Systematic studies on the genus *Zingiber* Mill. (Zingiberaceae) in North East India

Thesis submitted to the
University of Calicut in partial fulfillment of the requirement for
the degree of

DOCTOR OF PHILOSOPHY IN BOTANY

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CERTIFICATE

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This is to certify that the thesis entitled **"Systematic studies on the genus *Zingiber* Mill. (Zingiberaceae) in North East India"** submitted to the University of Calicut by **Mr. Jayakrishnan, T**., in partial fulfillment for the award of the degree of **Doctor of Philosophy** in Botany is a bonafide record of the research work carried out by him 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.

Calicut
26.04.2023

Dr. M. Sabu.

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CERTIFICATE

I certify that, no corrections were pointed out by the adjudicators in the thesis entitled **"Systematic studies on the genus *Zingiber* Mill. in North East India"** submitted by **Mr. Jayakrishnan T.,** hence a hard copy of the thesis with the original content along with soft copy is hereby submitted to the University of 3Calicut for the award of Ph.D. degree in Botany.

Calicut: **Dr. M. Sabu.**
Date:

DECLARATION

I, Jayakrishnan, T., hereby declare that the thesis entitled **“Systematic studies on the genus *Zingiber* Mill. (Zingiberaceae) in North East India”** submitted to the **University of Calicut** in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** in **Botany** is a bonafide record of the original research work carried out by me under the supervision and guidance of **Dr. M. Sabu**, (Retd.) Professor, Department of Botany, University of Calicut and that it has not been submitted earlier either in part or full for the award of any degree or diploma to any candidate of any University.

University of Calicut **Jayakrishnan, T.**

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CONTENTS

INTRODUCTION

The Zingiberaceae are one of the largest monocotyledonous families in the order Zingiberales with 53 genera and 1200 species all over the globe (Kress *et al.*, 2002). The family diversified in South East Asia and is distributed mainly in the tropics and subtropics with the center of distribution in the Indo-Malayan region but extending through tropical Africa to Central and South America (Kress *et al.*, 2002). Zingiberaceae are well known as they provide many economically useful products like food, spices, medicines, dyes, perfume etc. The recent classification of the family Zingiberaceae includes four subfamilies and four tribes viz., Siphonochiloideae (Siphonochileae), Tamijioideae (Tamijieae), Alpinioideae (Alpinieae & Riedelieae) and Zingiberoideae (Zingibereae & Globbeae). The new classification is based on phylogeny using DNA data of nuclear internal transcribed spacer (ITS) and plastid matK region (Kress *et al.*, 2002).

The recent classification of the family Zingiberaceae based on molecular phylogeny provides enough clarification to the generic relationship among the family but the interrelationship among the taxa in the lower rank was still poorly known.

The genus *Zingiber* Mill. forms the second largest and the type genus of the family Zingiberaceae represented by more than 150 species (Jayakrishnan *et al.*, 2021) and distributed mainly from South and South East Asia to China and eastward to Japan and northern Australia, with the center of diversity in monsoonal Asia (Larsen, 2005).

The name *Zingiber* was believed to be originated from the Tamil word "*ingiver*" which means ginger rhizome and it reached Greece and Rome via Arab traders (Ravindran & Babu, 2005). It was also believed that the Sanskrit word *Singibera* meaning Horn-root may be the possible word of origin which further give rise to the classical Greek word *Zingiberi* and finally evolved as the Latin name *Zingiber*.

Genus Zingiber in NE India

Members of the genus *Zingiber* are perennial herbs with subterranean tuberous rhizomes. The aerial shoot system developing from the rhizome forms the major vegetative part of the plant with alternately placed leaves having sheathing bases. The inflorescence is a spike that may develop directly from the rhizome or develop on the leafy shoot at the apex or through the leaf sheath. *Zingiber* is distinct from its related genera by a single anther with a beak or horn-like structure, which embraces the terminal portion of the style. The genus can be recognized in the vegetative stage by the presence of a pulvinus at the base of the petiole (Sabu, 2003).

The pioneer studies on the genus in India were carried out by Roxburgh (1810). A total of 11 species of *Zingiber* were observed by Roxburgh and he treated them under two sections based on the nature of their inflorescence. Section I is characterized by radical and section II by terminal spikes. Later, Baker (1892) recognized 24 species from British India and treated them under four infrageneric sections. The section *Crypatanthium* Horan. is characterized by a spike with a long procumbent peduncle; section *Zingiber* has a spike with an erect peduncle; section *Pleuranthesis* Benth. characterized by inflorescence emerging through the leaf sheath and section *Dymczewiczia* (Horan.) Benth. with terminal inflorescence. Schuman (1904) followed the same infrageneric classification in his monograph on Zingiberaceae. Fischer (1928) reported 7 species from the Western Ghats. Jha and Varma (1995) studied the genus in Bihar and Kumar (2001) reported 7 species from Sikkim. Sabu (2003) recorded 8 species from South India. Tripathi and Singh (2006) revised the genus in North East India and recorded the occurrence of 7 species. Vasantha (2009) carried out a systematic study on the genus *Zingiber* in South India and reported 9 species.

The northeastern part of India is one of the richest floristic regions of the country, known as the paradise of taxonomists. The South West and the North East monsoon greatly contribute to the dense vegetation of this particular area. The extensive fieldwork on the genus *Zingiber* in North East India were carried out by some botanists since 2006 (Tripathi & Singh, 2006; Thongam *et al.*, 2013; Sabu, *et* *al*., 2013; Kishor & Leong-Škorničková, 2013; Kumar *et al*., 2013, 2015; Thongam & Konsam, 2014), the presence of 16 *Zingiber* species have been confirmed in North East India before the commencement of the present study, among these 6 species were described as new to science and two species were reported as a new record to Indian flora. Thus, so far 16 taxa of *Zingiber* have been reported from North East India. However, this incredibly small number reflects the lack of exploration in the northeastern part of India for the last half-century. Therefore, we expect more taxa to be discovered from these extremely diverse habitats.

In the present study extensive fieldwork was carried out to revise the genus *Zingiber* in North East India and a detailed morphological investigation on each taxon was carried out. A key to all taxa of the genus in North East India is provided. Detailed description, distribution, ecology, IUCN status and notes of each taxon of *Zingiber* are given in the taxonomic treatment. Additionally, a detailed systematic study on the genus was carried out by studying anatomy, palynology, phytochemistry and molecular phylogeny to find out the interrelationships among the taxa.

Importance of the study

The genus *Zingiber* has great economic and medicinal potential. About 15 pharmacological properties were reported to ginger alone by various researchers. Very delicate and fleshy flowers with a short flowering period associated with rainy season, along with dense forest habitat make the collection and preservation of specimens difficult. The bulky and fleshy nature of spikes and rhizomes makes herbarium preparation and preservation more cumbersome. The herbarium does not help much for further studies because the nature of the peduncle, colour of bracts at different stages of inflorescence, life cycle and colour of labellum etc. are very important for taxonomic characterization, but these characteristics are less preserved in the herbarium (Sabu, 2006). High diversity, rich endemism and great economic potential make the study more fascinating. In this scenario, it is relevant to reveal the correct taxonomic identity of the taxa for characterization, utilization and conservation of the valuable natural resources.

The genus is less understood taxonomically and biologically as many taxa grow in dense forests during monsoon. Recent field explorations in North East India have proved that several new taxa are yet to be identified. This needs a thorough field exploration throughout India, especially in North East India.

Objectives

- Taxonomic revision of the genus *Zingiber* in North East India.
- Preparation of detailed taxonomic account of the genus in North East India with description, illustration, ecology, ethnobotanical notes, distribution and a dichotomous key for identification of taxa.
- Detailed study on anatomy, phytochemistry, palynology and molecular phylogeny of the taxa.
- Resolving nomenclature problems of all taxa under study including typification.
- Establishment of germplasm of all taxa in Calicut University Botanical Garden.
- Preparation of herbarium and pickled specimens of all Indian taxa for further studies.
- Identification of endemic, endangered and potential medicinal and ornamental taxa from North East India.

REVIEW OF LITERATURE

Taxonomy

Rheede published the first comprehensive work on the flora of the Malabar region (1678–1693). This is the foremost work that describes the natural wealth of Asia and the tropical region. The work *'Hortus Malabaricus'* was published in 12 volumes in Latin from Amsterdam with the assistance of local physicians of Kerala. The work described ten species of present-day Zingiberaceae, including two *Zingiber* species, *Zingiber officinale* as 'inschi' and *Zingiber zerumbet* as 'Katou-inschi Kua'. The book was later on translated to English (Manilal, 2003) and Malayalam (Manilal, 2008) with annotations.

Roxburgh, who is known as the father of Indian Botany, made an important contribution to Indian floristics. His book '*Plants of the Coast of Coramandel*' (1795–1820) contained 300 drawings and descriptions and included *Z. roseum* as *Amomum roseum* Roxb. The '*Flora Indica*' integrated a large portion of Roxburgh's (1820, 1824) work on Indian botany. Part of Roxburgh's Flora Indica manuscript, with additions by Wallich, was published posthumously under the title '*Flora Indica*' edited by William Carey. It includes *Z. capitatum* Roxb., *Z. cassumunar* Roxb., *Z. elatum*, *Z. ligulatum* Roxb., Z. *marginatum* Roxb., *Z. officinale* Roscoe, *Z. p*and*uratum* Roxb., *Z. roseum* Roscoe, *Z. rubens* Roxb., *Z. squarrosum* Roxb, *Z. squarrosum* Roxb. and *Z. zerumbet* (L.) Sm.

'*Icones Plantarum Indiae orientalis*', published by Wight (1838–1853), includes seven genera and fourteen species of Zingiberaceae which includes *Z. squarrosum* and *Z. zerumbet*. Graham (1839) studied 28 species of Zingiberaceae including 5 species of *Zingiber*, in his Catalogue of Plants Growing in Bombay. It contains *Z. cassumunar*, *Z. cernuum*, *Z. macrostachyum*, *Z. nimmonii* and *Z. zerumbet* subsequently Dalzell and Gibson (1861) published the Catalogue of plants indigenous to Western India in and near the Bombay Presidency, which listed 25 species of Zingiberaceae, including 5 species of *Zingiber* viz., *Z. cassumunar*, *Z. cernuum*, *Z. macrostachyum*, *Z. nimmonii* and *Z. zerumbet*.

Hooker's '*Flora of British India'* (1872-1897) is a historically accurate treatise on the flora of the Indian subcontinent. For the *'Flora of British India'*, Baker (1892) investigated Scitamineae. He classified 224 species of Zingiberaceae into 18 genera. The genus *Zingiber* includes *Z. barbatum*, *Z. capitatum Z. cassumunar*, *Z. cernuum*, *Z. chrysanthum*, *Z. clarkei*, *Z. cylindricum*, *Z. gracile*, *Z. griffithii*, *Z. intermedium*, *Z. ligulatum*, *Z. macrostachyum*, *Z. marginatum*. *Z. nimmonii, Z. officinale*, *Z. panduratum, Z. pardocheilum, Z. parishii*, f., *Z. roseum, Z. rubens, Z. spectabile, Z. squarrosum, Z. wightianum* and *Z. zerumbet*. Later Trimen (1898) explored the flora of Ceylon and published '*A Hand Book to the Flora of Ceylon*'. He studied 15 genera of Zingiberaceae including 32 species and the genus *Zingiber* with four species viz., *Z. cassumunar*, *Z. cylindricum*, *Z. wightianum* and *Z. zerumbet*.

Schumann (1904) recognized two subfamilies in family Zingiberaceae viz. Zingiberoideae and Costoideae. Zingiberoideae is again subdivided in to three tribes, Hedychieae, Globbeae and Zingibereae. The work includes 55 species of *Zingiber* viz., *Z. capitatum*, *Z. rufo-pilosum* Gagnepain, *Z. brevifolium* K.Schum., *Z. marginatum*, *Z. clarkei*, *Z. intermedium* Bak., *Z. officinale*, *Z. cholmondeleyi* (Bailey) K.Schum., *Z. zerumbet*, *Z. railletii* Durand, *Z. chrysostachys* Ridl., *Z. parishii* Hook., *Z. citrinum, Z. macradenium* K.Schum., *Z. inflexum* Blume, *Z. spectabile*, *Z. gramineum* Noronha, *Z. porphyrosphaera* K.Schum., *Z. stenostachys* K.Schum., *Z. gracile*, *Z. macrorrhynchum* K.Schum., *Z. puberulum, Z. griffithii*, *Z. coloratum* N.E. Brown., *Z. macrocephalum* (Zoll.) K.Schum., *Z. tongtak* K.Schum., *Z. cylindricum* Mood., *Z. odoriferum* Blume etc.

Cooke (1907) described 11 genera and 20 species of gingers in his *'Flora of the Presidency of Bombay'*, with five species belonging to the genus *Zingiber*, they are *Z. cassumunar*, *Z. cernuum*, *Z. macrostachyum*, *Z. nimmonii* and *Z. zerumbet*. Rama Rao (1914) listed 33 Zingiberaceae species from Kerala in his '*Flowering Plants of Travancore*'. This was merely a list of binomials, without any identification key or description provided. The work includes *Z. cassumunar*, Z. *macrostachyum*, *Z. nimmonii*, *Z. officinale* and *Z. wightianum*

In '*Plants of Punjab*', Bamber (1918) listed ten species belonging to five genera of Zingiberaceae, which include three *Zingiber* species viz., *Z. cassumunar*, *Z. officinale* and *Z. zerumbet*. In Gamble's *'Flora of Presidency of Madras'* (1916–1935), Fischer (1928) listed 34 species under 9 genera of Zingiberaceae, including 7 species of *Zingiber* viz. *Z. cassumunar*, *Z. macrostachyum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet*.

Ridley (1924) explored the *'Flora of the Malay Peninsula'* and identified 20 genera and 12 species, including *Z. aromaticum* Valeton, *Z. cassumunar*, *Z. chryseum* Ridl., *Z. chrysostachys* Ridl., *Z. citrinum* Ridl., *Z. gracile* Jack, *Z. griffithi* Baker, *Z. kunstleri* King, *Z. ottensii* Valeton, *Z. puberulum*, *Z. spectabile* Griff. and *Z. wrayi* Prain.

Major modifications to the subfamily Zingiberoideae were implemented by Holttum (1950). He rearranged Schumann's sub divisions of the subfamily Zingiberoideae by renaming it as Alpinieae. He separates the genus *Zingiber* from the tribe Zingibereae and places the genus *Zingiber* under the tribe Hedychieae. He divided the Zingiberaceae family into two subfamilies, Zingiberoideae and Costoideae and Zingiberoideae into four tribe's viz., Alpinieae, Hedychieae, Globbeae and Zingibereae.

Mitra (1958) examined the monocotyledons of Eastern India and observed 14 Zingiberaceae genera and 10 *Zingiber* species, including *Z. capitatum*, *Z. cassumunar*, *Z. chrysanthum*, *Z. clarkei*, *Z. elatum*, *Z. intermedium*, *Z. officinale*, *Z.* roseum, Z. *rubens* and *Z. zerumbet*. Duthie (1960) studied the *'Flora of the Upper Gangetic Plain and the Adjacent Siwalik and Sub-Himalayan Tracts'*. He identified and reported 11 species under seven Zingiberaceae genera including two *Zingiber* species, viz., *Z. capitatum* and *Z. officinal*e. Panchaksharappa (1962) investigated the two subfamilies of Zingiberaceae: Zingiberoideae and Costoideae and proposed that the two subfamilies are different and natural groups, with Costoideae being elevated to the level of a family.

Santapau (1967) in his *'Flora of Khandala'*, answered several nomenclatural problems surrounding Zingiberaceae and listed 6 species under 5 genera of Zingiberaceae, making his contribution significant. He reported two species of *Zingiber* viz., *Z. cernuum* and *Z. macrostachyum*. Backer and Bakhuizen (1968) recognized 53 species of Zingiberaceae under 14 genera in *'Flora of Java'* and the species include *Z. acuminatum*, *Z. inflexum*, *Z. odoriferum*, *Z. officinale*, *Z. ottensii*, *Z. purpureum* and *Z. zerumbet*.

Burtt (1972) proposed a new classification of the family Zingiberaceae and identified four tribes viz., Zingibereae, Globbeae, Hedychieae and Alpinieae. Burtt and Smith (1972a) provided a key to the subfamilies, tribes and genera of Zingiberaceae. Burtt and Smith (1972b) recorded the early history of Zingiberaceae classification through a historical examination of the important species involved in the typification of the main genera, sub genera and sections. Burtt and Olatunji (1972) proposed advanced grounds for confining the tribe Zingibereae to the genus *Zingiber* alone and morphological and anatomical features differentiating it from Hedychieae.

Rao and Verma (1972) surveyed the Zingiberaceae and Marantaceae of Assam and found 70 species under 16 genera, including seven *Zingiber* species viz., *Z. capitatum*, *Z. cassumunar*, *Z. chrysanthum*, *Z. intermedium*, *Z. officinale*, *Z. rubens* and *Z. zerumbet*. The study provides a short description and distribution of *Zingiber* sp. in Assam and a key to the species was also provided for identification. Holttum (1974) studied the family Zingiberaceae and provided a critical remark on the comparative morphology of Zingiberaceae in the Malay Peninsula and proposed that experimental studies could shed light on the structure of the family's condensed lateral cymes and inflorescence structure.

In the '*Flora of Hassan District*' Ramamoorthy (1976) found 13 species of Zingiberaceae under 9 genera with three species of *Zingiber* viz., *Z. cernuum*, *Z. montanum* and *Z. neesanum*. Srivastava (1976) identified four Zingiberaceae species under three genera with a single *Zingiber* species, *Zingiber officinale*, in '*Flora Gorakhpurensis*'. Burtt (1977) went over the nomenclature of turmeric and other

Ceylon Zingiberaceae in great depth. Burtt and Smith (1976) proposed some ways for collecting and preserving Zingiberaceae plants.

From Bhopal, Oomachan (1977) identified five species belonging to three Zingiberaceae genera, with a single *Zingiber* species (*Z. officinale*). Moo (1978) recognized 23 species under six Zingiberaceae genera and four *Zingiber* species, namely *Z. kawagoii*, *Z. koshunensis*, *Z. officinale* and *Z. zerumbet* in his '*Flora of Taiwan*'. In their interpretation of van Rheed's Hortus Malabaricus, Nicolson *et al*. (1988) have given scientific names for Katou-Inschi-Kua as *Z. zerumbet* and Inschi as *Z. officinale.* In the *'Flora of Calicut'*, Manilal and Sivarajan (1982) listed seven species belonging to four Zingiberaceae genera and three *Zingiber* species, including *Z. officinale*, *Z. wightianum* and *Z. zerumbet*. Manilal and Sivarajan confirmed the specimen treated as *Z. wightianum* is actually *Z. cernuum.*

Ghazanfar and Smith (1982) explored the '*Flora of Pakistan*' and identified five species belonging to three Zingiberaceae genera, including *Z. officinale*. Joseph (1982) reported 15 Zingiberaceae species and four *Zingiber* species in his '*Flora of Nongpoh and Vicinity*', East Khasi Hills District, Meghalaya, which includes, *Z. chrysanthum*, *Z. capitatum*, *Z. zerumbet* and *Z. cassumunar.* Subsequently, Deb in his '*Flora of Tripura*' in 1983 and recognized 24 taxa under nine Zingiberaceae genera with three *Zingiber* species viz., *Z. officinale*, *Z. rubens* and *Z. zerumbet*. Subsequently, Balakrishnan (1983) studied the '*Flora of Jowai and surroundings, Meghalaya*' and reported 28 species of Zingiberaceae under 13 genera and reported three *Zingiber* species, *Z. capitatum*, *Z. purpureum* and *Z. rubens*.

In the '*Revised Hand Book to the Flora of Ceylon*', of Dassanayake and Fosberg , Burtt and Smith (1983) listed 38 species under 15 genera of Zingiberaceae including 5 species of *Zingiber*, viz., *Z. cylindricum*, *Z. officinale*, *Z. purpureum*, *Z. wightianum* and *Z. zerumbet*. Sharma *et al*. (1984) classified 29 taxa into ten Zingiberaceae genera from Karnataka; it includes *Z. capitatum*, *Z. cernuum*, *Z. cylindricum*, *Z. montanum*, *Z. neesanum*, *Z. officinale*, *Z. wightianum* and *Z. zerumbet*. In the '*Flora of Himachal Pradesh*', Chowdhery and Wadhwa (1984) listed 12 species under seven Zingiberaceae genera, including *Z. zerumbet*. Nayar *et* *al.* (1986) reported five taxa under five genera of Zingiberaceae, including *Z. zerumbet*, in '*Flora of Tropical Botanical Garden, Palode*'.

Borneo's *Zingiber* genus was reviewed by Smith (1988) and he recognized 18 species, including *Z. acuminatum* var. *borneense* Val., *Z. albiflorum*, *Z. coloratum*, Z. *griffithii*, *Z. incomptum*, *Z. leptostachyum*, *Z. longipedunculatum*, *Z. martini*, *Z. odoriferum*, *Z. officinale*, *Z. pachysiphon*, *Z. pseudopungens*, *Z. puberatum* var. *borneense*, *Z. purpureum* and *Z. zerumbet*.

Rao (1986) reported six Zingiberaceae genera and three *Zingiber* species in '*Flora of Goa, Diu, Daman, Dadra and Nagar Haveli'*, including *Z. cassumunar*, *Z. macrostachyum* and *Z. zerumbet*. In the' '*Flora of West Godavari District Andhra Pradesh'*, Rao *et al*. (1980) identified eight taxa belonging to five Zingiberaceae genera and two *Zingiber* species, *Z. montanum* and *Z. roseum*. Subramanian *et al*. (1987) reported seven species of Zingiberaceae belonging to six genera, with one *Zingiber* species, *Z. roseum* in the *'Flora of Palghat'*.

Karthikeyan *et al.* (1989) in *'Flora Indicae Enumeratio Monocotyledonae'*, enumerated 21 species of *Zingiber*, viz., *Z. capitatum*, *Z. cernuum*, *Z. chrysanthum*, *Z. clarkei*, *Z. elatum*, *Z. capitatum* var. *elatum*, *Z. intermedium*, *Z. ligulatum*, *Z. marginatum*, *Z. neesanum*, *Z. macrostachyum*, *Z. nimmonii*, *Z. officinale*, *Z. purpureum*, *Z. roseum*, *Z. rubens*, *Z. spectabile*, *Z. squarrosum*, *Z. wightianum* and *Z. zerumbet*. Vajravelu (1990) found 13 Zingiberaceae species under 9 genera in the '*Flora of Palghat District'*, with *Z. montanum* and *Z. roseum* under the genus *Zingiber*.

Srivastava and Rao (1994) reported *Z. odoriferum*, from the Andaman Islands as a new record for India. Mohanan and Henry (1994) in the *'Flora of Thiruvananthapuram'* listed eight Zingiberaceae species under six genera, as well as two *Zingiber* species, *Z. zerumbet* and *Z. neesanum*. Later Saxena and Brahmam (1995) reported 24 taxa under 7 genera and 5 species of *Zingiber* viz., *Z. capitatum*, *Z. officinale*, *Z. purpureum*, *Z. rubens* and *Z. zerumbet* from Orissa.

Jain and Prakash (1995) worked on the phytogeography and endemism of Zingiberaceae in India. They studied 130 species under 22 genera and identified 88 species endemic to India. The study listed 19 species of *Zingiber* viz., *Z. capitatum*, *Z. cernuum*, *Z. chrysanthum*, *Z. clarkei*, *Z. elatum*, *Z. intermedium*, *Z. ligulatum*, *Z. marginatum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. purpureum*, *Z. cassumunar*, *Z. roseum*, *Z. rubens*, *Z. spectabile*, *Z. squarrosum*, *Z. wightianum* and *Z. zerumbet*, in which *Z. cernuum*, *Z. ligulatum*, *Z. neesanum* and *Z. nimmonii* are found endemic to peninsular India and *Z. clarkei* endemic to eastern Himalaya. *Z. intermedium* and *Z. rubens* are distributed only in Northeastern India, others in tropical Himalaya, North eastern region, South India and Andaman and Nicobar Islands. *Z. intermedium* has given an endangered status and *Z. officinale* is widely cultivated. It discusses the phytogeographical distribution of all Indian Zingiberacean species as well as their endemism status.

Mudgal and Khanna (1995) studied the *'Flora of Madhya Pradesh'* and reported five *Zingiber* species viz., *Z. capitatum*, *Z. officinale*, *Z. purpureum*, *Z. roseum* and *Z. rubens*. Theilade (1996) revised the genus *Zingiber* in Peninsular Malaysia and reported 19 species. Out of the 19 species, seventeen of them belong to section *Zingiber* while two belong to Sect. *Cryptanthium*. The study also described a new species of *Zingiber*, *Z. fraseri* Theilade and a new variety, *Z. officinale* var. *rubrum*. Based on the rediscovery of the specimens of Koenig from Phuket a new combination was proposed for *Z. montanum*.

In their *'Flora of China'*, Delin and Larsen (1996) recognised 20 Zingiberaceae genera and 42 *Zingiber* species.

Samvatsar (1990) listed four taxa under three genera of Zingiberaceae in his book the *'Flora of Western Tribal Madhya Pradesh, Jodhpur'* and included Z. *cernuum*. Sabu and Mangaly (1996) published a revision of the Zingiberaceae of South India, which included 11 genera and 55 species. It consists of the following *Zingiber* species, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet*. Sabu (2003) published a book on Zingiberaceae and Costaceae of South India, which included descriptions of *Z. capitatum* var. *elatum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, *Z. officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet*.

Theilade and Mood (1997b) have reported two new species of *Zingiber* from Borneo viz., *Z. eborinum* Mood & Theilade and *Z. flammeum*. Later Theilade and J. Mood (1997a) discovered 5 new species from Borneo viz., *Z. argenteum*, *Z. lambii*, *Z. latifolium*, *Z. pendulum*, *Z. vinosum*. Subsequently Theilade (1999) studied and reported 26 species of *Zingiber* from Thailand. They include *Z. affintegrum*. *Z. barbatum*, *Z. bradleyanum*, *Z. chrysostachys*, *Z. corallinum*, *Z. flavovirens*, *Z. gramineum*, *Z. junceum*, *Z. kerrii*, *Z. larsenii*, *Z. longibracteatum*, *Z. montanum*, *Z. newmanii*, Z. *officinale*, *Z. ottensii*, *Z. parishii*, *Z. pellitum*, *Z. peninsulare*, *Z. petiolatum*, *Z. puberulum* Ridl. var. *ovoideum*, *Z. rubens*, *Z. smilesianum*, *Z. spectabile*, *Z. villosum*, *Z. wrayii* and *Z. zerumbet*.

Theilade and Mood (1999a) also reported 6 new species of *Zingiber* from Borneo viz., *Z. chlorobracteatum*, *Z. flagelliforme*, *Z. georgei*, *Z. phillippsii*, *Z. velutinum*, *Z. viridiflavum*. Theilade and Mood (1999b) identified a new species of *Zingiber*, *Z. collinsii*. Srivastava (1998) investigated the Zingiberaceae in the Andaman and Nicobar Islands, finding 23 taxa in 10 genera and 5 species of *Zingiber*, including *Z. odoriferum*, *Z. officinale*, *Z. spectabile*, *Z. squarrosum* and *Z. zerumbet.* Subsequently Hajra *et al.* (1999) studied the *'Flora of Great Nicobar Island'* and reported three taxa under three Zingiberaceae genera, with Z. *zerumbet* as a single species under *Zingiber*. Delin *et al.* (2000) reported a new species of *Zingiber*, *Z. neotruncatum* from China.

Kumar (2001) studied the family Zingiberaceae of Sikkim and reported 53 taxa under 13 genera of Zingiberaceae. It includes *Z. capitatum*, *Z. clarkei*, *Z. chrysanthum*, *Z. rubens*, *Z. officinale*, *Z. zerumbet* and *Z. purpureum*. Mohanan and Sivadasan (2002) identified 12 taxa under seven Zingiberaceae genera and three *Zingiber* species, *Z. neesanum*, *Z. wightianum* and *Z. zerumbet*, in the *'Flora of Agasthyamala'*. Based on evidence from molecular data, Kress *et al.* (2002) proposed a new infra-familial classification of the Zingiberaceae family. They described 4 subfamilies: Siphonochiloideae, Tamijioideae, Alpinioideae and *Zingiber*oideae, with the genus *Zingiber* being under the latter.

Behura and Rout (2003) studied the diversity of Zingiberaceae plants in Orissa and which includes *Z. capitatum*, *Z. cassumunar*, *Z. officinale*, *Z. rubens* and *Z. zerumbet*. Tripathi and Singh (2006) revised the genus *Zingiber* in Northern India and reported *Z. capitatum*, *Z. chrysanthum*, *Z. intermedium*, *Z. montanum Z. officinale*, *Z. rubens* and *Z. zerumbet* and but the study failed to find out the occurrence and distribution of *Z. clarkei*, *Z. ligulatum* and *Z. marginatum*.

Vasantha, (2009) revised the genus *Zingiber* in South India and reported *Z. capitaum* var. *elatum*, *Z. cernuum*, *Z. montanum*, *Z. neesanum*, *Z. nimmonii*, Z. *officinale*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet.* Sabu *et al.* (2009) reported *Z. parishii* from Andaman and Nicobar Islands as a new distributional record to India. Later Sabu *et al*. (2013), reported *Z. neotruncatum* from Arunachal Pradesh as a new distributional record for India.

Sujanapal and Sasidharan (2010) described *Z. anamalayanam* from Kerala. Kumar *et al.* (2013) described a new species of *Zingiber* from Meghalaya viz., *Z. meghalayense* later Kumar *et al.* (2015) described two new *Zingiber* species from Mizoram viz., *Z. mizoramensis* and *Z. murlenica*. Kishor and Leong-Škorničková (2013) discovered a new species of *Zingiber* namely *Z. kangleipakense* from the State of Manipur. Thongam *et al.* (2013) reported *Z. kerrii* from Manipur as a new distributional record to India later, Thongam and Konsam (2014) identified a new species of *Zingiber*, *Z. pherimaense* from the Pherima village of Nagaland. Leong-Škorničková *et al.* (2014) described *Z. jiewhoei* from Laos. Das, Kumar and Dutta, (2015) discovered a new species of *Zingiber* namely *Z. bipinianum* from Arunachal Pradesh. Mibang and Das (2016) described a new species, *Z. siaginensis* from Siang Valley of Arunachal Pradesh. Prabukumar *et al.* (2016) discovered a new species of *Zingiber* from Kerala viz., *Z. sabuanum*. Singh and Singh (2016) described *Z. pseudosquarrosum* from Andaman and Nicobar Islands. Joe *et al.* (2017) described a new species, *Z. arunachalensis* from Arunachal Pradesh of Northeastern India.

Aung *et al.* (2015) reported the occurrence of *Z. orbiculatum* and *Z. flavomaculosum* in Myanmar. These represent the first records of these species for the *'Flora of Myanmar'*. Bai *et al.* (2015) studied the identity of *Z. menghaiense* and *Z. stipitatum* and treated them as a synonym of *Z. kerrii*. Later Bai *et al.* (2015) discovered a new species, *Z. tenuifolium* from Yunnan, China. Subsequently, *Z. ventricosum* was described by Bai *et al.* (2016) from Yunnan, China. Leong-Skornickova *et al.* (2015) described nine new *Zingiber* species from Vietnam among this Z. *lecongkietii* belongs to Sect. *Cryptanthium*. *Z. atroporphyreus*, *Z. cardiocheilum*, *Z. castaneum*, *Z. mellis* and *Z. plicatum*, are terminally flowering species belonging to the Sect. Dymczewiczia and, *Z. discolor*, *Z. microcheilum* and *Z. yersinii*, belong to sect. *Zingiber*. Lý *et al.* (2016) discovered a new species of *Zingiber*, *Z. skornickovae* from central Vietnam. Tanaka and Aung (2017) described a new species *Z. flavofusiforme* from Myanmar. The new taxon is characterized by terminal inflorescence. Recently, Odyuo and Roy (2019) reported this species from Assam which forms a new distributional record to Indian flora. Ardiyani *et al.* (2017) discovered a new species of *Zingiber*, *Z. ultrilimitale* from Indonesia.

