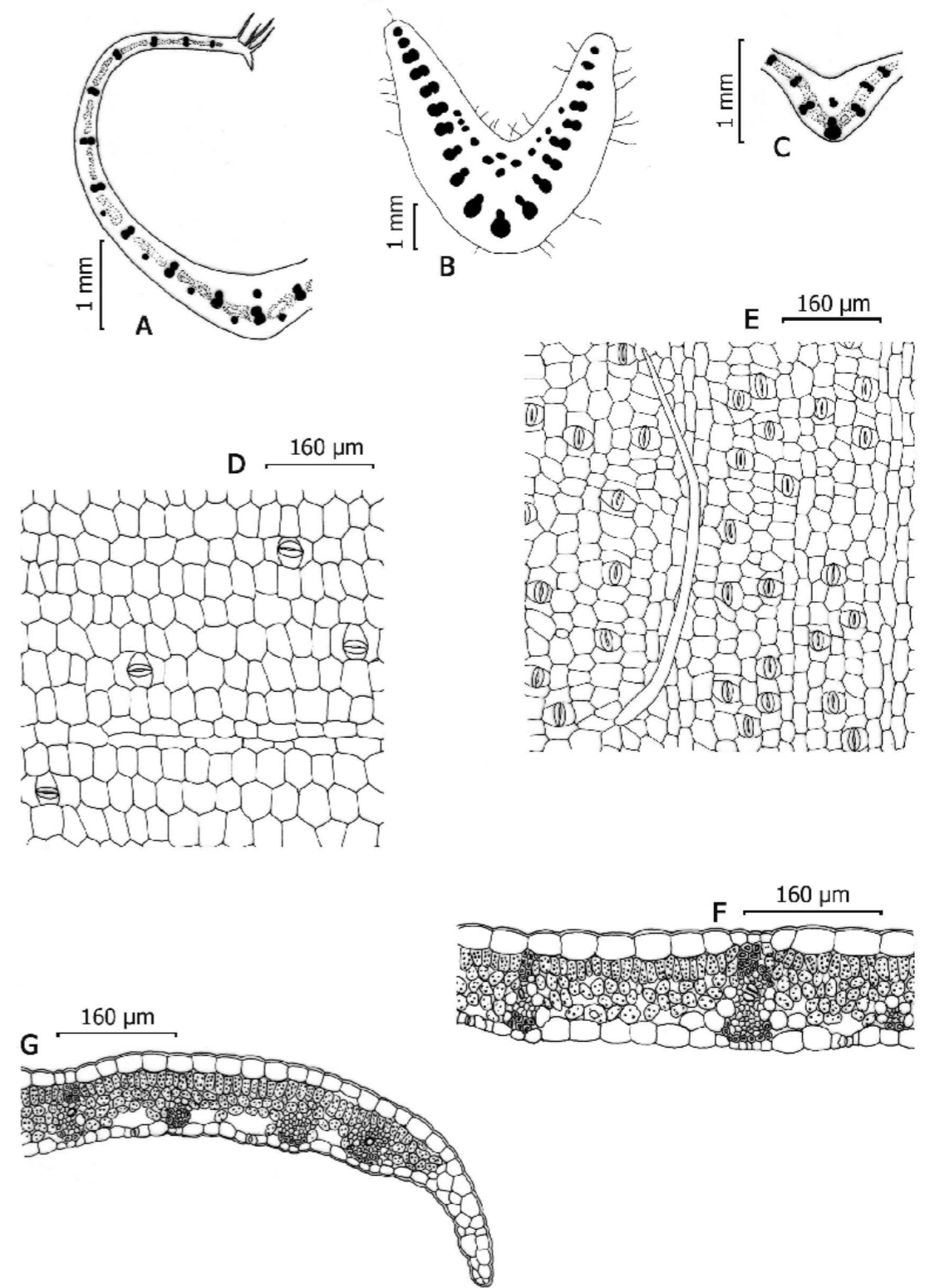


Fig. 66. *Zingiber montanum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

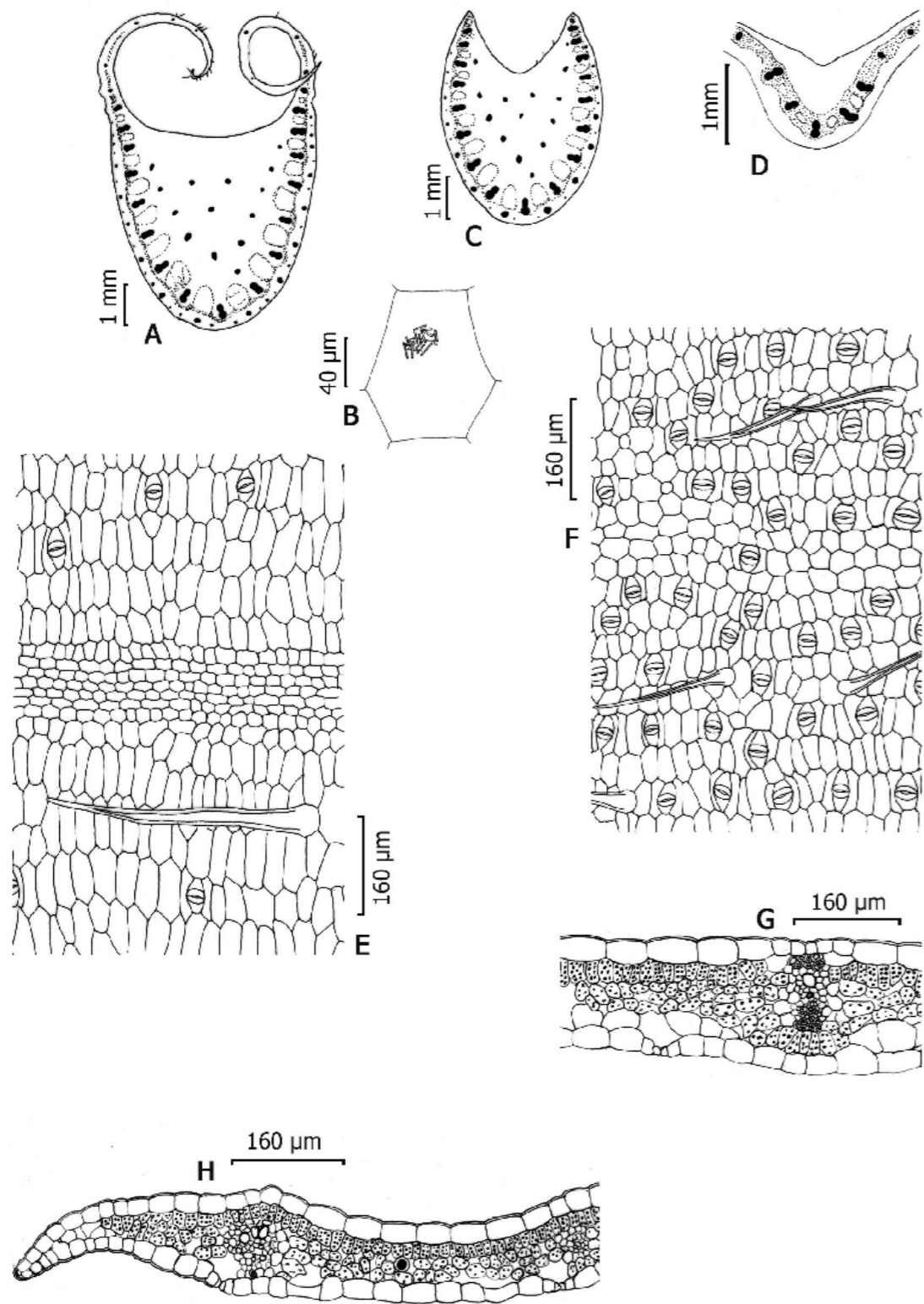


Fig. 45. *Curcuma oligantha* var. *lutea* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Rod shaped crystals in ground tissue of sheath; C. Petiole; D. Midrib; E. Adaxial epidermis; F. Abaxial epidermis; G. Lamina; H. Margin.

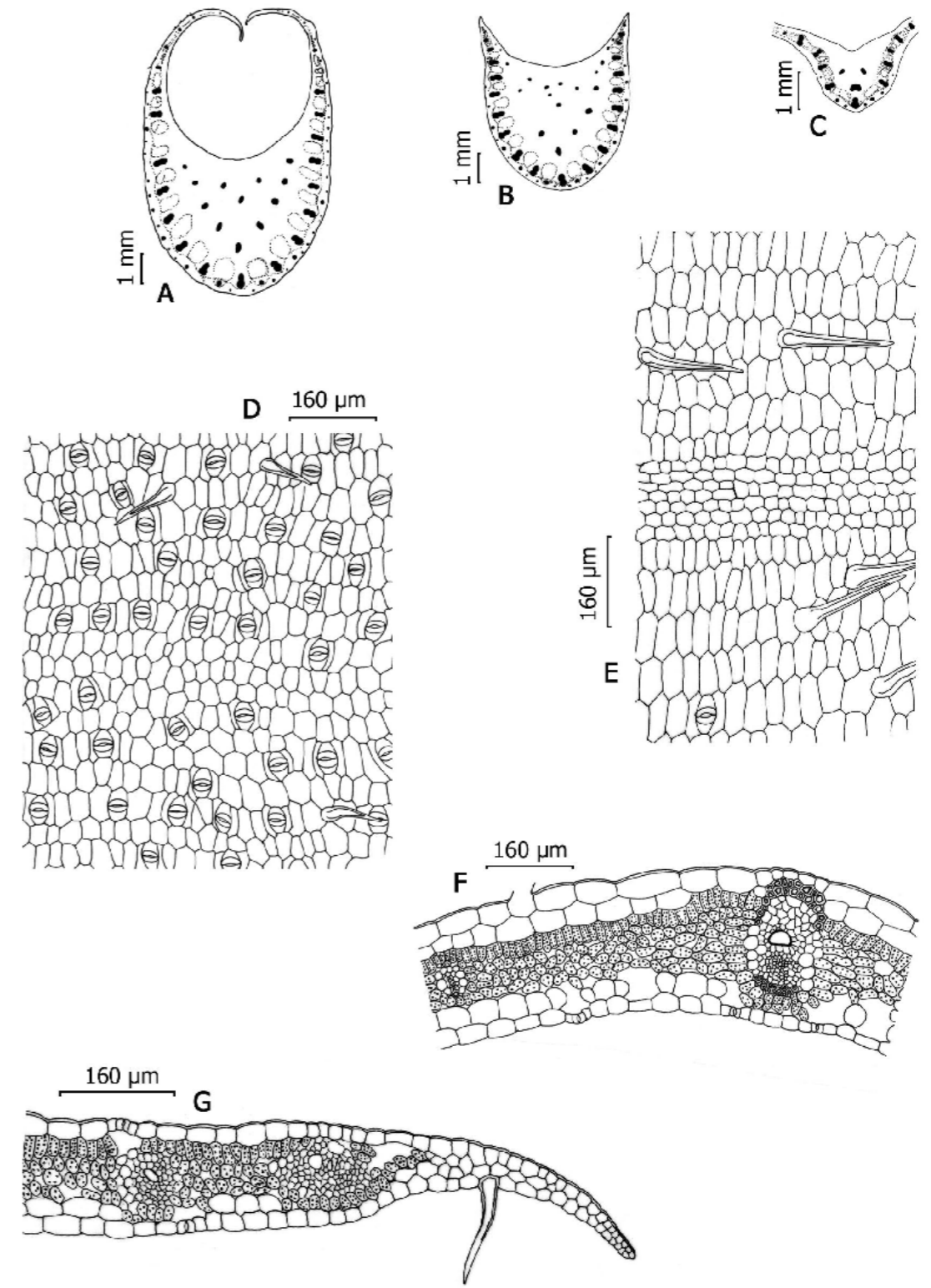


Fig. 46. *Curcuma pseudomontana* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

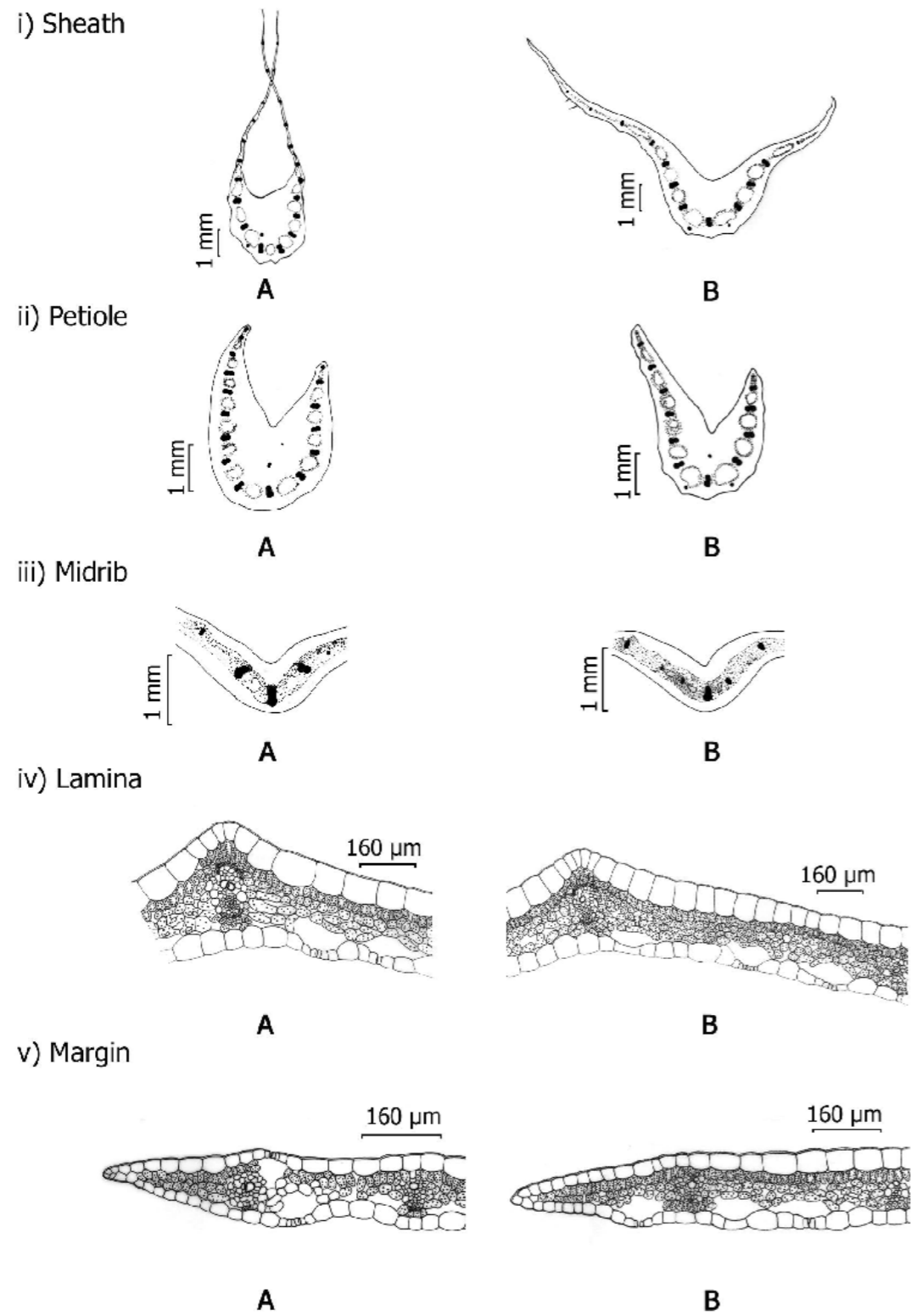


Fig. 29. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Boesenbergia* spp.: A. *B. pulcherrima*; B. *B. tiliaefolia*.

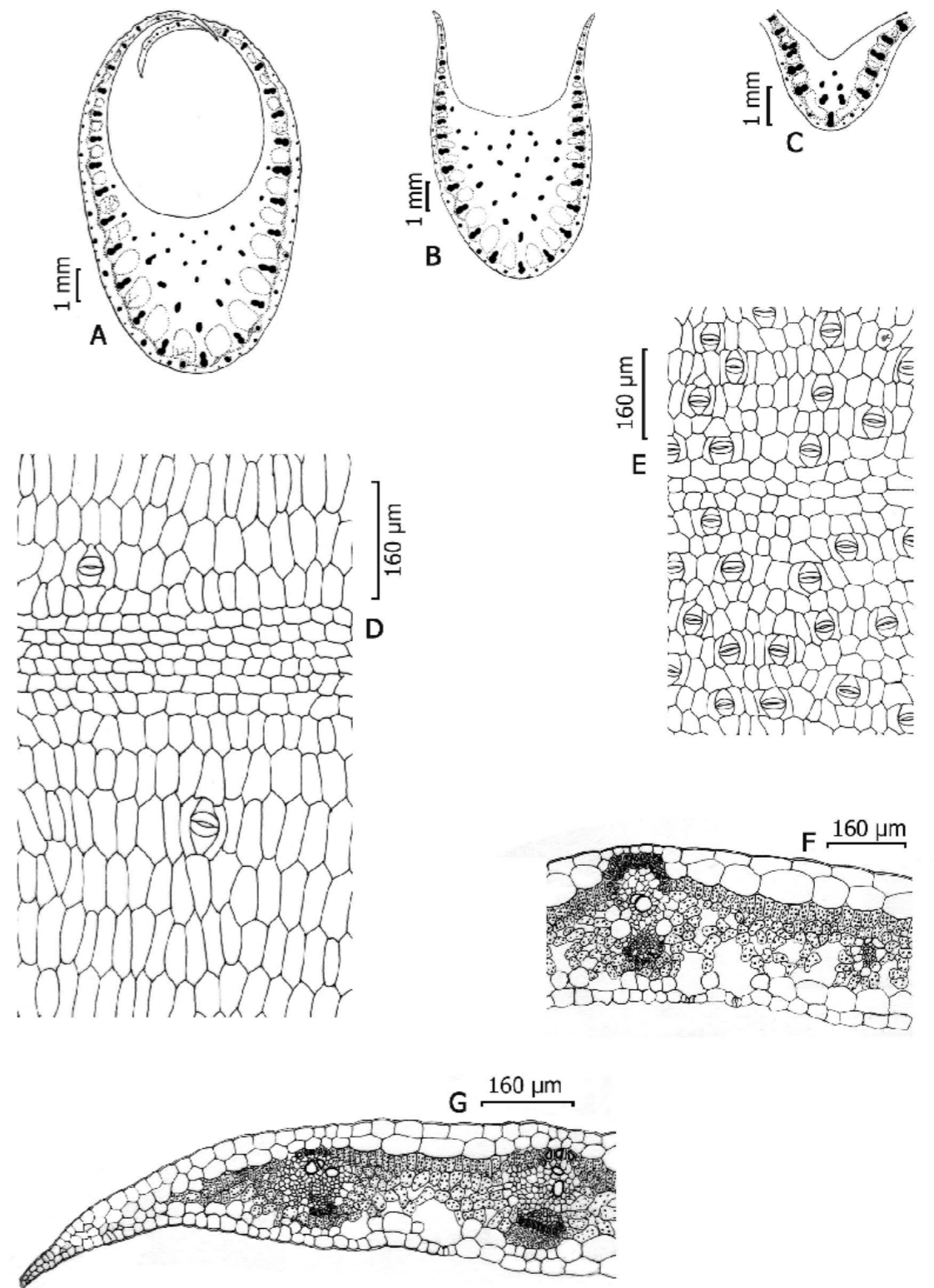
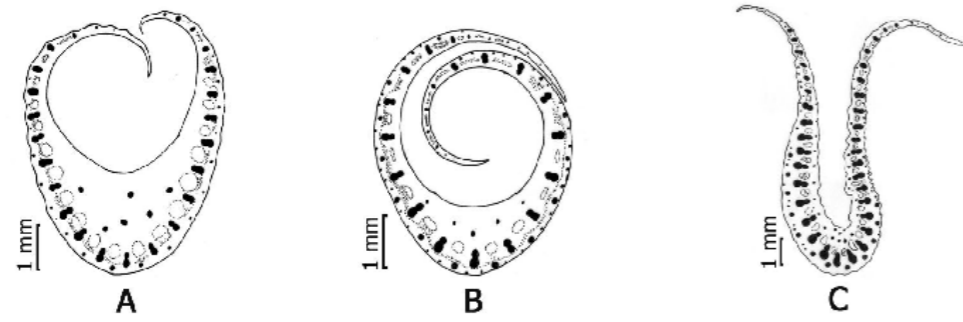
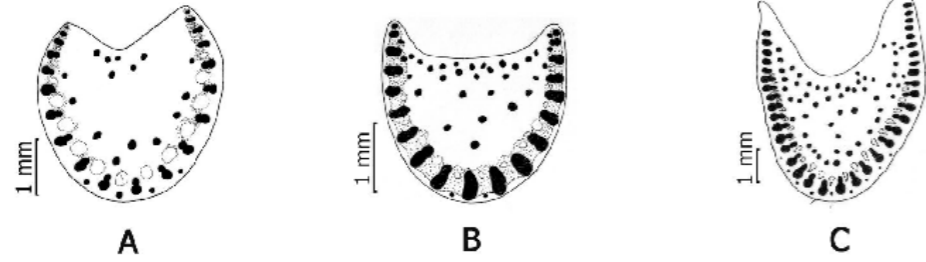


Fig. 30. *Curcuma aeruginosa* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