Thongam and Konsam, (2018) discovered a new species, *Z. caudatum* characterized by long caudate bracts from Arunachal Pradesh. Odyuo *et al.* (2019) described a new species of *Zingiber*, *Z. dimapurense* from Dimapur district of Nagaland. Later Odyuo *et al.* (2019) described *Z. perenense* from Nagaland. Bai *et al.* (2018 & 2020) described two new species of *Zingiber* viz., *Z. pauciflorum* and *Z. leucochilum* from China. Souvannakhoummane and Leong-Škorničková (2018) reported eight *Zingiber* species from Laos, viz., *Z. densissimum*, *Z. kerrii*, *Z. ligulatum*, *Z. nudicarpum*, *Z. orbiculatum*, *Z. parishii* subsp. *phuphanense*, *Z. recurvatum* and *Z. smilesianum*. Lê *et al.* (2019) described a new species of *Zingiber*, *Z. vuquangense* from Central Vietnam.

Aung and Tanaka (2019) studied the taxonomy of genus *Zingiber* in Myanmar and reported seven taxa as a new distributional record to the *'Flora of Myanmar'* viz., *Zingiber bradleyanum*, *Z. chrysanthum*, *Z. densissimum*, *Z. mekongense*, *Z. ottensii*, *Z. parishii* subsp. *phuphanense*, *Z. tenuiscapus*. Docot *et al.*

(2019) described two new *Zingiber* species from Sorsogan, Philippiines viz., *Z. aguingayae* and *Z. subroseum*.

Bai *et al*. (2019) studied the identity, taxonomy and nomenclatural history of *Z. montanum*, *Z. purpureum* and *Z. cassumunar*. They proposed that the correct name for Cassumunar ginger is *Z. purpureum* and *Z. montanum* is a different species. They have reduced *Z. newmanii*, *Z. nudicarpum* and *Z. peninsulare* as synonym of *Z. montanum* and *Z. cassumunar*, *Z. cassumunar* var. *subglabrum*, *Z. cliffordiae*, *Z. paucipunctatum* and *Z. pubisquamum* were treated as synonyms of *Z. purpureum*. They have also designated Neotypes for *Amomum montanum* and *Z. purpureum* and lectotypified the species such as *Z. cassumunar*, *Z. cassumunar* var. *subglabrum*, *Z. cliffordiae*, *Z. peninsulare* and *Z. pubisquamum*.

Singh and Srivastava (2020) published checklist of flowering plants of India which reports 33 *Zingiber* species viz., *Z. anamalayanum*, *Z. arunachalensis*, *Z. bipinianum*, *Z. capitatum*, *Z. cernuum*, *Z. chrysanthum*, *Z. clarkei*, *Z. diwakarianum*, *Z. elatum*, *Z. intermedium*, *Z. kangleipakense*, *Z. kerrii*, *Z. ligulatum*, *Z. marginatum*, *Z. meghalayense*, *Z. mizoramensis*, *Z. montanum*, *Z. murlenica*, *Z. neesanum*, *Z. neotruncatum*, *Z. nimmonii*, *Z. odoriferum*, *Z. officinale*, *Z. pherimaense*, *Z. parishii*, *Z. pseudosquarrosum*, *Z. roseum*, *Z. rubens*, *Z. sabuanum*, *Z. sianginensis*, *Z. squarrosum*, *Z. spectabile*, *Z. whightianum* and *Z. zerumbet*.

Based on a detailed morphological characterization, Thachat *et al.* (2020) treated *Z. sianginensis* as a synonym of *Z. officinale*. Ding *et al.* (2020) described *Z. porphyrochilum* from Yunnan, China. Huong *et al.* (2020) reported *Z. porphyrochilum* from Yunnan, China. Huong *et al.* (2020) reported *Z. mekongense* as a new distributional record in the *'Flora of Vietnam'* Ly *et al.* (2021) described two new species, *Z. magang* and *Z. tamii* from central Vietnam. Patil *et al.* (2021) reinvestigated the exact identity of *Z. neesanum*. The name was previously applied to two plants, one with white flowers and the other with yellow flowers and recently the yellow-flowered plants were named *Z. divakarianum*. The study recollected the plants from the type localities which proved that the yellow-flowered species is the true *Z. neesanum*, making *Z. diwakarianum* a synonym and that the existing name *Z. anamalayanum* has applied to the white-flowered species.

Jayakrishnan *et al.* (2021) described two new species of *Zingiber* from Arunachal Pradesh viz., *Z. camapanulatum* and *Z. cornigerum*. Subsequently, Hnialum *et al.* (2021) discovered a new variety of *Z. neotruncatum*, *Z. neotruncatum* var. *ramsawmii* from Mizoram. Recently Moaakum *et al.* (2022) reported the occurrence of *Z. callianthum* and *Z. mekongense* from Nagaland as a new distributional record to Indian flora.

Anatomy

Studies in the systematic anatomy of 41 species of Zingiberaceae by Tomilnson (1956), described the vegetative anatomy of the Zingiberaceae, with reference to the taxonomy of the family. The anatomy of this family deals largely with the differences between the subfamilies *Costoideae* and *Zingiberoideae* and where the differences are large, the structure of these two groups are described separately. These two subfamilies, differ markedly in the anatomy of the lamina, petiole and sheath, the structure of the node in the aerial stem and the structure of hairs and the type and distribution of silica inclusion. Oil cells are found only in *Zingiberoideae*. Anatomical evidence for the separation of the two subfamilies is supported by evidence from vegetative and floral morphology, etc. Tribes within *Zingiberoideae* can be distinguished only in the plane of insertion of the leaves and type of silica cell. Tomlinson (1961) studied the morphology of Marantaceae and suggested that *Calatheae* and *Maranteae* cannot be resolved solely based on morphological data and some genera share similar diagnostic characteristics. Tomlinson (1962) pointed out that the anatomical data of the order Scitamineae can be used as a tool for further classification of the order and give a clearer picture of the phylogeny of the order

Metcalfe (1959) suggested that anatomical characteristics like the type of stomata, silica bodies, sclerenchyma pattern and leaf epidermis can be used for the identification purpose at the species level instead of using as indicators of broad taxonomic affinities.

Dunn *et al.* (1965) investigated stomatal patterns in dicotyledons and monocotyledons across 443 species, 152 genera and 96 families and discovered that the size of stomata in monocotyledons was much more consistent than in dicotyledons and could be used as a relatively reliable character, whereas in dicotyledons it was found to be a poor or inconsistent character.

Ram and Nayar (1974) suggested treating plants with Cupric sulfate and Hydrochloric acid to generate epidermal peels quickly. Wagner (1977) studied monocotyledon vessel types and discovered that Zingiberaceae roots have more sophisticated vessel types than the other families. Paliwal and Anand (1978) suggested that anatomical characters alone cannot be used to build a categorization system, but they have proven to be very useful in situations where knowledge from other disciplines has failed or created problems. Olatunji (1980) studied the structure and development of stomata in 70 Zingiberales species and discovered that paracytic, tricytic, tetracytic and polycytic stomata exist in Zingiberales and that tetracytic stomata are abundant in Zingiberaceae and have a tetraperigenous mode of growth.

Bell (1980) described the vascular architecture of *Alpinia speciosa* L. stems, which reveal scattered vascular bundles in two distinct zones: an inner system and an outer system separated by a cylinder of undifferentiated tissues called the intermediate zone, which has meristem-like characteristics. The various terms used in literature to describe this zone are categorized. Dahlgren and Clifford (1982) compared the vessels of monocotyledon roots, stems and leaves, concluded that Zingiberaceae leaves lack vessels, while roots have vessels with scalariform perforation plates.

Histological examinations on *Z. officinale* rhizomes were conducted by Remashree *et al.* (1997) and the vascular patterns revealed an inner zone and an outer zone separated by intermediate layers. Vascular bundles are collateral and dispersed. They observed that both sides of the intermediate zone had starch grains, oil cells and canals and the fusiform and ray initials make up the meristematic layer between the cortex and the central cylinder. Remashree *et al.* (1999) investigated the growth, distribution and structure of oil cells, as well as the development of secretory ducts and oil diffusion in *Z. officinale.*

Hussin *et al.* (2000) studied the leaf anatomy of *Alpinia* species (*Zingiberaceae)* from China. The leaf anatomy of 20 *Alpinia* species from China was investigated. *Alpinia*, largest genus of the family Zingiberaceae consists of 230 species worldwide. They pointed out the possibility of using leaf anatomy for possible identification of species in Zingiberaceae, which is a difficult task due to similarities in leaf morphology and plant habit as well as in the frequency of flowering. They also suggested that there are interspecific variations in the structure of the leaf midrib and petiole which can be used for species identification. Other findings are the presence of adaxial hypodermis in the lamina in all species of subgenus *catimbium* and its absence in all species of subgenera *Dieramalpinia, probolocalyx* and *Alpinia,* excepting *A. conchigera, A. galanga* and *A. aquatics,* which appear to be closely allied in having sub-epidermal fibers in midrib and petioles, which are absent from the rest of species. They concluded that the interspecific anatomical variation of the leaves of *Alpinia* species studied possess common characteristics typical to the genus and many are common to the family. Leaf anatomical evidence can provide some support for taxonomic conclusions drawn using other characters in *Alpinia.*

Hussin *et al.* (2001) studied the anatomical variations in the leaves of *Bosenbergia* sp. (Zingiberaceae). The major differences noted between the species are variations in the type of stomata, the structure of the midrib, the outlines of the leaf margin and petiole in the transverse section and the presence or absence of abaxial or adaxial hypodermis and trichomes in the lamina. Das *et al.* (2004) investigated the anatomy and foliar morphology of *Curcuma caesia*, *C. longa*, *C. amada* and *Kaempferia galanga*. In addition to macro and micro-morphological characteristics, anatomical features also contributed to the distinctiveness of each species. These characters also contributed to reveal the pharmacological properties of these plants.

Jayasree (2007) conducted a detailed study on the morphological and anatomical characteristics of South Indian Zingiberaceae which include 7 taxa of the genus *Zingiber*, viz., *Z. officinale*, *Z. cernuum*, *Z. capitatum*, *Z. neesanum*, *Z. roseum*, *Z. wightianum* and *Z. zerumbet.* She reported the presence of pulvinus at the base of the petiole and characterized by collenchymatous bundle sheath in the pulvinus which forms a unique feature of the genus. Vasantha (2009) studied the comparative anatomy of genus *Zingiber*. A total of 9 taxa were studied viz., *Z. capitatum*, *Z. cernuum*, *Z. montanum, Z. neesanum*, *Z. nimmonii*, Z. *officinale, Z. roseum*, *Z. wightianum* and *Z. zerumbet.* The study resolved the *Z. cernuum* and *Z. nimmonii* using anatomical characters in addition to morphology and molecular characters and provided a key based on anatomical characters for the identification of species.

Nonkratok *et al.* (2012) studied the leaf surface anatomy of 19 species of *Curcuma* in northeastern Thailand. The study suggested that characteristics like type, length and density of trichome, presence or absence of tannin can be used for identification of the *Curcuma* species and the study recorded leaf surface anatomy of 14 species of *Curcuma* for the first time.

Alokesh *et al.* (2018) studied the anatomy, Micromorphology and histochemical localization of different phytochemicals of two medicinally important taxa of the family *Zingiberaceae*, viz., *Z. zerumbet* and *Amomum capactum*. They observed that the presence of oil cells and oleo-resin in the cortex and central cylinder region and globose, ovoid or irregularly rounded starch grains were distinguishing features and these could be used as anatomical markers of *Zingiber zerumbet*, whereas in *A. capactum*, epidermal cells were hexagonal, cell wall more or less straight, stomata paracytic, trichomes unicellular or multicellular with a pointed tip.

Uma and Muthukumar (2014) studied the root anatomy and morphology of 23 species of Zingiberaceae. Taxa were represented by three tribes and eight genera. The major anatomical characters noted in the root are a piliferous epidermis, followed by an exodermis with suberized cells. The cortex with outer and inner layers is characterized by intercellular air spaces that were radially extended, it is linear in *Curcuma* sp. and *Kaempferia galanga*, tetrangular or triangular in *Zingiber officinale*. The endodermis shows 'U'-shaped thickening at maturity. Stele with single-layered pericycle and polyarch vascular tissues. In *Alpinia*, *Curcuma*, *Hedychium* and *Zingiber* the phloem strands form phloem islands. The peripheral ground tissues of the stele were mostly fibrous and occasionally parenchymatous. The study confirmed the utility of anatomical characteristics of the roots in Zingiberaceae for identification of the plant species as well as authenticating plant materials used in medicine. They also performed a phylogenetic study using anatomical characters.

Kajornjit *et al.* (2018) investigated the foliar anatomy of 26 species of *Globba* in Thailand. The study revealed that types of stomata, types of trichomes, number of rows in intercostal regions, the position of hypodermis, shape of the midrib, types of the vascular system, shape of midrib and leaf margins in transverse sections and cell inclusion were found to be important leaf anatomical characteristics for species identification. For the first time, an identification key for *Globba* at the species level is provided based on these anatomical traits.

Mohamad and Kalu (2018) made a preliminary anatomical study on leaf surfaces of Bornean *Zingiberaceae* from Northeast Sarawak. Six species from different genera in the tribe *Alpinieae* were studied and they concluded that different species show different epidermal sizes, stomata distribution irregularly and show some irregularities. Trichomes are simple, unicellular and scattered on leaf surfaces in all five 5 species except in one species, which is devoid of trichomes.

Liu *et al.* (2020) studied the morphology and anatomy of leaf and rhizome in *Z. officinale*, with emphasis on its secretory structure. They studied various anatomical features of the leaf such as epidermis structure, arrangement of palisade parenchyma, vascular bundles, etc. The studies revealed that in the transverse section epidermis is uniseriate with stomata on adaxial and axial surfaces, with thin cuticle covering the outer cell wall. Mesophyll forming dorsiventrally with palisade and it contains numerous chloroplasts, air canals are seen in palisade and spongy, vascular bundles covered by a parenchymal sheath.

Anu and Mathew Dan (2020) studied the comparative petiole anatomy of twelve species of *Curcuma* (Zingiberaceae) from south India. The study revealed that petiole anatomical characters on the twelve species of *Curcuma* showed almost similar anatomical characteristics but some show important distinct features. Presence of trichomes, outline shape of the petiole (T.S) and air canals, number of main vascular bundles, the thickness of chlorenchymatous and hypodermic layer and width of middle portion and sheath, etc. are indeed important for taxonomic evaluation.

Zhao *et al.* (2022) studied the leaf epidermal characteristics of 22 species of Zingibers belonging to 3 sections from China. The major outcomes of the study are, in Sect. *Pleuranthesis* the stomatal index is significantly lower than the other two sections, reported two types of trichomes in *Zingiber* viz., “delicate” and “stout” the former was found in most species, whereas the latter in *Z. corallinum* and *Z. montanum* only, oils cells are found in both epidermis in most of the species but it in *Z. ellipticum* (Sect. *pleuranthesis*) oil cells are restricted to abaxial epidermis only. They also suggested that even if all *Zingiber* species have similar epidermal architecture, stomatal density, trichome type and location of oil cells and crystals provide useful information for systematic and taxonomic investigations in this genus.

Palynology

Erdtman (1952) conducted several in-depth researches on several species and pioneered the use of acetolysis to prepare pollen. Vishnu-Mittre (1964) studied the evolution of different pollen groups and pollen morphology in connection to the terms used to describe the pollen morphology as well as the difficulties of academic and applied interests that rely on the collaboration of several disciplines of research.

Skvarla and Rowley (1970) studied the pollen morphology of *Canna generalis* Bailey and found that the pollen wall is exceptionally thick without detectable amounts of sporopollenin. They also suggested that the pollen wall of *C. generalis* resembles the thick intine and thin exine found in many pollen grains. The pollen wall of *Canna* has an infinite number of aperture-like regions for pollen tube initiation which is different from other such pollen which lack an aperture.

Kress *et al.* (1978) studied the pollen morphology of *Heliconia* and many other relative Zingiberales members. The study identified the absence of a protective exine and the presence of a thick well-developed intine in the taxa studied. The study also mentioned the significance of intine structure in adaptation and classification. Stone and Kress (1979) observed that pollen from *Heliconia* and most of its Zingiberaceous relatives is destroyed by normal acetolysis preparation and the grain's fragility is caused by weak exine development and sporopollenin deposition.

Kress and Donald (1983) investigated the palynology of 27 species of *Heliconia* (19 species with pendent inflorescences; eight species with erect inflorescences). They found that pollen of species with erect inflorescences shares many characteristics in common with pollen of pendent species. Four groups were recognized based on pollen characters in species with pendent inflorescences. Based on the evidence from cladistic analysis of the 27 species based on pollen characters they also suggest that species with erect inflorescences have evolved independently several times from species with pendent inflorescences.

The ultrastructures of monocot pollen were studied by Zavada (1983) the findings made a clear understanding of the evolutionary trends in aperture and pollen wall structure. They also proposed that a parallel evolution occurred in monocot pollen ultrastructure and Dicot pollen ultrastructure as proposed by Walker (1976).

Yuan-Hui and Yuan-Hui (1988) studied the pollen morphology of 89 species and 3 varieties belonging to 18 genera of the family *Zingiberaceae* in China. The study revealed that Zingiberaceae pollen grains are spherical, subspherical or ovoid in shape and prolate, the size ranges from 36–225 μm, pollen are non-aperturate or aperturate (spiraperturate, porate) and the wall is composed of a very thin exine and a thick intine and pollen grains are almost not resistant to acetolysis. The study also described the pollen structure of 8 *Zingiber* species and recognized spherical pollens with cerebroid sculpturing and ellipsoid pollen with striate sculpturing characteristic of Sect. *Dymczewiczea* and Sect. *Cryptanthium* respectively.

Mangaly and Jyothi (1990) carried out the palynological study of South Indian Zingeberaceae members and revealed that exine is absent only in *Kaempferia*. In *Alpinia galanga* and *Amomum hypoleucum* a discontinuous exine layer consisting of circular plates joined together at margins was found while all other taxa possess an uninterrupted exine layer which is commonly 0.7 µm to less than 2.0 µm thick. In conclusion, based on palynological data *Alpinia, Amomum, Boesenbergia, Kaempferia and Zingiber* constitute one group while *Elettaria, Hedychium* and *Costus* constitute another.

Theilade *et al.* (1993) described the pollen morphology and internal wall structure of 18 *Zingiber* species. The pollen grains are spherical with cerebroid sculpturing in the sections *Zingiber* and *Dymczewiczia*. While the pollen is ellipsoid with spiro-striate sculpturing in Sect. *Cryptanthium*. On the premise of pollen morphology, it is proposed that the Sect. *Dymczewiczia* is included within the Sect. *Zingiber*.

Theilade and Theilade (1996) portrayed the ontogeny of the pollen wall in *Zingiber* to supply a premise for understanding the usefulness of mature pollen in evaluating the broader phylogenetic relationship within the order Zingiberales. When the Inflorescences of *Z. spectabile*, were processed for light and transmission electron microscopy, it shows that in *Zingiber* the microspores developed a thick primexine and the mature pollen exhibited an extremely thin and discontinuous exine. The advancement of a channeled intine was started after the deterioration of the callose wall when the microspores had entered the free stage. It comes to its most extreme thickness within the late microspore period, after which it diminished in thickness. A wide diversity in the development of the primexine was shown when a comparison of *Z. spectabile* with members of other genera of the Zingiberales were carried out.

Saensouk *et al.* (2009) studied the Pollen morphology of three species of the genus *Cornukaempferia* (Zingiberaceae) in Thailand by Light microscopy and scanning electron microscopy. The pollen grains were found to be spherical, monad and inaperturate. The exine sculpture is echinate with regulating between the spines for *C. larsenii* or echinate with psilate between the spines for *C. aurantiflora* and *C. longipetiolata*, this perception helps support the taxonomic status of *C. larsenii.*

Kaewsri and Paisooksantivatana (2007) investigated the morphological characteristics and pollen morphology of Thai *Amomum* to aid identification and classification. Pollen grains of 14 representatives were examined in the study using a scanning electron microscope (SEM) to reveal their morphology and usefulness for infrageneric classification. They have observed two types of exine sculpture, psilate and echinate. They suggested that classification by using pollen morphology does not support grouping by the previous authors that emphasized fruit shapes.

Chen and Xia (2011) investigated the pollen morphology of 20 populations of 16 species of Chinese *Curcuma* and *Boesenbergia* (Zingiberaceae) under SEM and TEM. The pollen grains are ovoid, spherical and nonaperturate. The pollen wall is composed of a thick intine and a very thin exine. The exine is psilate or echinate. The intine consists of two layers, ie., an inner homogenous layer (endintine) and a thick, channeled layer (exintine). According to the results, a morphological coinciding between the pollen grains of species of *Curcuma*, which agree to DNA arrangement information shows up to be a polyphyletic class.

Results about pollen morphology moreover don't give any extra proof to either join together or isolate *Boesenbergia albomaculata* and *Curcumorpha longiflora* within the same genus and illustrate that more ordered information on the genus *Boesenbergia* and its relatives are required some time before the last choice can be made.

Saensouk *et al.* (2015) studied the pollen morphology of 14 species of the genus *Curcuma* (Zingiberaceae) in northeastern Thailand using light microscope and scanning electron microscope. Monad, inaperturate, with radial symmetry and large with rugulose exine sculpturing pollen grains, were observed. Pollen grains with different shapes like subspheroidal, prolate spheroidal, spheroidal, subprolate and prolate shapes were noticed. Pollen shape can be utilized as a supplementary character for distinguishing proof of the *Curcuma* species.

Phytochemistry

Bestmann *et al.* (1992) studied the root oil constituents of *Zingiber chrysanthum* growing widely in India. 24 components were identified through GC, GC/MS and GC-FTIR, mainly monoterpenes with the major constituents 1, 8-cineole (42%), α-fenchyl acetate (15%), α-terpineol (6%) and camphene (6%).

Onyenekwe and Hashimoto, (1999) studied the essential oil composition of dried *Z. officinale* by GC and GC-MS techniques. The oil yield was 2.4% which consists of 1.6% esters, 2.4% monoterpene hydrocarbons, 5.6% alcohol, 6.6% carbonyl compounds and 64.4% sesquiterpene hydrocarbon. Zingiberene (29.5%) sesquiphellandrene were identified as the major compounds. Other compounds identified were 2, 6-dimethl hepten-1-ol, linalool oxide, α-gurjunene, isovaler-aldehyde, cadinol, 2-pentanone, eremophyllene, α- and γ-calaccorene, t-muurolol, α-cubebene acetic acid, α-himachallene, α- santalene, pinanol, geranoic acid, geranyl propionate, geranoic acid, (E, E)-α-farnesene, geranic acid and n-methyl pyrrole.

Srivastava *et al.* (2000) investigated the essential oil composition of rhizome of *Z. zerumbet* from India by hydrodistillation method and was subjected to GC/MS analysis. A total of 36 compounds were identified and the *major* compounds were curzerenone (14.4%), zerumbone (12.6%), camphor (12.8%), isoborneol (8.9%) and 1,8-cineole (7.1%).

Gurib-Fakim *et al.* (2002) investigated the essential oil composition of *Z. officinale*, *Hedychium coccineum, H. flavescens* and *H. coronarium* from Mauritius. geranial (16.3%), neral (10.3%), zingiberene (9.5%), β-sesquiphellandrene (6.3%)

and ar-curcumene (5.1%) were the major constituents of *Z. officinale*. (E)-nerolidol (44.4%), *trans*-sesquisabinene hydrate (24.2%) were the major constituents of *H. coccineum*. *H. flavescens* were characterized by linalool (35.0%), 1, 8-cineole (15.3%), β-pinene (14.7%), α-terpineol (14.5%) and α-pinene (5.3%) were the constituents of. α-muurolol (16.8%), α-terpineol (15.9%), 1, 8-cineole (11.2%), an unknown sesquiterpene alcohol (7.0%), α-fenchyl acetate (5.6%), citronellal (5.5%) and (E)-methyl cinnamate (5.1%) were the compounds identified in *H. coronarium.*

Pino *et al.* (2004) examined the chemical composition of the essential oil obtained from the rhizomes of *Z. officinale* Roscoe from Cuba by combined GC and GC/MS. The oil was distinguished by the presence of cadina-1,4-diene (12.5%), ar-curcumene (22.1%), β-bisabolene (11.2%) and zingiberene (11.7%).

Prakash *et al.* (2006a) investigated the phytochemical composition of essential oil from seeds of *Z. roseum* and its antispasmodic activity in rat duodenum. Altogether 60 compounds, out of which 47 compounds (96.2% of the oil) were identified. The major compounds were α-pinene, β-pinene, limonene, p-cymene, α-terpineol and verticiole. The presence of mono- and sesquiterpene hydrocarbons which make up about 82% of the oil was considered to be a unique feature. The oil also ha**s** myorelaxant activity on isolated rat duodenal smooth muscle. This study revealed a probable inhibitory effect of *Z. roseum* seeds essential oil on the influx of Ca^{2+} through the cell membrane of rat duodenal smooth muscle.

Prakash *et al.* (2006b) carried out the combination of GC and GC-MS analysis of essential oil from the rhizome of *Z. roseum* and found 44 compounds of which 36 compounds have been identified comprising 94.9% of the oil. Linalool (53.3%) was found to be the major compound in the essential oil with lesser amounts of limonene (14.0%), β-pinene (9.3%) and α-pinene (4.4%) being among the other constituents. Borneol (0.9%) and β-eudesmol (1.4%) which are considered to be the marker components of Zingiberaceae family were found to be present in relatively low concentrations in the oil.

The investigation of chemical characterization and antimicrobial activity of caryophyllene-rich rhizome oil of *Z. nimmonii* by Sabulal *et al.* (2006), 65 constituents accounting for 97.5% of the oil were identified. *Z. nimmonii* rhizome oil is a distinctive caryophyllene-rich natural source with α-humulene (α-caryophyllene, 27.7%) and isomeric caryophyllenes, β-caryophyllene (42.2%). The rhizome oil contained 1.3% non-terpenoid constituents, 1.9% oxygenated monoterpenes, 8.9% monoterpenes, 14.2% oxygenated sesquiterpenes and 71.2% sesquiterpenes. The oil showed notable inhibitory activity against the fungi, *Candida albicans, C. glabrata* and *Aspergillus niger* and the bacteria *Pseudomonas aeruginosa* and *Bacillus subtilis*. Singh *et al.* (2008) studied chemistry, antioxidant and antimicrobial investigations on essential oil and oleoresins of *Z. officinale* and found that geranial (25.9%) was the major component in essential oil. Eugenol (49.8%) in ethanol oleoresin. In the other three oleoresins, zingerone was the major component (33.6%, 33.3% and 30.5% for, methanol, CCl_4 $_{\text{and}}$ isooctane oleoresins, respectively). CCl_4 oleoresin and essential oil showed 100% zone inhibition against Fusarium moniliforme. The essential oil was found to be better than the oleoresins even though both were found to be effective.

Sabulal *et al.* (2007) isolated and characterized Essential oil from the rhizomes of *Z. neesanum* from the Western Ghats region of southern India, by GC and GC–MS. A total of Sixty-one constituents, comprising 97.4% of the oil, were identified. Phenylbutanoids like (*E*)-1-(3′,4′-dimethoxyphenyl) but-1-ene (23.1%) and (*E*)-1-(3′,4′-dimethoxyphenyl) butadiene (31.1%), a potent anti-inflammatory compound was isolated from the oil. Major terpenoid constituents in *Z. neesanum* rhizome oil were (*E*)-*β*-ocimene (12.7%), *β*-pinene (7.4%) and linalool (4.0%).

Sasidharan and Menon (2010) compared the chemical composition and antimicrobial activity of fresh and dry ginger oils (*Z. officinale*) and found that Zingiberene is the major compound in both ginger oils. Compared to dry ginger oil (14.4%), fresh ginger oil contained geranial (8.5%) the second main compound and had more oxygenated compounds (29.2%). Ar-curcumene (11%), β-bisabolene (7.2%), sesquiphellandrene (6.6%) and δ-cadinene (3.5%) were the other constituents of dry ginger oil. Antimicrobial activity of oils was assessed by disc diffusion method against *Bacillus subtilis, Pseudomonas aeruginosa, Candida* *albicans*, *Trichoderma* spp, *Aspergillus niger, Penicillium* spp. and *Saccharomyces cerevisiae*. Very significant MIC values ranging from 10µg/mL to 1 µg/mL were obtained. A broad application of ginger oil in the treatment of many bacterial and fungal diseases was also discussed.

Sivasothy *et al.* (2011) studied the essential oil composition of leaves and rhizome and the antibacterial activities *Z. officinale* var. *rubrum* Theilade. Fifty-four constituents were identified in the rhizome oil, while 46 were identified in the oil from the leaves. The rhizome oil was predominantly monoterpenoid, with camphene (14.5%), geranial (14.3%) and geranyl acetate (13.7%) the three most abundant constituents while the leaf oil was dominated by *β*-caryophyllene (31.7%). The antimicrobial studies revealed that both the leaf and rhizome oils were moderately active against the Gram-negative bacteria *Escherichia coli*, *Klebsiella pneumoniae* and *Pseudomonas stutzeri* and the Gram-positive bacteria *Bacillus licheniformis, Bacillus spizizenii* and *Staphylococcus aureus*.

Giang *et al.* (2011) investigated the essential oil from the fresh rhizomes of *Z. pellitum* of Vietnam by GC and GC-MS. The major constituents of the oil were found to be terpinen-4-ol (35.9 %), p-cymene (19.8 %) and sabinene (7.1 %). Monoterpenoids constituted 80.1 % of the oil. Minor compounds of the oil were Sesquiterpenoids and the identified compounds consisted of 2.5 % of the oil.

Kader *et al.* (2011) investigated the antimicrobial effects of ethanolic extract of *Z. zerumbet* and its chloroform and petroleum ether soluble fractions against pathogenic bacteria and fungi and found that potent antifungal and antibacterial phytochemicals are present in ethanol extract of *Z. zerumbet*. The highest activity against *Vibrio parahemolyticus* (*V. parahemolyticus*) was noticed in the crude ethanol extract.

Rana *et al.* (2012) studied the chemical composition of the rhizome essential oil of *Z. zerumbet* var. *darcyi* and identified thirty-three compounds, accounting for 93.6% of the oil including twenty compounds in minor (0.1-0.6%) and eight in trace (<0.05%) amounts. The major compounds identified were zerumbone (69.9%) α-humulene (12.9%), humulene epoxide II (2.5%), caryophyllene oxide (1.1%) and camphene (1.9%). This was the first report on the analysis of *Z. zerumbet* var. *darcyi* oil and found that this variety could be used as an additional new source of natural zerumbone besides *Z. zerumbet.*

Chemical constituents of the root essential oils of *Z. rubens* and *Z. zerumbet* were studied by Dai *et al.* (2013) and the major components identified in *Z. rubens* were (*Z*)-citral (30.1%), camphene (9.7%), *β*-phellandrene (7.5%), 1,8-cineole (7.0%) and zingiberene (5.3%). **(***Z*)-citral (26.1%), camphene (16.3%), sabinene (14.6%), zingiberene (7.2%) and lavandulyl acetate (6.7%) were the main oil constituents of *Z. zerumbet*. This species has low zerumbone (1.2%) content.

Finose and Gopalakrishnan (2014) evaluated the comparative antioxidant potential using Nitric Oxide Scavenging Assay, DPPH and superoxide scavenging assays of *Z. nimmonii*. The quantitative estimation of the total flavonoid content of three different extracts; n-Hexane, Chloroform and Methanol were also done. According to the results obtained, hexane was the most remarkable and promising extract among chloroform, hexane and methanolic extracts. Hence hexane was chosen to be the potential extract and was further screened for various characterization studies.

Singh *et al.* (2014) studied the biological activity and chemical composition of essential oil from the rhizome of *Z. zerumbet*. Major components were found to be zerumbone (75.2%), a- caryophyllene (7.1%), camphene (5.1%), eucalyptol (2.4%) and camphor (3.0%). Antioxidant activity and total phenol content assay were studied using the DPPH and Folin-Ciocalteu colorimetric methods. Antimalarial, anti-leishmanial and antimicrobial assays were analyzed for the essential oil and its major component, zerumbone. The essential oil and zerumbone exhibited antimalarial and antileishmanial activities whereas only *Cryptococcus neoformans* showed antimicrobial activity on the essential oil.

Salim *et al.* (2016) investigated the chemical profile, antiproliferative and antioxidant activities of rhizome oil of *Z. anamalayanum* from the Western Ghats in India. Twenty-one compounds constituting 99.47% of the oil were identified. *δ*-2-carene (52.83%), camphene (9.83%), endo-fenchol (9.42%), iso-dihydrocarveol

(6.44%) and cis-p-mentha-2,8-dien-1-ol (5.19%) were the major components in *Z. anamalayanum* rhizome oil. 65.81% of the rhizome oil constitutes Monoterpene hydrocarbons followed by oxygenated monoterpenes (23.78%) and sesquiterpene hydrocarbons (9.87%).