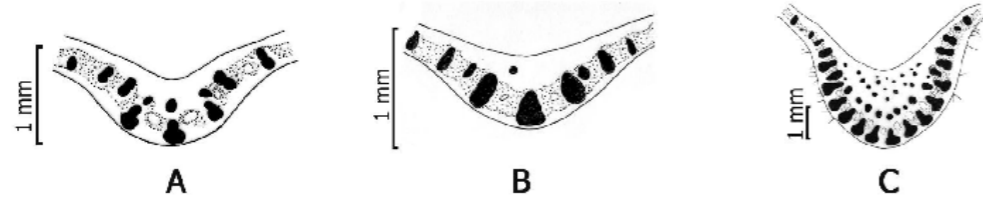
i) Sheath



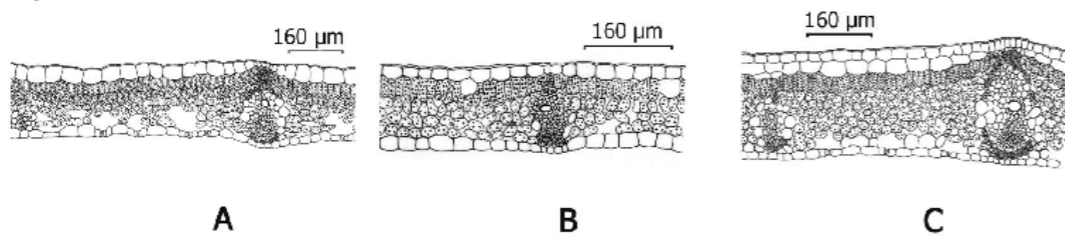
ii) Petiole



iii) Midrib



iv) Lamina



v) Margin

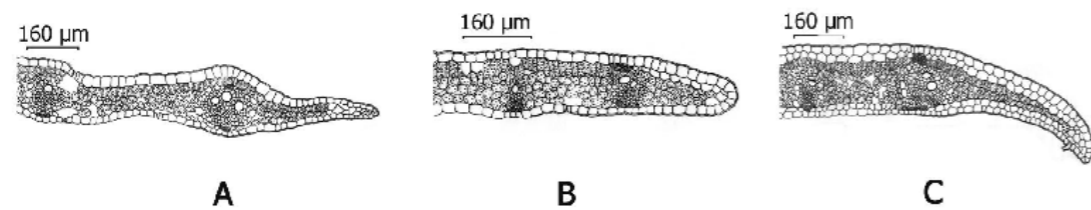


Fig. 09. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Alpinia* spp. I: A. *A. abundiflora*; B. *A. calcarata*; C. *A. fax*.

i) Sheath



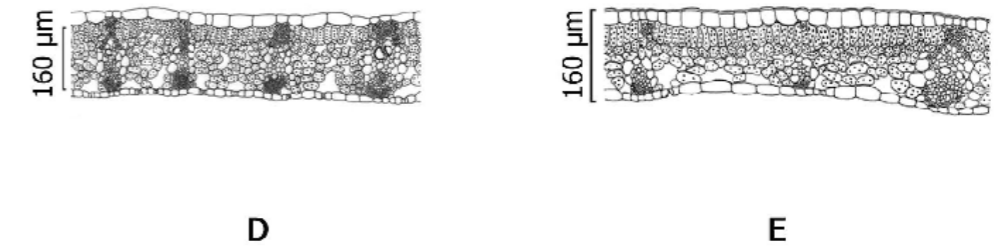
ii) Petiole



iii) Midrib



iv) Lamina



v) Margin

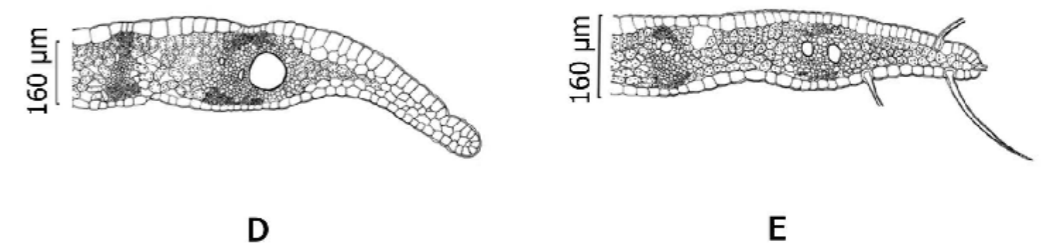


Fig. 10. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Alpinia* spp. II: D. *A. galanga*; E. *A. malaccensis*.

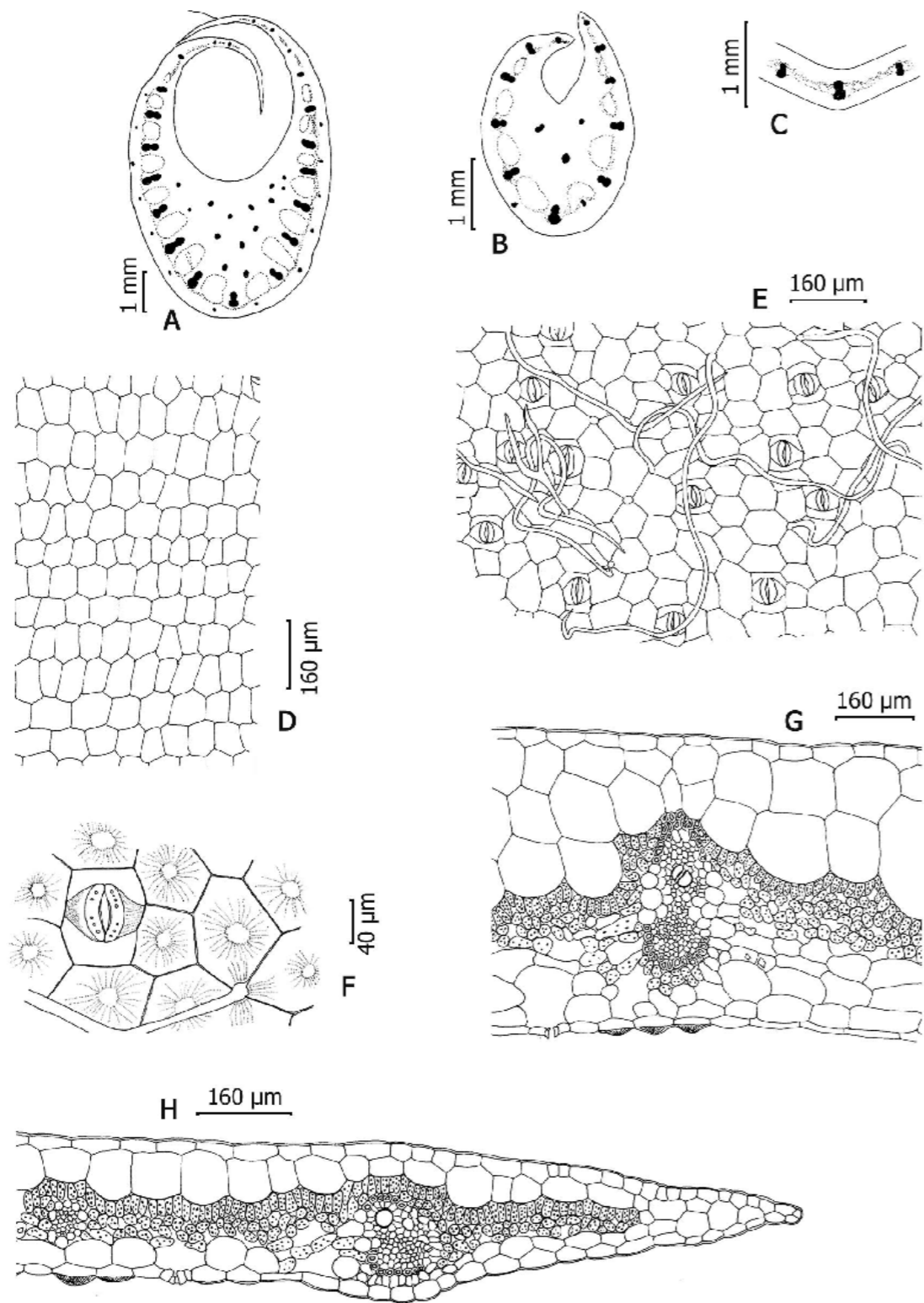


Fig. 61. *Kaempferia galanga* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Cuticular striations seen on abaxial epidermis; G. Lamina; H. Margin.

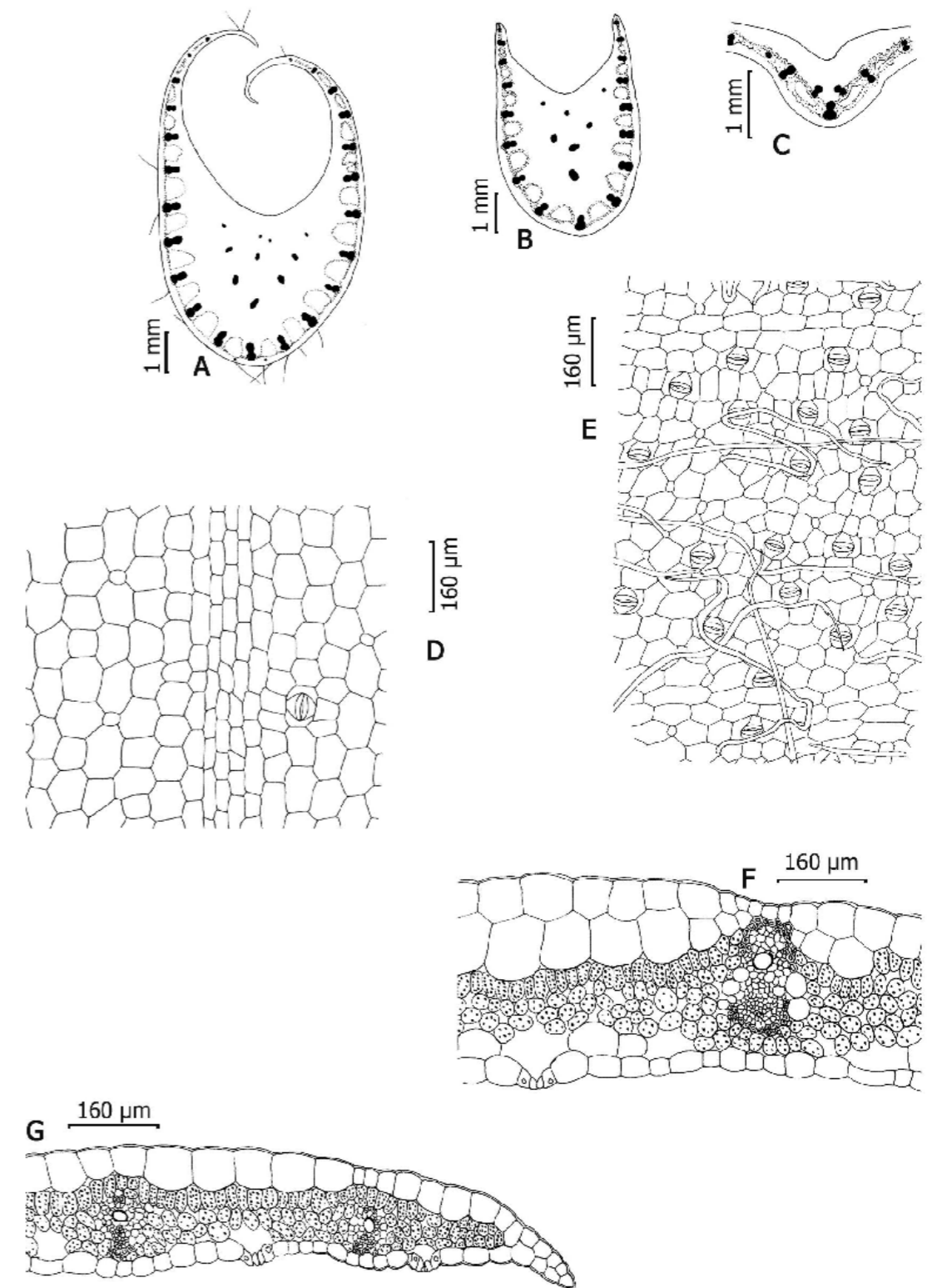


Fig. 62. *Kaempferia rotunda* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