Govindarajan *et al.* (2016) evaluated the larvicidal and repellent potential of *Z, nimmonii* rhizome essential oil against the malaria vector *Anopheles stephensi*, the dengue vector *Aedes aegypti* and the lymphatic filariasis vector *Culex quinquefasciatus*. A total of 33 compounds with major components; myrcene, β-caryophyllene, α humulene and α-cadinol were identified. The essential oil showed significant toxicity against the early third-stage larvae of *Anopheles stephensi, Aedes Aegypti and Culex* with LC_{50} values of 41.19, 44.46 and 48.26 µg/ml respectively.

Meranee *et al*. (20l7) studied the chemical constituents of ethanolic fresh rhizome extract from *Z. ligulatum* and isolated three pure compounds; kaempferol 7,4'-dimethyl ether, quercetin 7,4'-dimethyl ether and n-propyl p-hydroxybenzoate. The structures were elucidated and confirmed by spectroscopic data. Moreover, GC-MS analyses were carried out to analyze the volatile components.

Hung *et al.* (2017) studied the essential oil composition of *Z. nitens*, a new species using gas chromatography-flame ionization detector (GC-FID) and gas chromatography-mass spectrometry (GC-MS) techniques. δ-elemene (17.0%), β-pinene (12.8%) and β-elemene (8.8%) were the major constituents of the leaf oil. δ-elemene (20.1%), germacrene D (8.6%) and bicyclogermacrene (8.1%) were the major constituents of stem oil and β-pinene (21.0%), δ-elemene (12.8%) and bornyl acetate (11.8%) were the major constituents of root oil.

Mahboubi (2019) reviewed the chemical composition and biological activities of *Z. officinale* (ginger) essential oil. Through experimental and preclinical studies, the antibacterial, antifungal, analgesic, anti-inflammatory, anti-ulcer, immunomodulatory, relaxant and warming effects.

Huong *et al.* (2020) investigated the chemical composition and biological activities of essential oils of *Zingiber* species from Vietnam. The antibacterial activity of essential oil was assessed against a selection of Gram-positive and Gram-negative bacteria and for activity against *Candida albicans*. The mosquito larvicidal activities were assessed against *Culex quinquefasciatus*, *Aedes albopictus* and *Aedes aegypti*. *E*ssential oils rich in α-pinene and β-pinene showed the best larvicidal activity. The rhizome essential oil of *Z. nudicarpum* showed excellent antibacterial activity against *Enterococcus faecalis*, *Staphylococcus aureus* and *Bacillus cereus*, with minimum inhibitory concentrations (MIC) of 2, 8 and 1 μg/mL, respectively.

Baby *et al.* (2021) studied the phytochemical screening and antifungal evaluation of rhizome extract of *Z. wightianum*. Preliminary phytochemical screening of the methanolic extract proved the presence of alkaloids, carbohydrates, tannins, flavonoids, saponins and phenols. A minimum inhibitory concentration was determined when this extract was subjected to antifungal activity. This extract also has the potential to treat a fungal infection *Tinea versicolor*, caused by the fungus *Malassezia furfur*.

Aswati Nair *et al.* (2021) studied the polyphenolic characteristics, antimicrobial and antioxidant activity of rhizome of *Z. neesanum*, endemic to the Western Ghats and identified the volatile metabolites by GC-MS analysis. Antimicrobial activity against gram-negative *Enterococcus fecalis* (21.7 ± 0.6 cm) was due to high total tannin (TT) content in isopropanol extract [55.261 ± 6.623 mg TAE.100 g^{-1} DW] while the antifungal activity against *Mucor rouxii* (9.7 ± 0.6) was due to high total flavonoid (TF) content in ethyl acetate extract [681.94 ± 33.87 mg CE.100 g^{-1} DW]. 2-Methyl-7-nonadecene (13.99%; antimicrobial), Actinomycin C2 (8.57%; antineoplastic) and Deoxyspergualin (12.55%; immunosuppressive) were identified as the Major bioactive phytochemical constituents in *Z. neesanum* rhizome.

Molecular phylogeny

Kress (1990) proposed a new phylogenetic classification based on 32 morphological and anatomical characters. The phylogenetic analysis recognizes eight families viz., Marantaceae, Cannaceae, Zingiberaceae, Costaceae, Heliconiaceae, Lowiaceae, Strelitziaceae and Musaceae, two superfamilies viz., Zingiberariae and Cannariae and five suborders viz., Musineae, Strelitzinea, Lowinea, Heliconineae and Zingiberineae within the Zingiberales.

Smith *et al.* (1993) carried out a phylogenetic analysis of order Zingiberales using rbcL gene to find out the interrelationship within the order. A total of 21 species and proposed relatives were sampled for the analysis. Both equal and differential weights were performed for five analyses. The tree topology was found to be similar in all analyses with the outgroup comprising Commelinaceae/ Haemodoraceae/Pontederiaceae members but the tree topology was different from the previous morphological analyses by Kress (1990). The study divided the order Zingiberales into two sister groups, one with Costaceae and Marantaceae and the other six families clustered together in the second group. All families recognized in the study are monophyletic except the paraphyletic Musaceae and Cannaceae. They also suggest that the ability of rbcL sequence data to infer the phylogeny of Zingiberales is limited to interordinal and intrafamilial relationships.

Harris *et al.* (2000) conducted a phylogenetic analysis of the genus *Aframomum* using ITS nr DNA. A total of 42 accessions representing 28 species were sampled in the study. The size of the ITS 1 region in *Aframomum* varied from 187 bp to 190 bp and 215 bp to 216 bp for ITS 2. The pairwise sequence difference among taxa was not found significant as compared to a similar analysis of genus *Alpinia* of Southeast Asia. The analysis supports the monophyly of the genus *Aframomum* but it failed to resolve the in-group species and recognized four putative multispecies groups. The study concluded that the inability of ITS sequence data to reflect the high degree of variations found in the vegetative and floral characters were due to the rapid radiation under conditions.

Kanlayanapaphon and Newman (2000) studied the phylogeny of genus *Roscoea* using ITS nr DNA. Two species of *Cautleya* and two species of *Curcuma* were sampled as outgroups. The study revealed Roscoea as monophyletic group with genus *Curcuma* as sister group. The phylogenetic analysis resolved the genus *Roscoea* into two sister clades viz., a ‘Chinese’ clade and a ‘Himalayan’ clade which denotes their disjunct geographic distribution across the ‘Brahmaputra gap’.

Rangsiruji *et al.* (2000) studied the interrelationship among genus *Alpinia* using ITS and trnF regions. 17 taxa including 15 *Alpinia* and one outgroup were sampled for the analysis. The study suggests that *A. galanga* is closely related to *A. nigra* in sect. *Allughas* (with tubular bracteoles). The section shows a paraphyletic origin. The study also proposed that *A. galanga* evolved within sect. *Allughas* and the absence of tubular bracteoles are due to convergent evolution with sect. *Alpinia* may be the result of evolution under domestication.

Wood *et al.* (2000) carried out a phylogenetic analysis of genus *Hedychium* J. Koenig using ITS1, ITS2 (nrDNA). They have sequence of 29 taxa including 16 other related genera of Zingiberaceae. The Cladistic study supports the monophyletic origin of *Hedychium* whereas relationships to other genera are not satisfactory. Four major clades were recognized in genus *Hedychium* with weak bootstrap support and each clade is characterized by the number of flowers and distribution of bracts. Based on the study the tribes in Zingiberoideae are not showing a monophyletic origin.

Specht *et al.* (2001) investigated the phylogenetic relationships of Costaceae, a tropical monocotyledonous family sister to the gingers (Zingiberaceae). Both chloroplast (the trnL-F locus, including the trnL intron, the 3′trnL exon and the trnL-F intergenic spacer and the trnK locus, including the trnK intron and the matK coding region) and nuclear (ITS1–5.8s–ITS2) DNA data were utilized for the study. The study suggests that genus Costus is broadly paraphyletic but *Costus* subgenus *Eucostus* represents large monophyletic radiation.

Kress *et al.* (2005) studied the validity of earlier *Alpinia* species classifications using DNA sequencing and phylogenetic analysis using matK and ITS regions. The parsimony analysis of both individual and combined data sets recognized six polyphyletic clades within the tribe Alpinieae. A Bayesian analysis of the combined data set backed up the findings. The study revealed that both Schumann's and Smith's classifications of the genus do not correspond to these monophyletic groups of species.

Selvaraj *et al.* (2008) studied the matK gene from Zingibereceae for the analysis of variants, parsimony site, patterns, transition/transversion rates of of phylogeny. The study identified 24% variants between the species and 1.54. transition/transversion rate among the species. A phylogenetic tree was also designed to find the efficacy of matK region to define the inter and intera-generic relationships. The study concluded that the matK gene is a good candidate for DNA barcoding.

Theerakulpisut *et al.* (2012) carried out a phylogenetic analysis of genus *Zingiber* using the ITS region. The study resolved the species into four clades, which correspond with previously recognized sectional classification of the genus based on inflorescence type (Sects. *Zingiber*, *Dymczewiczia* (Horan.) Benth., *Pleuranthesis* Benth. and *Cryptanthium* Horan.). but the phylogenetic tree shows that sects *Zingiber* and *Dymczewiczia* are weakly supported as separate groups and are more closely related to each other than to Sect. *Pleuranthesis* and *Cryptanthium*. The analysis was supported by a previous observation on two species, *Z. junceum* and *Z. gramineum* which were previously tentatively placed in both Sect. *Zingiber* and *Dymczewiczia* due to their ability to develop two inflorescence types. The close relationship of the two sections based on ITS sequences together with similarity in pollen morphology supports an earlier proposal that Sect. *Dymczewiczia* should be amalgamated with Sect. *Zingiber*. Phylogenetic analysis indicated that Sect. *Dymczewiczia* and *Zingiber* are formed within the same clade. Thus, this analysis of nuclear ITS sequences is supportive of the pollen-based proposal by Theilade *et al.* (1993). Apart from the similar shape of pollen, members of these two sects are also characterized by having the same type of inflorescence shape. Therefore, the study proposed that based on both morphological characters, i.e. inflorescence habit and shape, pollen morphology and molecular phylogenetic evidence the Sect. *Dymczewiczia* should be included in the Sect. *Zingiber* as earlier proposed (Theilade *et al.*, 1993).

Vinitha *et al.* (2014) studied the efficacy of nine plastid (matK, rbcL, rpoC1, rpoB, rpl36-rps8, ndhJ, trnL-F, trnH-psbA and accD) and two nuclear (ITS and ITS2) barcode region in family Zingiberaceae by sampling 60 accessions of 20 species belonging to seven genera from India. Bidirectional sequences were obtained for all plastid loci by direct polymerase chain reaction (PCR) amplicons in all the accessions tested. Out of the 60 accessions, only 35 (58%) and 40 accessions (66%) yielded ITS and ITS2 sequences, respectively, by direct sequencing. matK and rbcL sorted 15 species (75 percent) into monophyletic groups and five species into two paraphyletic groupings in diverse bioinformatics analyses. Only 12 species (60 %) were distinguished from the 173 ITS sequences, which included 138 cloned sequences from 23 accessions. The remaining species were divided into three paraphyletic groupings. Natural hybridizations may have occurred in the evolutionary past, resulting in species paraphyly and intragenomic ITS heterogeneity in the species studied, according to phylogenetic and genealogic studies of plastid and ITS sequences. The findings support the use of matK and rbcL loci for barcoding Zingiberaceae members and emphasize the low usefulness of ITS and the highly regarded ITS2 in this family, as well as advice against proposing ITS loci for taxa based on inadequate sampling.

Augustine *et al.* (2018) studied the Conserved Ortholog Set (COS) markers in *Zingiber* and their utility in DNA barcoding and species identification. In their work, COS markers in the Zingiberaceae family were identified, functionally annotated and analyzed. COS indicators were discovered, verified and tested in a total of 37 cases. Housekeeping genes (85.7%), a defense gene, three mitochondrial proteins and one chloroplast protein were discovered during the functional annotation process. The study proposed that the use of a COS marker (ZE372342) as a barcode target for the *Zingiber* genus was useful and the findings indicate that this is a potential target.

Boer *et al.* (2018) resolved the paraphyly of the genus *Amomum* (Zingiberaceae) using a multi-marker phylogenetic analysis using matk and nrITS with multiple accessions of the type, the genus *Elettaria* and additional accessions of *Amomum*, *Alpinia*, *Elettariopsis*, *Geocharis*, *Geostachys* and *Hornstedtia*. The study recognized nine clades in *Amomum* and six in *Alpinia*. Within these clades include the genera *Elettaria*, *Elettariopsis*, *Plagiostachys* and species of *Hornstedtia*. The study also identified new genera that correspond to well-delimited clades in the evolutionary framework provided in the study is supported by morphological investigations of species formerly subsumed in *Amomum*. The study circumscribed the paraphyletic genus *Amomum* and made identification easier and provide nomenclatural stability. They revived three genera viz., *Conamomum, Meistera* and *Wurfbainia* and three new genera were newly described. The genera *Epiamomum*, *Lanxangia* and *Sundamomum* are described, together with a key to the genera and a nomenclatural synopsis that incorporates 384 specific names (including all synonyms) into the new generic framework. There are 129 new combinations and three replacement names among them. The study proposed that to resolve further branches of Alpinioideae containing other polyphyletic taxa, more research and sampling will be required.

Mood *et al.* (2018) studied taxonomy and botanical history of *Boesenbergia gelatinosa*, *B. jahaiana*, *B. parvula* and *B. phyllostachya.* The study used data from morphological comparisons, ecology and molecular phylogeny using plastid and nuclear DNA sequence data, the study revealed that these species are found to be conspecific with *B. parvula* and are reduced as synonyms. The study also described a new variety, *B. parvula* var. *major*.

Basak *et al.* (2019) evaluated the genetic structure among wild *Alpinia nigra* populations using random amplified polymorphic DNA (RAPD), inter-simple sequence repeat (ISSR) and barcoding loci (plastid and mitochondrial). The order (high to low) of Shannon's information index (I) and Nei's gene diversity (h) from the populations was found to be: "IIT Guwahati" > "Amingaon" > "Saraighat". The analysis confirmed that genetic diversity decreased and genetic differentiation increased among the three populations. They do not observe any isolation by distance among the population so a lesser amount of gene flow was observed. In dendrogram and principal component analysis, the geographical isolation was reinforced by a narrow range of genetic distance between the three populations and the formation of two different clusters. For seven plastid loci and two mitochondrial loci investigated, no mutation was found in any of the three groups, suggesting taxonomic homogeneity. The phylogeny based on nine barcoding loci confirmed their findings that IIT Guwahati population was somewhat separated from the rest of the population. According to the study, it will serve as a foundation for establishing methods to prevent Zingiberaceous plant habitat fragmentation.

Cui *et al.* (2019) sequenced the complete chloroplast genome of *Z. officinale* and identified its phylogenetic position in Zingiberaceae. The study shows that the chloroplast genome of *Z. officinale* is 162, 621 bp with a four-part circular structure and 36.1% GC content. Annotations were made for all 113 distinct genes. There were a total of 78 simple sequence repeats (SSRs) and 42 long repeat sequences discovered, all of which could be used to identify species. The comparative analysis revealed some highly variable regions, including rps16-trnQ-UUG, atpH-atpI, trnT-UGU-trnL-UAA, ycf1 and psaC-ndhE. They also found that, in all four shared regions, the short single-copy (SSC) region was the most variable, which indicates that the region may be undergoing fast nucleotide substitution in the Zingiberaceae family. According to the phylogenetic study, based on all accessible Zingiberales chloroplasts at the National Center for Biotechnology, Information *Zingiber* is found to be a sister branch to *Kaempferia* species. The study concluded that the availability of the chloroplast genome of *Z. officinale* offered vital data for species-level verification and phylogenetic analysis and can therefore aid future research on Zingiberaceae species.

Mood *et al.* (2020) studied the history of the genus *Haplochorema* (Zingiberaceae) and compared its morphology to *Boesenbergia* and molecular phylogenetic analysis was carried out using nrITS and trnK regions. The sampling includes other Zingiberaceae genus also. Based on a comparative analysis of molecular and morphological data, the study proposed that *Haplochorema* is reduced to *Boesenbergia* with eight new combinations. They also designated a lectotype for *B. loerzingii*.

AREA OF PRESENT STUDY

For the present study specimens were collected from the North-East Indian states of Arunachal Pradesh, Assam, Meghalaya, Sikkim, Mizoram, Tripura, Manipur and Nagaland (**Map 1**). The study covers an area of 262230 sq. km (101,250 sq mi), almost 8 percent of that of India. The area shares an international border of 5,182 kilometers (3,220 mi) (about 99 percent of its total geographical boundary) with several neighboring countries – 1,640 kilometers (1,020 mi) with Myanmar in the east, 1,395 kilometers (867 mi) with Tibet Autonomous Region, China in the north, 97 kilometers (60 mi) with Nepal in the west and 455 kilometers (283 mi) with Bhutan in the north-west, 1,596 kilometers (992 mi) with Bangladesh in the south-west (Gogoi *et al.*, 2009).

The Northeast region can be physiographically classified into the Eastern Himalaya, the Patkai and the Brahmaputra and the Barak valley plains. North-East India has a chiefly humid subtropical climate with hot, severe monsoons, humid summers and mild winters. This region has some of the Indian subcontinent's last remaining rainforests, which hold diverse flora and fauna and many crop species. Reserves of petroleum and natural gas in the area are evaluated to constitute a fifth of India's total potential.

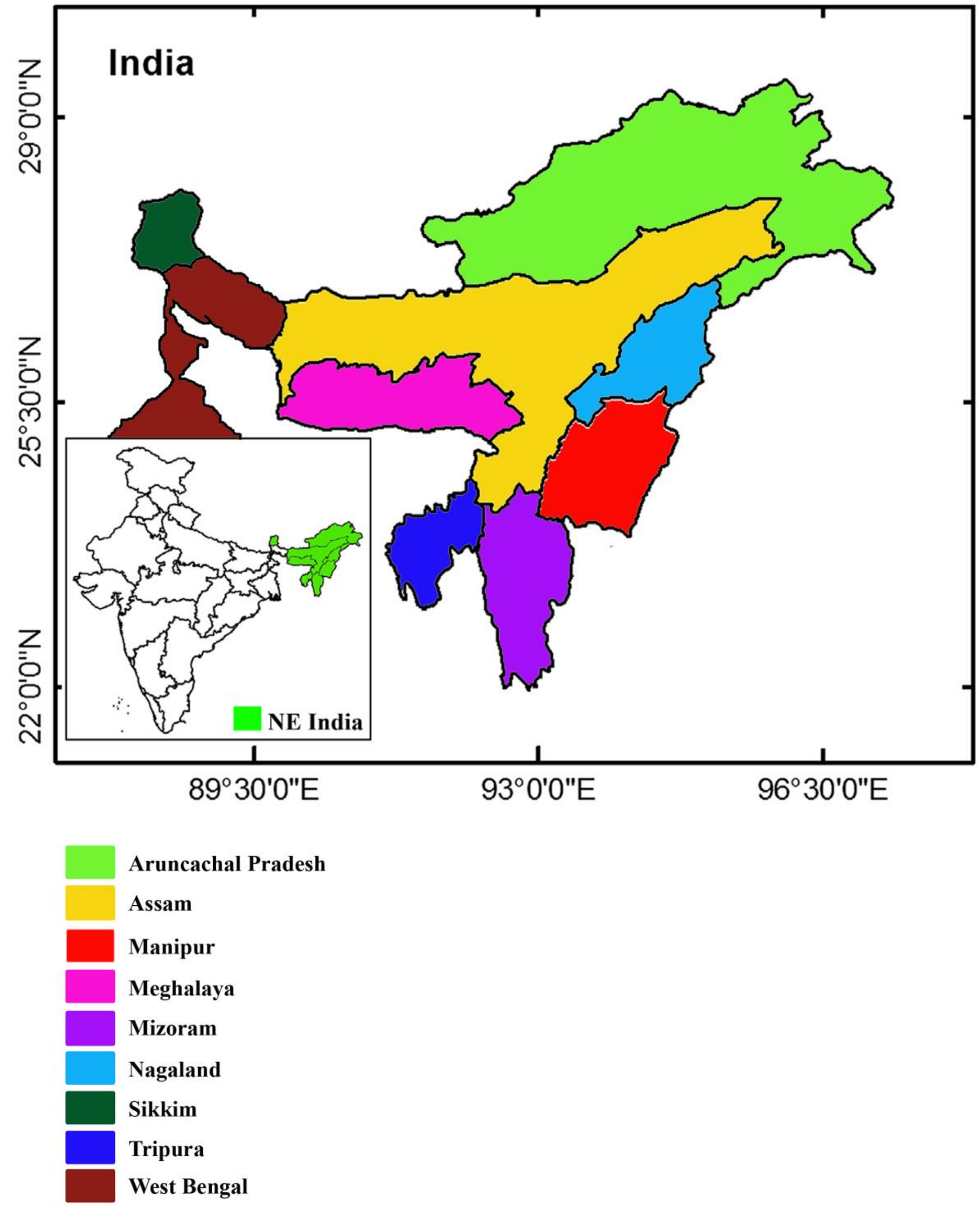
Brahmaputra-Barak river systems and their tributaries have contributed to covering this region. Geographically, two-thirds of the area is hilly terrain interspersed with valleys and plains; the altitude varies from almost sea level to over 7,000 meters (23,000 ft) above MSL, apart from the Brahmaputra, Barak and Imphal valleys and some flatlands in between the hills of Meghalaya and Tripura. The heavy rainfall, averaging around 10,000 millimeters (390 in) and above makes problems for the ecosystem, flood and high seismic activity. A montane climate with cold, snowy winters and mild summers are the characteristic features of the states of Arunachal Pradesh and Sikkim.

Climate

Northeast India has a subtropical climate which is influenced by its relief and influences from the southwest and northeast monsoons. The climate influences the

Himalayas to the North, Mizoram and Manipur to the East and the Meghalaya plateau to the South and the hills of Nagaland. Since rainstorm winds beginning from the Inlet of Bengal move northeast, these mountains constrain the damp winds upwards, causing them to cool adiabatically and condense into clouds, discharging overwhelming precipitation on these slants. It is the rainiest locale in the nation, with numerous places accepting normal yearly precipitation of 2,000 mm (79 in), which is generally concentrated in summer amid the storm season. Cherrapunji found on the Meghalaya level is one of the rainiest put in the world with a yearly precipitation of 11,777 mm (463.7 in). Temperatures are direct within the Brahmaputra and Barak valley stream fields which decreases with elevation within the uneven areas. At the most noteworthy elevations, there's changeless snow cover. In common, the locale has 3 seasons: Winter, summer and stormy season in which the stormy season coincides with the summer months much just like the rest of India. Winter is from early November until mid-March whereas summer is from mid-April to mid-October (Dikshit & Dikshit, 2014).

Beneath the Köppen climate classification, the locale is separated into 3 wide sorts: A (tropical climates), C (warm calm mesothermal climates) and D (snow microthermal climates). The tropical climates are found in parts of Manipur, Tripura, Mizoram and the Cachar fields south of 25^{o}N and are classified as tropical damp and dry. Much of Assam, Nagaland, northern parts of Meghalaya and Manipur and parts of Arunachal Pradesh drop inside the warm temperature mesothermal climates (sort C) where the average temperatures in the coldest months are between −3 to 18 °C (27 to 64 °F (Peel *et al*., 2007). The whole Brahmaputra valley includes a muggy subtropical climate (Cfa/Cwa) with hot summers. At heights between 500 to 1,500 m (1,600 to 4,900 ft) found within the eastern slopes of Nagaland, Manipur and Arunachal Pradesh, a (Cfb/CWb) climate wins with warm summers. Areas over 1,500 m (4,900 ft) in Meghalaya, parts of Nagaland and northern Arunachal Pradesh have a (Cfc/Cwf) climate with a cool and short summer.



Map 1. Map of North East India.

Temperature

Temperatures change by elevation with the hottest places being within the Brahmaputra and Barak Waterway fields and the coldest at the highest altitudes (Dikshit & Dikshit, 2014). It is additionally affected by the vicinity to the ocean with the valleys and western regions being near to the ocean, which moderates temperatures. By and large, temperatures within the uneven and hilly zones are lower than in the fields which lie at a lower altitude. Summer temperatures tend to be more uniform than winter temperatures due to tall cloud cover and humidity (Dikshit & Dikshit, 2014).

Within the Brahmaputra and Barak valley stream fields, average winter temperatures shift between 16 and 17 °C (61 and 63 °F) whereas peak summer temperatures are around 28 °C (82 °F). The highest summer temperatures happen within the West Tripura plain with Agartala, the capital of Tripura having the cruel greatest summer temperatures extending between 33 and 35 °C (91 and 95 °F) in April (Dikshit & Dikshit, 2014). The most elevated temperatures in summer happen sometime recently during the entry of storms and in this way, eastern regions have the most noteworthy temperatures in June and July when the storm arrives afterward than western areas. Within the Cachar Plain, found south of the Brahmaputra plain, temperatures are higher than the Brahmaputra plain even though the temperature run is littler owing to higher cloud cover and the rainstorm that direct night temperatures year circular (Dikshit & Dikshit, 2014).

Rainfall

No portion of Northeast India gets less than 1,000 mm (39 in) of precipitation a year. Zones within the Brahmputra valley get 2,000 mm (79 in) of precipitation a year whereas hilly zones get 2,000 to 3,000 mm (79 to 118 in) a year (Dikshit & Dikshit, 2014). The Southwest rainstorm is capable of bringing 90% of the yearly precipitation to the region. April to late October are the months where most of the precipitation in Northeast India happens with June and July being the rainiest months. In most parts of the locale, the normal date of onset of the storms is 1 June. Southern areas are the primary ones to get the storm (May or June) with the

Brahmaputra valley and the hilly north accepting afterward (afterward May or June) (Dikshit & Dikshit, 2014). Within the uneven parts of Mizoram, the closer vicinity to the Narrows of Bengal causes it to involve early storms with June being the wettest season.

Soil

Soils are formed from the withering of rocks due to different catastrophic events that occurred on the crust of the earth. It is a mixture of minerals and organic matter. Geographically Indian soils are categorized into three major groups

(i) Mature soils of Peninsular India (Red, Black and Lateritic soils)

(ii) Alluvial soils of Indo-Gangetic Plains

(iii) Scanty soils of Himalayas

The major types of soil met in Northeast India are;

a) Alluvial soil: This is the most productive type of soil in India, also present in the fringes of Peninsular India. It constitutes a high proportion of clay and is stickier and the texture may vary from sandy loam to clay. Its color varies from grey to reddish-brown. The quantity of potassium is higher in this soil, whereas nitrogen is deficient.

b) Forest soil: Forest soils are found within the sloping and precipitous ranges where adequate rainforests are accessible. The soil's surface changes agreeing to the mountain environment where they are shaped. They are loamy and silty on valley sides and coarse-grained within the upper slants. Within the snow-covered regions of the Himalayas, these soils experience denudation and are acidic with more humus substance. The soils found within the lower parts of the valleys, especially on the waterway porches and alluvial fans are prolific.

c) Black soil: also known as regur soil, dark soil is perfect for developing cotton and is known as dark cotton soil. They are wealthy in soil supplements, such as calcium carbonate, magnesium, potash and lime. These soils are for the most part destitute in phosphoric contents. The dark soils are made up of clayey soil, well known for its capacity to hold dampness. Since of their tall clay substance, dark soils create wide splits amid the dry season, but their iron-rich granular structure makes them safe from wind and water disintegration. They are destitute in humus however exceedingly moisture-retentive, hence reacting well to the water system. Those soils are moreover found on numerous fringe tracts where the fundamental basalt has been moved from its unique area by fluvial forms.

MATERIALS AND METHODS

1. Taxonomic Revision

Literature Survey

Relevant material and information for this study were gathered from various sources, including papers and articles published in scientific publications and books, as well as information retrieval systems and the University library. Electronic sources included the UGC-JCC-Infonet database, JSTOR, Springer link, Wiley, Elsevier, Science Direct, Oxford Journals, Pergamon, Shodhganga, Database of Indian dissertations and Ph.D. Thesis repository, etc. were also utilized. The following are some of the information retrieval systems that were used. International Plant Name Index (www.ipni.org), World Checklist of Selected Plant Families of the Royal Botanic Garden, Kew (apps.kew.org/wcsp), Zingiberaceae Resource Centre (ZRC) of the Royal Botanic Garden, Edinburgh (http://elmer.rbge.org.uk/zrc), Index to American Literature (http://sweetgum.nybg.org/science/iabl), Tropicos (www.tropicos.org) *etc*. Protologues and other scientific articles and books were obtained from the Biodiversity Heritage Library (BHL) (http://www.biodiversitylibrary.org) and botanical literature from the Missouri Botanical Garden Library (http://botanicus.org).

Herbaria Study

Studied the taxa based on the herbarium specimens, including types at various Herbaria like AAU, ASSAM, BK, BSHC, CAL, CALI, CDRI, K, KEP, KKU, LINN, MH, P, RAF, SING and TNS (continuously updated), some from direct visit and the others from the digitized collections at the department. Also, online digitized herbaria like Kew herbarium Catalogue (http://apps.kew.org/herbcat), Natural History Museum (http://www.nhm.ac.uk/ research-curation/scientific-resources/collections/ botanical-collections), the Linneaen Society Herbarium (http://linnean-online.org/linnaean_herbarium.html) and Fairchild Virtual Herbarium Web Portal (http://www.virtualherbarium.

org/vhportal.html) were utilized. The details regarding the herbaria in which the authors like Roscoe, Wallich, etc. had deposited their specimens, were retrieved from the *Taxonomic Literature* (Stafleu & Cowan, 1976−1978). *Index Herbariorum* (Thiers, continuously updated), accessed by http://sweetgum.nybg.org/science/ih, was used to check the acronyms of herbaria.

Specimen Collection

Field trips were conducted to northeastern states of India from July to September for collecting specimens in the flowering stage. The collected plants were preserved for the herbarium, palynology, phytochemistry, molecular and anatomical studies after studying their floral and vegetative morphology. The rhizomes were planted in Calicut University Botanical Garden (CUBG) for further studies and as part of germplasm conservation. The live germplasm of *Zingiber* maintained at CUBG which was collected from different parts of India, was also utilized for the study.

Herbarium Preparation

For the preparation of herbaria, the wet method (De Vogel, 1987; Forman & Bridson, 1998) was followed. The plants collected from the field were trimmed to an appropriate size and placed on old newspaper, then treated with formaldehyde and sealed in polyethylene covers. The specimens were dried in both sunlight and hot air oven at 60 degrees for fast drying and mounted on standard handmade sheets (28 × 42 cm). The sheets were labeled with standard labels (14.5 × 11 cm). These sheets are deposited in CALI.

Nomenclature and Citations

The citations of taxa followed IPNI, for which the online database of the IPNI (http://www.ipni.org) was accessed. Also, World checklist of selected plant families, a database of Royal Botanic Garden, Kew (http://apps.kew.org) was utilized. The citations of publications followed *Botanico-Periodicun-Huntianum* (B-P-H) (Lawrence *et al.,* 1968) and IPNI database. For author citation, IPNI database as well as '*Authors of Plant Name Index*' by Brummitt and Powell (1992) were followed. To obtain details about the authors and publications, *Taxonomic Literature* (Stafleu & Cowan, 1976−1978) was used. Herbarium acronyms used are as per ‘Index Herbariorum’ (Thiers, continuously updated). For Nomenclature and its clarifications, Shenzhen Code (Turland *et al.*, 2018) has been followed.

2. Morphological Study

Descriptions and Illustrations

The floral morphology of the specimens was studied from the field itself. The collected specimens were sealed airtight in polyethylene covers and brought to the laboratory for detailed micromorphological studies. Flowers and fruits were brought preserved in 4% formalin and 50% Formalin-Acetic acid-Alcohol (FAA). Their descriptions were noted in the description chart specifically prepared for the genus *Zingiber* (**Appendix I**) and Photographs were taken with a Nikon D750 Camera. Photomicrographs of smaller parts were taken using a stereo microscope, Leica M80 attached with Leica EC3 camera (Leica Microsystems, Switzerland Ltd.).

The description of each species includes details regarding the morphology of their rhizome, root, leafy shoot, leaves, inflorescence, bract, bracteole, flower, calyx, corolla, labellum, lateral staminodes, stamen, ovary, style, stigma and epigynous glands. For terminology and methodology of measurements, we followed the work of Bai *et al.* (2015a).