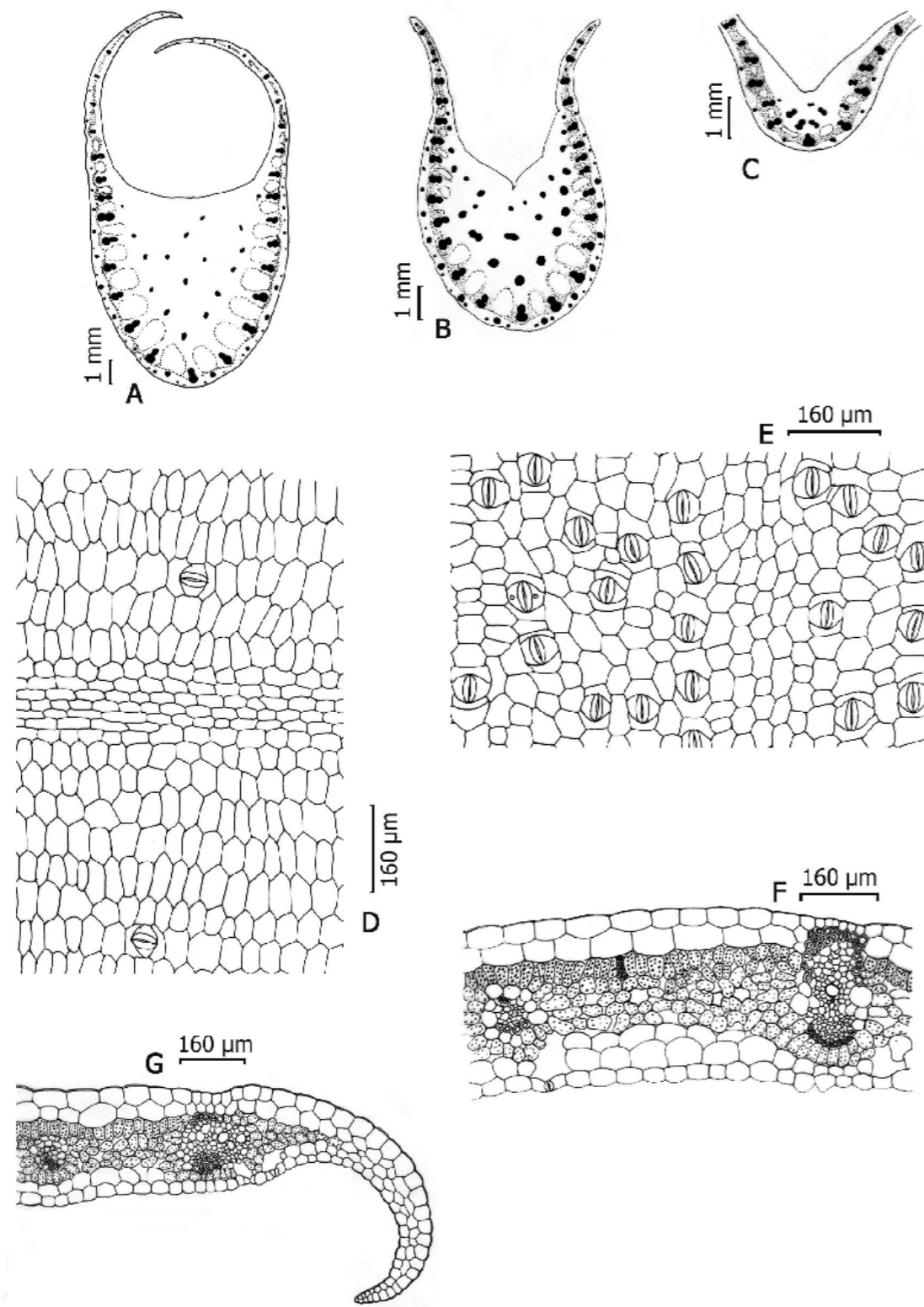


Fig. 47. *Curcuma raktanta* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

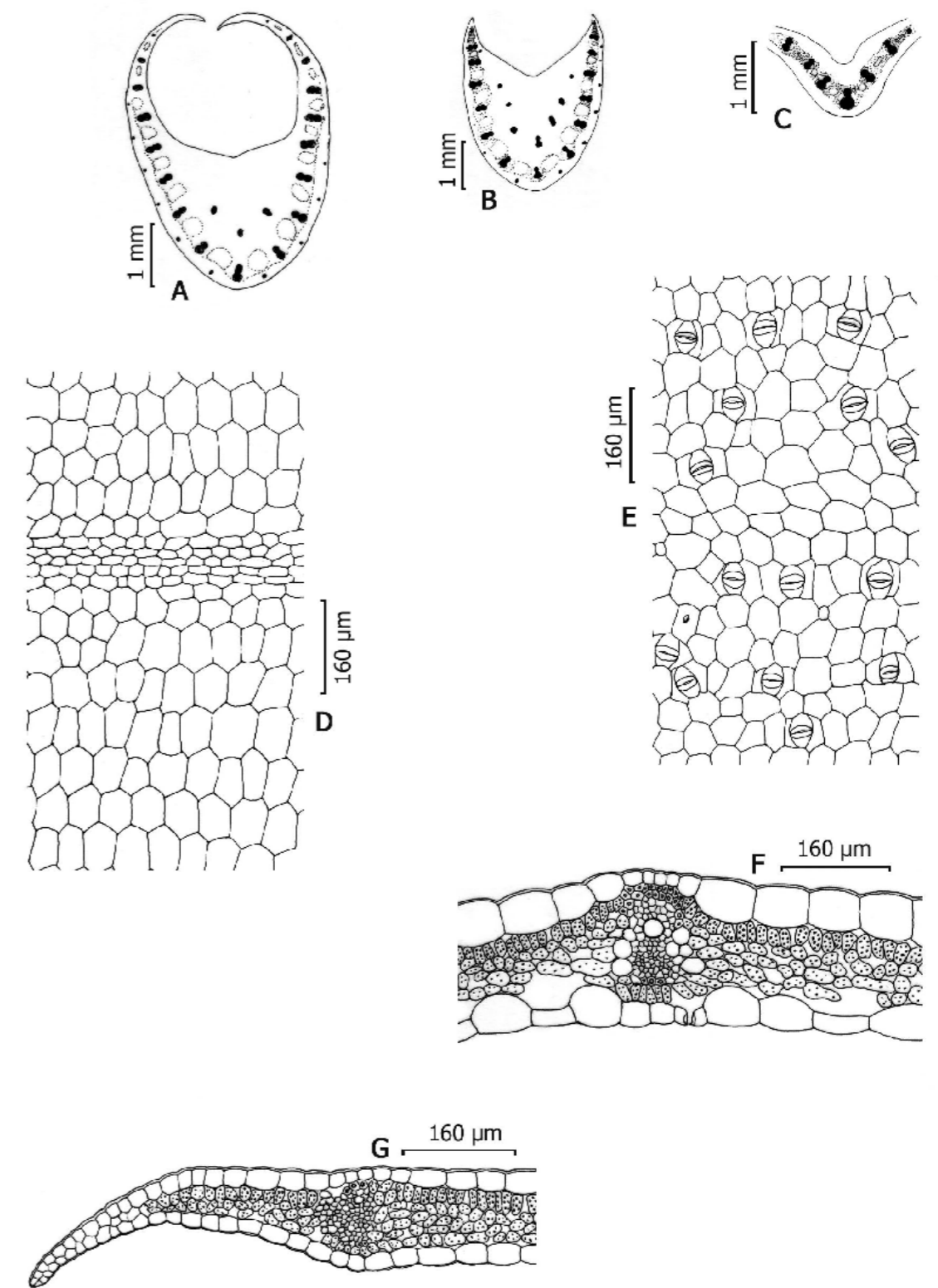


Fig. 48. *Curcuma vama* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

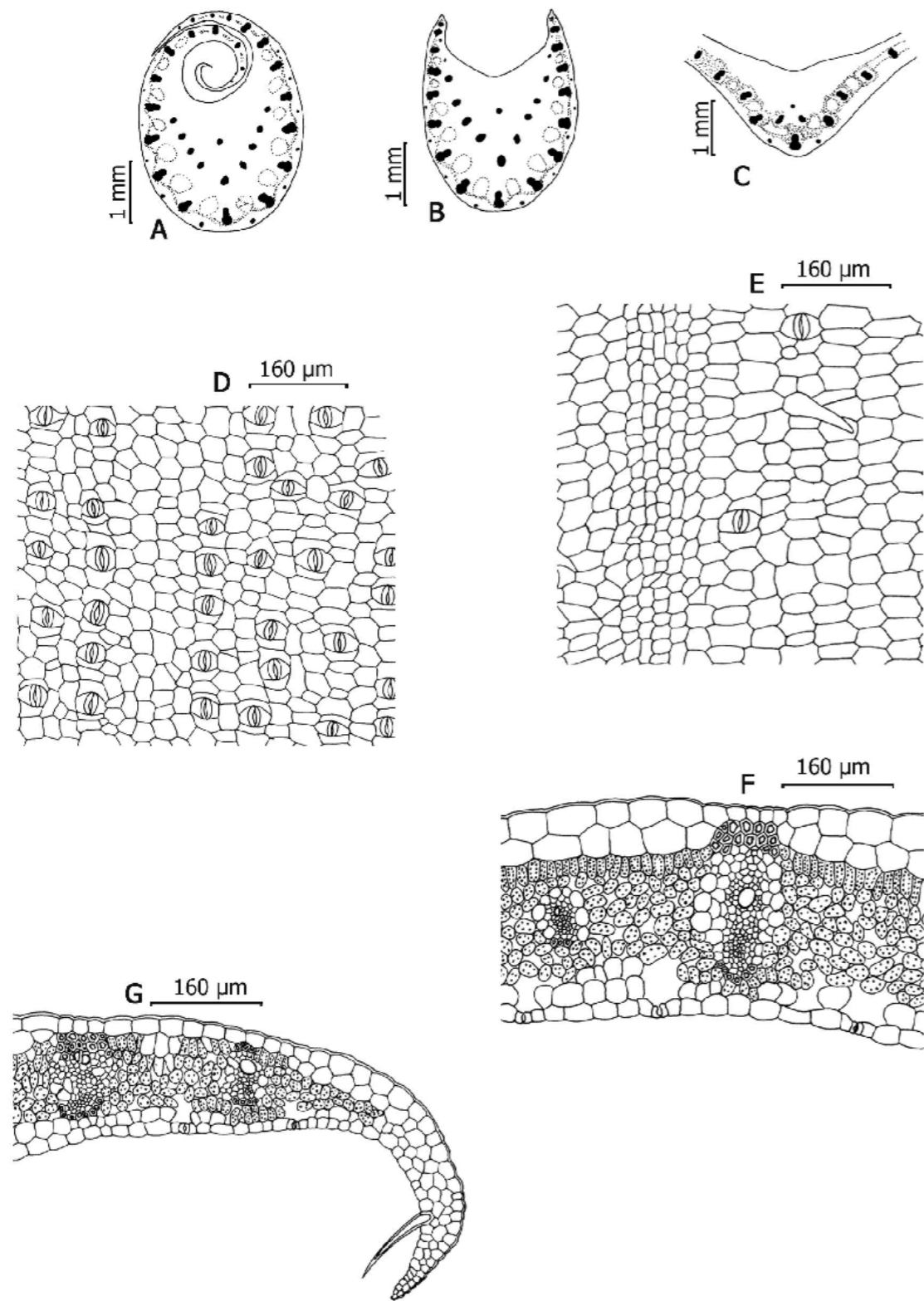


Fig. 35. *Curcuma coriacea* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

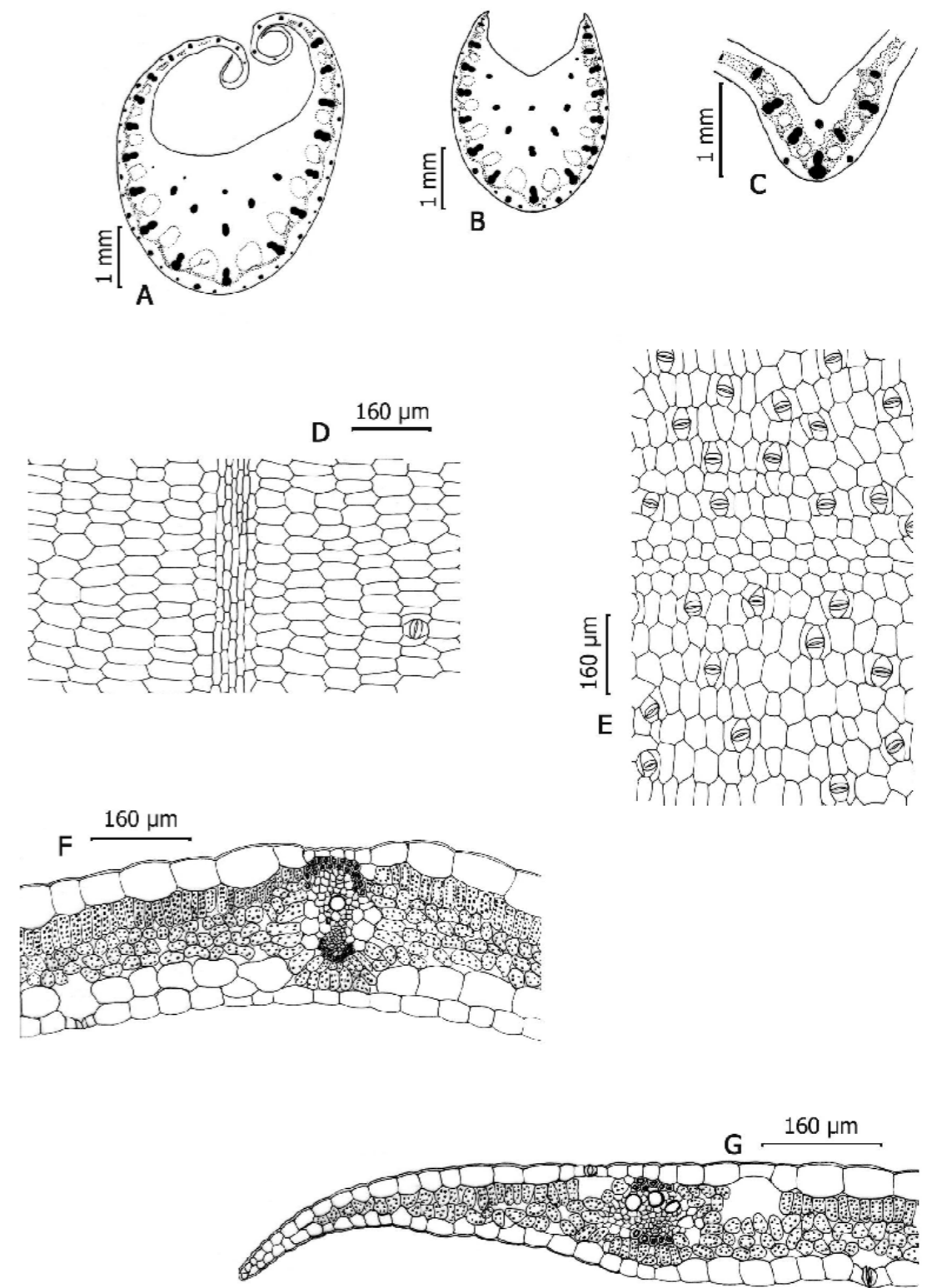


Fig. 36. *Curcuma decipiens* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

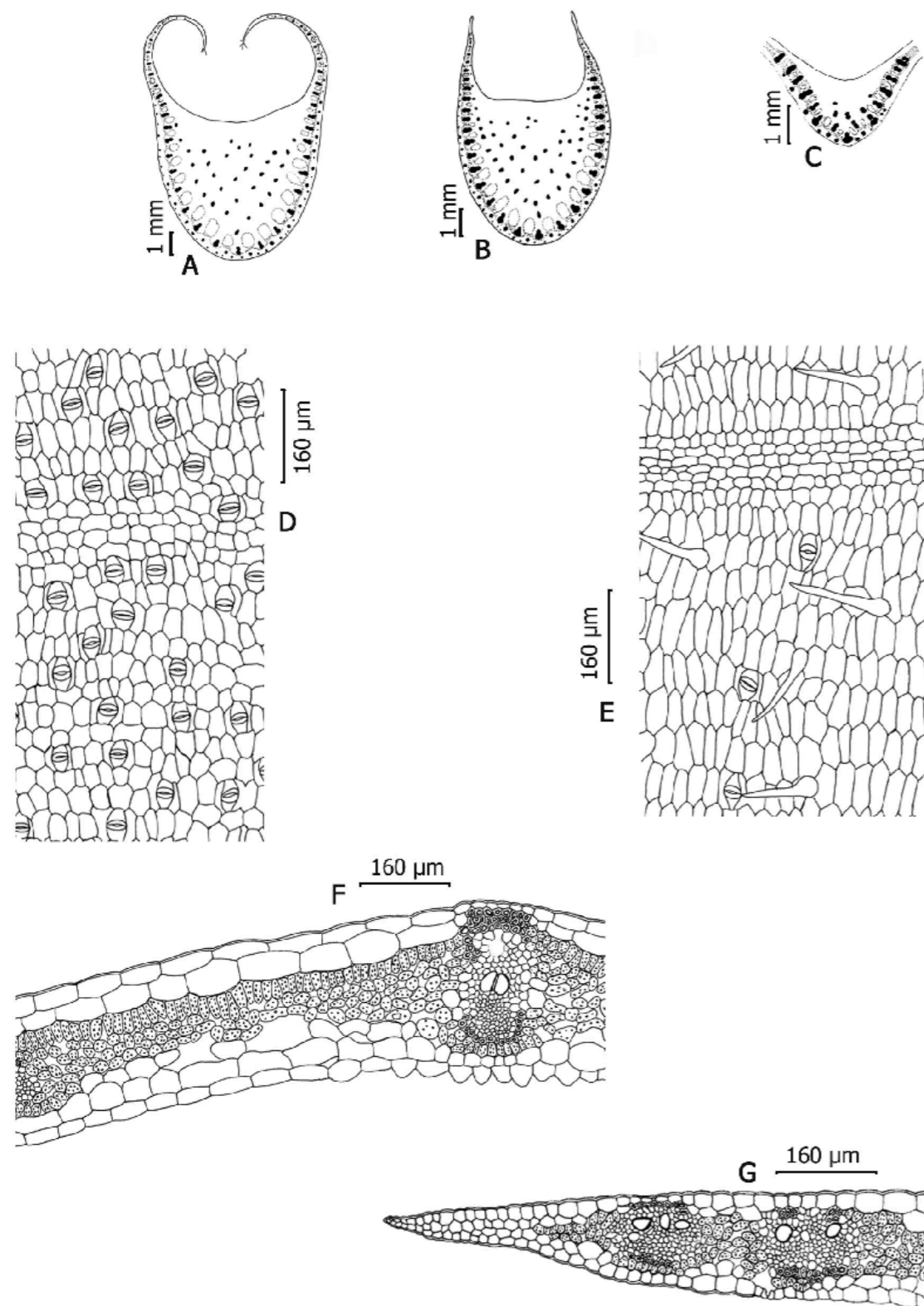


Fig. 41. *Curcuma montana* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

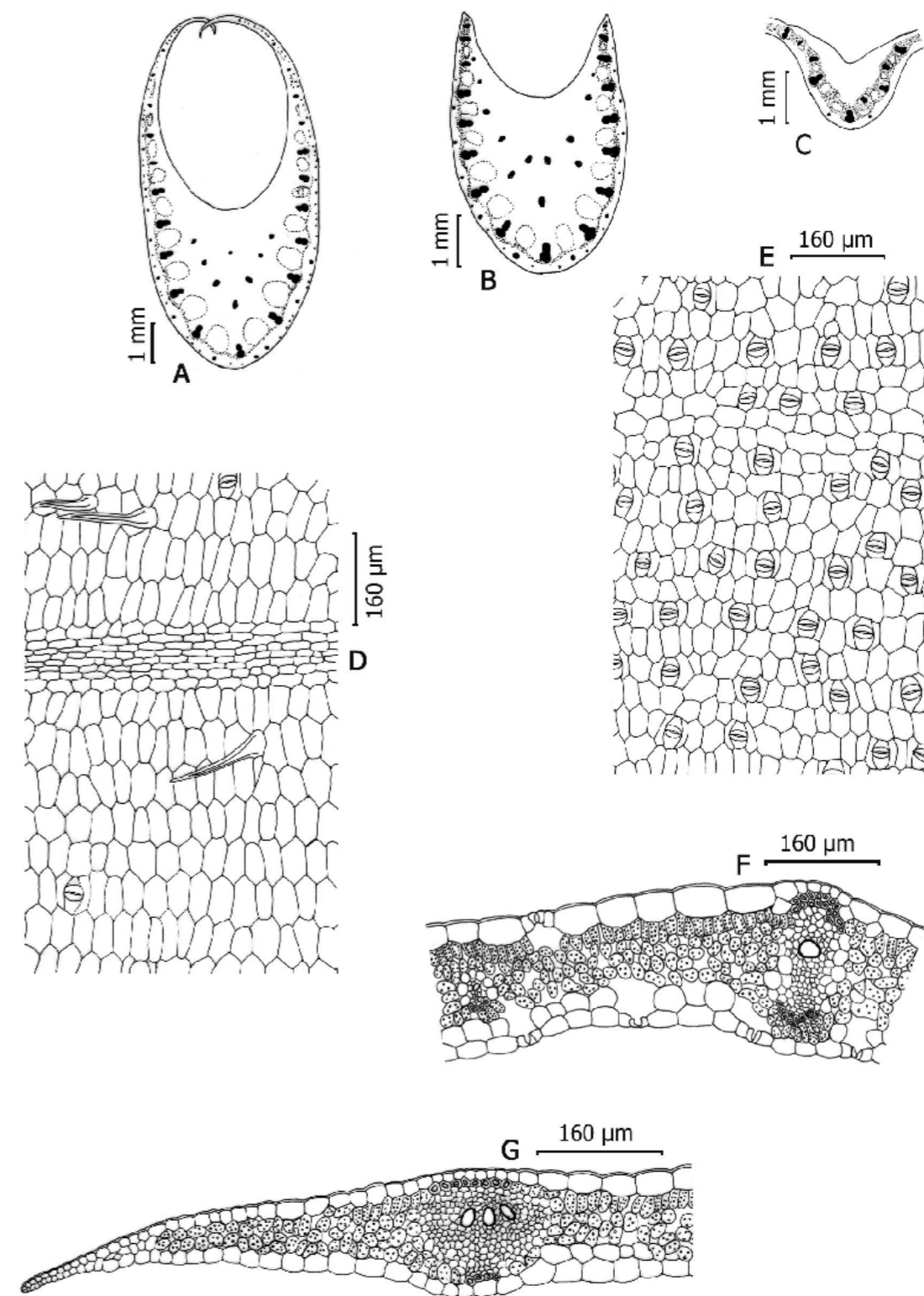


Fig. 42. *Curcuma mutabilis* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

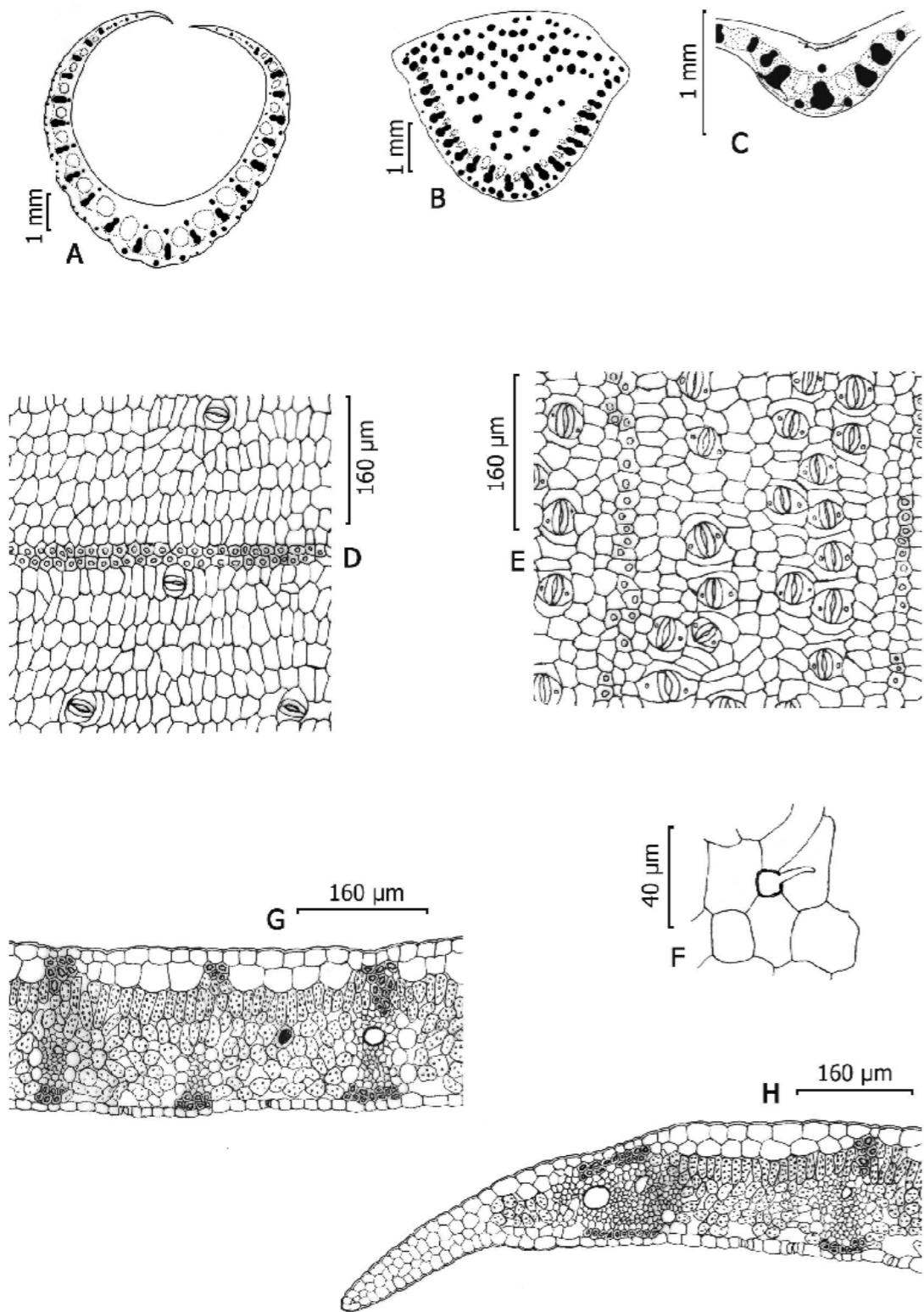


Fig. 07. *Alpinia nigra* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Hair on the abaxial leaf surface; G. Lamina; H. Margin.