Conservation status of each species was carried out based on the IUCN Standards and Petitions Committee 2022.

Identification

Specimens were identified by using previously published papers and articles, local and regional Floras etc. To confirm the identity of the taxa under study, type materials and protologues were utilized.

3. Anatomical Study

The anatomical study included 18 taxa of *Zingiber*. Aerial vegetative parts of the plants were selected for the study, viz., leaf (midrib, lamina & margin) and sheath. The fifth leaf from the apex was taken for the study. The sections were taken from the middle portion of the leaf and sheath **(Fig. 1)**.

Mainly fresh specimens were used for the study. The specimens preserved in 50% FAA were used where fresh specimens were not available. Free hand sections (transverse sections) were taken using a sharp stainless steel razor; sections were stained in safranin, mounted using glycerol and viewed under a microscope. Ground plans of the sections were viewed under a stereomicroscope (Leica M80 attached with Leica EC3 camera). For their microscopic examination, a phase-contrast microscope (Zeiss Lab.A1 attached with Axio CamERc5s Carl Zeiss Microimaging GmbH analyzer) was used. Photomicrographs of the sections were also taken.

4. Palynology

Palynological studies were carried out on pollen grains preserved in 70% ethanol and Acetic acid-Alcohol (FAA). The direct mounting method was adopted since the common acetolysis method was found unsuitable. Before the study, the pollen was washed in 1 ml of 70% alcohol and then centrifuged at 5000 rpm for 5 minutes. The supernatant was removed and sediment was resuspended in 1 ml of 70% alcohol. Pollen grains were directly placed on aluminum stubs using double-sided adhesive tape and sputter-coated with gold using a Hummer VII gold coating apparatus. They were observed and photographed under JEOL Model JSM - 6390LV SEM with different magnifications. The descriptive terminology for the pollen grains by Theilade *et al.* (1993) was followed.

5. Phytochemistry

Sample preparation

Fresh rhizomes of 17 taxa were used for the study. About 1 to 2 gm of fresh rhizomes were chopped and crushed in a headspace glass vial using a glass rod. The crushed samples were preheated at a temperature of 50^0C for releasing the volatile content.

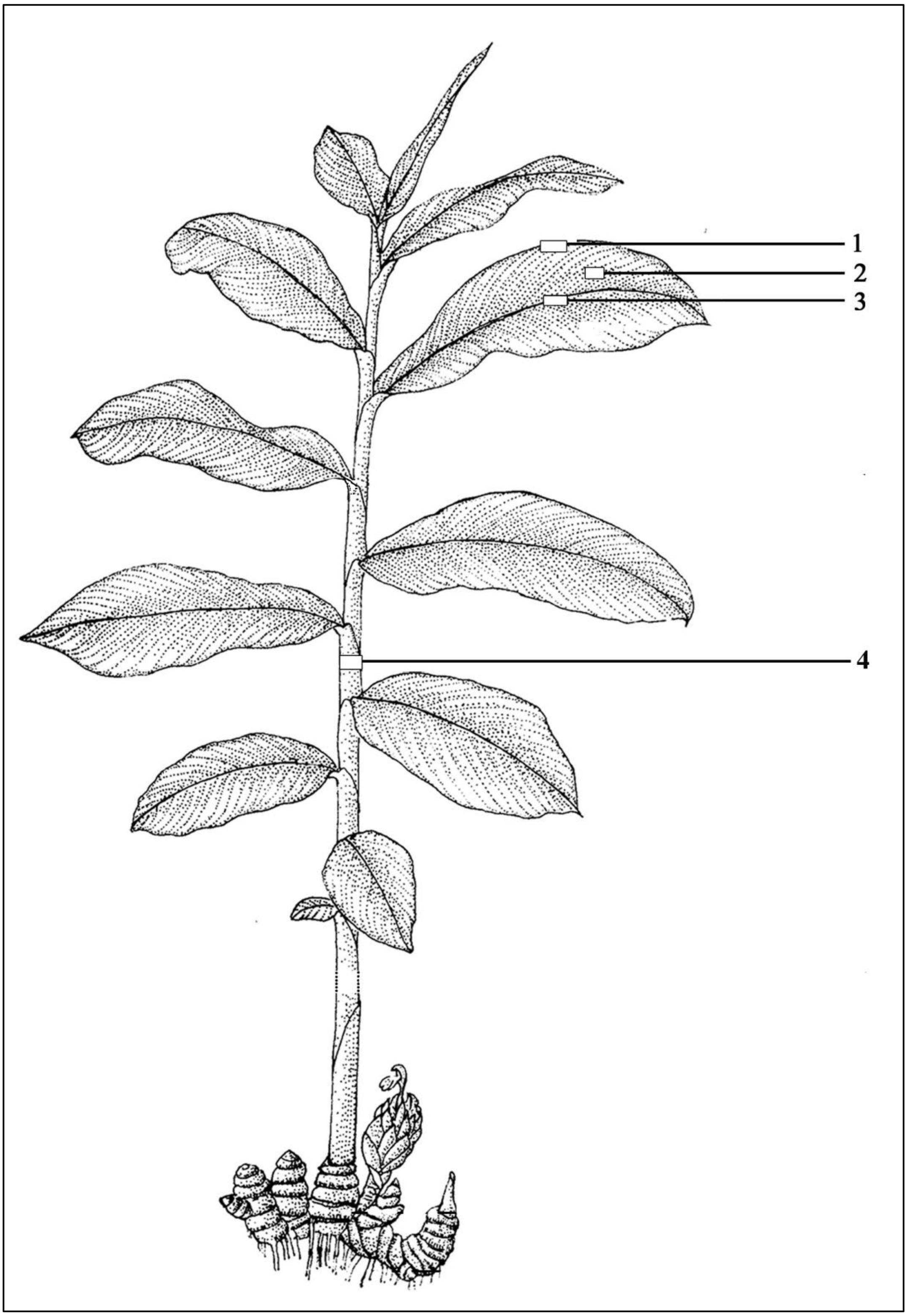


Fig. 1. Diagramatic representation of the portions of various foliar parts taken for anatomical study: 1. Leaf margin; **2.** Lamina; **3.** Midrib; **4.** Sheath.

GC-MS conditions

Gas chromatographic analysis was performed using GC-MS-TQ8030 SHIMADZU. 1µL of the preheated sample was injected onto a GC equipped with an MS and a medium polar capillary column Rxi-5Sil MS, (30m X 0.25mm I. D., 0.25µm), the oven program had an initial temperature of 60^0C for 2 min, increased to 200^0C for 2min at the rate of 5^0C/min followed by the temperature was increased to 220^0C for 1min at the rate of 3^0C/min. Finally, the temperature was increased to 250 at the rate of 6^0C/min for 7min. The total run time was 50 min. The detector temperature and injection temperature was 250^0C, helium is used the carrier gas with purity 99.999% at a flow rate of 1mL/min. The samples were injected in the splitless mode. The ion energy used for the electron impact ionization (EI) mode was 70eV. The mass range scanned was 100-1000 m/z.

Compound identification

The essential chemical constituents were identified by matching mass spectra with spectra of reference compounds in the mass spectral library of NIST and WILEY. The relative amounts of individual components were expressed as percent peak areas relative to the total peak area.

6. Molecular study

DNA sequencing of genus *Zingiber* represented in India was carried out using ITS gene loci. The sequence data were analyzed based on ITS locus. These data were utilized to infer the phylogeny of the genera and also as supportive data to confirm the identity of taxonomically problematic taxa.

Molecular Phylogeny of the genus *Zingiber* in India

A phylogenetic study using DNA sequence data of the genus *Zingiber* in India (including the species selected for the systematic studies) was carried out.

Taxon Sampling

26 species and one variety belonging to the genus *Zingiber* were sampled in the study. *Kaepmferia galanga* and *K. purviflora* were chosen as the out-group. The complete lists of samples are provided in **Table 1**.

Table 1: List of 29 taxa (28+1) of *Zingiber* and two species of *Kaempferia* used for the present phylogenetic analysis based on ITS sequences.

Sl. No.	Species name	Section	Locality	Voucher no.	GenBank accession no.
1.	*Z. neesanum* (J.Graham) Ramamoorthy	*Zingiber*	Mahabaleswar, Maharashtra	150230	Not deposited
2.	*Z. arunachalensis* A.Joe, T.Jayakr., Hareesh & M.Sabu	*Cryptanthium*	West kameng, Arunachal Pradesh	150201	MW251854
3.	*Z. bipinianum* D.K.Roy, D.Verma, Talukdar & Dutta Choud.	*Cryptanthium*	Barapani, Shillong, Meghalaya	130318	MW251853
4.	*Z. campanulatum* T.Jayakr., A.Joe, Hareesh & M.Sabu	*Cryptanthium*	Lower Dibang valley, Arunachal Pradesh	150203	MW251856
5.	*Z. capitatum* Roxb.	*Dymczewiczia*	Barapani, Shillong	95627	KM983536
6.	*Z. chrysanthum* Roscoe	*Cryptanthium*	Phamrong falls, Sikkim	159728	Not deposited
7.	*Z. clarkei* King ex Baker	*Pleuranthesis*	Darjiling, West Bengal	153730	Not deposited in GenBank
8.	*Z. cornigerum* T.Jayakr., A.Joe, Hareesh & M. Sabu	*Cryptanthium*	Lower Dibang valley, Arunachal Pradesh	150204	MW251857
9.	*Z. kangleipakens* Kishor & Jana Leong-Škorničk.	*Cryptanthium*	Barapani, Meghalaya	159501	Not deposited
10.	*Z. kerrii* Craib	*Zingiber*	Churachandpur, Manipur	153782	Not deposited
11.	*Z. ligulatum* Roxb.	*Cryptanthium*	Lumami, Nagaland	105515	KM983543
12.	*Z. meghalayense* Sushil K. Singh, Ram. Kumar & Mood	*Cryptanthium*	Meghalaya	153503	Not deposited
13.	*Z. mizoramensis* Ram.Kumar, Sushil	*Cryptanthium*	Aizawl, Mizoram	153522	Not deposited

	K.Singh & S.Sharma				
14.	*Z. murlenica* Ram.Kumar, Sushil K.Singh & S.Sharma	*Cryptanthium*	Barapani, Meghalaya	153538	Not deposited
15.	*Z. neesanum* (J.Graham) Ramamoorthy	*Zingiber*	Athirapally, Kerala	94840	KJ872228
16.	*Z. neotruncatum* var. *neotruncatum* T.L. Wu, K. Larsen & Turland	*Zingiber*	Tippi, Arunachal Pradesh	150202	Not deposited
17.	*Z. neotruncatum* var. *ramsawmii* Lalramngh., M.Sawmliana, T.Jayakr. & M.Sabu	*Zingiber*	Tamdil, Mizoram	153524	Not deposited
18.	*Z. nimmonii* Dalzell	*Cryptanthium*	Calicut, Kerala	105516	KF304552
19.	*Z. odoriferum* Blume	*Zingiber*	Andaman	94725	KF304555
20.	*Z. officinale* Roscoe	*Zingiber*	Cultivated	BBLZ5G15	KR816713
21.	*Z. parishii* Hook.	*Zingiber*	Thailand	336851	DQ064576
22.	*Z. pherimaiensis* Biseshwori & Bipin	*Cryptanthium*	BSI, Shillong, Meghalaya	150208	Not deposited
23.	*Z. purpureum* Roscoe	*Zingiber*	Pune, Maharashtra	94722	KJ872218
24.	*Z. roseum* (Roxb.) Roscoe	*Cryptanthium*	Ranipool, Sikkim	92705	KJ872271
25.	*Z. rubens* Roxb.	*Cryptanthium*	Mizoram	153523	Not deposited
26.	*Z. wightianum* Thawaites	*Cryptanthium*	Anamalai, India	86178	KM983550
27.	*Z. zerumbet* (L.) Roscoe ex Sm.	*Zingiber*	Nicobar, India	92608	KJ872294
	Genus *kaempferia* (outgroup)				
28.	*K. galanga* L.			97750	KF304538
29.	*K. purviflora* Wall. ex. Baker			97751	DQ064592.1

Fresh leaves of 14 taxa collected from the field were sealed in zip lock polyethylene covers containing silica crystals (Spectrum) and these silica-dried samples were used for the study and ITS sequence of the remaining 16 taxa were downloaded from GenBank.

DNA Isolation

The total genomic DNA was isolated from the fresh leaves using the Cetyl Trimethyl Ammonium Bromide (CTAB) method (Doyle & Doyle, 1987) with minor modifications.

- Crush approximately 1 gm of leaf tissue using mortar and pestle in liquid nitrogen into fine powder.
- Transfer the powder into a 2 ml sterile centrifuge tube.
- Add approximately 1 ml of pre-heated 2X CTAB buffer, 20 µl β-mercaptoethanol, 1 mg polyvinyl pyroledene and mix properly.
- Incubate at 65^0C for 30 minutes up to 1 hr.
- Add an equal volume of Phenol: Chloroform: Isoamyl alcohol (PCI) and shake well, Centrifuge at 10000 rpm for 10 minutes.
- Separate upper aqueous layer in a new centrifuge tube and add an equal volume of Chloroform: Isoamyl alcohol (CI), mix well by inverting the tube.
- Centrifuge at 10000 rpm for 10 minutes, separate upper aqueous layer in a new centrifuge tube.
- Add an equal volume of Isopropanol and keep at -20^0 C for 20-30 minutes.
- Centrifuge at 10,000 rpm for 10 minutes at 4^0 C. Remove supernatant and wash the pellet using 500 µL of 70% ethanol.
- Again centrifuge at 10,000 rpm for 10 minutes at 4^0 C. Remove supernatant and dry the pellet.
- Dissolve the pellet in 50-70 µL of 1 X TE buffer.
- Add 1 µL of RNase and incubate it at 37^0 C for 30 minutes.

Electrophoresis

To check the presence of appropriate bands, the isolated genomic DNA was visualized using 0.8% agarose gel electrophoresis. The agarose gel was prepared using 0.5X TBE (Tris-Borate-EDTA) buffer with 0.5 µg/mL ethidium bromide. 0.5X TBE buffer was used as an electrophoretic buffer. 5 µL DNA was mixed with 1 µL 6x gel-loading buffer (0.25% Bromophenol Blue and 30% Sucrose in TE buffer- pH 8) and each of the samples were loaded to the gel. Electrophoresis was performed at 50 V until the bromophenol dye front migrated to the bottom of the gel. Then the gels were visualized in a UV transilluminator (Bio-Imaging Systems) and the images were captured in a Gel documentation system (Syngene, UK).

Polymerase Chain Reaction (PCR)

The DNA amplification was carried out for ITS, encompassing the ITS1-5.8s-ITS2. The PCR was performed with the primers used in previous studies, *viz.*, ITS (Vinitha *et al.* 2014). The primer sequences, annealing temperature and expected amplicon size of ITS locus used for amplification are listed in **Table 2**. Polymerase Chain Reactions (PCR) were done in 25 µL using GT PCR Master Mix (TAKKARA BIO INC, Seta 3-4-1, Ostu, Shiga 520-2193, Japan), 1 µM of each primer and 1 µL unquantified genomic DNA. The DNA amplifications were performed using Master Cycler (Nexus gradient, Eppendorf, Germany) using a program consisting of an initial denaturing step of 5 min at 95^{o}C followed by 30 cycles of 90 seconds duration, (95^{o} C), 30 sec. annealing (55^{o} C), 30 sec. extension (72^{o} C), ending with final 7-minute extension (72^{o} C) PCR amplification profile is given in **Table 3**.

Table 2. Primer sequence, annealing temperature and expected amplicon size ITS loci used in the study.

Gene	Primer Name	Sequence	Annealing Temperature (°C)	Expected Amplicon Size (bp)
ITS	ITS-F5	AATGGTCCGGTGAAGTGTTC	58	650
	ITS-R2	CTCGCCGTTACTAGGGGAAT		

Table 3. PCR amplification profile

ITS

98^{o}C- 2 min

98^{o}C- 10 sec

58^{o}C- 20 sec　　35 cycles

72^{o}C- 30 sec

72^{o}C- 5 min

4^{o}C- hold

Amplified DNA was visualized on 1.2% agarose gel under a UV transilluminator to check the presence of appropriate bands **(Fig. 97)**. A 100 bp ladder (NEB) was used as the molecular standard.

Agarose Gel Electrophoresis of PCR products

The PCR products were checked in 1.2 % agarose gels prepared in 0.5X TBE buffer containing 0.5 µg/mL Ethidium Bromide. 1 µL of 6X gel loading dye (Himedia) was mixed with each sample and run the gel using Electrophoretic unit (Enduro, Labnet International inclusive) at 75 V power supply with 0.5 X TBE as an electrophoretic buffer for about 1-2 hours until the Bromophenol Blue Dye front had migrated to such an extent ie., Almost at the bottom of the gel. The 100 bp DNA ladder (Invitrogen 100 bp DNA ladder of 0.1 µg/ µL concentration was used to analyze the size of the amplified DNA. Gels were visualized in the UV transilluminator (Biotech R & D Laboratories, Yercaud, Salem, Tamil Nadu) and the particular images were documented using the Gel Documentation system (Enduro GDS, Labnet International Inclusive, aplegen).

Sequencing

Sanger's sequencing using the Big Dye Terminator v3.1; amplified product later on subjected to the Sangers sequencing which was carried out using the PCR thermal cycler (GeneAmp PCR System 9700, Applied Biosystems, USA) followed by manufacturer's instructions.

Table 4. Partculars used for sequencing

Particulars used	**Amount**
PCR Product (ExoSAP treated)	10-20 ng
Primer	3.2 pM (either forward or Reverse)
Sequencing Mix	0.28 µl
DMSO	0.30 µl
5X Reaction buffer	1.86 µl
Sterile distilled water	Makeup to 10 µl

Sequencing PCR was carried out. It consists of the first and foremost denaturation step of 96^{o}C for 2 minutes, followed by 30 cycles of 96^{o} C denaturation for 30 seconds, 50 ^{o} C annealing for 40 seconds and elongation at 60 ^{o} C for 4 minutes.

Procedure for Post Sequencing PCR clean up

The products after sequencing were cleaned up using Master Mix-I, Master Mix-II and 70% ethanol. 12 µl Master Mix-I and 52 µl Master Mix-II were needed for each sequenced reaction product.

Composition of the Master Mix

Master Mix-I - 2 µl of 125 mM EDTA in 10 µl Milli Q Water.

Master Mix-II- 2 µl of 3M Sodium Acetate at pH 4.6 in 50 µl ethanol.

To the 10 µl of each reaction product, 12 µl of Master Mix-I was added. Thoroughly mixed and to this 52 µl of Master Mix-II was added. The contents were mixed by inverting the tubes many times during incubation at room temperature for 30 minutes. After the incubation period, proper centrifugation has been carried out at 14,000 rpm for 20 minutes. Later on, the supernatant was discarded and the 70% ethanol wash was repeated. The supernatants were decanted and 70% of ethanol wash was repeated. After decanting the supernatant, the resultant pellet was kept for air drying. The cleaned air-dried products were sequenced in ABI 3730/3500 Genetic Analyzer (Applied Biosystems) at Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram.

Editing of Sequence and Multiple Sequence Alignment

The quality of the sequence data has been checked using quality value (QV) i,e. a widely accepted and established metric for determining the quality of the standard sequence data. The QV> 20, means the probability that the base was miscalled is not greater than 1%, which is an acceptable standard for a good sequence reaction. All the samples sequenced, showed a QV>20. Thus, practically all samples sequenced could be used for further studies. Forward and Reverse sequences were combined using Bioedit (Hall, 1999) software. Sequences were aligned using Clustal W (Thompson *et al.*, 1994) incorporated within MEGA 11 (Koichiro *et al.*, 2021) software. Alignments were thoroughly checked and manually edited using MEGA 11 software.

BLAST

The similarity of sequences obtained in the present study with those in the database was determined using the Basic Local Alignment Search Tool.

Phylogenetic Analysis

Maximum Likelihood analysis was performed using RAxML version 8: (Stamatakis, 2014) software to get the standard phylogenetic reconstruction of DNA sequence data.

RAxMLGUI 1.5 – Randomized Axelerated Maximum Likelihood

Commonly RAxML (Randomized Axelerated Maximum Likelihood) is regarded as a sequential and parallel Maximum Likelihood based inference program to construct large phylogenetic trees. The analysis started with importing 29 taxa contained 679 characters into the RAxML GUI 1.5 software. Settings had been changed accordingly to the data set: ML + thorough bootstrap was used; the number of replications was set to 1000, bootstrap per branch length was selected, the evolutionary model was set to GTRGAMMA and run the analysis, tree with robust topology was obtained after a couple of minutes with good bootstrap supporting values.

Bayesian analysis using MrBayes version 3.2

The Bayesian analysis was conducted using MrBayes v3.2 (Ronquist, 2003). J ModelTest 2.1.3 (Darriba *et al.,* 2012) was used to determine the most appropriate molecular model for each data set. The models used for ITS was SYM + I + G. Four Markov chain Monte Carlo (MCMC) chains, one cold and three heated, were performed. In order to more fully explore tree space and stationarity of parameters, four MCMC, each of one million generations, starting from different random points in parameter space (Miller *et al.,* 2002; Jordan *et al.,* 2003; Kress *et al.,* 2005), were performed of every 100th cycle from the chain, trees were sampled.

7. UPGMA cluster analysis

Eighteen Indian Zingiber species for 15 anatomical characters were considered for the cluster analysis based on anatomical data and 22 Zingiber species for 7 palynological characters were considered for cluster analysis based on palynological data. PAUP* 10th version software was used for analysis and construction of tree, Unweighed Pair Group Mathod with Arithmetic Mean (UPGMA) method (Optimum criterian = distance; Branch swapping algorithm – Tree Bisection Reconnection (TBR); Bootstrap = 100) was used. The characters were directly convereted to codes using different character states.

CLASSIFICATION

The first reference to the family Zingiberaceae was in ‘*Species Plantarum*’ by Linnaeus (1753). He has described five genera in his Monandria Monogynia which include *Amomum zingiber* L., *A. zerumbet* L., *A. cardamomum* L., *Alpinia racemosa* L., *A. grana-paradisi* L., *Costus arabicus* L., *Curcuma rotunda* L., *C. longa* L., *Kaempferia rotunda* L. and *K. galanga* L. Later, some of these species have been moved to other genera, viz., *Amomum zingiber* to Z*ingiber officinale* Roscoe, *A. zerumbet* to *Zingiber zerumbet* (L.) Smith, *Amomum cardamomum* to *Elettaria cardamomum* (L.) Maton and *Curcuma rotunda* to *Boesenbergia rotunda* (L.) Mansf.

Based on the number of anthers and position of style, Roscoe (1807) divided Monandria Monogynia into two families: Cannae (using the name of Jussieu's tribe) and Scitamineae. Cannae comprised genera such as *Canna, Maranta, Thalia* L., *Phrynium* Willd. and *Myrosma* L.f. *Philydrum* Willd., *Hedychium, Alpinia, Zingiber, Costus, Kaempferia, Amomum, Curcuma* and *Globba* were among the nine genera listed in Scitamineae. Later, in Monandrian Plants of the Order Scitamineae (Roscoe, 1824-1828), he eliminated *Philydrum* and *Myrosma,* which did not even belong in Zingiberales and added *Roscoea, Renealmia* L. and *Hellenia* to Scitamineae.

Roxburgh (1810) placed the monandrous plants of India belonging to the orders Scitamineae (of Linnaeus) and Cannae (of Jussieu) under the class Monandria monogynia and divided them into two based on the number of anthers (ie., anther simple or anther double). *Canna* and *Phrynium* were placed in the group with simple anther and *Kaempferia*, *Curcuma, Amomum, Costus* and *Alpinia* in the group with double anther. He followed the same classification in his subsequent works also, viz., Roxburgh (1814, 1820).

Blume (1827) classified Scitamineae into five sections. The sections were *Zingibera* Blume (which includes *Zingiber*, *Curcuma* & *Kaempferia*), *Amomae*

Blume (which includes *Amomum*, *Elettaria*, *Donacodes* Blume, *Diracodes* Blume & *Hedychium*), *Alpiniae* Blume (which includes *Alpinia*, *Hellenia* and *Cenolophon* Blume), *Costi* Blume (which includes *Costus*) and *Globbeae* Blume (which includes *Globba*) and treated *Canneae* as a distinct section.

Lestibodois (1841) divided the Zingiberaceous taxa into six tribes: Kaempferiees, Hedychiees, Curcumees, Alpinees, Costoidees and Mantisiees, with *Zingiber* placed in the Hedychiees tribe. Duchartre (1849) adopted the same classification.

A more natural classification was proposed by Bentham and Hooker (1862-1883) in their '*Genera Plantarum*,' which contained four tribes under the order Scitamineae. They divided the order Scitamineae into four tribes viz., Canneae (1), Maranteae (ten), Museae (4) and Zingibereae (21). Their classification was chiefly based on floral characteristics such as the degree of fusion of sepals, the number of fertile stamens and satminodes, the number of locules and placentation in the ovary, structure of style and stigma and position of embryo.

Engler and Prantl (1887-1899) elevated Scitamineae, the ordinal level and recognize four families in it which include Zingiberaceae, Marantaceae, Cannaceae and Musaceae.

Baker (1892) in '*Flora of British India'* divided the order Scitamineae into four tribes viz., Zingibereae, Maranteae, Canneae and Museae. In Engler and Prantl's Die Naturlichen Pflanzenfamilien, Petersen (1899) classified the order Scitamineae into four families viz., Zingiberaceae, Marantaceae, Cannaceae and Musaceae. He also divided the Zingiberaceae tribes into three groups: Hedychieae, Zingibereae and Globbeae. In contrast to the tribe Hedychieae, where lateral staminodes are free and highly developed, Zingibereae is distinguished by the absence of lateral staminodes, which are united with the labellum.

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

Loesener (1930) followed the same classification as Schumann in Engler and Prantl's '*Die Naturilichen Pflanzenfamilien*' and he treated *Zingiber* under the tribe Zingibereae. Subfamily Costoideae was elevated to the status of family Costaceae by Nakai (1941).

Holttum (1950) reorganized Schumann's classification of the Zingiberoideae subfamily by separating the genus *Zingiber* from the tribe Zingibereae, renaming it Alpineae and placing the genus *Zingiber* under the tribe Hedychieae and family Zingiberaceae is divided into two subfamilies, Zingiberoideae and Costoideae, with Alpineae, Hedychieae, Globbeae and Zingibereae being the four tribes of Zingiberaceae.

In contrast to Holttum's treatment Burtt and Olatunji (1972) placed the genus *Zingiber* in monogeneric tribe Zingibereae.

Burtt and Smith (1972a) updated Schumann's (1904) classification of the family Zingiberaceae and gave a new infra-familial classification with a key to the genera. They classified the Zingiberaceae family into two subfamilies viz., Costoideae and Zingiberoideae. The absence of lateral staminodes and epigynous glands as well as the absence of aromatic oil cells, characterizes the Costoideae subfamily, whereas distichous leaves, open sheaths, lateral staminodes and epigynous glands characterize Zingiberoideae. Globbeae (4 genera), Zingibereae (1 genus), Hedychieae (16 genera) and Alpinieae are the four tribes under the Zingiberoideae subfamily (24 genera).

All of these Zingiberaceae classifications took into account based on vegetative and floral traits. Despite the changes in the number and composition of families by various authors and Scitamineae's taxonomic position was increased to that of a superorder (Zingiberanae) or an order Zingiberales. The Bentham and Hooker's classifications remain unaltered. It forms a very closely interrelated assemblage of monocotyledonous taxa, probably very distinct from other groups.

Zingiberaceae are classified into four tribes by Larsen *et al.* (1998): Hedychieae Petersen (19 genera), Globbeae Petersen (4 genera), Zingibereae Petersen (1 genus) and Alpinieae Meisn (21 genera).

Based on molecular evidence, Kress *et al.* (2002) proposed a new classification of the Zingiberaceae family, which is adopted in the current treatment. Four subfamilies were identified. The Siphonochiloideae subfamily contains only one tribe, Siphonochileae, which contains only one genus, *Siphonochilus*. *Tamijia* is the only genus in the Tamijioideae subfamily and it belongs to the Tamijieae tribe. There are 21 genera in the Alpinioideae subfamily, divided into two tribes viz., Alpinieae and Riedelieae. *Aframomum*, *Alpinia*, *Amomum*, *Aulotandra*, *Cyphostigma*, *Elettaria*, *Elettariopsis*, *Etlingera*, *Geocharis*, *Geostachis*, *Hornsteditia*, *Leptosolena*, *Paramomum*, *Plagiostachys*, *Renealmia* and *Vanoverberghia* are among the 16 genera in the Alpinieae family whereas *Burbidgea*, *Pleuranthodium*, *Riedelia*, *Siamanthus* and *Siliquamomum* are the five genera in the Riedelieae family. The Zingiberoideae subfamily is divided into two tribes viz., Zingibereae and Globbeae. There are 25 genera in the Zingibereae tribe (*Boesenbergia*, *Camptandra*, *Cautleya*, *Cornukaempferia*, *Curcuma*, *Curcumorpha*, *Distichochlamys*, *Haniffia*, *Haplochorema*, *Hedychium*, *Hitchenia*, *Kaempferia*, *Laosanthus*, *Nanochilus*, *Parakaempferia*, *Pommoreschea*, *Pyrgophyllum*, *Rhynchanthus*, *Roscoea*, *Scaphochlamys*, *Smithatris*, *Stahdiochilus*, *Stahlianthus* and *Zingiber*). The tribe Globbeae with 5 genera (*Gagnepainia*, *Globba*, *Hemiorchis*, *Mantisia* & *Caulokaempferia*).

The classification of Kress *et al.* (2002) was followed by Takano and Nagamasu (2007) and they have added one genus, *Myxochlamys* A. Takano and Nagam. to the tribe Zingiberae.

Both the Angiosperm Phylogeny Group III (APG III, 2009) and the Angiosperm Phylogeny Group IV (APG IV, 2016) systems treated the Zingiberaceae family as one of eight in the Zingiberales order. Although these systems were largely molecular, Tomlinson's (1962, 1969) families can be seen in them. Cannaceae, Costaceae, Heliconiaceae, Lowiaceae, Marantaceae, Musaceae and Strelitziaceae are some of the other Zingiberales family members.

Genus History

The family Zingiberaceae was placed in class 1. 'Monogyna Monandria' by Linnaeus (1753) in his *'Species Plantarum*'. *Amomum zingiber*, *A. zerumbet*, *A. cardamomum*, *A. granaparadisi*, *Costus arabicus*, *Alpinia racemosa*, *Curcuma rotunda*, *Curcuma longa*, *Kaempferia rotunda* and *Kaempferia galanga* were among the plants listed in it. Later, *Amomum zingiber* and *A. zerumbet* was moved to *Zingiber* Mill. as *Zingiber officinale* Roscoe and *Zingiber zerumbet*, respectively.

Zingiber Adans. was incorporated in tribe Zingibeaceae Petersen. by Schumann (1904). Holttum (1950) separated *Zingiber* from the *Alpinia* group and renamed the tribe Alpinieae. He placed *Zingiber* in Hedychieae without modifying the tribe's name for fear of confusion. It was adopted by several authors, including Weisse (1932), Mahanty (1970) and others.

Roxburgh (1810) investigated the genus in India and documented 11 species. Based on the nature of inflorescence he placed them in two sections. Section-1. Spike radical, which comprises *Zingiber officinale* Roscoe, *Z. zerumbet* (L.) Smith, *Z. cassumunar* Roxb., *Z. roseum* (Roxb.) Roscoe, *Z. ligulatum* Roxb., *Z. rubens* Roxb. and *Z. squarrosum* Roxb. Section-2. Spike terminal, includes *Z. capitatum* Roxb. and Z. *marginatum* Roxb.

Baker (1892) described 24 *Zingiber* species from British India and treated them under four sections. Section I. *Cryptanthium* Horan. - Spikes emerge immediately from the rhizome and are small and thick, with a short peduncle (11 species.). *Lampuzium* Horan. (Section II) - Spikes with sheathing scariose bracts developed from the rootstock with more or less erect-extended peduncles (10 species). *Pleuranthesis* Benth. - A sessile spike that emerges through the leafy stem (1 species). *Dymczewiczia* (Horan.) Benth. - Spikes on the apex of the leafy stem (2 species).

Later, Burtt and Smith (1972) renamed Sect. *Lampuzium* Horan. to Sect. *Zingiber* without changing the member taxa because it comprises the type species *Zingiber officinale*, According to Theilade *et al.* (1993), dividing plants into Sections *Zingiber* and *Dymczewiczia* only based on inflorescence habit was insufficient. They discovered that the two Sections had spherical pollen with cerebroid sculpturing in common and that pollen morphology is a more useful criterion for sectional classification than inflorescence behavior.

SYSTEMATIC TREATMENT

Zingiber Mill.

Zingiber Mill. (*nom. et orth. cons*.) Miller, Gard. Dict. Abr., ed. 4, 3: 1545. 1754; Boehm. in Ludwig, Defin. Gen. Pl. 89. 1760; Roxb., Asiat. Res. 11: 345. 1810, Fl. Indica 1: 46. 1820; Dalzell & Gibson, Bombay Fl. 272. 1861; Benth. & Hook.f., Gen. Pl. 3: 646. 1883; Baker in Hook.f., Fl. Brit. India 6: 243. 1892; Trimen, Handb. Fl. Ceylon 4: 256. 1898; K.Schum. in Engler, Pflanzenr. 4 (46): 165. 1904; T.Cooke, Fl. Bombay 2: 733. 1907; C.E.C.Fisch., Rec. Bot. Surv. India 9: 178. 1921, in Gamble, Fl. Madras 8: 1487. 1928; Holttum, Gard. Bull. Singapore 13: 48. 1950; A.S.Rao & D.M.Verma, Bull. Bot. Surv. India 14: 136, 1972; Ramamoorthy in Saldanha & Nicolson, Fl. Hassan Dist. 768. 1976; B.L.Burtt & R.M.Sm. in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 4: 492. 1983; Manilal, Fl. Silent Valley 314. 1988; R.M.Sm., Notes Roy. Bot. Gard. Edinburgh 45: 409. 1988; S.Kumar, Zingiberaceae of Sikkim 66. 2001; M.Sabu, Folia Malaysiana 4(1): 25-52. 2003; M.Sabu, Zingiberaceae and Costaceae of South India, 225-250. 2006; Tripathi & Singh, J. Econ. Taxon. Bot. 30: 526. 2006; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020.

Type species: *Zingiber officinale* Roscoe Trans. Linn. Soc. London 8: 348. 1807

Plants perennial rhizomatous herbs. Rhizome, stoloniferous or clump-forming, thick, fleshy, branched, subterranean, aromatic or nonaromatic, colored usually cream with bluish, purplish or yellowish tinge, 1–2 cm diam., tubers if present fusiform or oval. Leafy shoot, 70–180 cm tall, Leaves 8–24 when flowering, shortly petiolate or subsessile, pulvinate; pseudostem 30–90 cm tall, pubescent or glabrous; basal sheath without blade 2–5 in number, green or purplish green, pubescent or glabrous; ligule short or long, entire or deeply bilobed, 0.5–4 cm long, green or hyaline with reddish tinge, membranous, glabrous or pubescent, apex acute, truncate or round; lamina ovate to narrowly ovate or oblong to elliptic, broad or narrow, 20–45 × 2–15 cm, apex acuminate or acute, base round or cuneate, margins entire or undulate, adaxially dark or light green, pubescent or glabrous, abaxially light green or purplish, pubescent or glabrous, Inflorescence terminal, arising through the leaf sheath or on a separate shoot, 1-4 per plant. Peduncle short or long or absent, eruct or procumbent, clothed with leafless sheaths. Spikes short or long, ovoid or cylindrical, half immersed in soil or completely exposed, growth racemose type. Bracts persistent, 5–8× 0.8–3 cm, fleshy, loosely or closely imbricating, variously colored usually green, red, brown or purplish rarely yellow, with a membranous hyaline margin, pubescent or glabrous, enclosing a single flower. Bracteoles persistent, shorter than or as long as bract, split up to the base, apex rarely bifid, creamy white, brown or greenish, pubescent or glabrous. Calyx tubular, tip 2 or 3-toothed, shorter than the bracteole, hyaline, membranous, pubescent or glabrous. Corolla tube cylindrical, tubular, longer than or as long as the bract, white, creamy white or yellow, glabrous; dorsal corolla lobe broader than and longer than the lateral lobes, 2–3 × 1–1.2 cm, narrowly ovate, narrowed to the tip and edges inflexed, tip curved, white, yellow or cream with reddish or purplish tinge; lateral lobes narrowly ovate, situated just below the labellum, joined together partly by their adjacent sides and to the labellum, white, yellow cream, cream with reddish or purplish tinge. Labellum 3-lobed, ovate or obovate, 2–3 × 0.5–1 cm, margin crisped or entire, recurved or emarginate, apex notched or acute or round, lateral staminodes fused with the midlobe, fusion may be total, $^{1}/_{3}$ or $^{1}/_{2}$ of the lateral staminode, 0.2–2.3 cm long, erect on either side of the stamen, white, yellow, cream or purple sometimes spotted with yellow, purple or yellow, mid lobe equal or shorter than lateral corolla lobes, variously colored usually white, cream, yellow or purple etc., may be unspotted or white, purple, yellow, cream or sometimes deeply purple spotted. Filament short or highly reduced, c. 1mm, broad, anther 0.5–1 cm long, connective prolonged into a slender, curved crest, enclosing the upper part of the style. Stigma ciliate, cup-shaped, project below the apex of the crest. Epigynous glands two, linear, shorter or as long as ovary. Ovary cylindrical, 0.4–1 cm long, hairy or glabrous, cream or cream with purple tinge, 3-locular with many ovules on axile placenta. Fruit a capsule, 2–4 × 1–1.8 cm, fleshy when fresh, leathery when dry, enclosed within persistent bract and bracteole, dehiscing loculicidally. Fruit turns to dark red at maturity. Seeds many, ellipsoid, arillate, aril black or dark brown.

Distribution**:** India, Malaysia, Queensland, New Guinea, Thailand, Borneo, Kampuchea, Cambodia, Japan, East Indies, Java, Laos, Philippines, China, Sri Lanka, Bangladesh etc.

Phenology**:** July to December. The flowering period is very short and usually associated with the rainy season. Plants with white and cream-colored flowers open in the evening and last for 12 hrs., whereas the rest produce flowers in the morning.

Habitat & Ecology**:** Grows in moist shady evergreen, semi-evergreen and mixed deciduous forests; even in margins of the road, cultivation fields, margins of streams and disturbed forest margins. They prefer black humus-rich soil with leaf mulch for better growth. Plants are also observed in sandy loam and clayey soil. The altitude preference ranges from 100 m to 1500 m; no plants were observed above 1500 m altitude. The plants are usually found associated with other Zingiberaceae members, Musaceae members, Urticaceae members and Poaceae members.

Notes**:** *Amomum, Hedychium* and Z*ingiber* look similar in the vegetative stage but the fleshy leafy shoot of *Zingiber* makes it distinct from *Amomum* and *Hedychium* which are characterized by the hard woody leafy shoot. *Zingiber* is characterized by a swollen pulvinus at the base of the petiole. Anatomically the pulvinus is characterized by a bundle sheath made up of collenchyma tissue (Tomlinson, 1956; Jayasree, 2007) whereas, in the other genera of Zingiberaceae, the bundle sheaths are sclerenchymatous. The present phylogenetic analysis based on ITS shows that the genus can be sub-divided into three major groups which correspond to the previously proposed sectional classification. Three sections recognised in the present study are Sect. *Pleuranthesis*, Sect. *Zingiber* and Sect. *Cryptantium*. The present study also supports the amalgamation of Sect. *Dymczewiczia* in Sect. *Zingiber* as previously proposed by Theilade *et al*. (1993) and Theerakulpisut *et al*. (2012).

Infrageneric Classification

Based on the nature of inflorescence, four infrageneric sections are recognized in the genus *Zingiber* (1) *Z.* Sect. *Cryptanthium* Horaninow (1862), having a radical inflorescence with procumbent peduncle; (2) Z. Sect. *Zingiber* with long erect peduncle; (3) Z. Sect. *Pleuranthesis* Benth. (Benth. & Hook.f., 1883) characterized by a spike emerging through the leaf sheath and (4) Z. Sect. *Dymczewiczia* with a terminal inflorescence (Benth. & Hook.f., 1883). The present phylogenetic analysis using ITS region does not support the sectional status of sect. *Dymczewiczia* as proposed by Theilade *et al.* (1993) the inflorescence character alone was not satisfactory to treat sect. *Zingiber* and Sect. *Dymczewiczia* as distinct sections. They both share spherical pollen with cerebroid sculpturing and they suggested that pollen morphology can use as a clearer criterion for sectional classification instead of inflorescence habit. A previous phylogenetic study by Theerakulpisut *et al*. (2012) also strongly suggests the amalgamation of Sect. *Zingiber* and Sect. *Dymczewiczia*. Hence based on the present study and previous studies the Sect. *Dymczewiczia* is merged with Sect. *Zingiber*.

Key to the genus *Zingiber* in North East India

1. Inflorescence emerging through the leaf sheath .... **8. *Z. clarkei***

1. Inflorescence terminal or developing from the rootstalk 2

2. Peduncle very short or absent 3

2. Peduncle present 5

3. Bracts obovate with broad transparent membranous margin .... **16. *Z. marginatum***

3. Bracts ovate to narrowly ovate with a narrow membranous margin.................... 4

4. Labellum yellow, unspotted, apex bilobed or notched lamina linear, spike bright green .... **5. *Z. capitatum***

4. Labellum creamy yellow with maroon spots, apex trilobed lamina broad, spike yellow. ....**11. *Z. flavofusiforme***

5. Spike on procumbent peduncle 6

5. Spike on erect peduncle.. 20

6. Rhizome stoloniferous.. 7

6. Rhizome clump-forming 11

7. Labellum white, pink or purple blotched 8

7. Labellum white, yellow and red blotched 9

8. Bracteole apex acuminate, lateral staminodes free from labellum.................... 10

8. Bracteole apex bifid or horned, lateral staminodes adnate to labellum..................
.... **9. *Z. cornigerum***

9. Ligule 3–4 cm long, hyaline, lanceolate…................................. **15. *Z. ligulatum***

9. Ligule 1–2 cm long, green, narrowly ovate.....................................**26. *Z. roseum***

10. Bracts apex caudate .... **6. *Z. caudatum***

10. Bracts apex acuminate.. **2. *Z. bipinianum***

11. Corolla lobes, yellow or cream or cream with reddish tinge at middle and apex ..
....16

11. Corolla lobes, cream with pinkish tinge at middle and apex............................. 12

12. Bracts loosely imbricate. 14

12. Bracts closely imbricate 13

13. Lamina oblong-lanceolate, bracts red, calyx tridentate......... **19. *Z. mizoramensis***

13. Lamina elliptic- lanceolate, bracts creamy white, purple at apex and margin calyx bidentate,... **10. *Z. dimapurense***

14. Bracts linear 15

14. Bracts obovate. .... **24. *Z. pherimaense***

15. Lateral staminodes cream with red spots...................................**3. *Z. callianthum***

15. Lateral stamindoes bright yellow unspotted......................... **17. *Z. meghalayense***

16. Labellum bright yellow unspotted... 17

16. Labellum cream, purple or red spotted.. 18

17. Bracts pale green, apex acuminate, twisted, reflexed, labellum, apex notched, lateral staminode 1–1.5 cm long.. **7. *Z. chrysanthum***

17. Bracts green, purplish tinged, apex cuspidate, reflexed, labellum, apex round, lateral staminode 1mm long .... **13. *Z. kangleipakense***

18. Rhizome internally creamy yellow with bluish tinge in some areas and outer pinkish circle mouth of the flower bell– shaped .... **4. *Z. campanulatum***

18. Rhizome internally cream or brownish, mouth of the flower tubular... 19

19. Lateral staminodes free, 1–1.5 cm long.. 20

19. Lateral staminodes adnate, 1–1.5 mm long... 21

20. Corolla lobes cream.. **1. *Z. arunachalensis***

20. Corolla lobes red.. **17. *Z. mekongense***

21. Bracts dull red, acute at apex, lateral staminode yellow .... **27. *Z. rubens***

21. Bracts pinkish green, acuminate at apex, reflexed, lateral staminode purple spotted...**20. *Z. murlenica***

22. Labellum white or pale yellow unspotted 24

22. Labellum dark maroon or reddish black with yellow spots 23

23. Leaves 1–3 cm thick, narrowly ovate, labellum dark maroon with yellow Spots .... **23. *Z. officinale***

23. Leaves 6–7 cm thick, lanceolate or oblanceolate labellum reddish black with yellow spots.. **12. *Z. intermedium***

24. Bracts greenish brown with reddish at base .... **25. *Z. purpureum***

24. Bracts bright red or green turn dark red at maturity.. 25

25. Peduncle 5–13 cm long, leaves linear, narrowly ovate, bract acute at apex 26

25. Peduncle 20–50 cm long, leaves broad, lanceolate , bract round at apex.. .... **28. *Z. zerumbet***

26. Lateral staminodes free from labellum, linear bracts with reddish spot at apex ... .**14. *Z. kerrii***

26. Lateral staminodes adnate to labellum, obovate, bracts light green or bright red.. 27

27. Bracteoles and corolla lobes with reddish tinge at apex, bracts bright red .... **21. *Z. neotruncatum* var. *ramsawmii***

27. Bracteoles and corolla lobes are creamy white, bracts light Green....................... .... **22. *Z. neotruncatum* var. *neotruncatum***

1. *Zingiber arunachalensis* A. Joe, T.Jayakr., Hareesh & M.Sabu, Phytotaxa 309 (1): 095. 2017; S.K.Singh & S.K.Srivast. in A.A. Mao & S.S. Dash, Fl. Pl. India

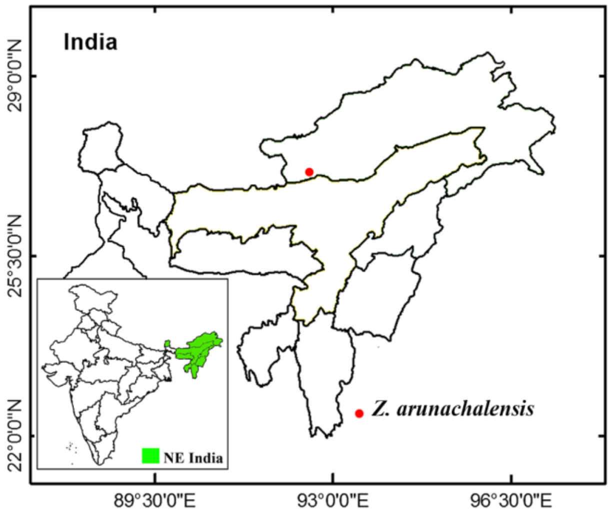
Annot. Checkl. Monocot. 133. 2020; U. Shankar, Eco. Patt. Assem. Veg. Fl. Nor. Re. Ind. 1: 152. 2021. ***Type***: **India, Arunachal Pradesh,** West Kameng District, Durga Mandir, on the way to Bomdilla from Balukpong, 774 m, 30 June 2015, *A.Joe & V.S.Hareesh 121844* (holo CALI; iso CAL). **Fig. 2**

Perennial, non-stoloniferous, clump forming, rhizomatous herbs, not spreading by running rhizomes. Rhizomes fleshy, not so much branched, roots thick, long, externally light to dark brown, internally cream with an inner white circle, tubers absent. Leafy shoots 70–145 cm tall, pseudostem 40–50 cm tall, green, glabrous, hairy towards leaves, basal sheaths with pale purple coloration, glabrous. Leaves 3–7 nos. when flowering, subsessile, pulvinate. Lamina ovate-lanceolate, 26–32.5 × 13.4–14 cm, adaxially green, glabrous, abaxially light green, slightly tomentose, base cuneate, apex acuminate, margin wavy. Ligules 5–6 mm long, bi-lobed, pubescent, light green, apex truncate. Inflorescences one to four, 1–2 flowers open at a time, radical, spicate, 11–17 cm long, peduncle 4.5–8 cm long, glabrous, green, covered with purple sterile bracts. Spikes narrowly ovate, fertile bracts narrowly ovate, closely imbricating, 4.5–7 × 1.5–2 cm, lower ones bigger than upper one, ovate, 4.5–6 × 3.5–4.5 cm, apex acuminate, inner glabrous and shiny, outer hairy, purplish or purplish with green base or light green with purplish tinge, enclosing a single flower. Bracteoles linear-lanceolate, 4–4.5 × 0.8–1 cm, cream with a purple tinge at apex, sparsely pubescent externally, glabrous internally, apex acute. Flowers 7.8–9.4 cm long. Calyx tubular with a unilateral split, 2–2.5 × 0.8–1 cm creamy white, externally pubescent, internally glabrous, apex tri-lobed. Floral tube 4.5–5.3 × c. 0.3 cm, glabrous, cream, apex creamy yellow; dorsal corolla lobe narrowly ovate, 3.5–3.8 × 0.9–1.3 cm, concave, acuminate at apex, glabrous internally and externally, creamy with translucent veins; lateral corolla lobes narrowly ovate, 2–2.7 × 0.3–0.4 cm, cream with slight yellow or orange tinge and with translucent veins, glabrous on both sides, acute or acuminate at apex, incurved soon after opening of flower. Labellum ovate, 2–2.5 × 1.2–1.4 cm, deep violet-purple or purple with creamy yellow base and some cream dots towards the centre and line at periphery, apex acute, margin slightly recurved, crispy. Lateral staminodes oval, 9–14 × 3–4 mm, apex acute, free from labellum, apex purple with some cream dots, base cream or cream with yellow tinge, curved inwards. Stamen 2.4–2.8 cm long, filament 5–10 mm long, anther thecae 1–1.2 × 0.3–0.4 cm, cream, connective tissue glabrous, cream, anther crest (beak) 1–1.2 cm long, deep violet-purple, wrapped around stigma, glabrous. Style filiform, glabrous, white. Stigma cup-like, ostiole ciliate. Ovary cylindrical, 0.7–0.9 × 0.3 cm, cream, densely pubescent, trilocular with axile placentation. Epigynous glands same or much longer than the ovary, 0.8–1.6 cm long, apex pointed, cream. Fruit not seen.

***Distribution*: Currently known only from West Kameng District, Durga Mandir, on the way to Bomdilla from Balukpong (**Map 2**).

Phenology: June to October.

Etymology: The specific epithet ‘arunachalensis’ refer to the name of the state from where the species was described.



Map 2. Distribution of *Z. arunachalensis*.

Habitat & Ecology: *Z. arunachalensis* is known only from Durga Mandir, on the way to Bomdilla from Balukpong, West Kameng district of Arunachal Pradesh. The plants are growing in the understorey of evergreen forests at an elevation ranging from 700–800 m in association with *Musa arunachalensis*, *M. velutina* subsp. *markkuana* etc.

IUCN status: As the occurrence of this taxon is found in highly restricted in 1–2 km^2 area, the species is likely to fall within a category of threat. Probable threat to its existence in this locality is due to widening of the roads and other developmental activities, which may lead to the loss of its natural habitat. Thus, based on the present knowledge and available data, conservation status is assessed as Critically Endangered (CR) (IUCN criteria: CR Ba; C2b).

Fig. 2. ***Zingiber arunachalensis***. A.Joe, T.Jayakr., Hareesh & M.Sabu. **A.** habit; **B.** rhizome; **C.** portion showing leaf bases and ligules; **D.** basal part of plant showing inflorescences; **E.–F.** flower lateral and front view and showing the variations in labellum color pattern; **G.** single flower; **H.** flower close-up; **I.–J.** bract showing variations in color pattern; **K.** bracteole; **L.** ovary with epigynous glands and basal portion of style; **M.** corolla lobes; **N.** labellum with lateral staminodes; **O.** stamen with style & stigma.

***Notes*:** Z. *arunachalensis* shows affinity towards *Z. bipinianum* but differs from latter in having non-stoloniferous rhizomes, purple lateral staminodes with creamy spots and deep purple anther crests. It also resembles *Z. mizoramensis* but is distinct from it in having purplish-red, narrowly ovate spikes with 6.5–8.0 cm long peduncles, narrowly ovate bracts with acuminate apices, creamy yellow corolla lobes and free, ovate lateral staminodes with acute apices.

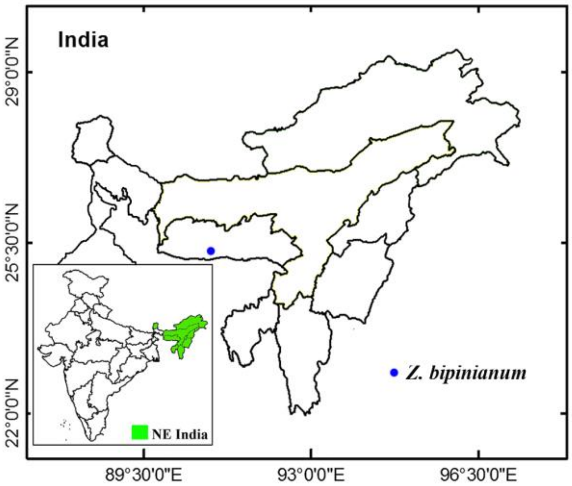
***Specimens examined*:** **India**, **Arunachal Pradesh**, West Kameng District, Durga Mandir, On the way to Bomdilla from Balukpong, 774 m, 14 July 2016, *T. Jayakrishnan & Nikhil Krishna 150201* (CALI); *Ibid.*, 26 August 2017, *Nikhil Krishna 153547* (CALI).

2. *Zingiber bipinianum* D.K.Roy, D.Verma, Talukdar & Dutta Choud., J. Jpn. Bot. 90: 298. 2015; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. Nor. Re. Ind. 1: 152. 2021. ***Type***: **India**, **Meghalaya**, South Garo Hills District, Balpakram National Park, Hatisia Beat, Teptepa, 25°13’21.23’’N 90°54’27.24’’E, 257 m, 11 June 2014, *D. K. Roy130318* (holo ASSAM). **Fig. 3**

Perennial, stoloniferous rhizomatous herbs. Rhizome thin, not so much branched, externally creamy white with brown tinge, internally creamy white or translucent white with an outer brown circle, 1–1.2 cm in diameter; roots thin, long, tubers absent. Leafy shoots 50–70 cm tall. Leaves 6–10 nos. when flowering; pseudostem 30–50 cm long, purplish green sparsely pubescent; basal sheaths 3–4 in number, purplish towards the base, green towards apex, glabrous or sparsely pubescent; ligules 4–5 mm long, bi-fid, divided at base, green with purplish tinge, glabrous margin ciliated, triangular, apex acute; petiole villous, 0.3–0.5 cm long, pulvinate; laminae elliptic to narrowly ovate, 15–25 × 6–10 cm, adaxially green, glabrous or sparsely pubescent, abaxially light green with purple tinge at midrib, villous, base rounded, apex acuminate, margin entire. Inflorescence one to three, one to two flower at a time, radical spicate, 5–7 × 2–2.5 cm; peduncle 5–6 × 0.7–0.8 cm, fully immersed in soil, covered with closely imbricating cream sterile bracts with purple tinge at apex; spikes narrowly ovate; sterile bracts ovate, purple, inner

Fig. **3**. ***Zingiber bipinianum*** D.K. Roy, D. Verma, Talukdar & Dutta Choud. **A.** habit; **B. & C.** flower side & front view; **D.** inflorescence with flower; **E.** rhizome; **F.** ligule; **G.** C. S. of rhizome; **H.** single flower; **I.** bract; **J.** bracteole; **K.** calyx; **L.** corolla lobes; **M.** labellum adaxial & abaxial view; **N.** stamen side & front view; **O.** ovary with epigynous glands.

glabrous and shiny, outer glabrous or sparsely pubescent, acuminate; fertile bracts enclosing a single flower, closely imbricating, narrowly ovate, 4–4.5 × 1.2–1.5 cm, purple with cream at base, apex acuminate; bracteoles narrowly ovate, 2.5–2.7 × 0.4–0.5 cm, creamy white with purple tinge at apex, apex acute, inner glabrous and shiny, outer pubescent at base, apex acute. Flowers 6–7 cm long; calyx 1.4–1.6 × 0.7–1 cm long, tubular with unilateral split, translucent white, apex bi-lobed, glabrous; floral tube 4–5 cm long, white, glabrous; dorsal corolla lobe triangular or narrowly ovate, 2.5–2.7 × 0.6–0.8 cm, creamy white, glabrous both internally and externally, apex acute; lateral corolla lobes narrowly ovate, 2–2.2 × 0.4–0.5 cm, creamy white, glabrous both internally and externally, incurved soon after opening of flower; labellum elliptic, 2.5–2.7 × 0.9–1 cm, purple and creamy white blotched, apex acute margin slightly recurved, glabrous; lateral staminode triangular or narrowly ovate, 1.6–1.7 × c. 0.2 cm, free from labellum, creamy white, apex acute. Stamen 2.3–2.6 × c. 0.2–0.3 cm; filament c. 1 mm long, connective tissue glabrous, creamy white; anther thecae size 1–1.2 × 0.2–0.3 cm, cream; anther crest 1.3–1.4 × c. 0.1 cm long, creamy white, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-shaped; ostiole ciliate. Ovary cylindrical, cream with purple spots and lines, 0.7–0.8 × 0.3–0.4 cm, trilocular with axile placentation, pubescent; epigynous glands two, creamy white, c. 0.4 cm long, linear. Fruit not found.



Map 3. Distribution of *Z. bipinianum*.

Distribution: Currently known only from the type locality (**Map 3**).

Phenology: Flowers June to July.

Etymology: The specific epithet is in honor of Dr. Bipin Kumar Sinha, Scientist, Industrial Section, Indian Museum and Botanical Survey of India.

IUCN status: Known from a single collection, hence its conservation status remains Data Deficient (DD).

Notes: *Z. bipinianum* is unique in having broadly ovate to ovate-lanceolate purple bracts, bi-dentate calyx, linear-lanceolate, free lateral staminodes and creamy-white with the purple blotched labellum, which distinguishes it from all allied species. But this species shows a close relationship with *Z. roseum* (Roxb.) Roscoe and *Z. meghalayense*. We couldn't get any data regarding the local use and vernacular name of the taxon from the local people.

Specimen examined: **India, Meghalaya,** Shillong, Botanical survey of India experimental garden, 09 July 2017, *Jayakrishnan 153509* (CALI).

3. Zingiber callianthum ut "*callianthus*" Triboun & K. Larsen in Triboun *et al.*, Thai J. Bot. 6: 59. 2014; Tanaka *et al.*, Thai J. Bot. 13: 55. 2021. **Type**: **Thailand**, Tak, Mae Ramad, montane forest, alt. 800–1,200 m, 15 July 2002, *P.Triboun 3344* (holo BK; iso AAU!, KKU). **Fig. 4**

Perennial, non stoloniferous rhizomatous herbs. Rhizome light purple internally. Leafy shoots 1–12 m tall, leaves 10–13 numbers. when flowering; basal sheaths 3–5 in number, maroon; ligules bilobed, 5–8 mm long, green, sometimes pale red on the lower leaves, glabrous or pubescent, obtuse or acuminate; petiole 1–2 cm long, green, pilose (on young leaves) to glabrous, pulvinate; laminae oblong or ovate-lanceolate, 45–50 × 10–18 cm, slightly plicate, green on both surface, younger leaves are maroon on lower surface, glabrous or slightly pubescent on the upper surface, glabrous and pubescent near the midrib in lower surface, base attenuate or cuneate, apex acuminate, margin entire. Inflorescence one to five, 1–2 flowers at a time, radical spicate, 7–10 cm long; peduncle procumbent with inflated sheathing bract 8–15 cm long, pink to red; spikes consisting of 12–15 loosely imbricating floral bracts; bracts linear, 5.5–6.5 × 1.3–1.5 cm, cream or red, apex acute, glabrous internally and sparsely pubescent externally; bracteoles linear, 4–4.7 × 1.2–1.4 cm, slightly convolute, pale red, pubescent internally and externally, apex acute. Flowers 6.5–8 cm long; calyx tubular with unilateral split, c. 2.5 cm long, pale pink, apex tri-lobed, outer pubescent, inner glabrous; floral tube 5.3–5.5 cm long, glabrous or

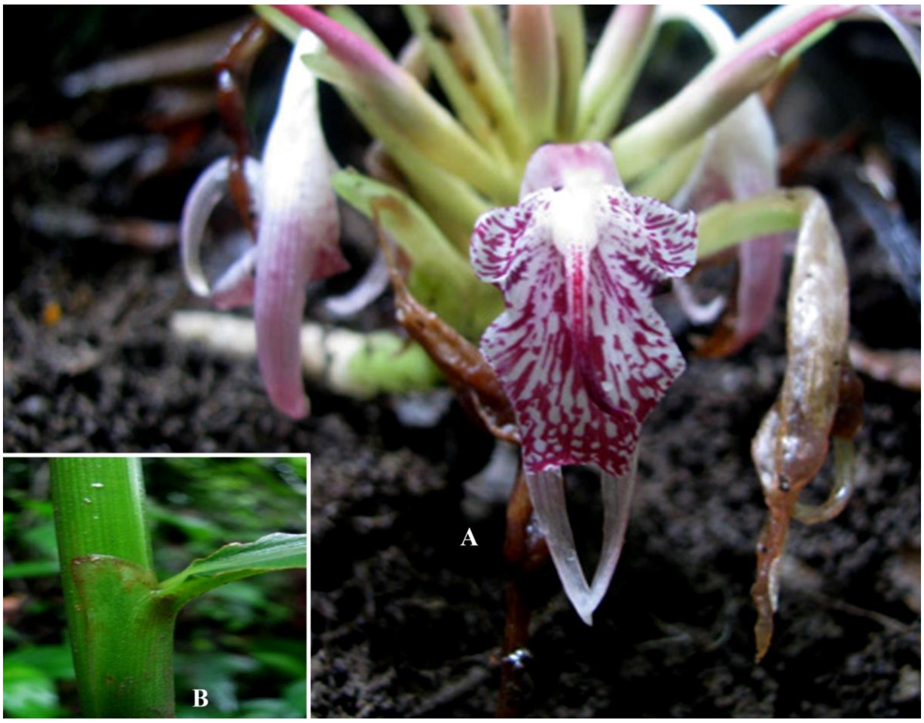
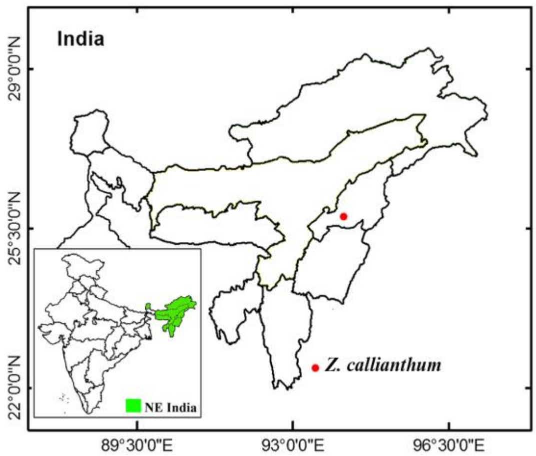


Fig. 4. ***Zingiber callianthum*** Triboun & K. Larsen. **A.** Inflorescence showing open bracts and flowers; **B.** a portion of leaf base showing ligule (**Photos by Tanaka.**).

sparsely pubescent, white; dorsal corolla lobe narrowly ovate, 3.4–3.6 × 1.3–1.5 cm, pale pink with translucent veins, acuminate at apex; lateral corolla lobes narrowly ovate, 2.8–3.2 × 0.8–1 cm, pale pink with translucent veins, apex acute, incurved soon after opening of flower; labellum 1.8–2.0 × 2.3–2.5 cm, cream with red molted, apex truncate, emarginated; lateral staminodes, 7–11 × 4–6 mm, 3/4th adnate to labellum, cream with red molted, apex rounded. Stamen 1.8–2 × 0.3–0.4 cm; filament reduced to c. 4 mm long, connective tissue glabrous, pale pink; anther crest (beak) 1–1.5 cm long, red, wrapped around the stigma, glabrous. Style filiform, white, stigma cup-shaped, ostiole ciliate ovary cylindrical, cream, c. 1 × 0.3 cm, trilocular with axile placentation, villous; epigynous glands two, linear. Fruit unknown. **(Taken from protologue)**



Map 4. Distribution of *Z. callianthum*.