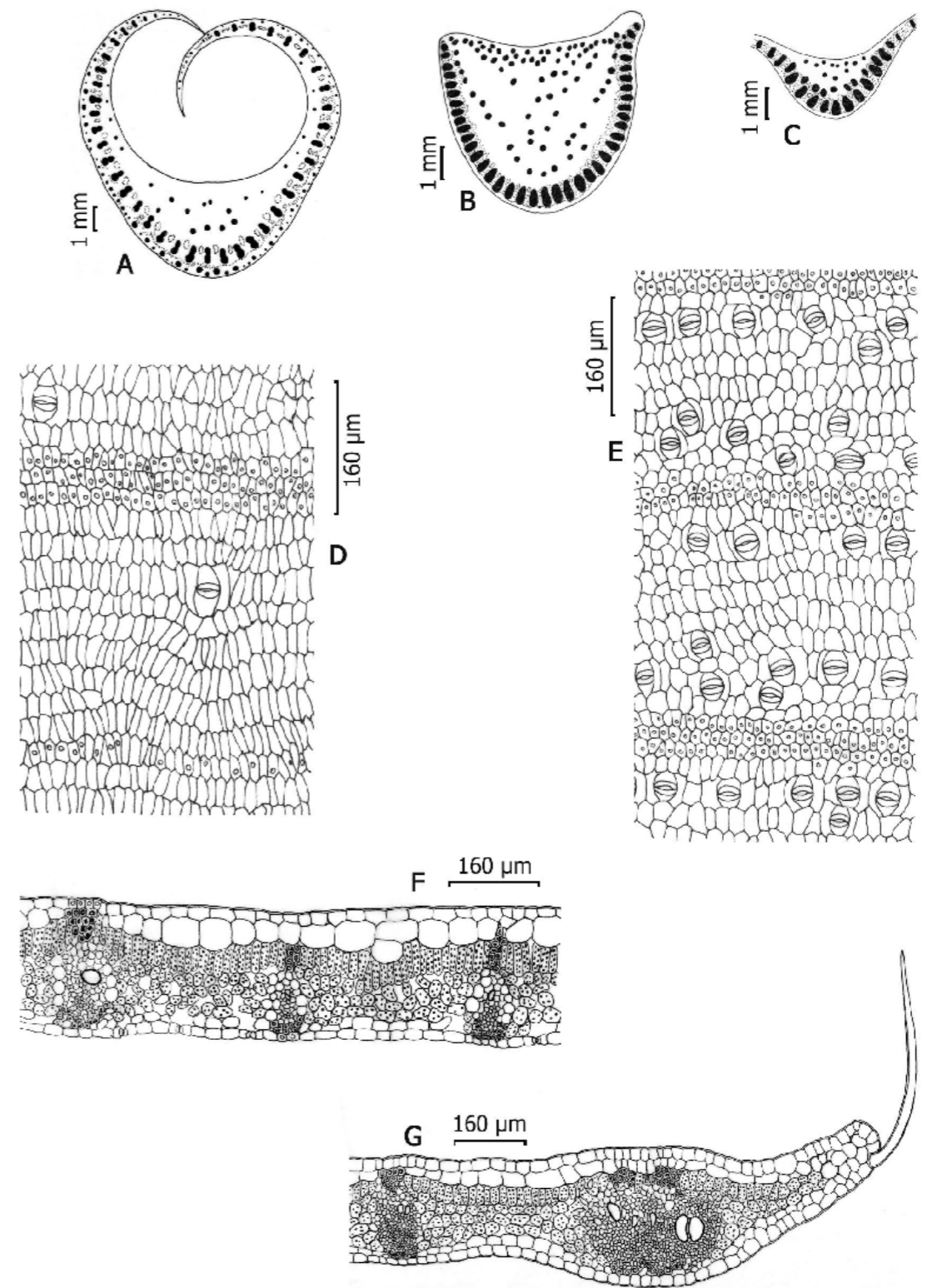


Fig. 08. *Alpinia zerumbet* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

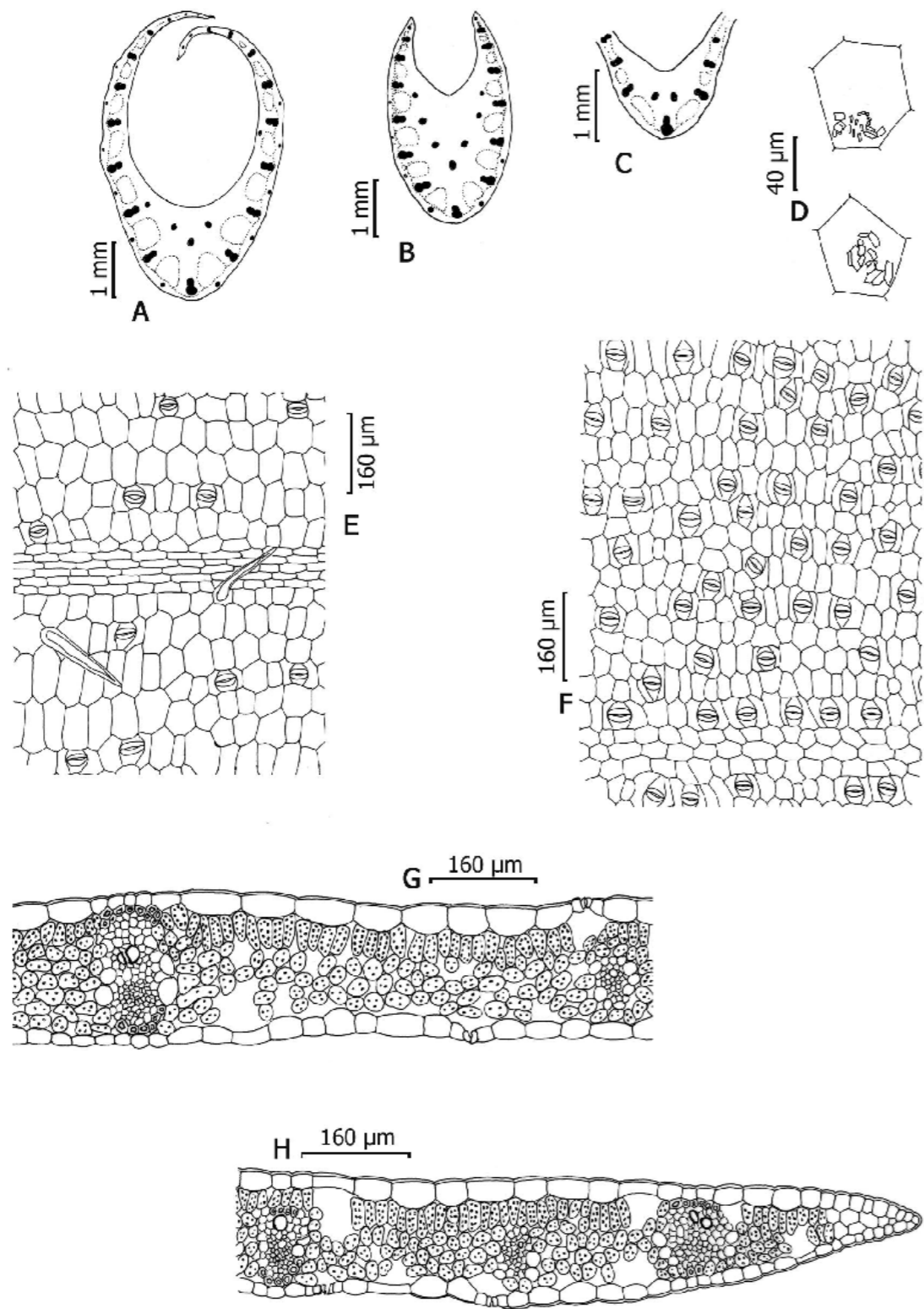


Fig. 63. *Kaempferia scaposa* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Crystals in the ground tissue of petiole; E. Adaxial epidermis; F. Abaxial epidermis; G. Lamina; H. Margin.

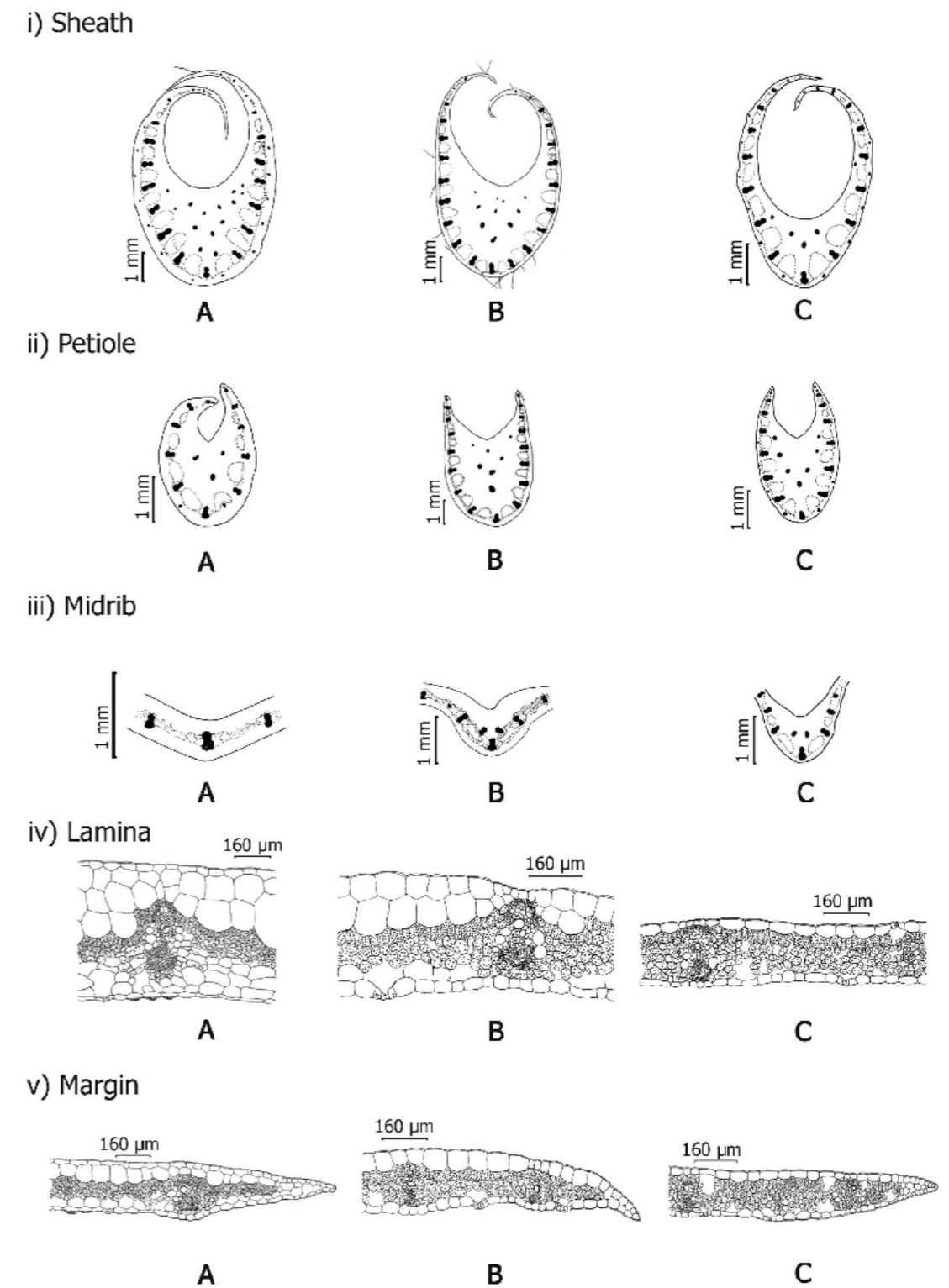


Fig. 64. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Kaempferia* spp.: A. *K. galanga*; B. *K. rotunda*; C. *K. scaposa*.

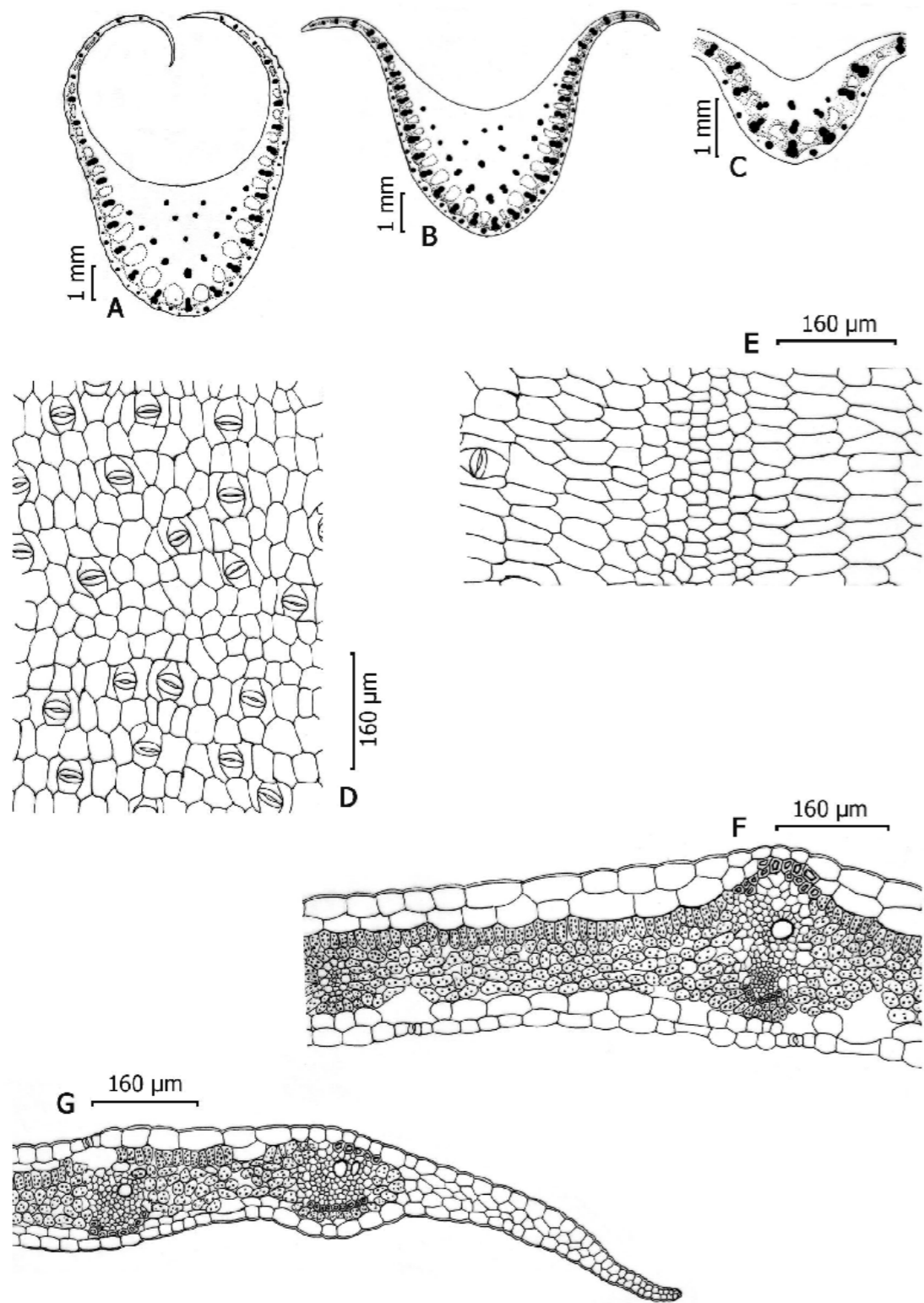


Fig. 31. *Curcuma amada* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

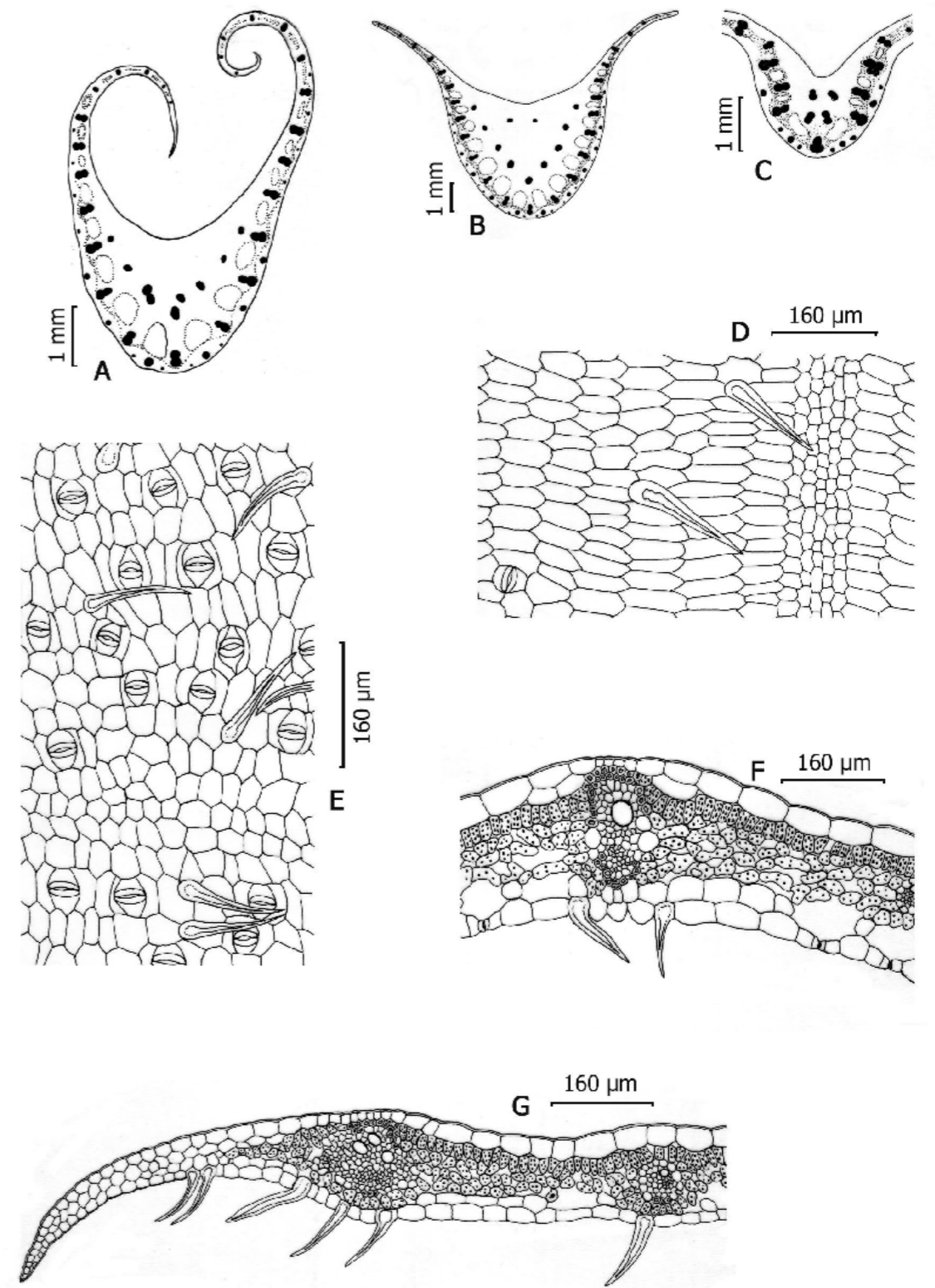


Fig. 32. *Curcuma aromatica* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

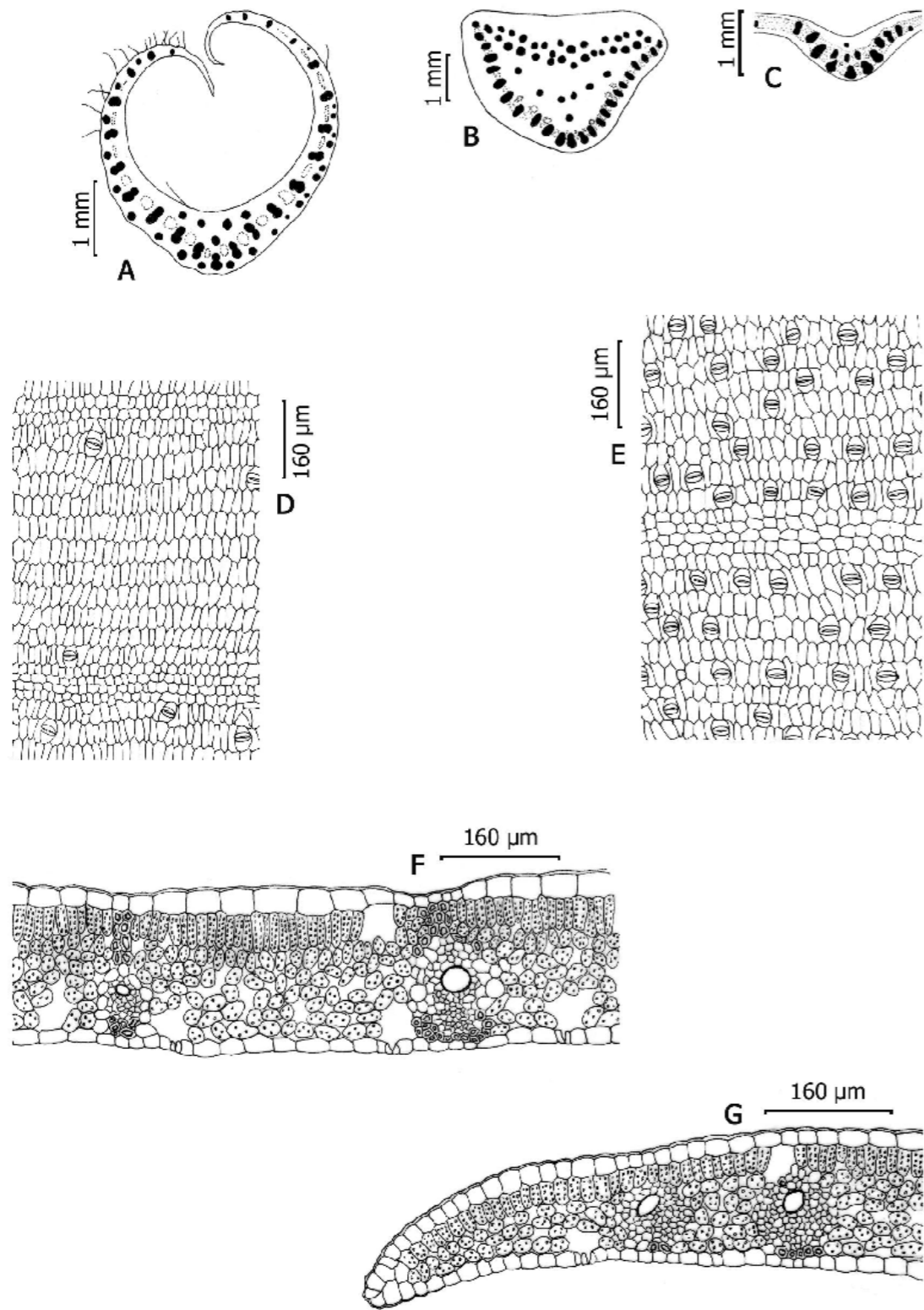


Fig. 15. *Amomum masticatorium* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

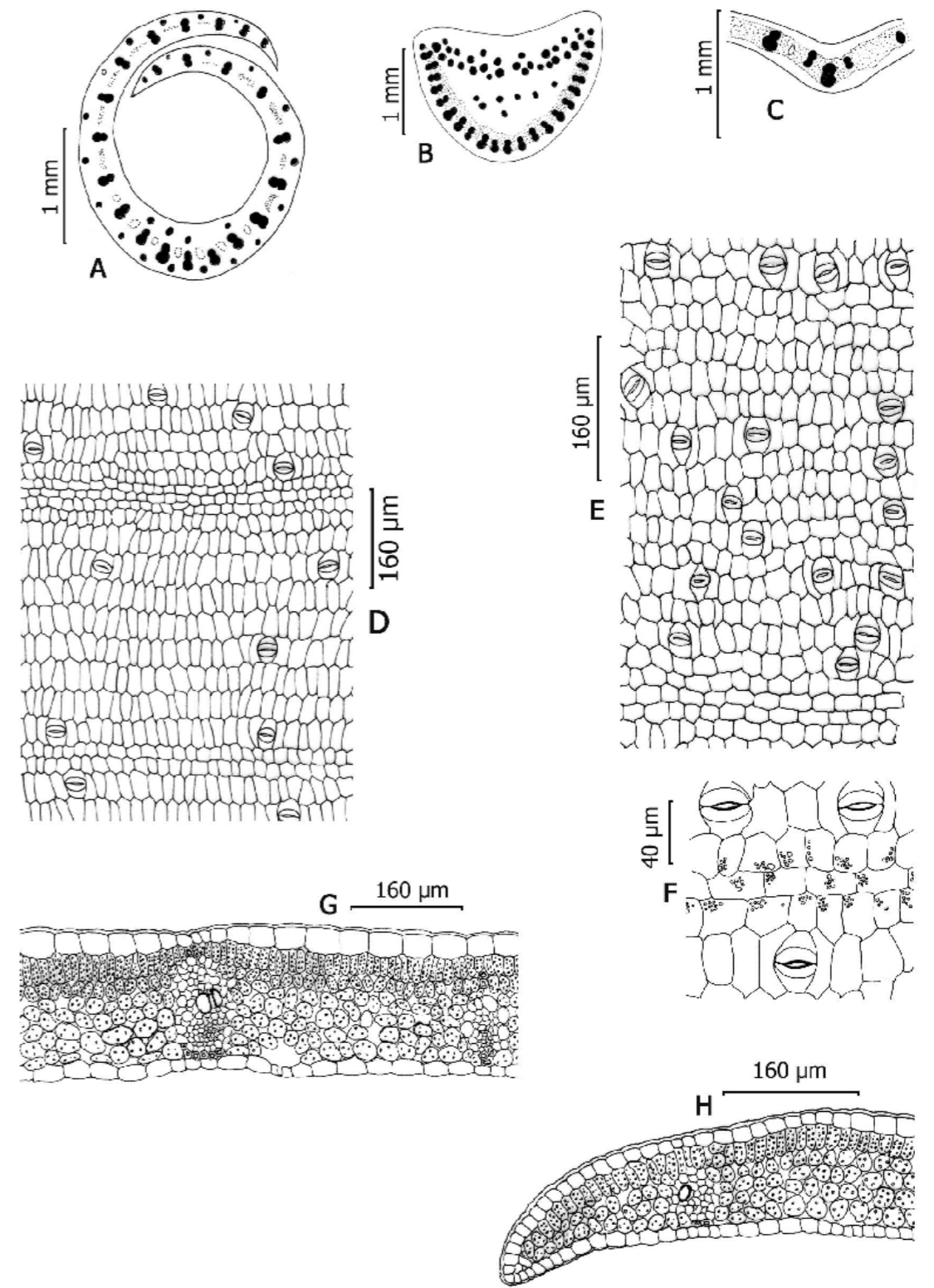


Fig. 16. *Amomum muricatum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Costal cells containing silica sand; G. Lamina; H. Margin.

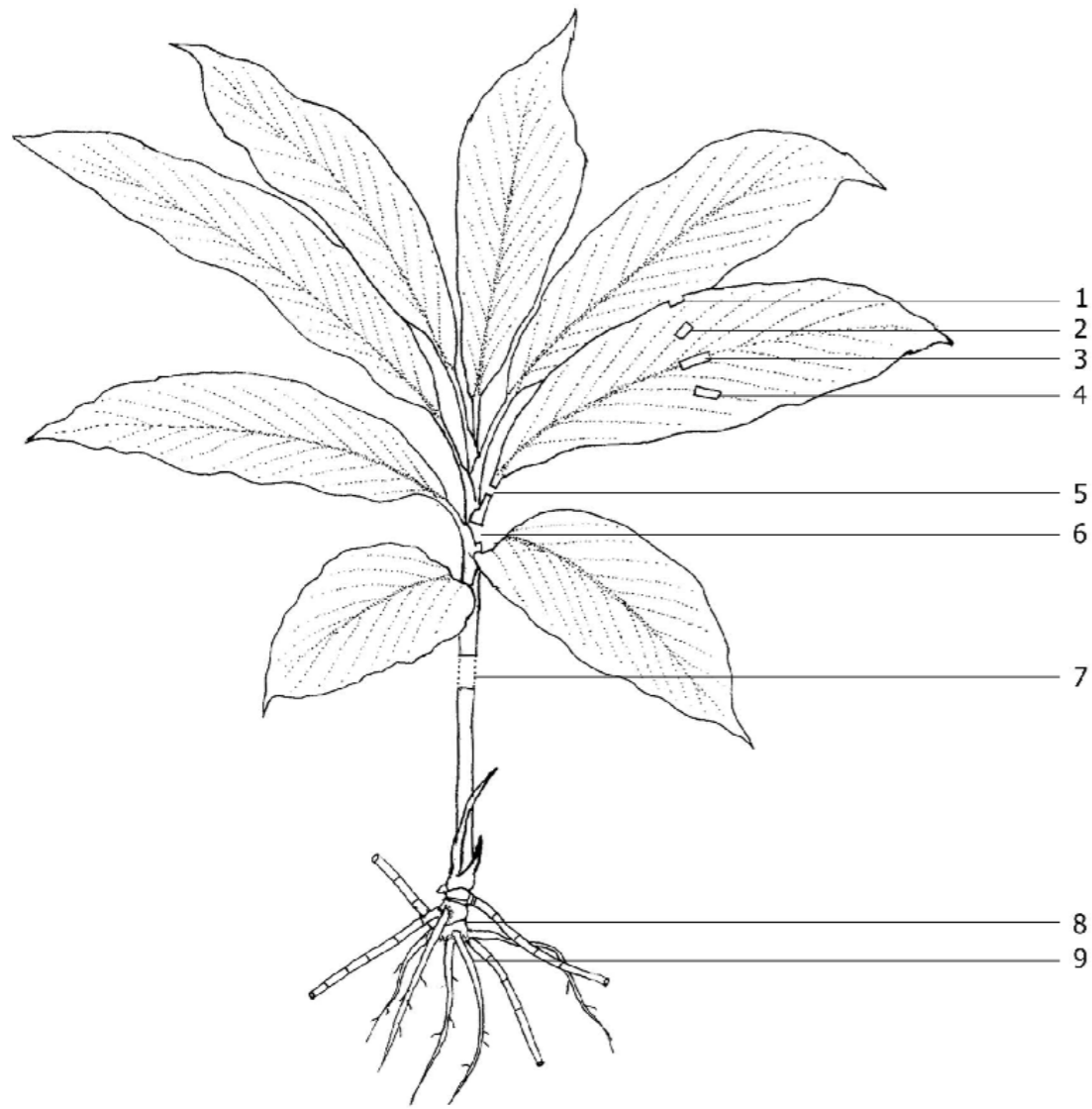


Fig. 01. Diagrammatic representation of a typical Zingiberaceous plant showing the portions of various parts taken for study: 1. Margin; 2. Lamina; 3. Midrib; 4. Epidermis; 5. Petiole; 6. Sheath; 7. Aerial stem; 8. Rhizome; 9. Root.

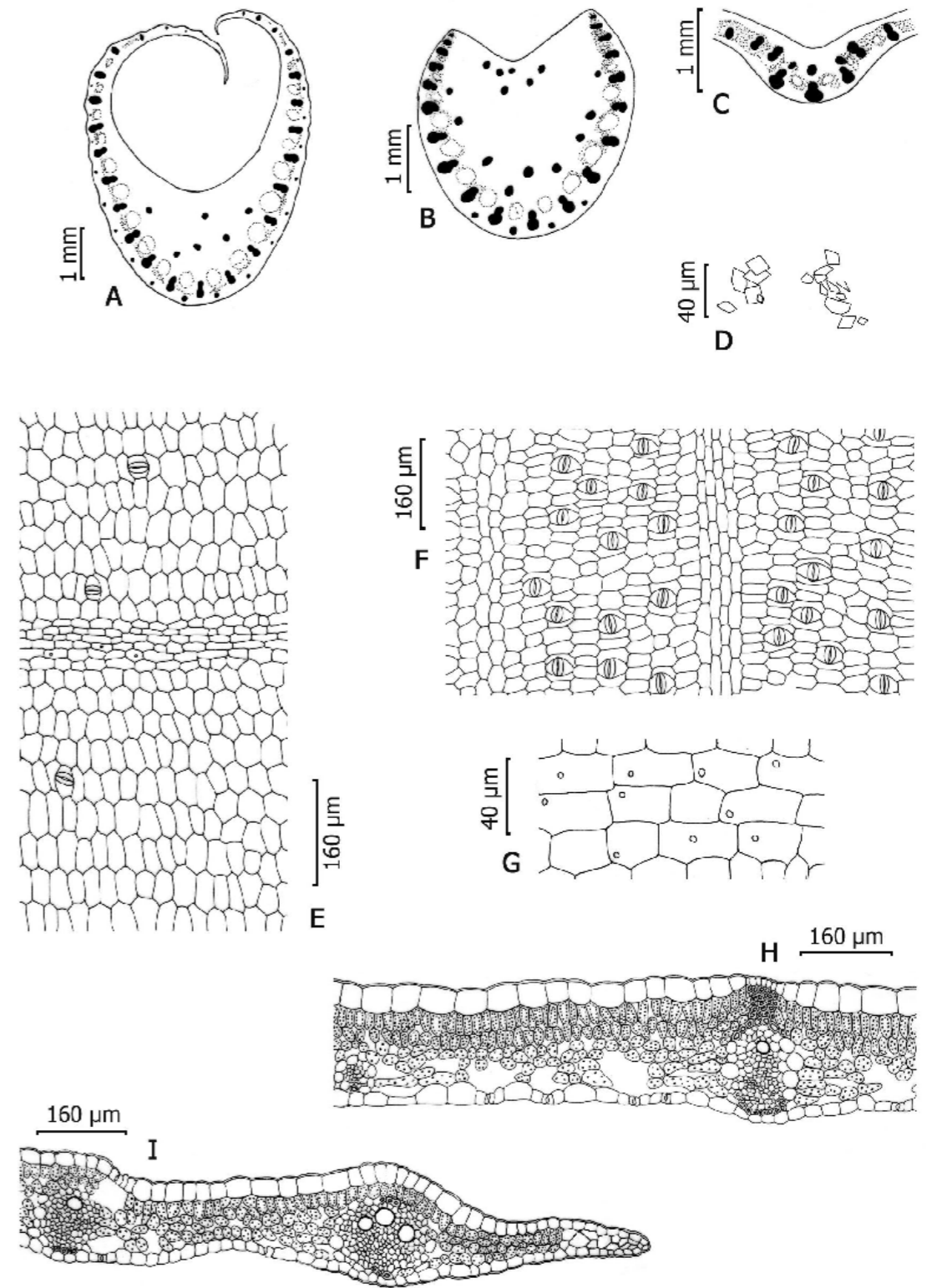


Fig. 02. *Alpinia abundiflora* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Crystals in the ground tissue of petiole; E. Adaxial epidermis; F. Abaxial epidermis; G. Costal cells containing silica body; H. Lamina; I. Margin.

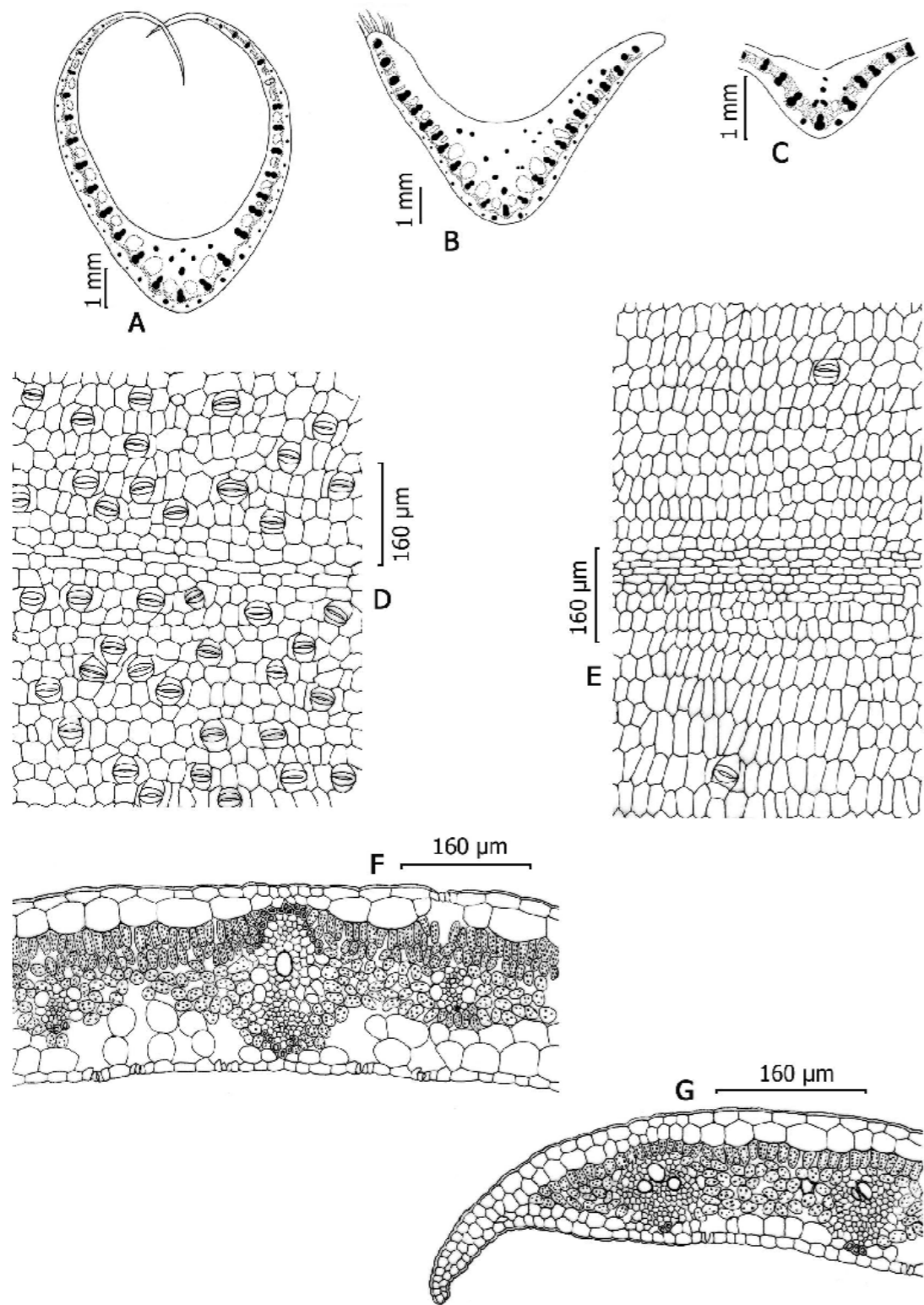


Fig. 57. *Hedychium coronarium* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

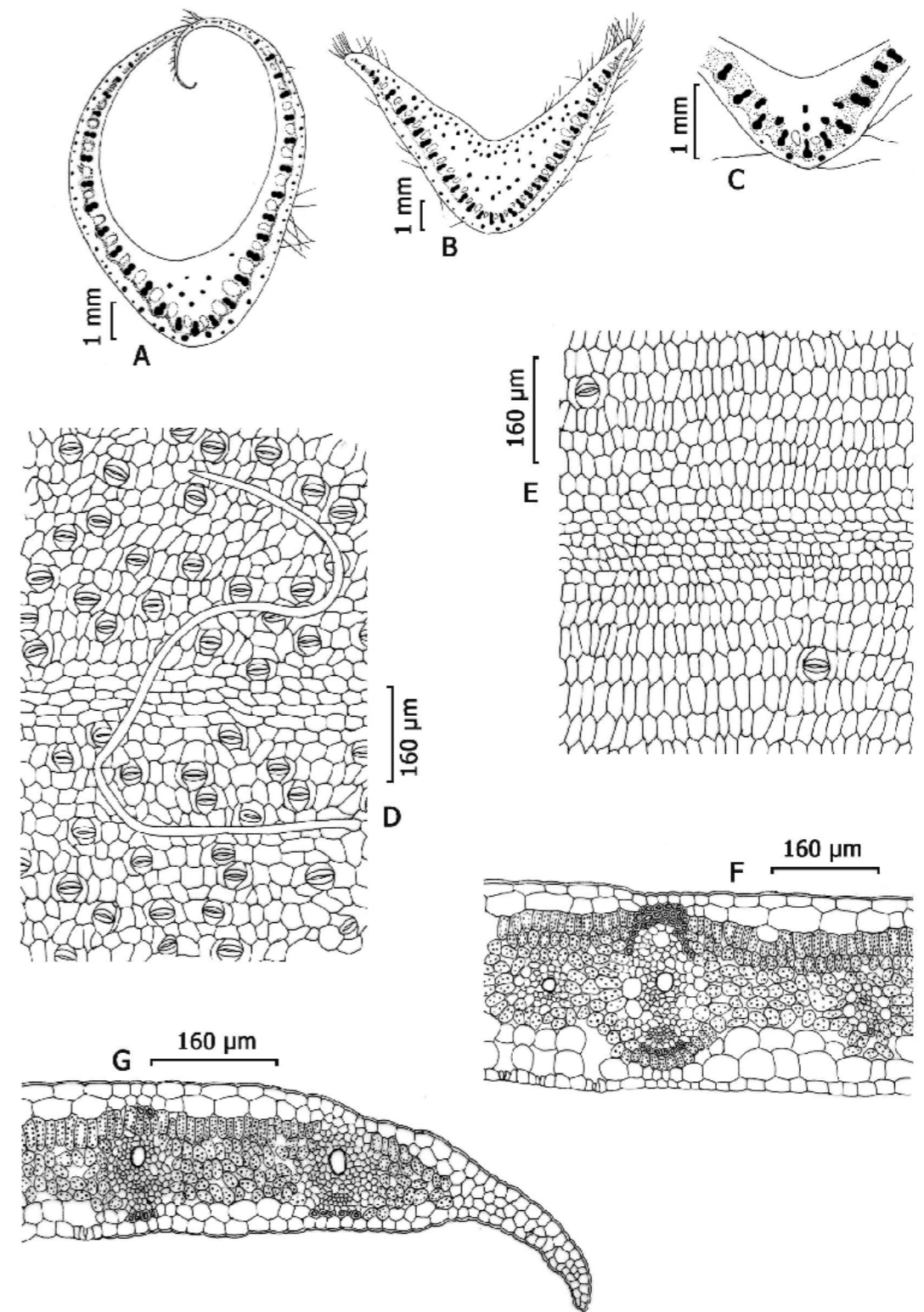
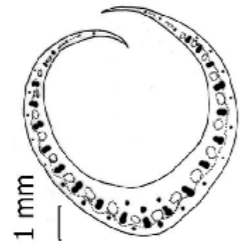


Fig. 58. *Hedychium flavescens* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Lamina; G. Margin.

i) Sheath

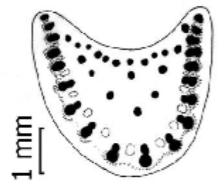


D

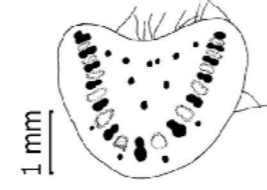


E

ii) Petiole

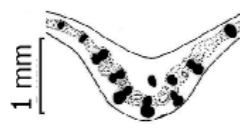


D



E

iii) Midrib

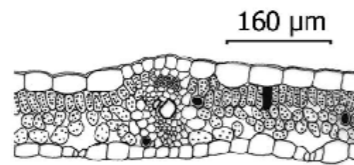


D

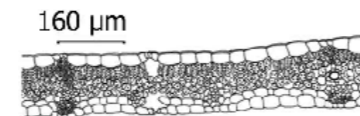


E

iv) Lamina

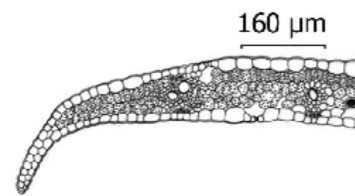


D

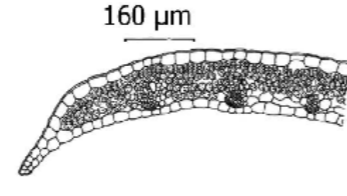


E

v) Margin

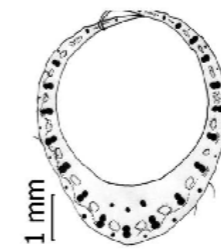


D



E

i) Sheath

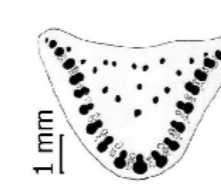


F

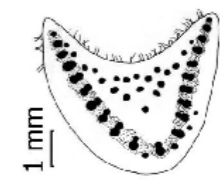


G

ii) Petiole

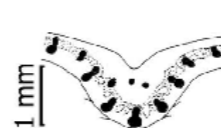


F



G

iii) Midrib

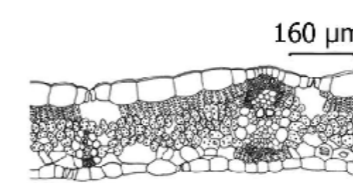


F

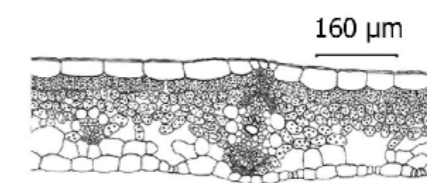


G

iv) Lamina

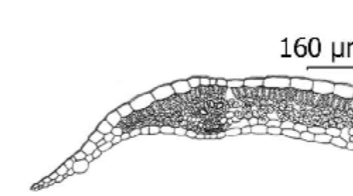


F

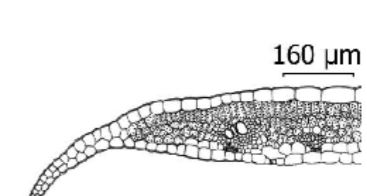


G

v) Margin



F



G

Fig. 73. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Zingiber* spp. II: D. *Z. nimmonii*; E. *Z. officinale*.

Fig. 74. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Zingiber* spp. III: F. *Z. wightianum*; G. *Z. zerumbet*.