***Distribution*:** In India known from Nagaland. Native to Thailand and known from Myanmar (**Map 4**).

***Phenology*:** Flowers from July to August, opening at 11 am and senescing at 3 am. Fruiting unknown.

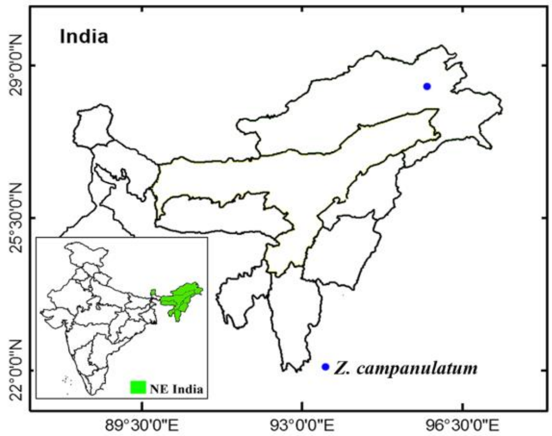
***Habitat & Ecology*:** The plants are growing in wet moist place along the stream of degraded secondary moist deciduous forest in association with *Begonia* sp. (Begoniaceae), *Elatostema* sp. (Urticaceae) and *Strobilanthes* sp. (Acanthaceae) etc.

***IUCN status*:** Data deficient (DD)

***Notes*:** *Z. callianthum* was first reported from Thailand by Triboun and K. Larsen as *Z. callianthus* later Triboun changed the specific epithet to 'callianthum'. The plants are characterized by loosely imbricating or open bracts with visible inflorescence rachis. Recently this plant was reported from Myanmar by Tanaka (2021), later Dey and Tanaka (2022) reported this plant from Nagaland as a new distributional record to India. According to Tanaka in Indian plants, the bracts are more greenish and the ligule lobes are ovate, whereas in Tai and Myanmar plants the bracts and labellum are more reddish and the ligule is ensiform, but both these characteristics fall within the range of variation. Unfortunately, we could not collect this plant during our study and the information mentioned here is taken mostly from the protologue.

4. *Zingiber campanulatum* T.Jayakr, A.Joe, Hareesh & M.Sabu, Taiwania 66(1): 109. 2021. ***Type***: **India**, **Arunachal Pradesh**, Lower Dibang Valley District, near Chidu, 20 km from Roing to Chidu, 300–400 m, 18 July 2016, *T. Jayakrishnan & Nikhil Krishna 150203* (holo CALI; iso CAL). **Fig. 5**

Perennial, nonstoloniferous rhizomatous herbs. Rhizome fleshy, not so much branched, externally light brown, internally creamy yellow with bluish tinge in some areas and an outer pinkish circle, 1.5–2 cm in diameter; roots thick, long, tubers 4–6 × 3–3.5 cm, cream, fusiform. Leafy shoots 80–175 cm tall, leaves 8–14 nos. when flowering; pseudostem 60–90 cm long, green sparsely pubescent; basal sheaths 3–5 in number, purplish towards the apex, green towards base, glabrous or sparsely pubescent; ligules 5–8 mm long, green with purplish tinge at apex, pubescent, apex truncate; petiole subsessile, pulvinate; laminae oblong, 29–35 × 9.5–10.5 cm, adaxially green, glabrous, abaxially light green with purplish tinge, sparsely pubescent, base cuneate, apex acuminate, margin entire. Inflorescence one to three, 1–2 flowers at a time, radical spicate, 7.5–25 cm long; peduncle with inflated sheathing bract 6–13 × 1–2 cm, creamy white, covered with cream sterile bracts with purplish tinge at apex and margin; spikes ovate; fertile bracts narrowly obovate, 4–5 × 1.5–1.7 cm, purplish towards apex and margin with creamy center and base, apex acute, pubescent internally and glabrous externally; sterile bracts larger than upper one, enclosing a single flower, widely ovate; bracteoles triangular to narrowly ovate, 3–4 × 1–1.3 cm, cream with purplish tinge at apex, glabrous internally and externally, apex acute. Flowers 6–8 cm long; calyx 1.5–1.7 × 0.8–1 cm, tubular with unilateral split, white, apex tri-lobed, outer pubescent, inner glabrous; floral tube 5–5.3 cm long, glabrous, creamy white, apex creamy yellow; dorsal corolla lobe ovate-narrowly ovate, concave, 3–3.5 × 1–1.2 cm, creamy with translucent veins, externally pubescent, internally glabrous, acuminate at apex; lateral corolla bell-shaped; labellum, elliptic, 2.3–2.5 × 1.5–1.9 cm, deep purple with creamy yellow base, creamy lines towards the center and creamy dots at the periphery, apex round; lateral staminodes ovate, 1.25–1.3 × 0.5–0.7 cm, $^{3}/_{4}{}^{th}$ portion adnate with labellum, cream with pinkish dots and lines, base creamy white, apex truncate. Stamen 3–3.4 × 0.5–0.6 cm; filament reduced to c. 1 mm long, connective tissue glabrous, creamy yellow; anther thecae 1.5–1.8 × 0.25–0.3 cm; anther crest (beak) 1–1.5 cm long, deep purple, wrapped around the stigma, glabrous. Style filiform, white, lobes triangular, 2.4–2.6 × 1–1.2 cm, creamy or creamy yellow with translucent veins, outer hairy, inner glabrous, apex acute, incurved soon after opening of flower; mouth of the flower stigma cup-shaped, ostiole ciliate. Ovary cylindrical, 0.6–0.7 × c. 0.5 cm, cream, trilocular with axile placentation, densely pubescent; epigynous glands same as the length of ovary, cream, 0.7–0.8 cm long, linear. Fruit capsule, reddish white, 4–5 × 2–2.5 cm, trilocular, glabrous, calyx and base of corolla tube persistent, bract and bracteole persistent. Seeds 5–6 × c. 3 mm, white when young, arillate, 8–10 nos. in a locule.



Map 5. Distribution of *Z. campanulatum*.

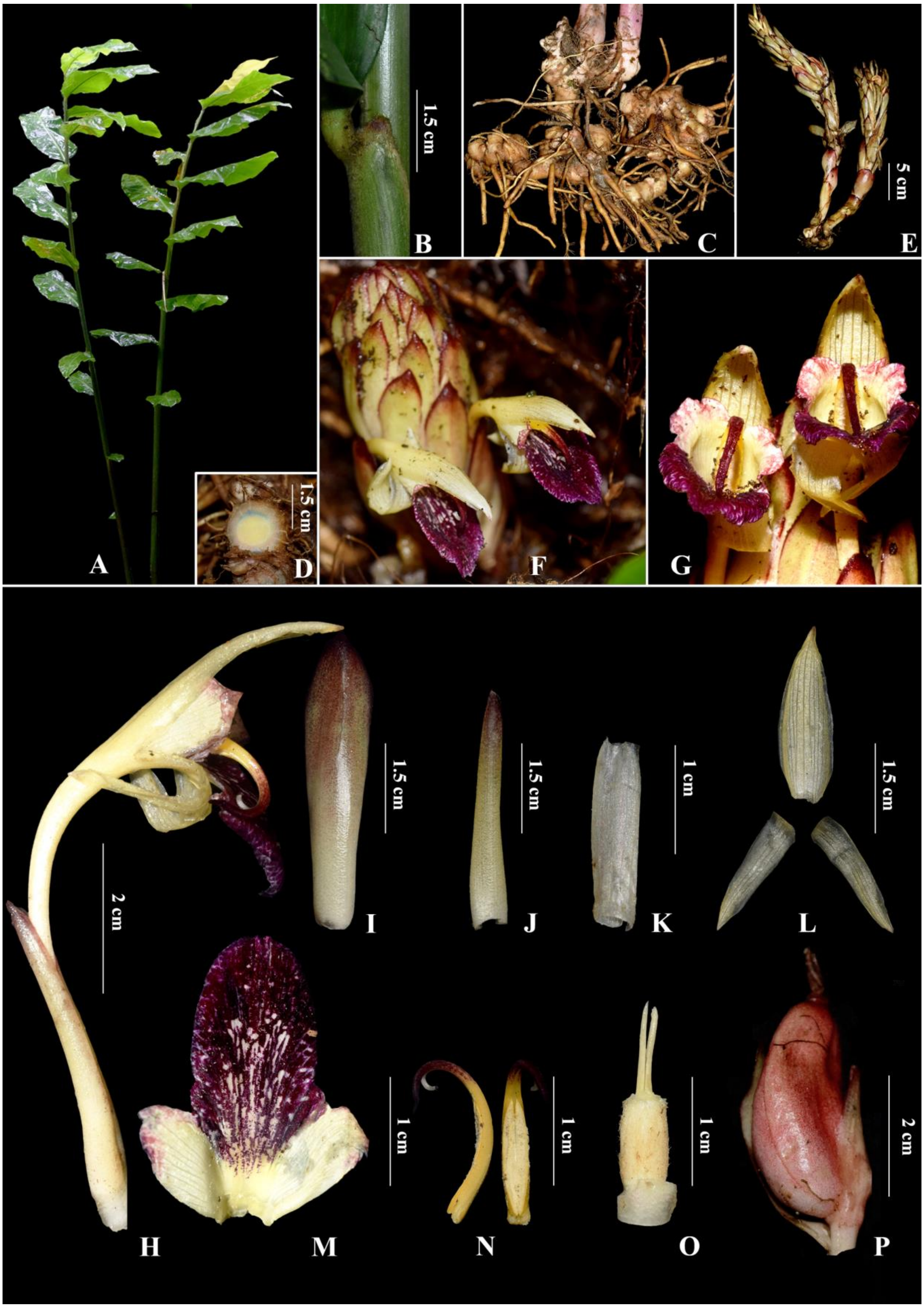


Fig. **5.** ***Zingiber campanulatum*** T.Jayakr, A.Joe, Hareesh & M.Sabu **A.** habit; **B.** ligule; **C.** rhizome; **D.** C. S. of rhizome; **E.** infructescence; **F.** inflorescence with flowers; **G.** flowers front view; **H.** single flower; **I.** bract; **J.** bracteole; **K.** calyx; **L.** corolla lobes; **M.** labellum; **N.** stamen side & front view; **O.** ovary with epigynous glands; **P.** fruit.

Distribution**:** *Z. campanulatum* is known only from Chidu, Lower Dibang Valley district of Arunachal Pradesh (**Map 5**).

Phenology**:** Flowers from June to August, opening in the morning and senescing within 24 hours. Fruits from August to September.

Etymology**:** The specific epithet 'campanulatum' in Latin means 'bell-shaped' regarding the shape of the mouth of the flower.

Habitat & Ecology**:** The plants are growing in the margins of water streams in the understorey of evergreen forest at an elevation of 300–400 m in association with *Musa itinerans* Cheesman, *M. cheesmanii* Simmonds, *M. sikkimensis* Kurz., *Impatiens roingensis* Hareesh *et al.*, *Begonia* sp. and *Hedychium* sp.

***IUCN status* (Proposed here):** *Z. campanulatum* is known only from the type locality. Three populations are observed with a total of 9 individuals. Based on the available data this plant is treated as Vulnerable (VU). (IUCN criteria: VU D2).

Notes**:** *Z. campanulatum* is unique in having bracts with deep purple margin and it is similar to *Z. mizoramensis* and *Z. arunachalensis*. These three species show a purple labellum with cream spots and long creamy corolla tube, but differ from *Z. mizoramensis* in having a pubescent ligule, 6–13 cm long peduncle, triangular narrowly-ovate bracteole, creamy corolla lobes, adnate lateral staminodes and differs from *Z. arunachalensis* in having oblong laminae, 7.5–25 cm long inflorescence with creamy oblong spike, narrowly obovate bracts, cream with purple at the margin, mouth of the flower bell-shaped and elliptic labellum with round apex.

Specimens examined**: India**, **Arunachal Pradesh**, Lower Dibang Valley District, Roing, Chidu, 300–400 m, 04 July 2015, *A. Joe* & *V.S. Hareesh 121876* (CALI); *Ibid.*, 27 August 2018, *Nikhil Krishna 159508* (CALI).

5. *Zingiber capitatum* Roxb., Asiat. Res. 11: 348. 1810 & Fl. Ind. 1: 54. 1820; Roscoe, Monandr. Pl. Scitam. T. 86. 1828; Baker in Hook.f., Fl. Brit. India 6: 248. 1892; Prain, Bengal Pl. 1045.1903; Mitra, Fl. Pl. East India 1: 252. 1958; Rao &

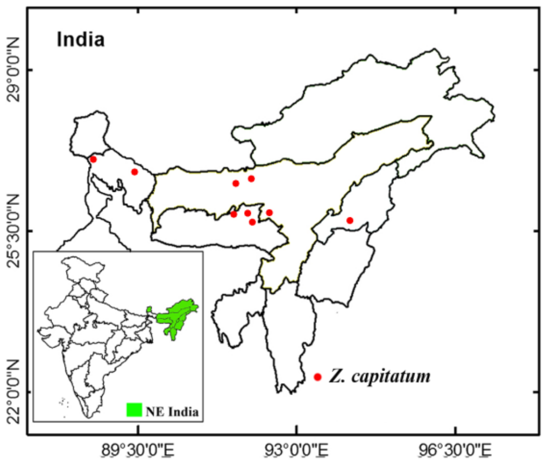
Verma, Bull. Bot. Surv. India 14: 138. 1972; Kumar & Raju in Gupta, High. Pl. Indian Subcont. 2: 251. 1991; Haines, Bot. Bihar & Orissa 3: 1193. 1961; Kumar in Hajra *et al.*, Fl. Sikkim 1: 132. 1996; S.Kumar, Zingib. Sikkim 69. 2001; Sabu, Folia Malayisiana 4(1): 30. 2003; Tripathi & Singh, J. Econ. Taxon. Bot. 30: 526. 2006; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U. Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 1: 152, 2021. **Fig. 6**

Type: **India, Hindostan,** 1810, *Wallich N. Cat.6560* 1820.

Dymczewiczia capitata (Roxb.) Horan., Prodr. Monogr. Scitam. 26. 1862.

Perennial, non stoloniferous rhizomatous herbs. Rhizome thick, branching sympodial, externally brown, internally yellow, diameter 1.8–2 cm; tubers many. Leafy shoot 100–150 cm tall, leaves 10–16 in number when flowering; pseudostem 60–70 cm long; basal sheaths 4–6 in number, dark green, sparsely pubescent; ligules c. 1 mm long, green, glabrous; petiole subsessile, pulvinate; lamina narrowly ovate, 32–45 × 2–3.3 cm, green and glabrous adaxially light green and sparsely pubescent abaxially, base rounded, apex acuminate, margin recurved. Inflorescence terminal, 4–6 flowers at a time, spike single, terminal, sessile, linear, 12–14× 2–3.5 cm; fertile bracts enclosing a single flower, narrowly ovate, 3.3–3.8 × 1–1.5 cm, green with red margins and white below, apex acute, pubescent; bracteoles linear to lanceolate, 2.5–3 × 1.8–2.2 cm, green at apex greenish white at the middle and base, margin smooth and light green, acute, sparsely hairy on both surface. Flowers 4.8–5.2 cm long; calyx tubular with unilateral split, 1.2–1.4 × 1–1.3 cm, membranous, hyaline, apex tri-lobed, pubescent on the margin; floral tube 1.5 cm long, light yellow, glabrous; dorsal corolla lobe broadly ovate, 2.5–2.8 × 1.3–1.6 cm, yellow, glabrous, apex acute, hooded lateral corolla lobes narrowly ovate, 2–2.3 × 0.5 cm, yellow, glabrous; labellum broadly ovate, 2.5–2.9 × 2–2.4 cm, yellow, deep yellow at center, apex notched, emarginate, margin wavy; lateral staminodes narrowly ovate, 1.8–2 × c. 0.5 cm, adnate $^{1}/_{2}$ length to labellum, yellow, apex wavy. Stamen 2.3–2.5 × 0.2–0.3 cm; filament size c. 0.1 cm long, connective tissue glabrous, yellow; anther thecae 1.2 × 0.3 cm, yellow; anther crest 1.2–1.3 cm long, yellow, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma funnel-shaped; ostiole ciliate. Ovary cylindrical, cream, 3.8–4 × c. 0.2 cm, triocular with axile placentation, pubescent; epigynous glands two, cream, c. 0.5 cm long, linear. Fruit not seen.

Distribution: In India, this species is reported from Assam, Bihar, Meghalaya, Nagaland, Sikkim, Uttar Pradesh and West Bengal; it can also see in Nepal and Bangladesh (**Map 6**).



Map 6. Distribution of *Z. capitatum*.

Phenology: July to September. Flowers open in the afternoon and last for 24 hrs, 4–6 flowers will open simultaneously in an inflorescence.

Etymology: The specific epithet "capitatum" in Latin means "head" which denotes the terminal inflorescence of the plant.

Habitat & Ecology: These plants are usually found in forest margins and open grass fields at an altitude of 100–1100 m. *Z. capitatum* is found in association with other plants such as *Cleistanthus collinus* (Roxb.) Hook.f., *Boswellia serrata* Roxb., *Emblica officinalis* Gaertn., *Phoenix sylvestris* (L.) Roxb., *Curculigo orchioides* Gaertn., *Sterculia urens* Roxb., *Chloroxylon swietenia* Dc., *Butea superba* Roxb. ex Willd., *Helicteres isora* L., *Holarrhena pubescens* Wall. ex G.Don, *Hemidesmus indicus* (L.) R.Br. etc.

IUCN status: Least concerned (LC)

Notes: Roxburgh (1810) described two new species, *Z. capitatum* and *Z. elatum* from British Inida. Subsequently, Baker (1892) altered the rank and treated *Z. elatum* as a variety of *Z. capitatum* Roxb. But Horaninow (1892) placed both under a new genus *Dymczewiczia*. Furthermore, the identity of *Z. capitatum* var. *elatum* was confirmed by Verma *et al.* (1991). Kumar and Raju (1991) reported var. *elatum* from Sikkim without citing proper locality and specimen. We have made extensive

Fig. **6.** ***Zingiber capitatum*** Roxb. **A.** habit; **B. & C.** inflorescence with flower; **D.** single flower; **E.** bract; **F.** bracteole; **G.** calyx; **H.** corolla lobes; **I.** labellum; **J.** corolla tube with stamen side view; **K.** stamen front view; **L.** ovary with epigynous glands.

field studies in Northeast India and unfortunately, we could not come across any specimens which match with this variety, instead many populations of the typical variety were observed from Meghalaya and Assam.

***Specimens examined*: India, Andhra Pradesh**, Visakhapatnam District , Way to Gudem to Chitapalli, 825 m, 13 November 1970, J. L. Ellis 37129 (MH); Warangal District, Pakhal, 24 December 1960, *K. M. Sebastine 11704* (MH); **Assam.** Dargong, Cornum, September 1816, *s.coll., s.n.* (CAL); *s.loc., s.d., s.coll. 1415* (CAL); Gualhara, Charaidakka, 8 July 1919, *Upendra Nath Kanjilal 7577* (ASSAM); Kamrup District, Mothorguri, 1000 m, 11 July 1957, *R.S. Rao 10020* (ASSAM); Khasi & Jayantia Hills, 26 August 1968, *N. P. Balakrishnan 47142* (ASSAM). **Bihar,** *s.loc.* 18 June 1915, *K. C. Kanodia 1122* (CAL); Dharampur, 14 December 1957, *M. Panigrahi 20919* (CAL). **Madhya Pradesh**, Hoshangabad District, way from Bunglapur to Churna, 430 m, 2 October 1960, *J. Joseph 11200* (MH); Saugor District, Mahli reserve forest, 8 November 1960, *N.P. Balakrishnan 11539* (MH). **Meghalaya,** Khasi Hills, *J. D. Hooker & T. Thomsan s.n.* (CAL); Umsaw, 26 August 1968, *N. P. Balakrishnan 47147* (ASSAM); Shillong, Barapani lakeside, 14 August 2004, *Sanoj 95627*, *95628* (CALI). **Nagaland,** Burinahah, November 1811, *s.coll. 1827* (CAL). **Orissa**, Khandagiri, 7 November 1959, *M. Panigrahi 20919* (ASSAM); *s.loc.*, 7 November 1959, *M. Panigrahi 20948* (ASSAM). **Sikkim**, Terrai, 14 October 1884, *C. B. Clarke 36976A* (CAL). **Uttar Pradesh**, Kheri, Duduwa, 1 September 1972, *K. K. Singh 3027* (CDRI); Belrayan, 23 September 1974, *K. K. Singh 7526* (CDRI); Maila, 30 October 1976, *K. K. Singh 7896* (CDRI). **West Bengal,** Jaldapara, Malangi forest, 22 October 1986, *L.K. Banargi 14842* (CAL); Bamkura District., 30 September 1965, *M.N. Yonnayal 829* (CAL).

6. ***Zingiber caudatum*** Bhiseshwori & Bipin, J. Jpn. Bot. 93 (1): 31. 2018; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U. Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 1: 152, 2021. ***Type*: India, Manipur,** Imphal, cultivated at Institute of Bioresources and Sustainable Development (IBSD), 20 March 2014, Bipin IBSD/Z–139 (holo ASSAM; iso IBSD). **Fig. 7**

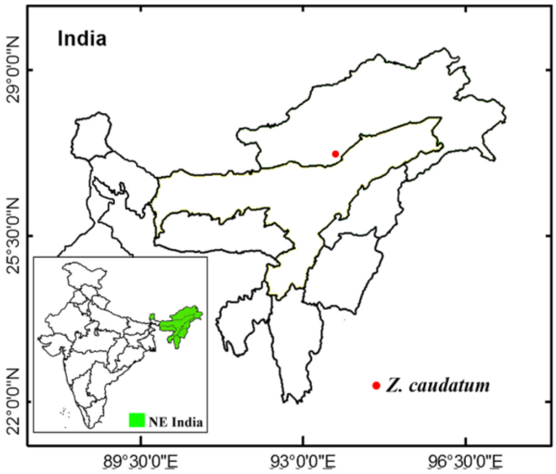
Perennial rhizomatous herbs. Rhizome slender, stoloniferous, horizontally elongate, very short, 2.5 cm diameter, externally tan white, internally white with two concentric rings, inner c. 1.2 mm diam. outer 3 mm wide; tubers not seen; roots numerous. Leafy shoot 75 cm tall, leaves 9–10 in number when flowering; pseudostem 30 cm long, pubescent; basal sheaths 2–3 in number, green; ligules 5–6 mm long, bilobed, light green, sericeous, margin hairy, round at apex; petiole reduced to pulvinous, light green, glabrous; lamina oblong-elliptical, 28–30 × 9–11 cm, adaxially light green, glabrous, abaxially light green or purplish green on young leaves, sericeous, base cuneate, apex acuminate, margin entire. Inflorescence radical, procumbent, 2–3 per plant, one flower at a time, 14–19 cm long; peduncle 1.5–3 × c. 1 cm, white, glabrous; spikes narrowly ovate, 6–7 × c. 2 cm; fertile bracts enclosing a single flower, narrowly ovate, 4–5.5 × 0.5 cm, green or brown with red spots, apex caudate, externally sericeous, internally glabrous; bracteoles narrowly ovate, 3.0 × 0.5 cm, semi-translucent greenish, externally pubescent, internally glabrous, apex acute. Flowers 6–7 cm long; calyx c. 1.5 cm, tubular with unilateral split, hyaline, apex tri-lobed with reddish tinge, pubescent; floral tube slender, white, 3–3.5 cm long, externally sparsely pubescent, internally glabrous; dorsal corolla lobe narrowly ovate, c. 3 × c. 0.5 cm, creamy white with translucent veins, apex acute with slight pink tinge, curved; lateral corolla lobes narrowly ovate, c. 2.3 × c. 0.4 cm, creamy white with translucent veins, glabrous on both sides; labellum obovate, c. 2.2 × c. 0.7 cm, white with dark violet or purple blotches and dots, apex rounded to emarginate, margin undulate, irregular, glabrous; lateral staminodes narrowly sharply triangular, 8–10 × c. 3 mm long, white, ½ length adnate to labellum. Stamen c. 2.1 × 0.3 cm; filament reduced to c. 1 mm long, connective tissue glabrous, white with magenta spots; anther thecae c. 1 × 0.3–0.1 cm, creamy white; anther crest 0.9–1 mm long, white, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, creamy yellow, 0.5–0.6 × c. 0.4 cm, trilocular with axile placentation, villous with soft brown hairs; epigynous glands two, cream, 0.3–0.4 cm long, linear. Fruit not seen.

Fig. 7. ***Zingiber caudatum*** Bhiseshwori & Bipin. **A.** habit; **B.** inflorescence with flower; **C.** a portion of sheath showing ligule; **D.** single flower **E.** bract; **F.** bracteole; **G.** calyx; **H.** corolla lobes; **I.** labellum; **J.** stamen; **K.** ovary with epigynous glands. (**Photos by Alfred Joe**)

Distribution: Arunachal Pradesh, Northeast India (Currently known from the type locality) (**Map 7**).

Etymology: The name "caudatum" refers to the long caudate apex of bracts.

Phenology: Flowering from July to October. Flowers open in the morning and last for 24 hours.



Map 7. Distribution of *Z. caudatum*.

Habitat & Ecology: The typical habitat is a mixed evergreen forest. They prefer dark soil enriched with leaf mulch and humus. Plants found growing near bamboo thickets associated with ferns and some Poaceae members between an altitude of 150–600 m.

IUCN status: Data Deficient (DD)

Notes: *Z. caudatum* shows many overlapping characters with *Z. bipinianum.* The bracts with caudate and loosely imbricating apex were seen in some mature inflorescence of Z. *bipinianum* as well. As the type localities of both taxa fall within the same geographic range (Arunachal Pradesh) we strongly believe *Z. caudatum* could be an ecotype or variation of *Z. bipinianum*. Further explorations in the type locality and remote areas are required to find out the degree of variation and to confirm the identity of *Z. caudatum.*

Specimens examined: Known from a single collection and we could not collect the plant from wild.

7. *Zingiber chrysanthum* Rosc. Monandr. Pl. t. 86. 1828; Baker in Hook.f. Fl. Brit. India 6: 243. 1892; Mitra, Fl. Pl. East. India 1: 253. 1958; Rao & Verma in Bull. Bot. Surv. India 14: 136. 1972; Smith in Fl. Bhutan 17: 187. 1987; Kumar & Raju in Gupta, High. Pl. Indian Subcont. 2: 252. 1991; Kumar in Hajra *et al.*, Fl. Sikkim 1: 133. 1996; Tripathi & Singh, J. Econ. Taxon. Bot. 30: 526. 2006; A.A. Mao *et al.*, Checkl. Fl. Nagaland 1: 143. 2017; Aung, M.M. & Tanaka, N., Bull. Natl. Mus. Nat. Sci. 45: 1-8. 2019, S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 1: 152, 2021. ***Type*****:** *Zingiber chrysanthum* Rosc. Iconotype: t. 86 in Roscoe, Monandr. Pl. Scitam. 1828.

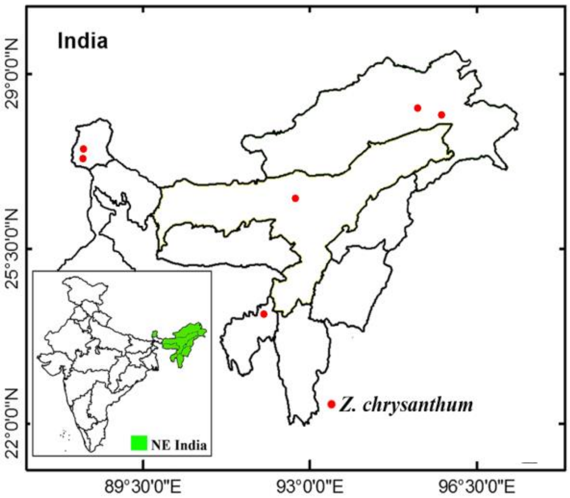
Z. flavescens Link ex A. Dietr. Sp. Pl. 1: 54. 1831. **Fig. 8**

Perennial, non-stoloniferous rhizomatous herbs. Rhizome thick, short, externally brown, internally yellow, 1.5–2 cm diam.; tubers absent. Leafy shoot 1.5–2.3 m tall, leaves 12–16 in number when flowering; pseudostem 70–100 cm long, sparsely pubescent; basal sheath without blade, 3–4 in number, greenish white with purple tinge at base, sparsely pubescent; ligules bilobed, 5–7 mm long, purple, pubescent, apex rounded; petiole 2–3 mm long, green, glabrous, pulvinate; laminae oblong-lanceolate, 27–34 × 5–7 cm, apex acuminate, base cuneate, margin entire, adaxially green, glabrous, abaxially light green, pubescent. Inflorescence 2–3, radical, spicate, spikes globose to ovate, 6–8 cm long, single flower opening at a time; peduncle 4–5 × 1.8–2.2 cm, sheathing bracts pale red with whitish tinge; sterile bracts broadly ovate, apex acuminate, pale red with narrow yellowish stripes, glabrous internally and pubescent externally; fertile bracts broadly ovate or boat-shaped, 5–6.5 × 2–2.2 cm, apex acuminate, twisted, reflexed, margin wavy, white at base, purple at the middle and pale green at the tip, each enclosing a single flower; bracteoles narrowly ovate (open), 3.6–3.8 × 0.4–0.5 cm, apex acute, slightly notched, white with purplish tinge at middle and tip, pubescent at apex. Flowers bright yellow, 8–10 cm long; calyx tubular with unilateral split, c. 2.8 × c. 0.8 cm, apex tri-dentate, membranous, hyaline, pubescent; Corolla tube yellow, 5.5–6.2 cm long, glabrous; dorsal corolla lobe narrowly ovate, 3–3.3 × 0.4–0.5 cm, apex acute, beaked, light yellow with translucent veins, sparsely pubescent internally and glabrous externally; lateral corolla lobes triangular-narrowly ovate, 3–3.2 × c. 0.3 cm, apex acute, light yellow with translucent veins, margin hyaline, glabrous externally, pubescent internally, incurved soon after opening of flower; labellum suborbicular, 2–3 × 2–2.6 cm, apex deeply notched, margin entire, bright yellow, unspotted, glabrous; lateral staminodes

Fig. **8.** ***Zingiber chrysanthum*** Rosc. **A.** Habit, inset: basal part of the plant; **B. & C.** inflorescence with flowers; **D.** ligule; **E.** rhizome; **F.** single flower; **G.** bract; **H.** bracteole; **I.** calyx; **J.** corolla lobes; **K.** fruit; **L.** labellum; **M.** stamen front & side view; **N.** ovary with epigynous glands.

ovate, 2.2–2.3 × c. 0.8 cm, apex acute, bright yellow, $^{1}/_{2}$th portion adnate with labellum. Stamen 2.5–2.6 × 0.2–0.3 cm; filament reduced to c. 1 mm long, connective tissue bright yellow, glabrous; anther thecae cream, c. 1.3 × c. 0.2 cm; anther crest deep yellow, 1 cm long, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, 6 × 2 mm, cream, trilocular with axile placentation, pubescent; epigynous glands two, 3–4 mm long, cream, linear. Fruit a capsule, ellipsoid-oblong, seeds brown, sub globose, aril membranous.

***Distribution*:** Its native range is Himalaya to Myanmar. In India, the plants are mainly distributed in Arunachal Pradesh, Meghalaya, Sikkim, Uttarakhand and Tripura (**Map 8**).



Map 8. Distribution of *Z. chrysanthum*.

***Phenology*:** July–October.

***Habitat & Ecology*:** The plants are growing on vertical cuttings in the understorey of the evergreen forest at an elevation of 600–700 m in association with *Begonia* sp., *Pteris* sp., *Globba* sp. *Impatiens* sp. and some Urticaceae members. They prefer humus-rich black soil for growth. Some populations are also observed on rock cliffs.

***IUCN status* (Proposed here):** Near Threatened (NT)

***Notes*:** *Z. chrysanthum* is similar to *Z. meghalayense* in having bright yellow labellum and bright yellow, adnate lateral staminodes, terminally reflexed bracts but differs from latter in having pale red bracts with a crumbled margin that are compactly arranged. This plant is a traditional medicinal plant species used to treat body pain, gastritis and piles.

***Specimens examined*: India**, **Arunachal Pradesh**, Pasighat District, 13 December 1911, *Burkill 37113* (CAL); Roing District, Hadil Nala, 10 October 1997, *Sunil*

Tripathi 21846 (CDRI). **Assam**, Duphala Hills, Barhuni, 1974, *J. L. Lister 73* (CAL); Nowgong, 31 August 1938, *R. N. De 20321* (ASSAM). **Sikkim**, West Sikkim District, 24 July 1882, *H.B. Cal 2/A* (CAL); *Ibid.*, 1 August 1899, *P.W. Mackinnon 467896, 467893* (CAL); Pelling, Phamrong falls, 29 July 2018, *Jayakrishnan T 159729* (CALI). **Tripura**, Chandrapur, 29 August 1957, *R.S. Rao 8966* (ASSAM).