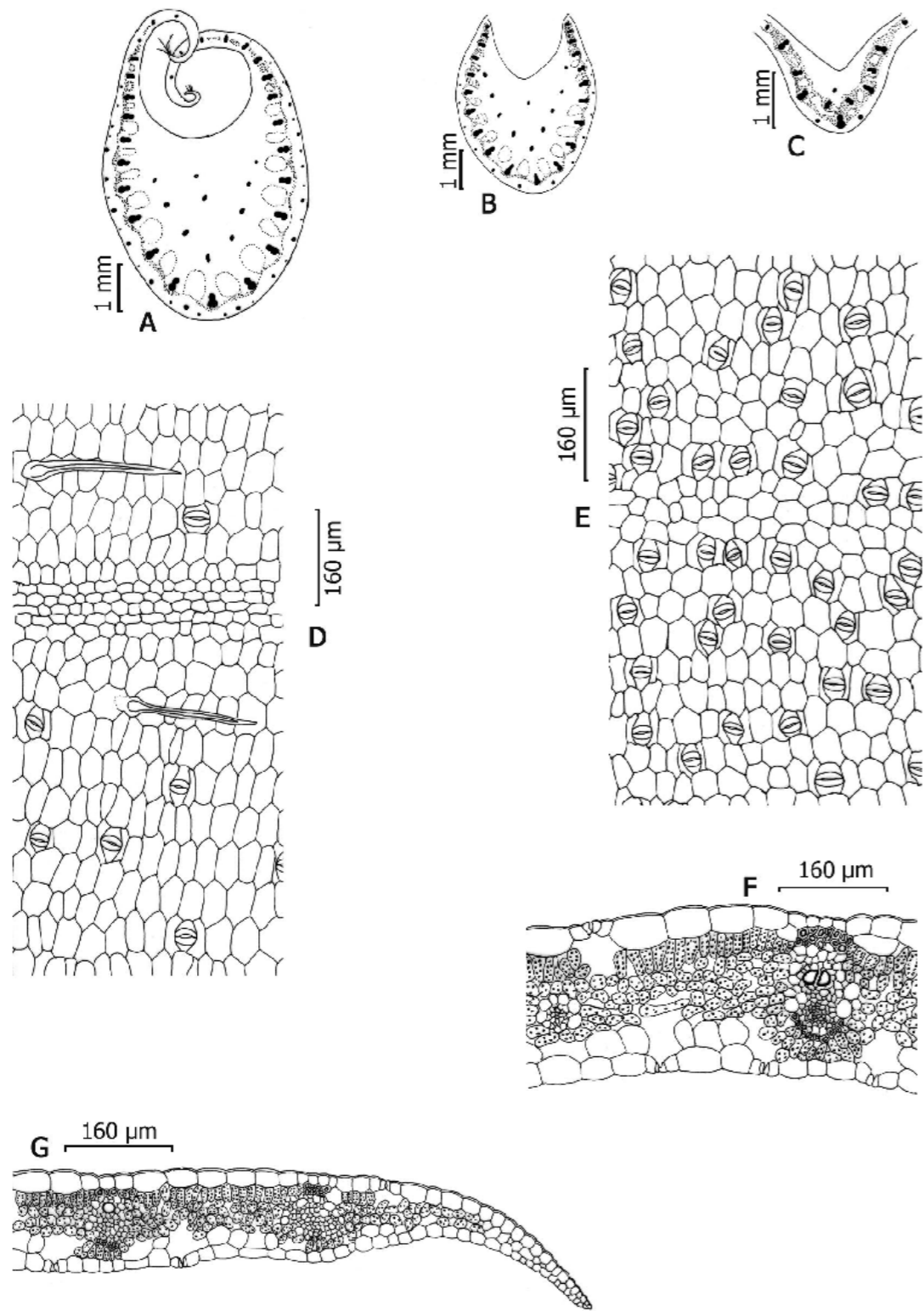


Fig. 39. *Curcuma karnatakensis* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

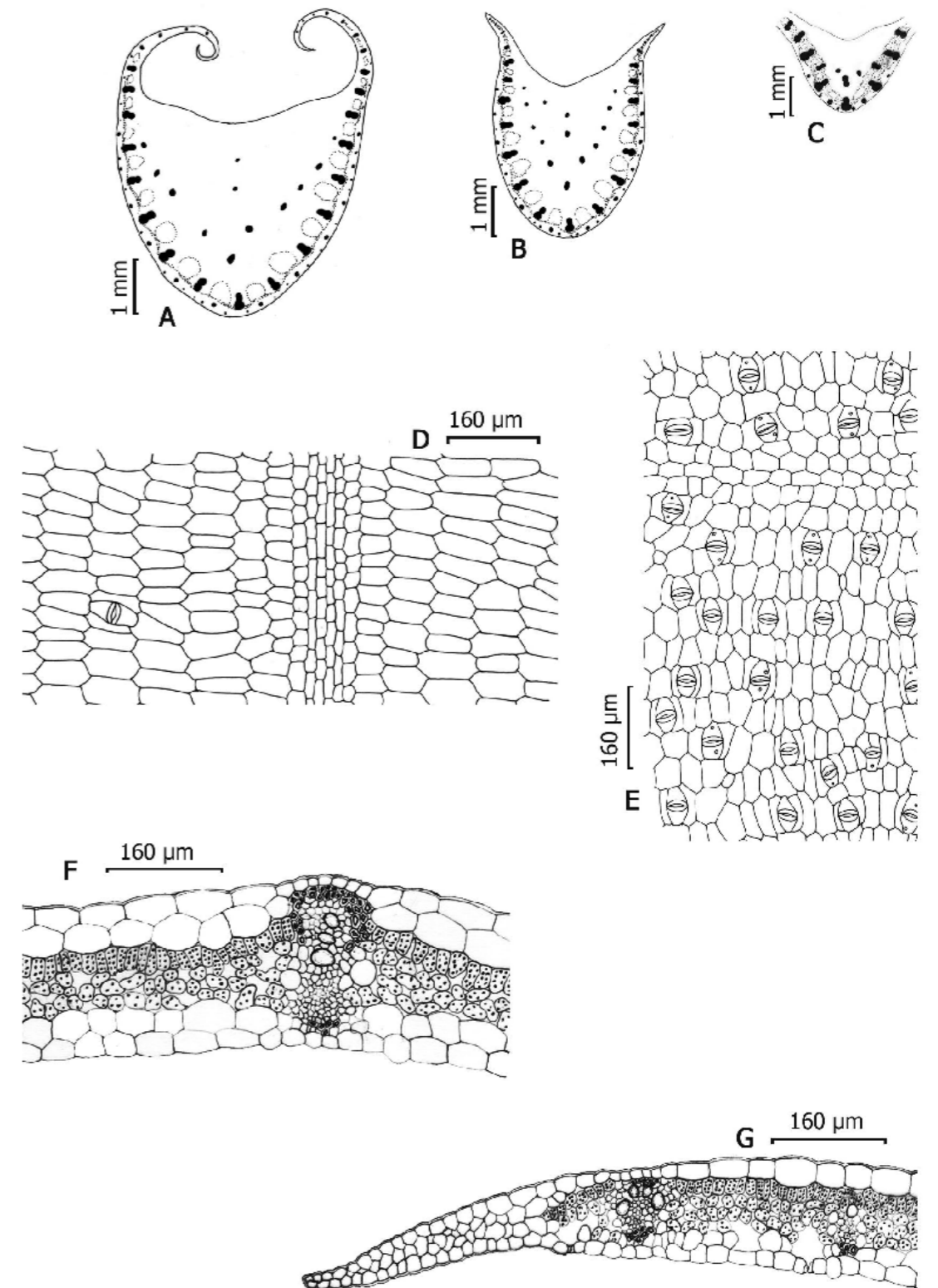
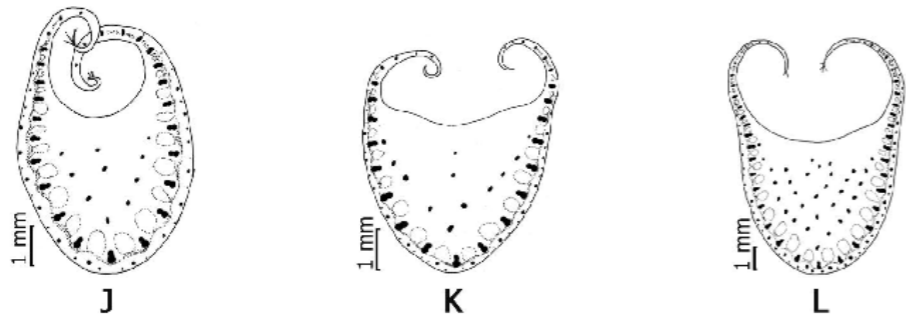
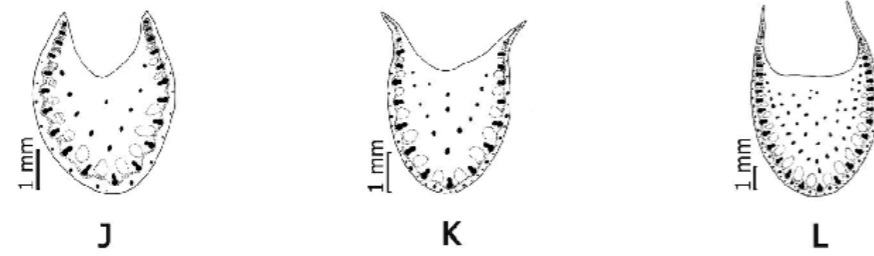


Fig. 40. *Curcuma longa* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

i) Sheath



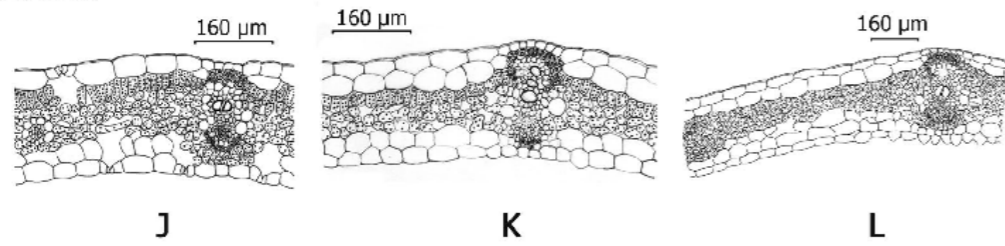
ii) Petiole



iii) Midrib



iv) Lamina



v) Margin

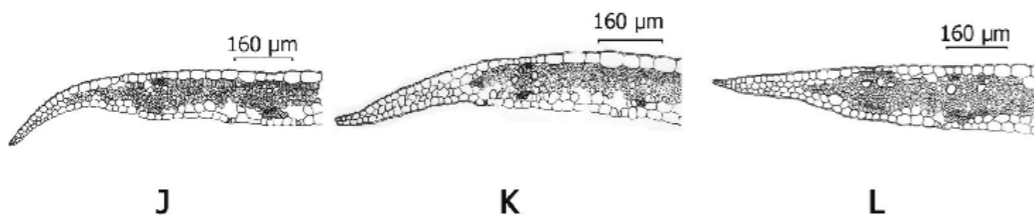
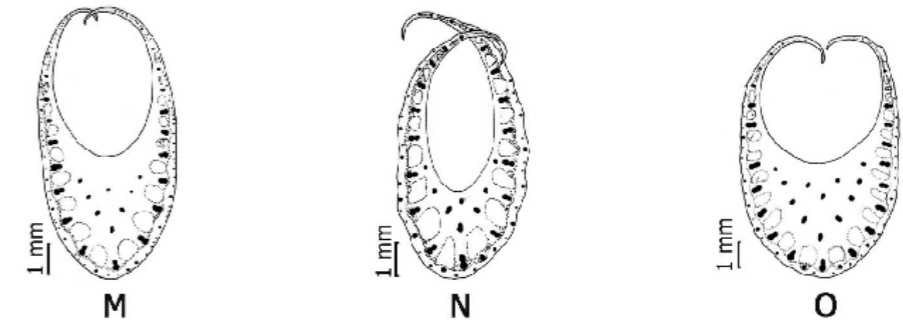
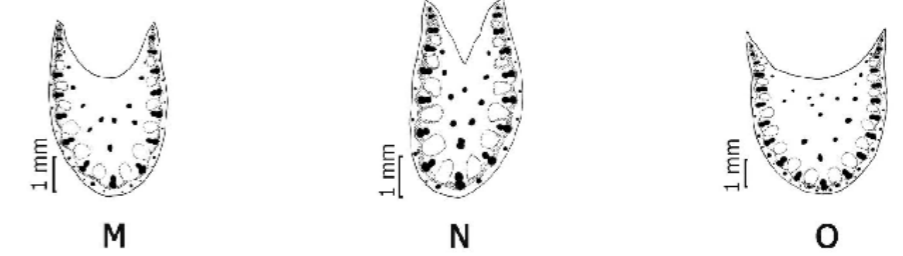


Fig. 53. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Curcuma* spp. IV: J. *C. karnatakensis*; K. *C. longa*; L. *C. montana*.

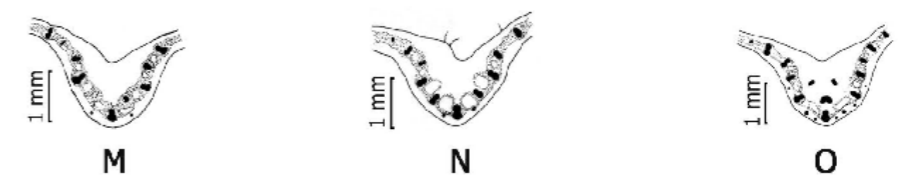
i) Sheath



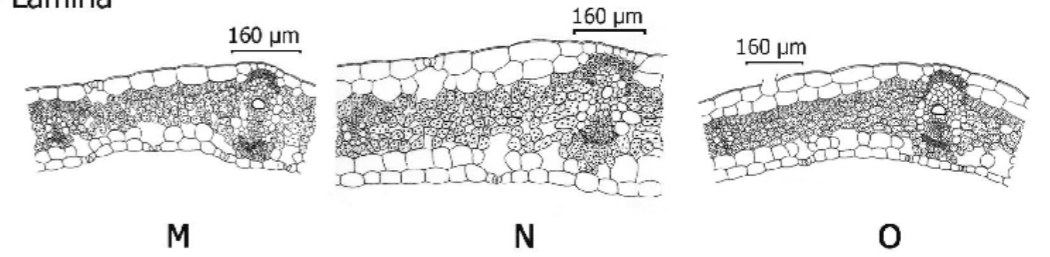
ii) Petiole



iii) Midrib



iv) Lamina



v) Margin

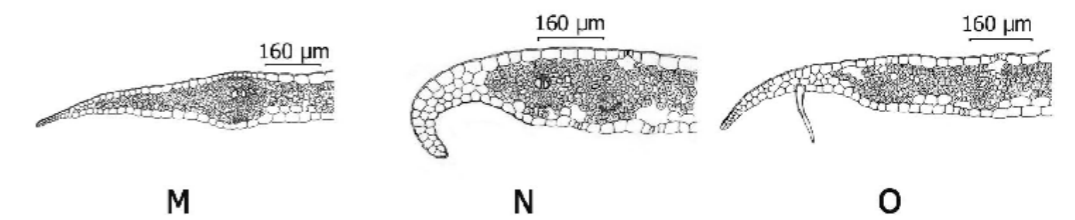


Fig. 54. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Curcuma* spp. V: M. *C. mutabilis*; N. *C. neilgherrensis*; O. *C. pseudomontana*.

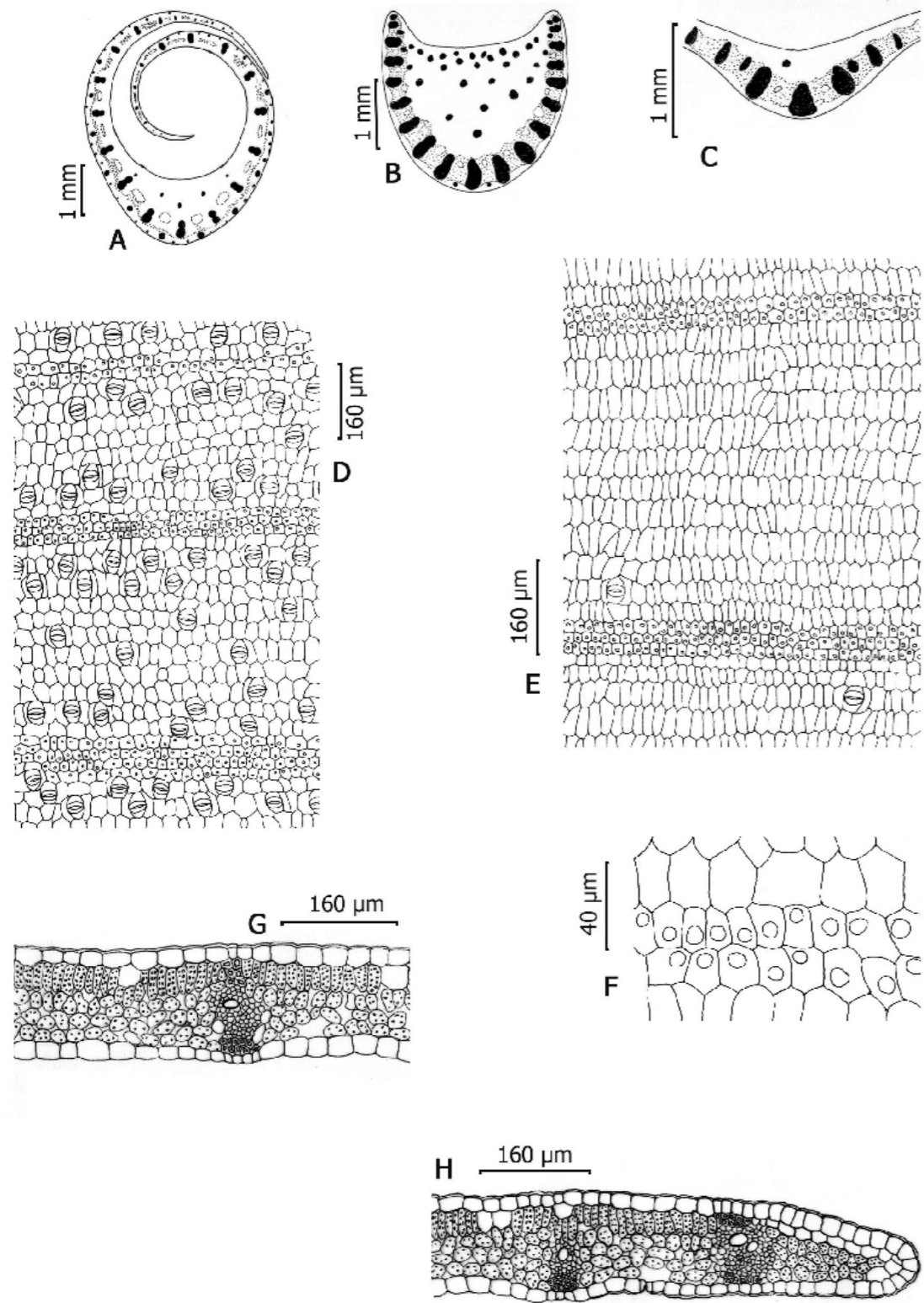


Fig. 03. *Alpinia calcarata* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Abaxial epidermis; E. Adaxial epidermis; F. Costal cells containing silica body; G. Lamina; H. Margin.

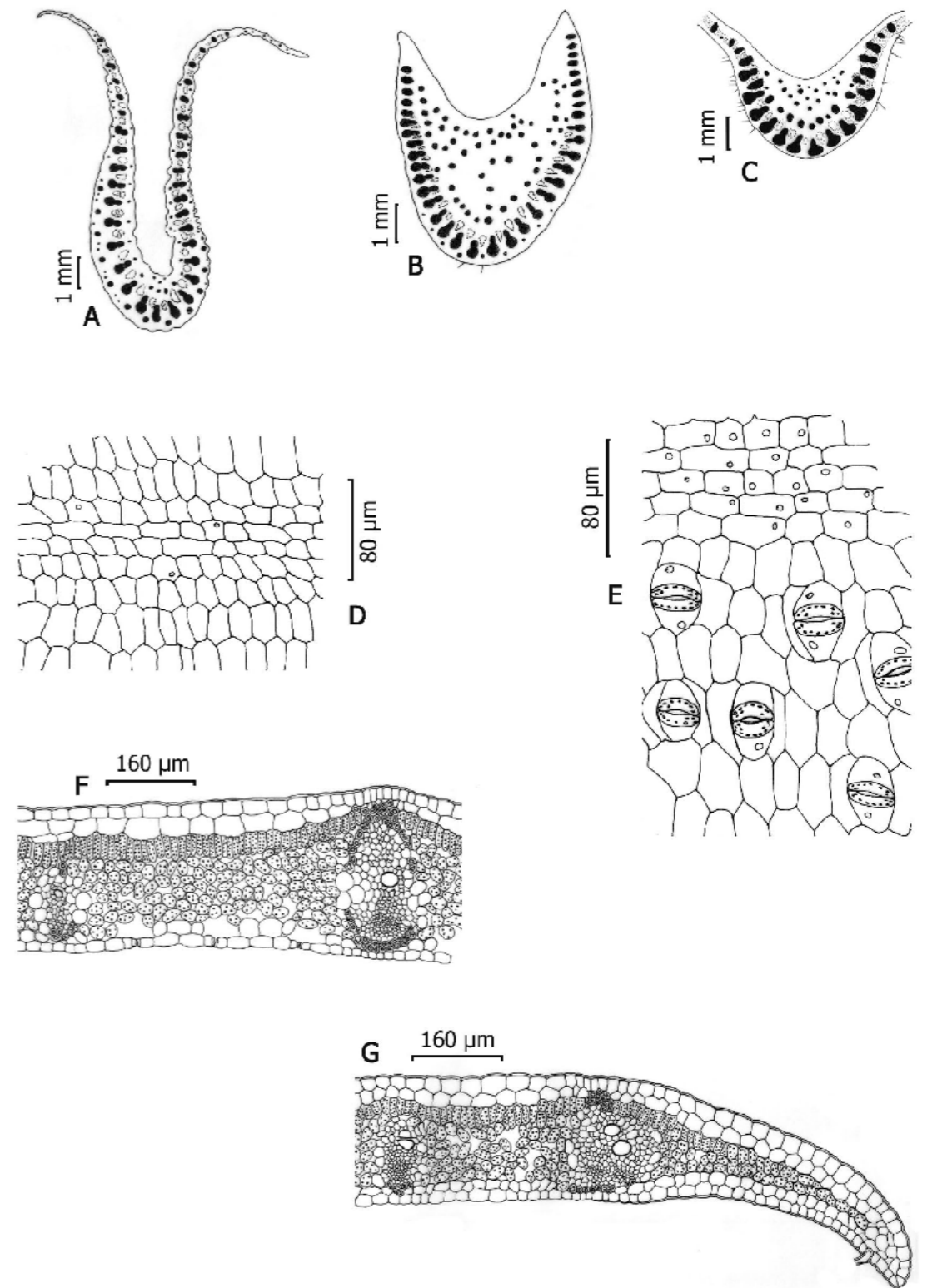


Fig. 04. *Alpinia fax* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

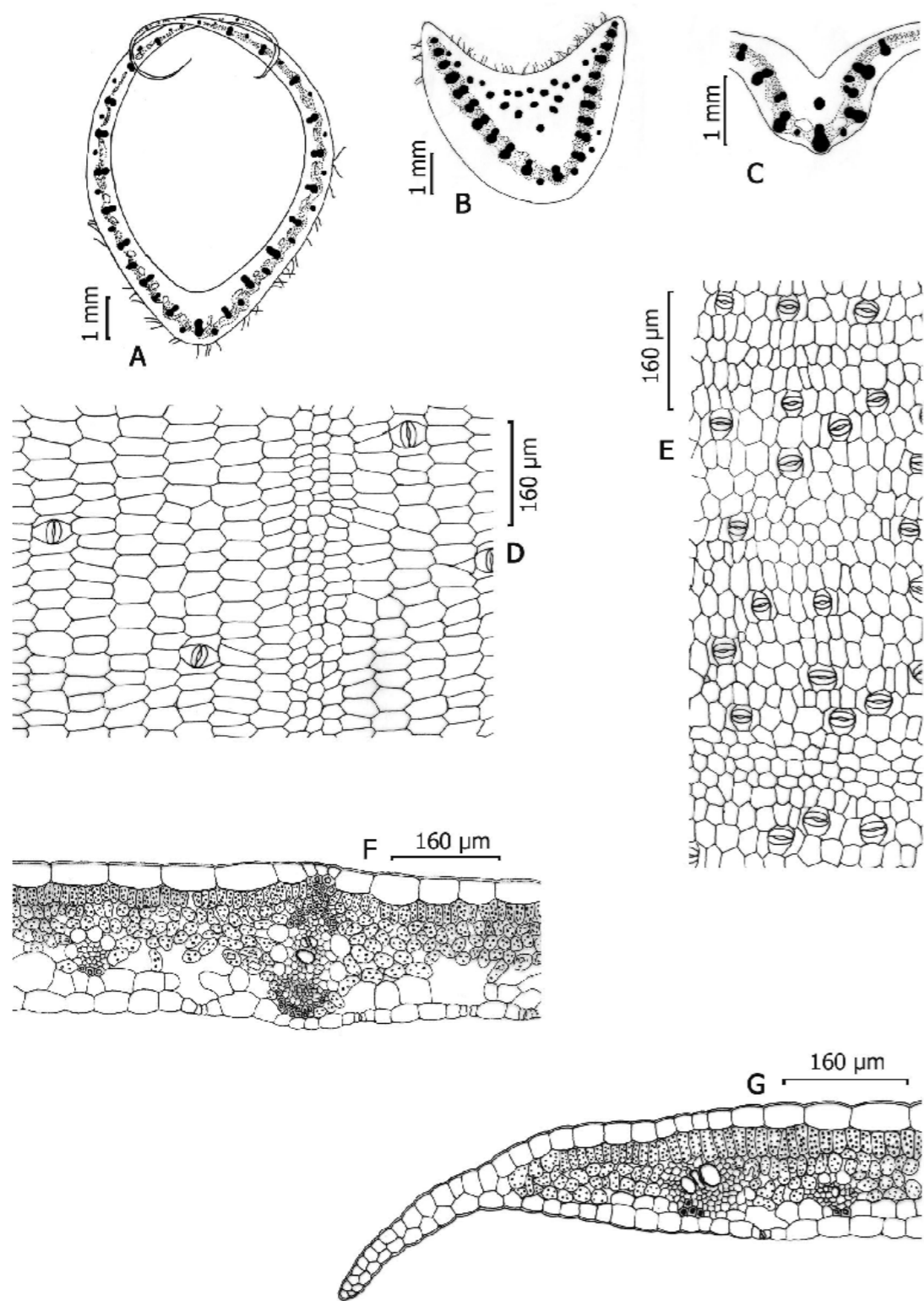


Fig. 71. *Zingiber zerumbet* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

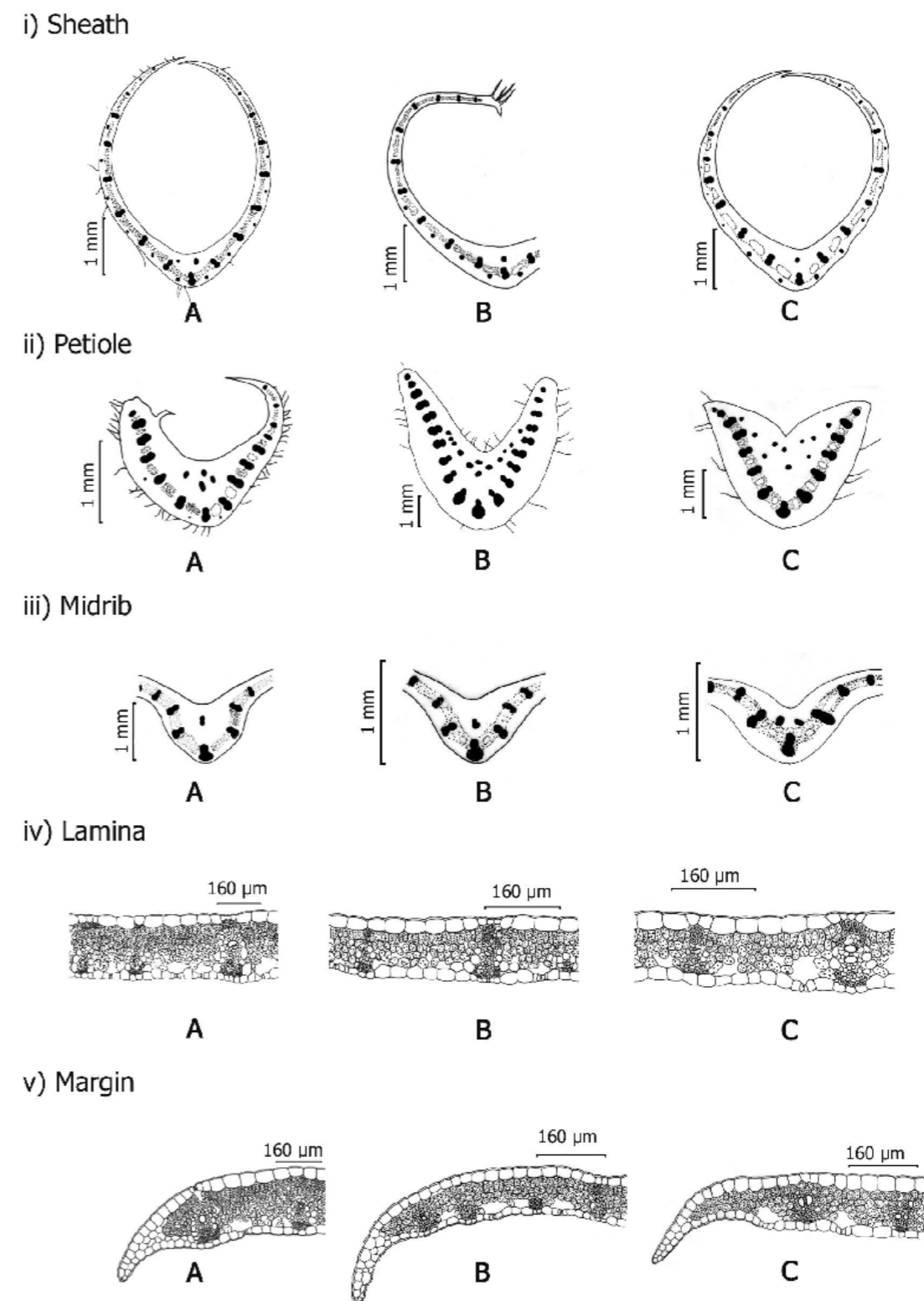


Fig. 72. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Zingiber* spp.I: A. *Z. capitatum* var. *elatum*; B. *Z. montanum*; C. *Z. neesanum*.

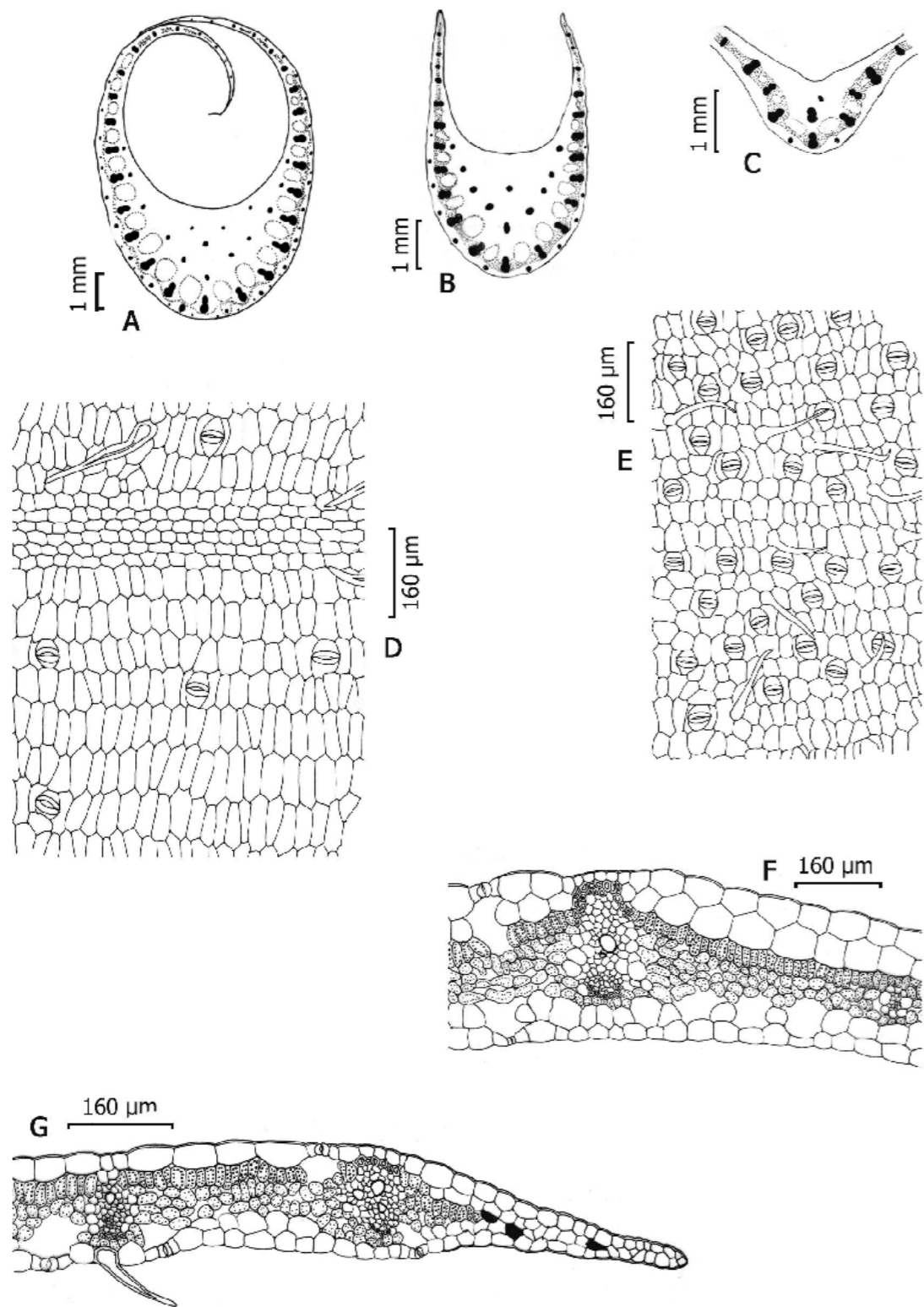


Fig. 37. *Curcuma haritha* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

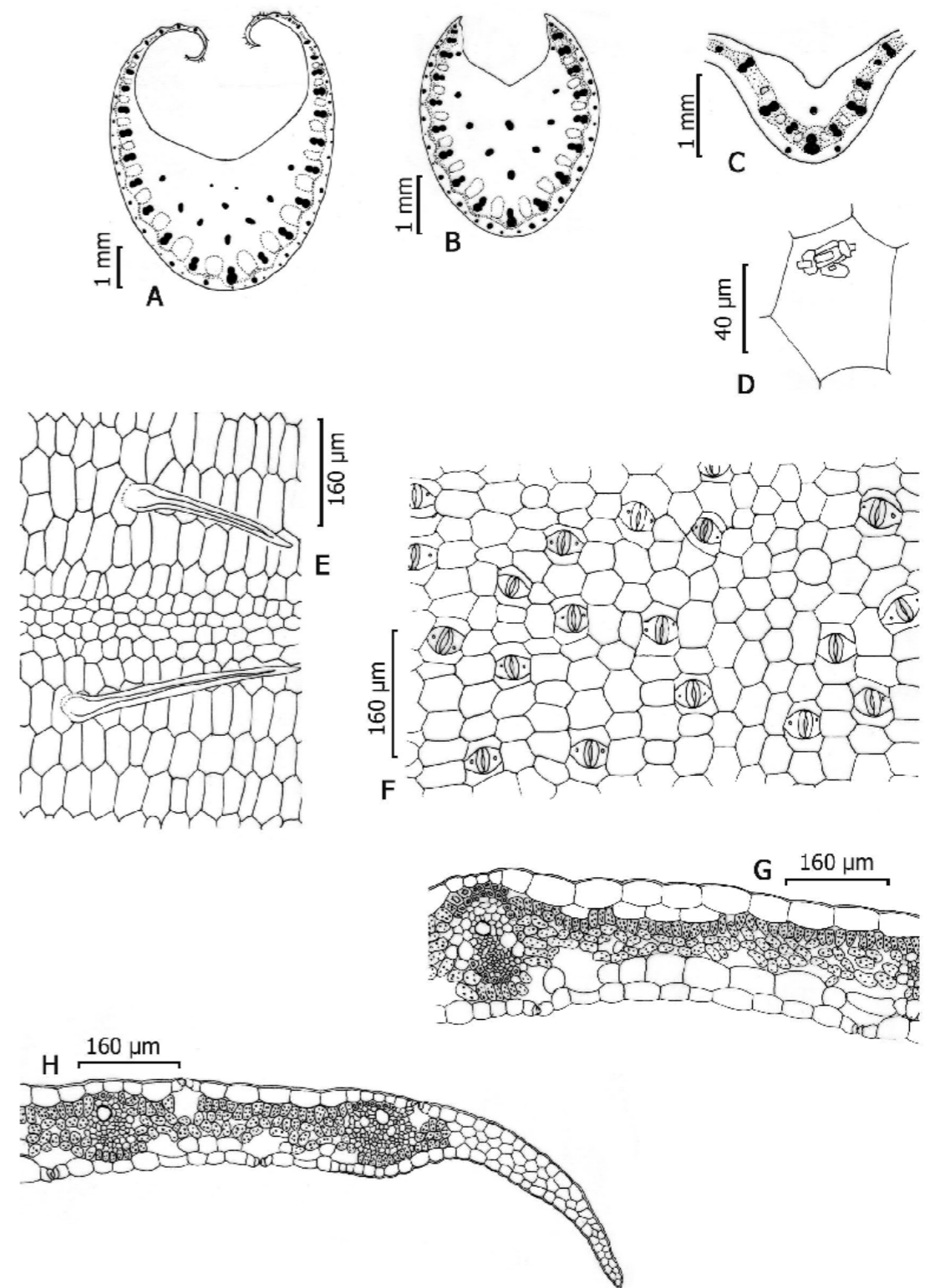


Fig. 38. *Curcuma inodora* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Crystals in the ground tissue of petiole; E. Adaxial epidermis; F. Abaxial epidermis; G. Lamina; H. Margin.

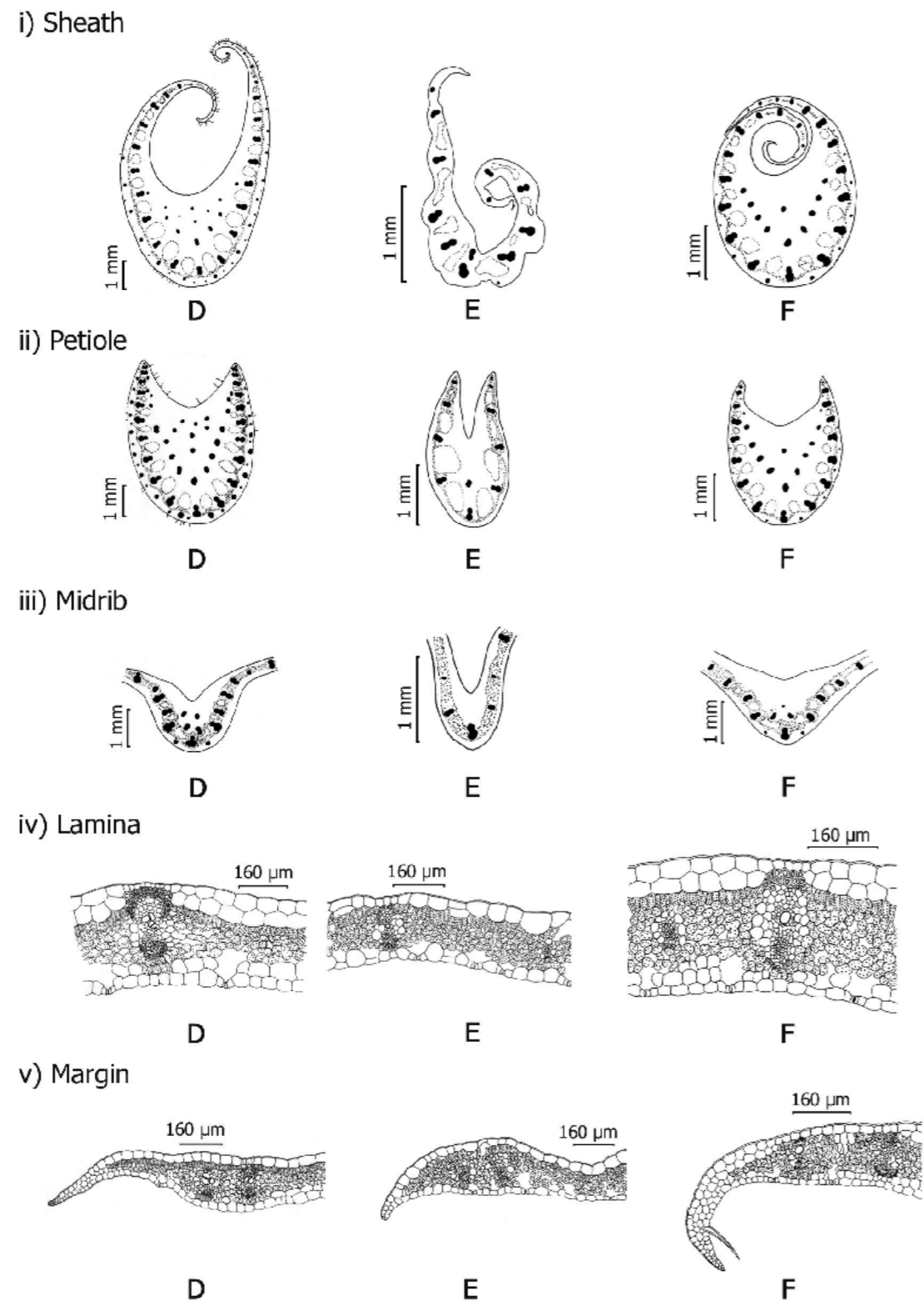


Fig. 51. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Curcuma* spp. II: D. *C. aurantiaca*; E. *C. bhatii*; F. *C. coriacea*.