8. *Zingiber clarkei* King ex Baker in Hook. f., Fl. Brit. India 6: 248. 1892; D.C.S. Raju in B.K. Gupta, High. Pl. Indian Subcont. 2: 249–255. 1991; S. Kumar in Hajra *et al.*, Fl. Sikkim 1: 120–134. 1996; Singh A. K, Spic. Condim. Wil. Cultiv. Pl. India. 137–154. 2017; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U. Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 152. 2021. ***Type***: **India**, **West Bengal**, Darjeeling, Rishap, 3500 ft., 18 August 1870, *C.B. Clarke 12393* (holo K!). **Fig. 9**

Perennial, stoloniferous rhizomatous herbs. Rhizome fleshy, not so much branched, creamy white with brownish tinge, 1–2 cm in diameter; roots thin, long, tubers not seen. Leafy shoots 1–1.6 cm tall, leaves 8–10 nos. when flowering; pseudostem 40–50 cm long, green sparsely pubescent or glabrous; basal sheaths 2–3. in number, green, glabrous or sparsely pubescent; ligules 0.8–10 mm long, light green, sparsely pubescent, truncate; petiole sub-sessile, glabrous, 0.4–0.5 cm long, pulvinate; lamina lanceolate, 25–30 × 6–10 cm, adaxially dark green, abaxially light green color, pubescent on both sides, base cuneate, apex acuminate, margin undulate. Inflorescence one, one to two flowers at a time, spicate, spike emerging through the leaf sheath, 12–16 cm long; peduncle 6–8 cm, green, covered with broadly obovate sterile bracts with truncate apex; spikes cylindrical; sterile bracts oblong to obovate, green, apex truncate, glabrous internally and sparsely pubescent externally; fertile bracts enclosing a single flower, oblong to obovate, 2.5–2.8 × 1.8–2 cm, light green, apex truncate; bracteoles cylindrical, 2.2–2.3 × 1–1.2 cm, creamy white, apex truncate, glabrous internally, sparsely pubescent externally. Flowers 4–4.5 cm long; calyx c. 1 × c. 0.5 cm, tubular with unilateral split, creamy white, bifid, pubescent; floral tube, 2–2.5 cm long, glabrous; dorsal corolla lobe narrowly ovate,

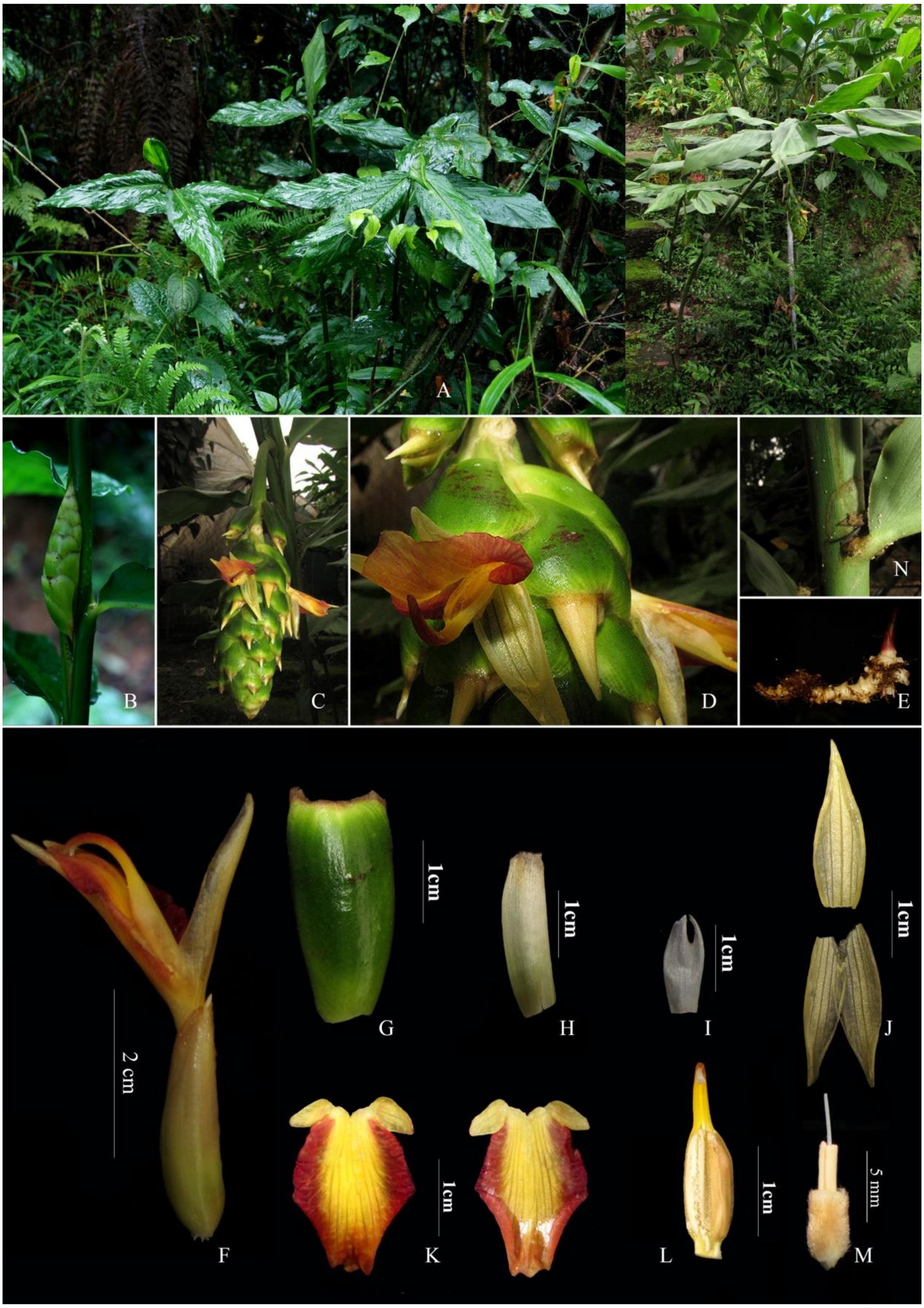


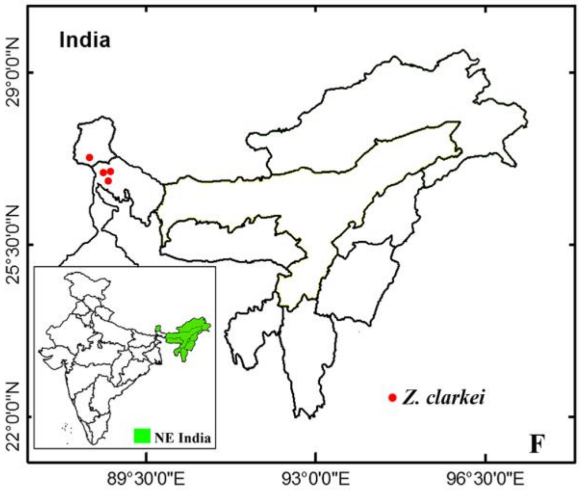
Fig. **9.** ***Zingiber clarkei*** King ex Baker. **A.** habit; **B.** young inflorescence emerging through the leafy sheath; **C. & D.** inflorescence with flower; **E.** rhizome; **F.** single flower; **G.** bract; **H**. bracteole; **I.** calyx; **J.** corolla lobes; **K.** labellum adaxial & abaxial view; **L.** stamen front view; **M.** ovary with epigynous glands; **N.** ligule.

2.1–2.3 × 0.8–1 cm, cream, glabrous internally and externally, apex acute; lateral corolla lobes narrowly ovate, 2–2.2 × c. 0.6 cm, cream, glabrous; labellum broadly obovate, 1.8–2.2 × 1.2–1.3 cm, yellowish orange at the center, red with orange tinge at the margin, apex notched, margin wavy, glabrous; narrowly ovate, 5–6 × c. 3 mm, free, creamy yellow, apex acute. Stamen 2.3–2.4 × 0.2–0.4 cm; connective tissue glabrous, creamy yellow; anther thecae 1.3 × 0.4 cm, cream; anther crest 1.2–1.3 cm long, yellow with red spots, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-shaped; ostiole ciliate. Ovary cylindrical, 5–6 × c. 3 cm, creamy white, trilocular with axile placentation, densely pubescent; epigynous glands two, linear, cream, c. 0.4 cm long. Fruit not seen.

Distribution**:** In India *Z. clarkei* is known only from Sikkim and West Bengal (**Map 9**).

Phenology**:** Flowers from July to August and fruits from September to October.

Etymology**:** The specific epithet refers to C. B. Clarke, a well known taxonomist.



Map 9. Distribution of *Z. clarkei*.

Habitat & Ecology**:** The plants were found to be growing in a humid climate in between *Cinchona* plantations of Mungpoo, 41 km away from Darjeeling, West Bengal. The black soil rich in leafy mulch and other organic matters are ideal for the growth of this plant. They prefer shady habitat and usually grow the understorey of evergreen forests at an elevation ranging from 800–1700 m in association with *Cinchona* plants, *Pilea melastomoides* (Poir.) Borgn., *Elatostema lineotum* Wight, *Begonia palmata* D. Don etc.

***IUCN status* (Proposed):** This taxon is used as an ornamental plant and is currently known only in the states of Sikkim and West Bengal in India. We have observed many populations from Darjeeling district. Because of the narrow distribution, a detailed study is required to assess the survival status of the taxon hence currently treated as Data Deficient (DD).

Notes: *Z. clarkei* is the only member of the Sect. *Pleuranthesis* in India. This species is characterized by an inflorescence arising through the leafy shoot. The plant is endemic to Sikkim Himalayas and is also available in the local nurseries of West Bengal. Kumar and Raju (1991) and Kumar (2001) have reported the occurrence of *Z. clarkei* from the state of Sikkim but no herbarium specimens from their collections were available in Indian herbaria. Tripathi and Singh excluded this species from their revision as the specimens of the taxon are not available in any of the Indian Herbaria. Despite our best efforts, we could not find any wild population of *Z. clarkei* from Sikkim instead many populations of these plants were observed in Darjeeling district of West Bengal. A single herbarium sheet of *Z. clarkei* was available at BSHC, which helped us to locate the wild population of this interesting species.

Specimens examined: **India**, **West Bengal**, Darjeeling, 27 August 1871, C.B. Clarke 12624 (CAL); Kalimpong, on the way to Darjeeling, 1250 m., 30 August 2018, Jayakrishnan 159730 (CALI); Peshok, on the way to Darjeeling, 5000 ft., 08 September 1989, S. kumar 11456 (BSHC); Rishap, Darjeeling, 3500 ft., 02 August 1870, C.B. Clarke 12305 (K!); Sureil, 2 October 1900, D. Prain s.n.; Mungpoo *Cinchona* plantations, on the way to Darjeeling, 1200 m., 03 July 2018, Jayakrishnan 159755 (CALI); (some specimens without collection details are also observed at CAL (468051 & 468055).

9. ***Zingiber cornigerum*** T.Jayakr., A.Joe, Hareesh & M.Sabu, Taiwania. 66(1): 101–112. 2021. ***Type***: **India**, **Arunachal Pradesh**, Lower Dibang Valley District, Iduli, 26 km from Roing to Iduli, elev. 152 m 21 July 2016, *T. Jayakrishnan & Nikhil Krishna 150204* (holo CALI; iso CAL). **Fig. 10**

Perennial, stoloniferous rhizomatous herbs. Rhizome slender, not so much branched, covered by numerous thin roots along the entire length, externally creamy white, internally divided into three circular zones, inner cream, middle creamy yellow and outer dark brown, 1–1.5 cm diameter; tubers absent. Leafy shoot 90–170 cm tall, leaves 8–10 in number when flowering; pseudostem 30–60 cm long, glabrous or sparsely pubescent; basal sheaths 3–4 in number, purplish green, pubescent; ligules 5–6 mm long, green, glabrous, acute; petiole green, glabrous, 1.0–1.2 cm long, pulvinate; lamina elliptic-lanceolate, 25–35 × 6.5–10.5 cm, adaxially dark green, glabrous, abaxially purple, pubescent at the base and along the mid rib, base cuneate, apex acuminate, margin entire. Inflorescence one to two, one flower at a time, radical spicate, 11–16 cm long; peduncle 3–6 cm long, creamy white, sheathing bracts creamy white with purplish tinge at apex; spikes narrowly ovate 10–12 × 3–4.5 cm; sterile bracts ovate-lanceolate, creamy white with purplish tinge, apex acute, glabrous internally and pubescent externally; fertile bracts each enclosing a single flower, broadly ovate, 5–6 × 0.8–1.0 cm, creamy white with purplish tinge, apex acuminate; bracteoles ovate-lanceolate, 2.5–3.0 × 0.8–1.0 cm, creamy white, purplish tinge at apex, glabrous internally, pubescent externally, apex horned or bifid with a long acute lobe and a small lobe. Flowers 8–10 cm long; calyx tubular with unilateral split, c. 1.4 × 0.7 cm, white, apex bi-lobed, glabrous; floral tube white, 6–7 cm long, glabrous; dorsal corolla lobe triangular-lanceolate, 2.5–2.7 × 0.6–0.7 cm, white with translucent veins, glabrous internally and pubescent externally, apex acute, curved; lateral corolla lobes triangular-lanceolate, 2.2–2.4 × c. 0.4 cm, white with translucent veins, glabrous on both sides, incurved soon after opening of flower; labellum elliptic, 2.0–2.3 × 1.2–1.5 cm, creamy white with reddish pink blotches, apex round margin recurved, glabrous; lateral staminodes triangular, 1–1.3 × c. 0.3 cm, adnate up to middle of the labellum, white, apex beak-shaped. Stamen 2.3–2.5 × 0.5–0.6 cm; filament reduced to ca. 1 mm long, connective tissue glabrous, white; anther thecae 1.6–1.8 × 0.3–0.4 cm, creamy white; anther crest 1–1.2 cm long, white, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, creamy white, 0.8–0.9 × 0.4–0.5 cm, trilocular with axile placentation, pubescent; epigynous glands two, linear, 0.8–0.9 cm long, cream. Fruit not seen.

Distribution**:** Arunachal Pradesh (Currently known only from the type locality) (**Map 10**).

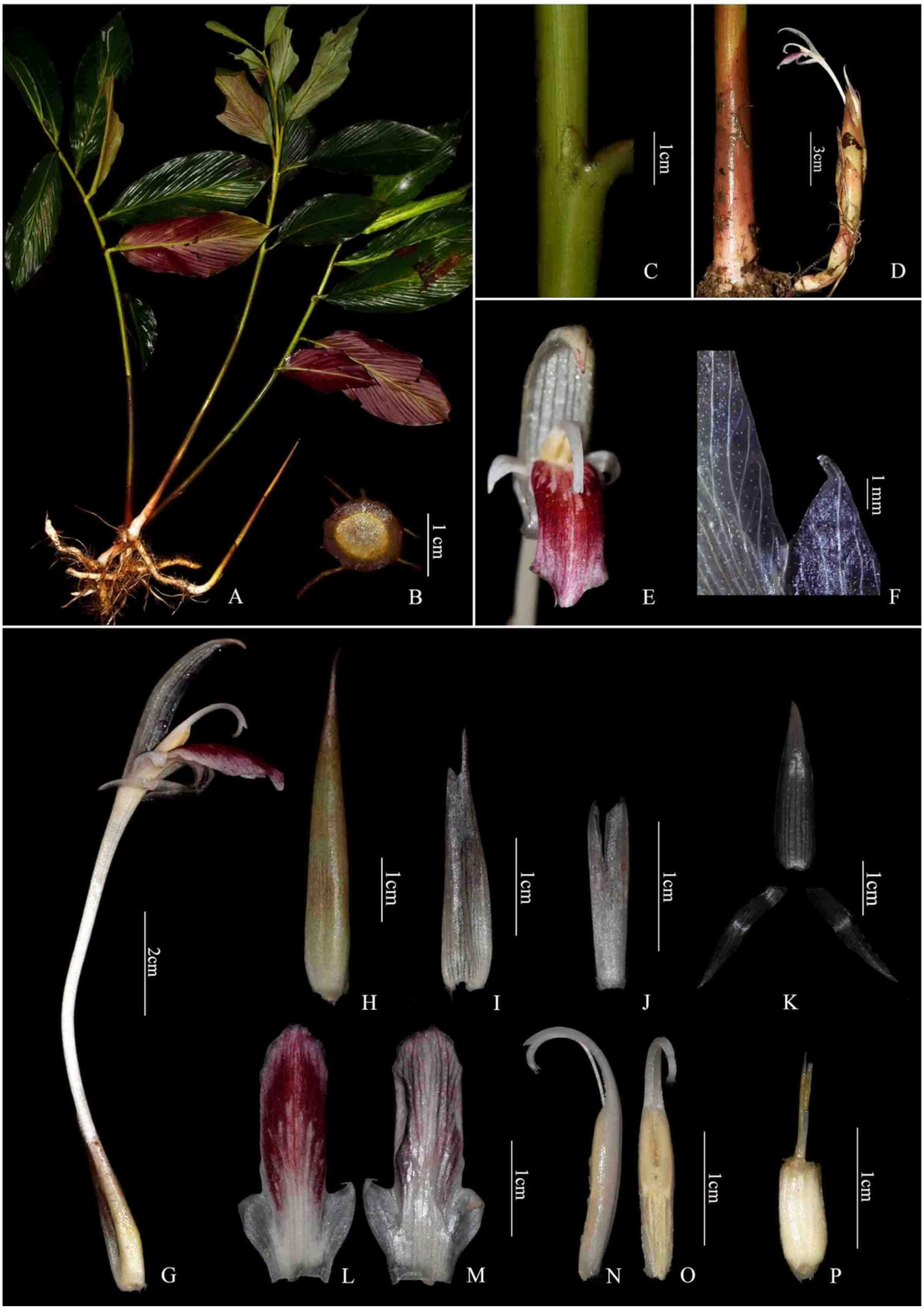
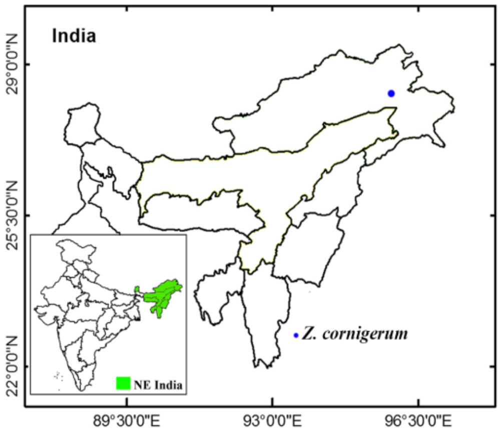


Fig. 10. ***Zingiber cornigerum*** T.Jayakr., A.Joe, Hareesh & M.Sabu **A.** habit; **B.** C. S. of rhizome; **C.** a portion of petiole showing ligule; **D.** basal part of pseudostem showing inflorescence; **E.** flower front view; **F.** lateral staminode with beaked apex; **G.** single flower; **H.** bract; **I.** bracteole; **J.** calyx; **K.** corolla lobes; **L.–M**. labellum adaxial & abaxial views; **N.–O.** stamen side & front views; **P.** ovary with epigynous glands.

***Phenology*:** Flowers from June to August, opening in the morning and senescing within 24 hrs.

***Etymology*:** The specific epithet 'cornigerum' is derived from Latin means horn, which refers to the horned bracteoles of the flower.



Map 10. Distribution of *Z. cornigerum.*

***Habitat & Ecology*:** *Z. cornigerum* is known only from Iduli, Lower Dibang Valley district of Arunachal Pradesh. The plants are growing in the margins of rice fields and small water streams in black clayey soil. It grows at an elevation of 100–200 m in association with *Musa velutina* H.Wendland & Drude, *M. itinerans* Cheesman, *Alpinia nigra* (Gaertn.) Burrt, *Curcuma* sp. etc.

***IUCN status*:** Near Threatened (NT). Probable threat to its existence includes loss of habitat due to widening of the cultivation fields and flooding.

***Notes*:** *Z. cornigerum* is similar to *Z. bipinianum*, in having stolonifrous rhizome, narrowly ovate spike with purplish brown bracts, white floral tube and lateral staminodes but differs from the latter in having glabrous ligules, abaxially purple leaves, bracteole with horned apex, lateral staminodes apex beaked and lower half adnate to the labellum.

***Specimens examined*: India, Arunachal Pradesh,** Lower Dibang Valley District, Iduli, 10 km from Roing to Iduli, 150 m, 5 July 2015, *A. Joe & V.S. Hareesh 121887* (CALI).

10. *Zingiber dimapurense* N.Odyuo, D.K.Roy & A.A.Mao, NeBIO 10(2): 60. 2020. ***Type*: India**, **Nagaland**, Dimapur District, Medziphema sub-division, Hekeshe village forest, 1003 m, 10 July 2018 ex hort. in Garden of Botanical Survey of India (Eastern Regional Centre, Meghalaya, East Khasi Hills, Shillong, Woodland Campus), *N. Odyuo & D.K. Roy 138356* (holo ASSAM). **Fig. 11**

Perennial, rhizomatous herbs. Non-stoloniferous, Rhizome compact, odorless, externally brown, internally divided into two circular zones, white, 1–2 cm diameter; tubers absent. Leafy shoot 90–120 cm tall, leaves 10–20 in number when flowering; pseudostem 30–60 cm long, glabrous or sparsely pubescent; basal sheaths 4–5 in number, green with purple at margin, pubescent; ligules 5–10 mm long, bilobed, green with purple tinge, hairy, acute; petiole green, hairy, 0.5–1 cm long, pulvinate; laminae elliptic-lanceolate, 10–30 × 4–9 cm, adaxially dark green, pubescent, abaxially pale green, pubescent, base rounded, apex acuminate, margin entire. Inflorescence two, one to two flowers at a time, radical spicate, 11–16 cm long; peduncle 2.5–5 cm long, creamy white, sheathing bracts creamy white with purplish tinge at apex; spikes narrowly ovate, 4.5–6 × 1.3–3 cm; sterile bracts narrowly ovate, creamy white with purplish tinge, apex acute, glabrous internally and pubescent externally; fertile bracts each enclosing a single flower, narrowly ovate, 5–6 × 0.8–1.0 cm, creamy white with purplish tinge, apex acuminate; bracteoles ovate-lanceolate, 2.2–3.2 × 0.7–1.2 cm, creamy white, purplish tinge at apex, glabrous internally, pubescent externally, apex acute. Flowers 6.5–7.5 cm long; calyx tubular with unilateral split, c. 1.2 × c. 0.4 cm, white, apex bi-lobed, glabrous; floral tube white, 4.5–5.5 cm long, glabrous; dorsal corolla lobe narrowly ovate, 3–3.2 × 0.3–0.6 cm, purplish pink at middle and apex, white at base with translucent veins, glabrous, apex acute, curved; lateral corolla lobes narrowly ovate, 2.6–2.9 × c. 0.4 cm, purplish pink at middle and apex, white at base with translucent veins, glabrous on both sides, incurved soon after opening of flower; labellum ovate to lanceolate, 2.8–3.3 × 1.2–1.3 cm, creamy purplish pink with white blotches, apex acuminate, glabrous; lateral staminodes triangular, 1.4–1.8 × c. 0.32 cm, adnate $^{3}/_{4}{}^{th}$ length adnate to the labellum, white, apex acuminate. Stamen 2.5–2.7 × 0.5–0.6 cm; filament reduced to c. 1mm long, connective tissue glabrous, white; anther thecae 1.2–1.5 × 0.3–0.4 cm, creamy white; anther crest 1.5–1.7 cm long, white with purplish streaks, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, creamy white, 0.5–0.7 × 0.3–0.4 cm, trilocular with axile placentation, pubescent; epigynous glands two, linear, 0.4–0.5 cm long, cream. Fruit not seen.

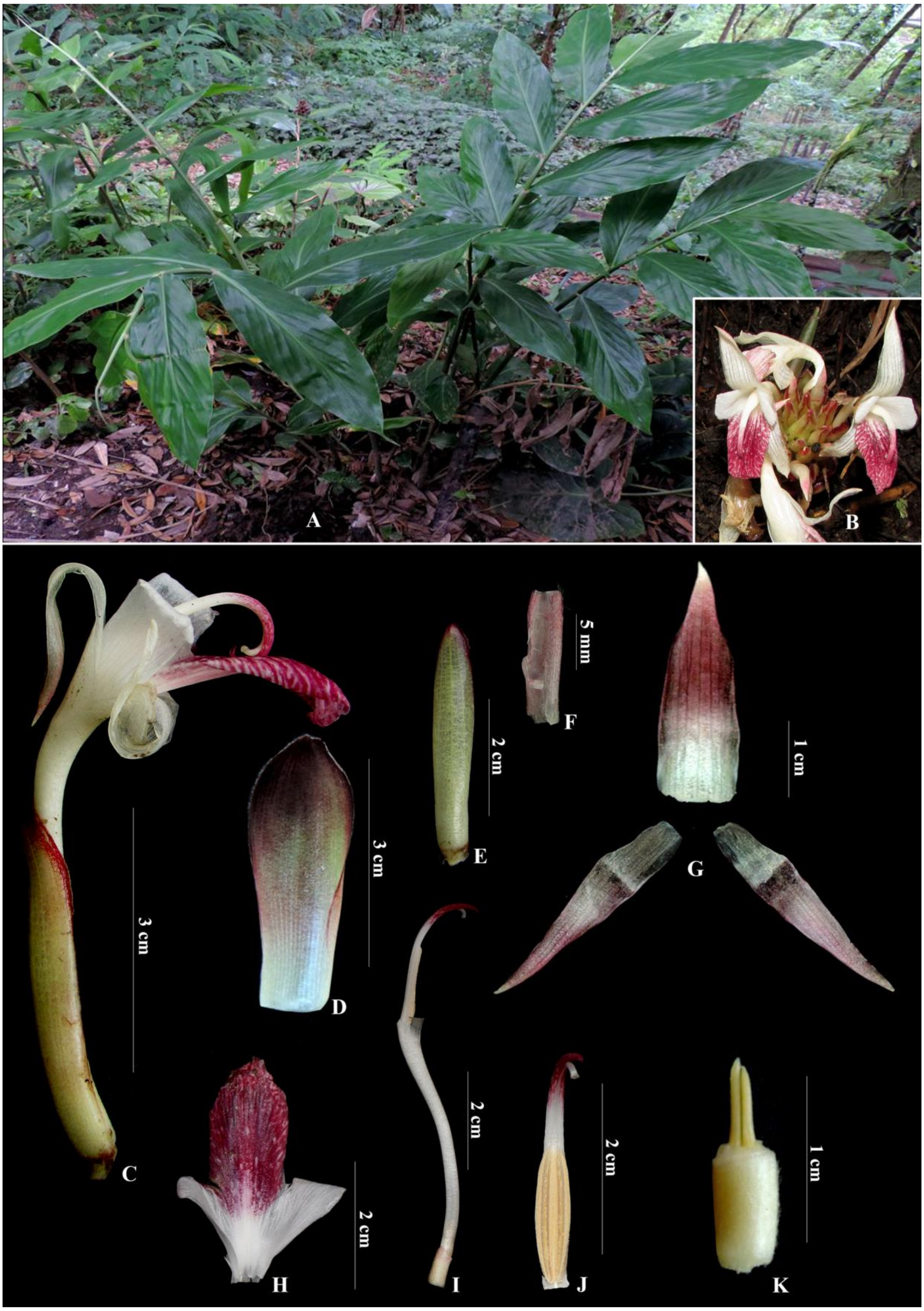
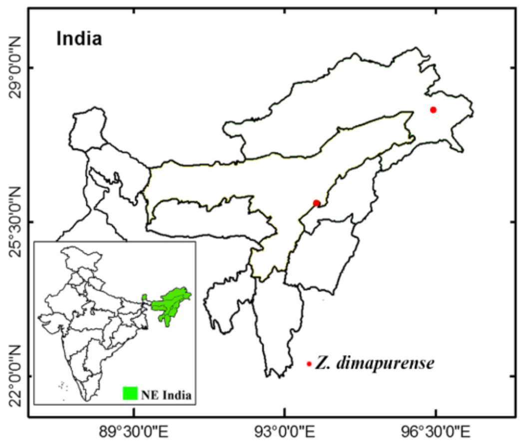


Fig. 11. ***Zingiber dimapurense*** N.Odyuo, D.K.Roy & A.A.Mao. **A.** habit; **B.** inflorescence with flower; **C.** single flower; **D.** bract; **E.** bracteole; **F.** calyx; **G.** corolla lobes; **H.** labellum; **I.** corolla tube with **s**tamen; **J.** stamen front view; **K.** ovary with epigynous glands.

Distribution**:** In India *Z. dimapurense* is known from Nagaland (Dimapur district, Hekeshe village forest) and Arunachal Pradesh (Anjaw District, Tidding Bridge) (**Map 11**).

Phenology**:** Flowering starts from June to July. Flowers last for one day. Fruting from August to September.

Etymology**:** The specific epithet '*dimapurense*' refers to the Dimapur district, type locality of this species.



Map 11. Distribution of *Z. dimapurense.*

Habitat & Ecology**:** The plants are growing in mixed evergreen forests associated with bamboo thickets at an elevation of 1000–1030 m. They prefer black humus-rich soil. Some populations were also observed in roadside vertical cuttings. A total of six populations were observed in the type locality and an average of three to five individuals were observed in each population.

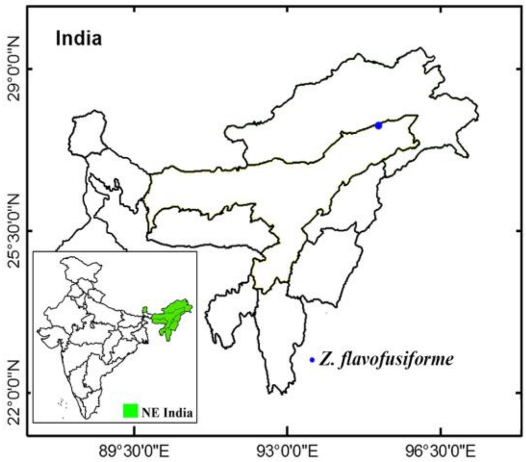
IUCN status **(Proposed here):** Vulnerable (VU) (IUCN criteria: VU D2)

Notes**:** *Z. dimapurense* is similar to *Z. mizoramensis* in having creamy white bracteoles with purplish red tinges along the margins, narrowly ovate subequal, purplish pink corolla lobes with white base and creamy white anther crest with purplish apex.

Specimen examined**: India**, **Arunachal Pradesh**, Anjaw District, 1030 m, 21 July 2018, *Jayakrishnan T* & *Nikhil Krishna 159732* (CALI).

11. ***Zingiber flavofusiforme*** M.M.Aung & Nob.Tanaka, Phytotaxa 319 (2): 195–199. 2017; N.Odyuo & D.K.Roy, Bull. Arun. Fr. Res., 34: 21. 2019; Deiji N. *et al.*, J. Jpn. Bot., 95(2): 102. 2020. ***Type***: **Myanmar**, **Sagaing Region**, Nam Ei Mae, along the Nam Ei Zu River, branch of the Chindwin, Htamanthi Wildlife Sanctuary, Khamti Township, 120 m alt., 12 September 2016, *Tanaka et al.*, *MY850* (holo TNS!; iso NY, RAF). **Fig. 12**

Perennial rhizomatous herbs. Rhizome slender, branched, horizontally elongate, very short, externally dirty white, internally creamy white, 2.5 cm diam.; tubers ovoid, outer dirty white, inner grayish blue. Leafy shoot 90–120 cm tall, leaves 7–9 in number when flowering; pseudostem 60–90 cm long, sparsely pubescent; basal sheaths 2–3, reddish green; ligules 5–6 mm long, shallowly bilobed, hyaline with reddish tinge, glabrous; petiole subsessile, light green, glabrous, pulvinate; laminae narrowly ovate-lanceolate, 20–25 × 5–5.5 cm, adaxially dark green, glabrous, abaxially purplish green, sparsely pubescent along the midrib, base obtuse, apex attenuate, margin entire. Inflorescence terminal on leafy shoots, one flower at a time, 12–14 cm long; peduncle sessile; spikes narrowly ovate, 12–14 × 3.5 cm; fertile bracts (all bracts usually fertile) each enclosing a single flower, ovate, 3.5–3.8 × 2.5 cm orange yellow, turning yellow when mature, apex acute, glabrous; bracteoles ovate–triangular, 3.0 × 1.0 cm, creamy white at base reddish tinged at apex, glabrous, apex acute. Flowers 6.5–7 cm long; calyx tubular with unilateral split, c. 2 × c. 0.4 cm, hyaline, apex bi-lobed, glabrous; floral tube creamy white, 3.5–4 cm long, glabrous; dorsal corolla lobe ovate, 2.5–2.7 × c. 0.9 cm, creamy yellow with translucent veins, glabrous, apex acute, curved; lateral corolla lobes triangular–lanceolate, 2.2–2.5 × c. 0.7 cm, creamy yellow with translucent veins, glabrous on both sides; labellum broadly ovate, 2.3–2.5 × 1.2–2.5 cm, maroon with creamy white blotches and dots, apex trilobed, margin undulate, glabrous; lateral staminodes reduced, c. 4 mm long, creamy yellow, with maroon blotches, adnate to labellum. Stamen 2.6–2.8 × c. 0.3 cm; filament reduced to c. 1 mm long, connective tissue glabrous, creamy yellow with maroon spots; anther thecae 1.4–1.5 × 0.3–0.4 cm, creamy white; anther crest 1.1–1.3 cm long, maroon, wrapped around



Map 12. Distribution of *Z. flavofusiforme*.