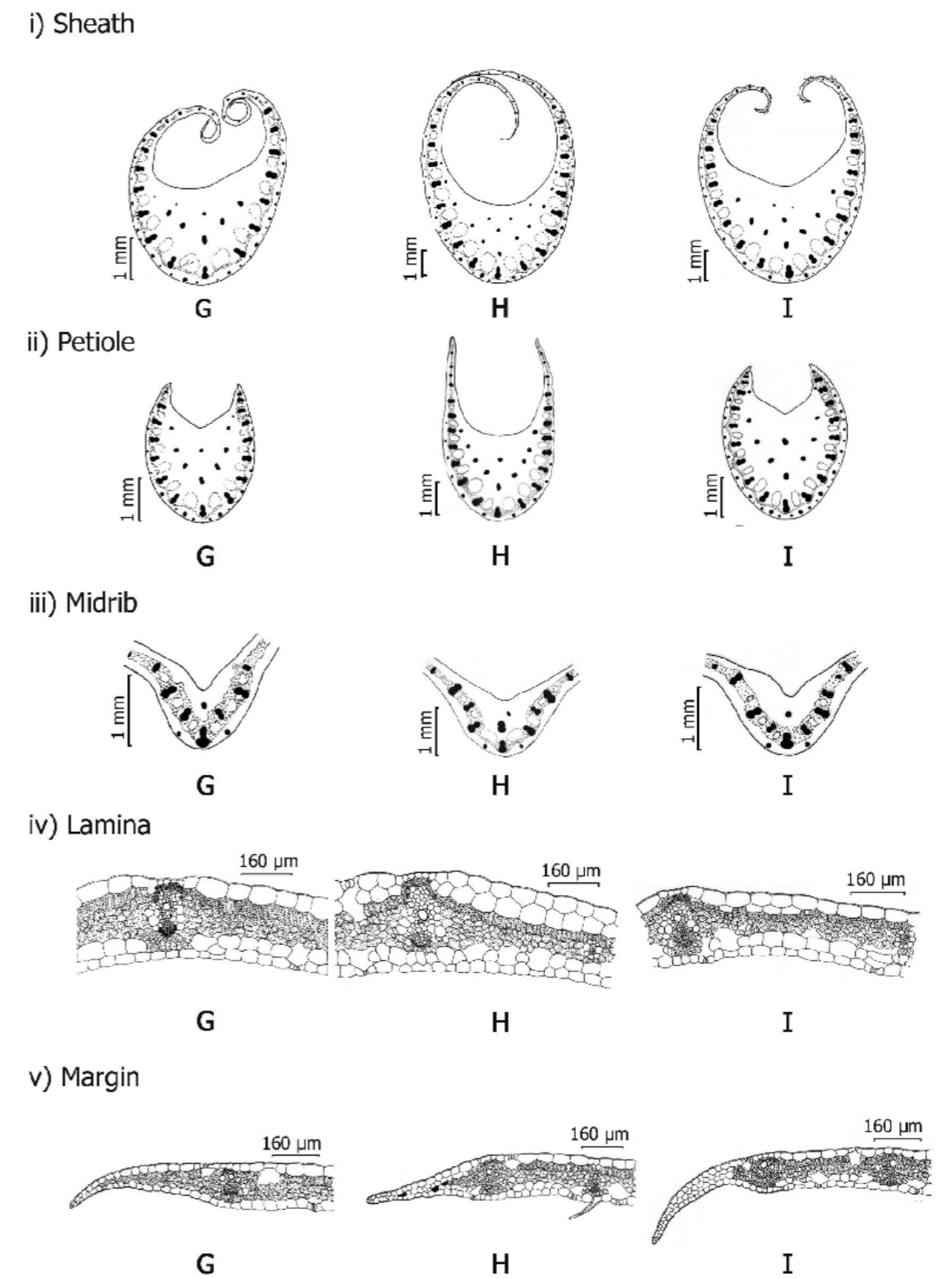


Fig. 52. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Curcuma* spp. III: G. *C. decipiens*; H. *C. haritha*; I. *C. inodora*.

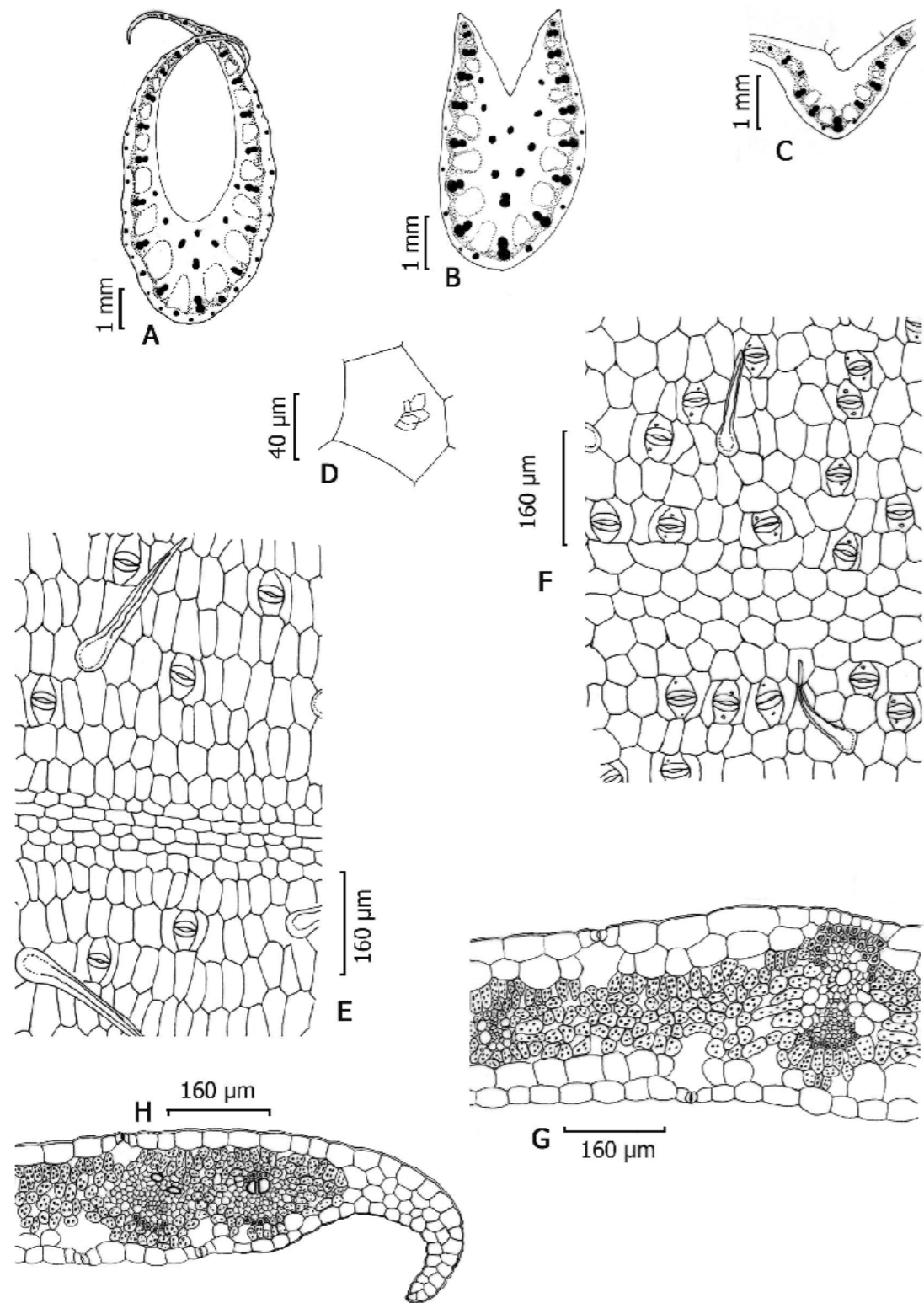


Fig. 43. *Curcuma neilgherrensis* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Crystals in the ground tissue of petiole; E. Adaxial epidermis; F. Abaxial epidermis; G. Lamina; H. Margin.

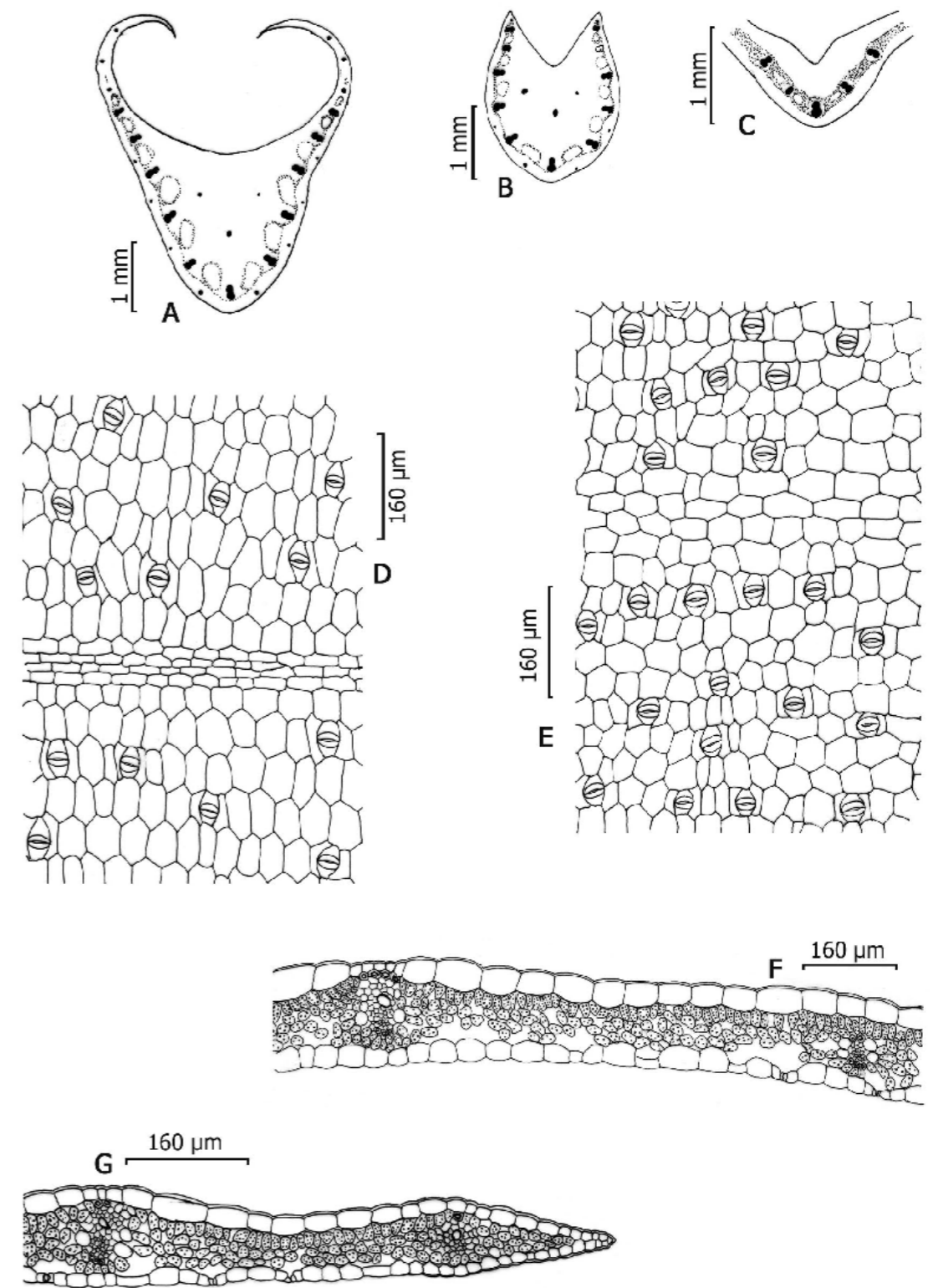
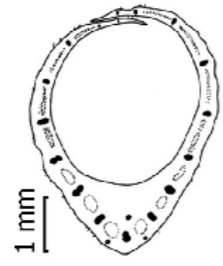
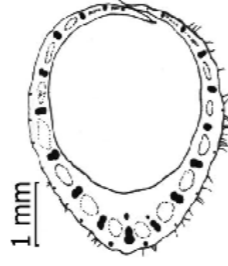


Fig. 44. *Curcuma oligantha* var. *oligantha* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Lamina; G. Margin.

i) Sheath

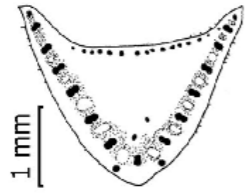


A

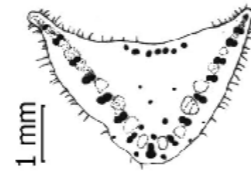


B

ii) Petiole

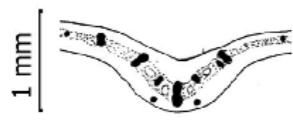


A

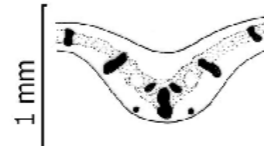


B

iii) Midrib

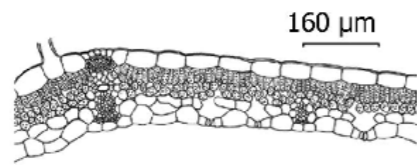


A

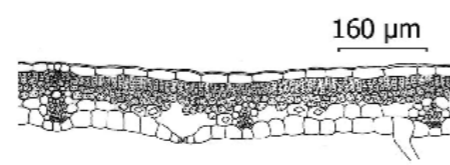


B

iv) Lamina

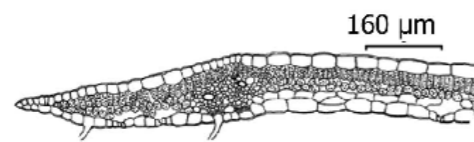


A



B

v) Margin



A



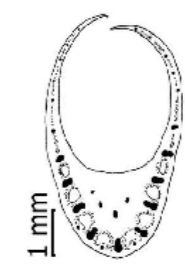
B

Fig. 25. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Globba* spp. I: A. *G. marantina*; B. *G. ophioglossa*.

i) Sheath

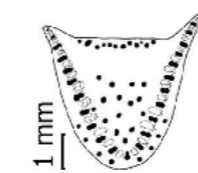


C

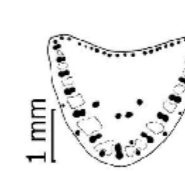


D

ii) Petiole

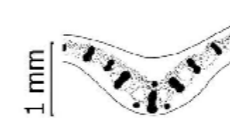


C



D

iii) Midrib

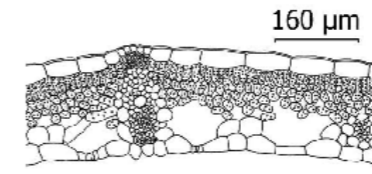


C

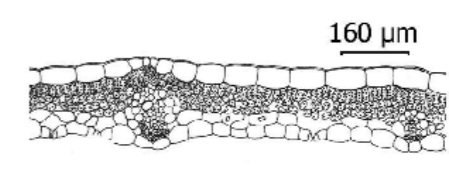


D

iv) Lamina



C

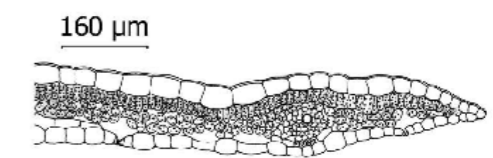


D

v) Margin



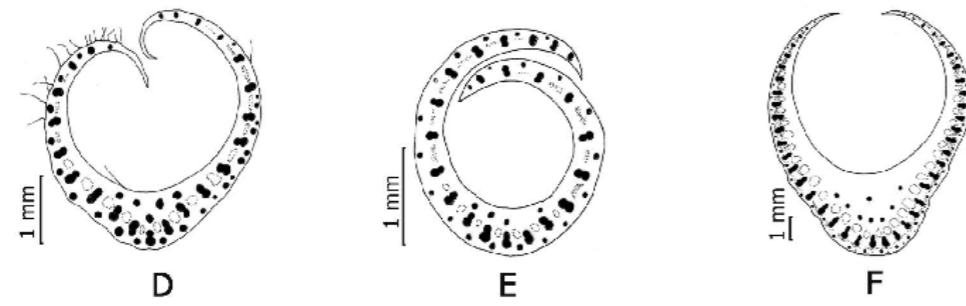
C



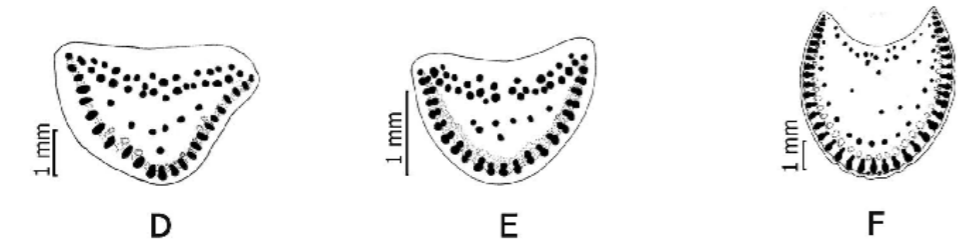
D

Fig. 26. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Globba* spp. II: C. *G. orixensis*; D. *G. schomburgkii*.

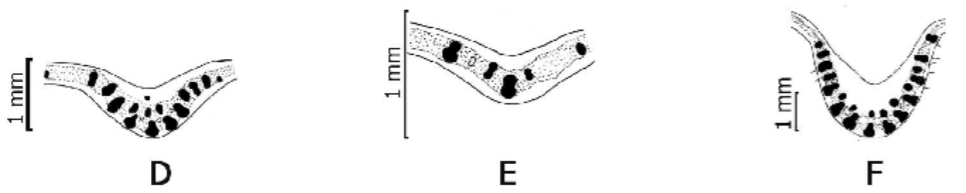
i) Sheath



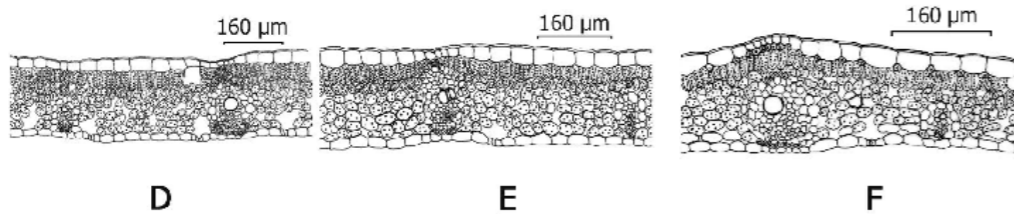
ii) Petiole



iii) Midrib



iv) Lamina



v) Margin

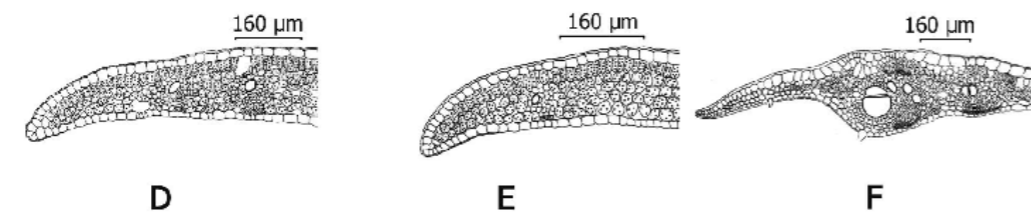


Fig. 19. Comparison of T. S. of sheath, petiole, midrib, lamina and margin of *Amomum* spp. II: D. *A. masticatorium*; E. *A. muricatum*; F. *A. pterocarpum*.

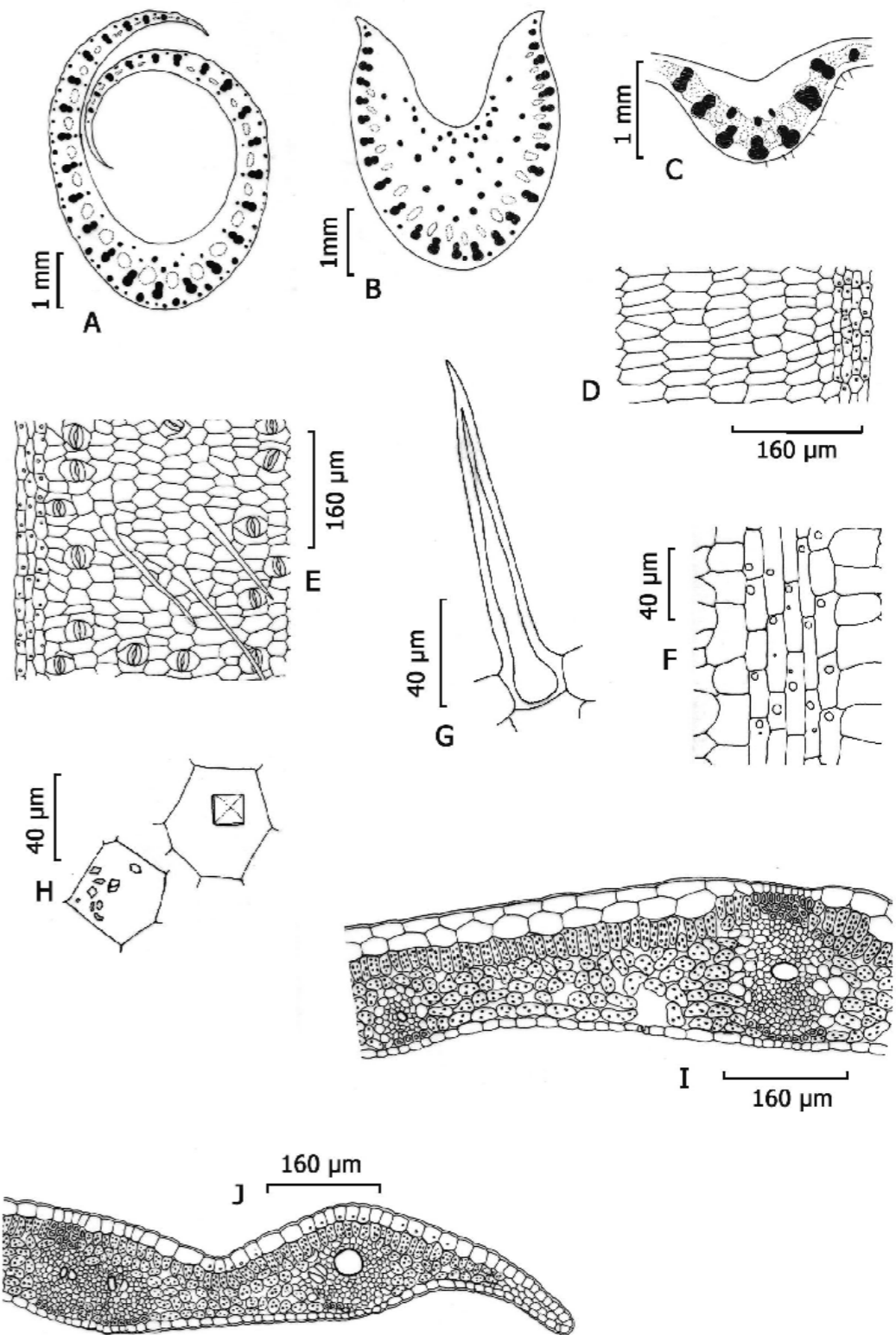


Fig. 20. *Elettaria cardamomum* - Transverse sections and epidermal peelings of aerial parts: A. Sheath; B. Petiole; C. Midrib; D. Adaxial epidermis; E. Abaxial epidermis; F. Costal cells with silica body; G. Hair on the abaxial leaf surface; H. Crystals in the ground tissue of sheath; I. Lamina; J. Margin.