Fig. 12. ***Zingiber flavofusiforme*** M.M.Aung & Nob.Tanaka. **A.** habit; **B.** inflorescence with flower; **C.** inflorescence at young stage; **D.** ligule; **E.** rhizome; **F.** C. S. of root tubers; **G.** single flower; **H.** bract; **I.** bracteole; **J.** calyx; **K.** corolla lobes; **L.** labellum adaxial & abaxial view; **M.** stamen along with corolla tube; **N.** ovary with epigynous glands.

the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, 0.5–0.6 × 0.4–0.5 cm, creamy yellow, trilocular with axile placentation, glabrous; epigynous glands two, linear, 0.8–0.9 cm long, cream. Fruit not seen.

Distribution**:** India, Assam, Kakoi Reserve forest and Myanmar (Htamanthi Wildlife Sanctuary, Sagaing Region) (**Map 12**).

Phenology**:** Flowering from August to September. Flowers open in the morning and last for 24 hrs. Fruiting period unknown.

Etymology**:** The specific epithet refers to yellow to orange colored and fusiform shaped inflorescence.

Habitat & Ecology**:** The plants prefer to grow near the bank of streams or rivers as lithophytes. The typical habitat is found to be semi-evergreen forest. They grow as scattered small populations with one or two individuals. Moist dark soil is suitable for natural growth and flowering. It grows in association with *Globba multiflora* Wall. ex Baker, *Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult., *Ardisia humili* Vahl., *Callicarpa longifolia* Lam., *Chloranthus elatior* Link, *Ocotea lancifolia* (Schott) Mez etc.

IUCN status (Proposed here)**:** Data Deficient (DD)

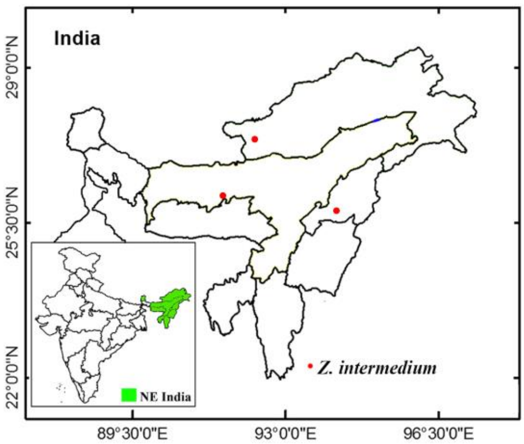
Specimens examined**: India. Assam,** North Lakhimpur district, Kakoi Reserve forest, Bank of Kakoi river, 20 August 2018 ex hort. in Garden of Botanical Survey of India (Eastern Regional Centre, Meghalaya, East Khasi Hills, Shillong, Woodland Campus), *N. Odyuo & D.K. Roy 128913* (ASSAM!).

Notes**:** *Z. flavofusiforme* was originally described from Myanmar by and Tanaka & Aung in 2016 and later Odyuo and Roy reported the plant from Assam in 2019 as a new distributional record to India. We couldn’t collect the plants from the wild. The descriptions are based on the live specimens growing at the experimental garden of the Botanical Survey of India, Shillong, Meghalaya. *Z. flavofusiforme* in India shows an extensive intraspecific variation while evaluating it to the specimens from

Myanmar. The distinctions become mainly found in the inflorescence as their form and size vary considerably with the age of the plant. The younger plants are characterized by more fusiform and cylindrical spikes because of their closely imbricating bracts while the mature plant seems greater of a flattened spike because the bracts get loosen in due course. The rhizome color also varies and intensifies as the plant grows for two or three years.

12. *Zingiber intermedium* Baker in Hook.f., Fl. Brit. India 6: 246. 1892; Mitra, Fl. Pl. East. India 1: 253. 1958; Rao & Verma in Bull. Bot. Surv. India 14: 137. 1972; Tripathi & Singh, J. Econ.Taxon. Bot. 30: 526. 2006; A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. 1:133. 2020. ***Type*: India, Meghalaya,** Khasi Hills, Bhorlassa, *s.d*., 3500 ft, *Clarke s.n.* (K). **Map 13**

Perennial rhizomatous herbs. Leafy shoot 90–100 cm tall, leaves subsessile; laminae lanceolate or oblanceolate, 25–27 × 6–7 cm, abaxially sparsely pubescent along the midrib, base obtuse, apex acuminate. Ligules membraneous c. 5 mm long. Inflorescence radical, peduncle c. 20 cm; spikes globose, 10 × 5 cm; bracts lanceolate, membraneous, c. 3.7 cm long; bracteoles shorter than bracts. Flowers reddish black; calyx tubular with unilateral split, c. 3.2 cm long; floral tube as long as bracts; corolla lobes pale red, c. 3 cm long narrowly ovate; labellum suborbicular, c. 2.5 × 2.3 cm, reddish black with yellow blotches and dots; lateral staminodes oblong; filament reduced; anther c. 7 mm long; anther crest longer than anther theaca, reddish black, wrapped around the stigma; Ovary trilocular with axile placentation; epigynous glands two, cream, c. 2 mm long, linear. Fruit not seen.



Map 13. Distribution of *Z. intermedium.*

***Distribution*:** Endemic to Northeast India, known from Arunachal Pradesh, Nagaland and Meghalaya.

***Phenology*:** July to October.

***IUCN status*:** Data deficient (DD)

***Notes*:** We couldn't collect any specimens of *Z. intermedium* from Northeast India during the study and the short description is given above is based on herbarium specimens and largely on Baker and Rao & Verma. Further exploration is needed to assess the survival status of this species.

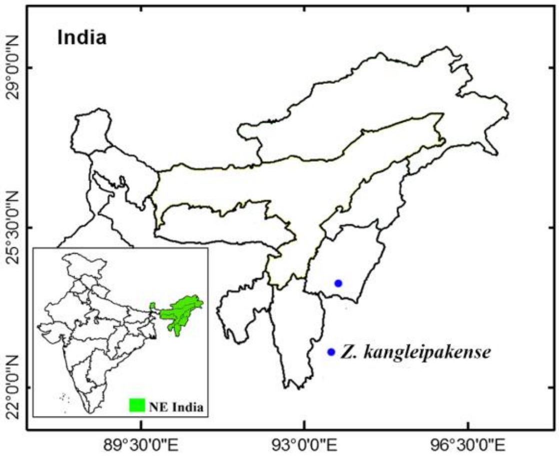
***Specimens examined*:** **India, Arunachal Pradesh,** West Kameng District., Tipi Nala, 12 October 1996, *Sunil Tripathi 20331* (CDRI). **Assam,** North Khasia, Bhoilasa, 06 August 1886, *C. B. Clarke 44443* (K!). **Nagaland**, Kohima District, 4500 m, 30 October 1989, *C. B. Clarke 41389* (CAL).

13. *Zingiber kangleipakense* Kishor & Škorničk., Gard. Bull. Singapore 65(1): 40. 2013; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. Nor. Reg. Ind. 1: 152. 2021. ***Type***: **Inida, Manipur**, Imphal, Sagolband, c. 24º48'N 93º55'E, 780 m. 20 July 2000, *Kishor 9* (holo CAL!; iso SING!, iso Herbarium of Institute of Bioresources and Sustainable Development, Imphal). **Fig. 13**

Perennial, non-stoloniferous rhizomatous herbs. Rhizome thick, dichotomously branched, externally light brown, internally pale cream when mature, 1.8–2 cm diameter. Leafy shoot 150–170 cm tall, leaves 8–15 in number when flowering; pseudostem 70–90 cm long, sparsely pubescent; basal sheath without blade 3–4, green, sparsely pubescent; ligules bilobed, 2–3.2 mm long, hyaline, glabrous, apex acute; petiole subsessile, pulvinate; laminae oblong–lanceolate, 35–42 × 7–8 cm, apex acuminate, base cuneate, margin entire, adaxially dark green, pubescent near the vein, abaxially light green, pubescent. Inflorescence generally arising from the rhizome on a separate short peduncle, rarely breaking through the leaf-sheaths up to 25 cm above the ground, radical, spicate, spikes ovate, 5–8 × 3–4 cm, two flowers opening at a time; peduncle 0.5–1 cm, white, sheathing bracts white; sterile bracts broadly ovate, apex rounded, white with pale reddish lines at the apex, glabrous internally and sparsely pubescent externally; fertile bracts each enclosing a single flower, ovoid, 3.2–3.5 × 1.8–2.3 cm, white or pale green with purplish or yellow

Fig. **13.** ***Zingiber kangleipakense*** Kishor & Škorničk. **A.** habit; **B. C. & D.** inflorescence with flowers; **E.** rhizome; **F.** single flower; **G.** bract; **H.** bracteole; **I.** calyx; **J.** corolla lobes; **K.** labellum adaxial & abaxial view; **L.** stamen side & front view; **M.** ovary with epigynous glands.

tinge at apex, apex acute; bracteoles narrowly ovate, 3.2–3.8 × c. 0.8 cm, apex bilobed or notched, white with yellowish tinge at apex, glabrous internally, sparsely pubescent externally. Flowers 6–6.5 cm long; calyx tubular with unilateral split, c. 2.5 × c. 0.5 cm, apex tri-lobed, hyaline, membranous, pubescent; corolla tube cream, 5 cm long, glabrous; dorsal corolla lobe narrowly ovate, 2.3–2.5 × 0.4–0.6 cm, apex acute, pale yellow at middle and apex white at base with translucent veins, glabrous; lateral corolla lobes narrowly ovate, 2.3–2.5 × c. 0.4 cm, apex acute, pale yellow at middle and apex white at base with translucent veins, glabrous on both sides, incurved soon after opening of flower; labellum oblong to obovate, 1.8–3 × 1–1.5 cm, apex rounded, margin wavy and crisped, yellow, glabrous; lateral staminodes very small or reduced, c. 0.2 × c. 0.2 cm, yellow, adnate. Stamen c. 1.5 × c. 0.2 cm; filament reduced to c. 1 mm long, connective tissue yellow, glabrous; anther thecae cream, c. 1 × c. 0.2 cm; anther crest deep yellow, 0.5–0.6 cm long, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, 3–4 × c. 3 mm, cream, trilocular with axile placentation, densely pubescent; epigynous glands two, 2–3 mm long, cream, linear. Fruit not seen.



Map 14. Distribution of *Z. kangleipakense*.

Distribution**:** We have collected this species from the state of Meghalaya and Mizoram. Young rhizomes and shoots are available in the local markets of Manipur and Mizoram (**Map 14**).

Phenology**:** Flowering starts from June to July. Flowers last for one day. Fruiting from August to September.

Etymology**:** The specific epithet '*kangleipakense*' refers to the Kangleipak, an old name of Manipur, which is the natural habitat of *Z. kangleipakense*.

Habitat & Ecology**:** *Z. kangleipakense* prefers moist and shady areas for growth. Some populations are also observed in open fields. This particular species shows a narrow distribution in Northeast India. A previous study reports its occurrence in Manipur only. The plants are growing in a mixed evergreen forest along with *Hypoestes phyllostachya* Baker, *Crotalaria retusa* L., *Impatiens balsamina* L., *Pandanus* sp., *Rungia* sp. etc. They are usually found in clayey soil. The annual rainfall of the typical localities is 1000–1300 mm and has a temperature range of 12– 27^{o}C.

***IUCN status* (Proposed here):** As this species is locally cultivated and plenty available in the local market made us to conclude that the status is least concerned (LC).

Notes**:** *Z. kangleipakense* is closely allied to *Z. roseum* in having thick, fleshy, creamy white or pale yellow rhizome, subsessile leaves of similar size and shape, yellowish white labellum with very small lateral staminodes, but differs by yellow corolla lobes and anther crest. *Z. kangleipakense* shares some characteristics with Chinese *Z. longiligulatum* S.Q.Tong, but the latter only has a height of 1 m, poses larger leaves, narrower bracts orange anther crest. According to the observation by Rajkumar (2013), it was difficult to place *Z. kangleipakense* in Sect. *Cryptanthium* as it sometimes produces an inflorescence emerging through the leaf sheath which is a characteristic feature of Sect. *Pleuranthesis*. But we couldn't come across such type of inflorescence development in any of the population studied. We have observed a similar situation in the case of *Z. mizoramensis* which also produces an inflorescence which is the characteristic feature of Sect. *pleuranthesis*. Based on the evidence from pollen studies we have decided to place *Z. kangleipakense* in Sect. *Cryptanthium* as it produces elliptic pollen with spirostriate sculpturing. In addition, anatomical characters delimit Sect. *pleuranthesis* from the rest of the *Zingiber* Sect. in having a well defined adaxial and abaxial hypodermis in the leaf lamina.

Specimen examined: **India**, **Manipur**, Imphal west District, 1000 m, 23 July 2018, *Rahul 153564* (CALI). **Meghalaya**, East Khasi Hills, Shillong, Laitumakhrah, 1220 m, 3 August 2017, *Jayakrishnan T*. 159501; Jaintia Hills District, Jowai, 1380 m, 11th July 2017, *Jayakrishnan T. 153510* (CALI); **Mizoram**, Champai District, Murlen National Park, 24 August 2008, *Prasanth & shameer 42868* (CALI); *Ibid.*, 1250 m, 25 July 2017, *Jayakrishnan T.* & *Nikhil Krishna 153528* (CALI).

14. *Zingiber kerrii* Craib, Bull. Misc. Inform., Kew. 403. 1912; Loes-ener in Nat. Pflanzan fam. ed.2. 15a: 588. 1930; Ida Theilade, Nordic J. Bot.19 (4): 397. 1999; Thongam *et al.*, Taiwania 58 (4): 291–294. 2013; Bai *et al.*, Gard. Bull. Singapore 67(1): 137. 2015; Souvannakhoummane & Škorničková, Edinbugh J. Bot., 75 (1): 4. 2018; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. Nor. Re. Ind. 1: 152, 2021. ***Type***: **Thailand**, **Chiang Mai province,** Doi Sootep, 900–1200 m, 24 July 1910, *A.F. Kerr 1290* (lecto K!; isolecto K!, P!). **Fig. 14**

Zingiber menghaiense S.Q.Tong, Acta Phytotax. Sin. 25(2): 145–146. 1987; Wu & Larsen in Fl. China 24: 326. 2000; Bai *et al.,* Gard. Bull. Singapore 67(1): 137. 2015.

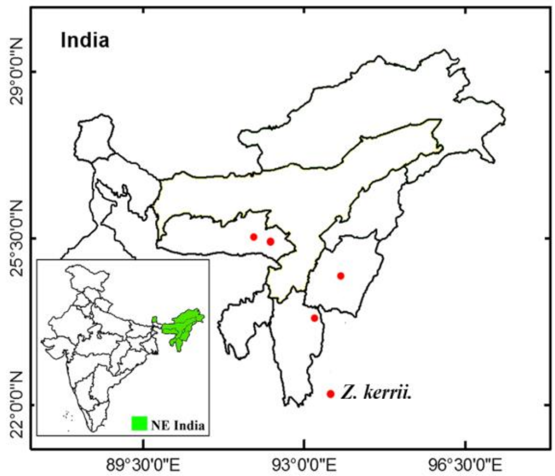
Zingiber stipitatum S.Q.Tong., Acta Phytotax. Sin. 25(2): 146–147. 1987; Wu & Larsen in Fl. China.24: 326.2000; Bai *et al.*, Gard. Bull. Singapore 67(1): 137. 2015.

Perennial rhizomatous herbs. Rhizome thick, pleasant aroma, branching with short dichotomies, externally brown with greenish tinge, internally cream, 1.3–2 cm diameter. Leafy shoot 1–1.5 m tall, leaves 30–35 in number when flowering; pseudostem 40–50 cm long, glabrous; Basal sheath without blade, 3–4 in number, dark green, glaucous; ligules bilobed, 2–3 mm long, membranous, sparsely pubescent; leaves subsessile, pulvinate; laminae linear-lanceolate, 22–25 × 4.5–5 cm, adaxially dark green, glabrous, abaxially light green, glabrous, base rounded, apex acuminate, margin entire. Inflorescence 2–3, basal, separate from the leafy shoot, spikes narrowly ovate, 7–10 cm long, single flower opening at a time; peduncle 10–12 × 1.3–1.6 cm, green, sheathing bracts dark green with purplish tinge towards the apex; sterile bracts broadly ovate, apex rounded, light green with purple patch at apex, glabrous internally and externally; fertile bracts broadly ovate, 3–3.5 × 2–2.5 cm, apex rounded, light green with purplish spot at the apex, green changes

Fig. 14. ***Zingiber kerrii*** Craib. **A.** habit; **B. & C.** inflorescence with flower; **D.** single flower; **E.** bract; **F.** bracteole; **G.** calyx; **H.** corolla lobes; **I.** labellum with lateral staminodes; **J.** stamen side & front view; **K.** ovary with epigynous glands; **L.** ovary with style and stigma.

to dark purple when mature, closely imbricating, each enclosing a single flower; bracteoles narrowly ovate, 2–2.5 × 0.7–0.8 cm, apex truncate, hyaline, glabrous; flowers 4.8–5.3 cm long; calyx tubular with unilateral split, c. 1.2 × c. 0.4 cm, apex tri-lobed, white, hyaline, membranous, glabrous; Corolla tube creamy white, 2.8–3 cm long, glabrous; dorsal corolla lobe ovate, 2–2.3 × 0.5–0.6 cm, apex acute, creamy white with translucent veins, sparsely pubescent internally and glabrous externally; lateral corolla lobes triangular or narrowly ovate, 2–2.3 × c. 0.4 cm, apex acute, creamy white with translucent veins, glabrous on both sides; labellum sub-orbicular, 2–2.5 × 0.5–0.7 cm, apex deeply notched, margin entire, creamy white, unspotted, glabrous; lateral staminodes linear, 1–1.3 × c. 0.3 cm, apex acute, creamy white, free from labellum. Stamen 1.8–2 × 0.1–0.3 cm; filament reduced to c. 1 mm long, connective tissue cream, glabrous; anther thecae cream, 0.8–1 × c. 0.3 cm; anther crest cream, c. 0.8 cm long, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-shaped; ostiole ciliate. Ovary globose, c. 2.5 × c. 2.5 mm, cream, trilocular with axile placentation, glabrous; epigynous glands two, linear, 2.5–2.7 mm long, cream. Fruit not seen.

***Distribution*:** *Z. kerrii* is known from Louangphabang province in Laos. This species, was originally described from Thailand and it has been reported from Churachandpur district of Manipur, India in 2013 (Thongam *et al.*, 2013) and also from Myanmar and China (Bai *et al.*, 2015a) (**Map 15**)



Map 15. Distribution of *Z. kerrii*.

***Phenology*:** Flowering from June to August. The flowers open in the morning. Fruit setting from August onwards.

***Etymology*:** The specific epithet "Kerrii" is in honor of Arthur Francis George Kerr (1887–1942) an Irish physician and a botanist known as the founding father of botany in Thailand. He made the first collections of *Z. kerrii*.

***Habitat & Ecology*:** This species grows in deciduous forest and mixed bamboo forest, at about c. 600 m altitude along with other Zingiberaceae species such as *Larsenianthus* sp., *Hedychium* sp. and other *Zingiber* sp. In China it has been reported to occur in grassy areas at the edge of the forest and in evergreen broad-leaved forests between 700–1300 m altitudes (Bai *et al.*, 2015a).

***IUCN status*:** Least Concern (LC)

Notes: *Z. kerrii is* only known from a single locality in India. In Thailand and Myanmar the plant occurs in Shan district (Kress *et al.*, 2003). The natural habitat is found to be degraded due to anthropogenic activities threatening its habitat. This species is used by the local people as vegetables and people harvest the plants from the forest. Young inflorescences and tender shoots are boiled or steamed or fried with chilli and dried fish.

***Specimens examined*: India, Manipur**, Churachandpur District, Ngaloi hill, 1200 m, 13 July 2018, *Murugeshan 159736* (ASSAM).

15. *Zingiber ligulatum* Roxb., Asiat. Res. 11: 348. 1810; Roxb., Fl. Ind. 1: 51. 1820; Baker, Fl. Brit. India 6: 245. 1892; K. Schum., Pflanzenr. IV, 46: 186. 1904; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot.133. 2020. ***Type*:** Hindostan, Pre-dating 1810, *Roxburgh* (n.v).

Fig. 15 & 16

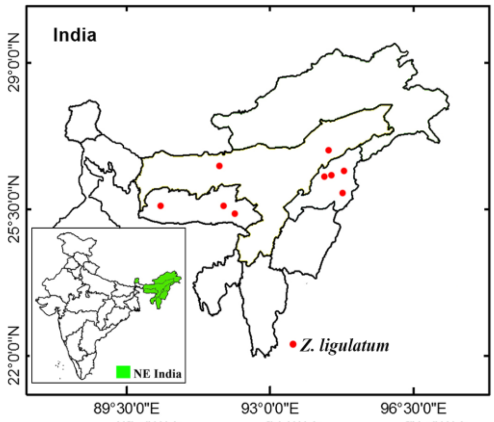
Perennial rhizomatous herbs. Rhizome thick, running, branched, horizontally elongate, externally dirty white with reddish tinge, internally creamy white, c. 2.5 cm diameter; tubers absent. Leafy shoot 100–150 cm tall, leaves 9–12 in number when flowering; pseudostem 45–80 cm long, sparsely pubescent; basal sheaths 2–3 in number, green; ligules 2.5–4 cm long, deeply bilobed and separated from the stem as a flap, hyaline with greenish tinge, glabrous; petiole light green, pubescent, pulvinate; laminae narrowly ovate, 25–30 × 8–12 cm, adaxially dark green, glabrous, abaxially light green, sparsely pubescent, base attenuate, apex acuminate, margin undulate. Inflorescence radical, spikate, half immersed in soil, one flower at a time, 7–10 cm long; peduncle 3–5 cm; spikes ovate, 7–10 × c. 5 cm; fertile bracts

Fig. 15. ***Zingiber ligulatum*** Roxb. **A.** habit; **B.** inflorescence; **C.** flower side view; **D.** flower front view; **E.** a portion of leaf base showing ligule; **F.** single flower; **G.** bract; **H.** bracteole; **I.** calyx; **J.** corolla lobes; **K.** labellum adaxial & abaxial view; **L.** stamen front & side view; **M.** ovary with epigynous glands.

Fig. 16. *Zingiber ligulatum* Roxb. Icones Roxburghianae *t. 288* (K)

each enclosing a single flower, ovate, 5–5.8 × c. 3 cm, white at middle with purplish green at apex, apex acute, glabrous; bracteoles narrowly ovate, c. 3.0 × c. 1.0 cm, creamy white at base yellowish tinged at apex, glabrous, apex deeply bifid. Flowers 6.4–7 cm long; calyx tubular with unilateral split, c. 2 × c. 0.5 cm, hyaline, apex tri-lobed, pubescent externally; floral tube cream, 4.5–5 cm long, glabrous; dorsal corolla lobe narrowly ovate, 2.8–3 × c. 0.8 cm, red with translucent veins, apex acute, curved backward when flower is open; lateral corolla lobes narrowly ovate, 2.3–2.5 × c. 0.7 cm, red with translucent veins, glabrous on both sides; labellum oblong, c. 2.6 × 1.2–2 cm, pale yellow, apex recurved and slightly notched, margin recurved at middle, glabrous; lateral staminodes acute, c. 8 mm long, pale yellow, $^{3}/_{4}{}^{th}$ portion adnate to labellum. Stamen c. 2.6 × c. 0.3 cm; filament reduced to c. 1 mm long, connective tissue glabrous, yellow; anther thecae c. 1.4 × 0.3–0.4 cm, creamy white; anther crest 1.2–1.3 cm long, deep yellow, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma funnel-shaped; ostiole ciliate. Ovary cylindrical, creamy yellow, 0.6–0.8 × c. 0.4 cm, trilocular with axile placentation, densely pubescent; epigynous glands two, linear, 0.2–0.3 cm long, cream. Fruit not seen.

***Distribution*:** This species was first reported from India. In India this species is known from Nagaland, Assam, Tripura and Meghalaya. It was also reported from Myanmar, Thailand and Laos (**Map 16**).



Map 16. Distribution of *Z. ligulatum*.

***Phenology*:** Flowering starts from late May to August and fruiting from late August to November. Flowers open in the early morning and last up to 24 hrs.

***Etymology*:** The specific epithet “ligulatum” refers to the exceptionally large flap-like ligules of the plant.

***Habitat & Ecology*:** This species has been seen growing in the margins of evergreen forests, margins of cultivation fields, roadsides etc. each population is represented by 3 to 4 individuals. They grow well in dark clayey soil, sandy soil etc. at an elevation of 500 to 1000 m in association with some Asteraceae members. The probable threats to the species are clearing of forest margins, widening of cultivation fields and clearing of roadsides.

***IUCN status* (proposed):** Least concerned (LC)

***Notes*:** The proper identification of *Z. ligulatum* has yet to be determined. According to a note in the prologue, the species is a native of India, where it was originally observed by Colonel Hardwicke and described by Roxburgh but his specimen of *Z. ligulatum* has not been found. The protologue description is sparse, consisting of only four lines, but there is more extensive explanation and a colour illustration in a subsequent work by Roxburgh (1820). This species has an identical colour painting in the Icones Roxburghianae, of which we have seen a duplicate placed at K. Our collections are a close match to the description and colour illustration published by Roxburgh in 1820. The flowers show similarities with *Z. roseum* and *Z. longligulatum* but *Z. ligulatum* can be easily recognized by its exceptionally large ligule.

***Specimens examined*: India, Assam,** Kamrup District, Boko, 20 July 2009, *Thomas & Prabhu 1207046* (CALI); Chandrapur, 18 July 2009, *Thomas & Prabhu 1207018* (CALI); Sivasagar District, Amguri, 17 July 2009, *Thomas & Prabhu 1207003* (CALI). **Meghalaya,** East Khasi Hills District, Shillong, Nortiang road, 18 August 2004, *Sanoj 95647* (CALI); West Garo Hills, Tura, Selbalgri, 07 August 2007, *Sanoj & Rajesh kumar 95127* (CALI); West Jaintia Hills district, Jowai, Tyrshi falls, 11 July 2017, *Jayakrishnan & Nikhil 153510* (CALI). **Nagaland,** Kohima District, behind secretariat, 02 September 2006, *Sanoj & Thomas 105583* (CALI); Longleng District, on the way to Dikku, 28 August 2006, *Sanoj & Thomas 105551* (CALI); Longleng District, Dikku, 17 May 2007, *Thomas & Nissar103677* (CALI); Mokokchung, near Dikku road, 19 May 2006, *Sabu & Pradeep 103614* (CALI); Tuensang District, On the way to Tuensang from Mokokchung, 29 July 2016, *Jayakrishnan & Nikhil 150210* (CALI); Zuheboto District, Lumami, 22 June 2005, *Sanoj 92107* (CALI); Lumami, Govt. Hospital, 14 May 2007, *Thomas & Nissar*

103684 (CALI); Lumami, Nagaland University campus, 26 August 2006, *Sanoj & Thomas 105515* (CALI).

16. *Zingiber marginatum* Roxb., Asiat. Res. 11: 349. 1810; Roxb., Fl. Ind. 1: 57. 1820; Baker, Fl. Brit. India 6: 249. 1892; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020. ***Type*:** Roxburgh's specimen or color drawing is not available in any of the Indian or international herbaria hence this species is to be typified.

Dymczewiczia marginata (Roxb.) Horan., Prodr. Monogr. Scitam. 26. 1862.

Leafy stem 3 to 4 ft., leaves 4 to 6, ligule very large, lanceolate, brown; spike terminal, sessile, bracts obovate with broad transparent membranous margin, closely imbricate, hairy, brown when dried, obtuse, corolla and lip not seen. (**Taken from protologue**)

***Notes*:** *Z. marginatum* was described by Roxburgh in 1810 but his description was very brief and no locality was mentioned. Blume and Miquel give the species as Javan but the origin and identity of the species are still in question. Despite our best effort, we couldn't locate any herbarium specimen from Indian herbaria. As this taxon is characterized by a terminal inflorescence we strongly doubt this may be conspecific with *Z. capitatum* or *Z. flavofusiforme*, the two currently known species with terminal inflorescence from India. According to Roxburgh *Z. marginatum* is characterized by bracts with transparent membranous margins and we couldn't come across such a species during the expedition to Northeast India. In many species when the inflorescence matures the bracts get dehydrated and the margin becomes membranous so it is difficult to confirm the exact identity using this character hence the identity of *Z. marginatum* will remain a question until Roxburgh's specimen is obtained.

17. *Zingiber meghalayense* Sushil K. Singh, Ram.Kumar & Mood, Phytotaxa 77(4): 61. 2013; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U. Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg.

India. 1: 152, 2021. ***Type*****: India**, **Meghalaya**, Garo Hills, Nokrek Biosphere Reserve, c. 800 m, 26 March 2011, *R. Kumar 104078* (holo ASSAM; iso CAL).

Fig. 17

Perennial, non stoloniferous rhizomatous herbs. Rhizome fleshy, not so much branched, externally dark brown, internally brown with a creamy outer circle, 1–1.5 cm in diameter; tubers ovate, 2.8–3.1 × 1.8–2 cm, cream. Leafy shoots 1.5–1.8 cm tall, leaves 10–14 nos. when flowering; pseudostem 20–40 cm long, dark green with purplish tinge sparsely pubescent; basal sheaths 2–3 nos., purplish brown, sparsely pubescent; ligules 7–8 × 4–6 mm, green, margin hyaline, pubescent at base and margin, apex round; petiole subsessile, pulvinate; laminae narrowly ovate, 20–22 × 3–3.5 cm, adaxially dark green, glabrous, abaxially light green, pubescent, base cuneate, apex acuminate, margin undulate. Inflorescence radical, spicate, one flower at a time, 3.5–6.5 × 2.3–3.5 cm; peduncle 4.5–7 cm long, covered with bright red sterile bracts; spikes cylindrical with loosely imbricating bracts; sterile bracts ovate, red, apex acute, pubescent internally and externally; fertile bracts enclosing single flower, spatulate, 4–5.5 × 1–1.4 cm, bright red, apex acute to round broader than middle and base; bracteoles involute, linear, 2.9–3.4 × 0.8–1.2 cm, cream with reddish tinge at apex, pubescent both internally and externally, apex truncate. Flowers 6.5–7.5 cm long; calyx tubular with unilateral split, c. 1.4× c. 2 cm long, white, tri-lobed, pubescent externally and glabrous internally; floral tube creamy yellow, 2.8–3 cm long, glabrous; dorsal corolla lobe narrowly ovate, 3.2–4.1 × 0.8–1 cm, reddish orange with creamy yellow at base, glabrous both internally and externally, apex acute; lateral corolla lobes narrowly ovate, 2.5–3 × 0.6 cm, reddish orange with creamy yellow at base, glabrous; labellum obovate, 2.8–3.2 × 1.2–1.5 cm, creamy yellow with purple blotches, apex slightly notched, margin smooth, glabrous; lateral staminodes obovate, 2–2.5 × c. 0.7 cm, adnate, creamy yellow, apex round. Stamen 2–2.2× c. 0.1 cm; filament c. 0.1 cm long, connective tissue glabrous, creamy yellow; anther thecae c. 1 × c. 0.2 cm, cream; anther crest 0.8–1 cm long, creamy yellow with purple lines at apex, wrapped around the stigma, glabrous.Style filiform, white, glabrous, stigma cup-shaped; ostiole ciliate; Ovary

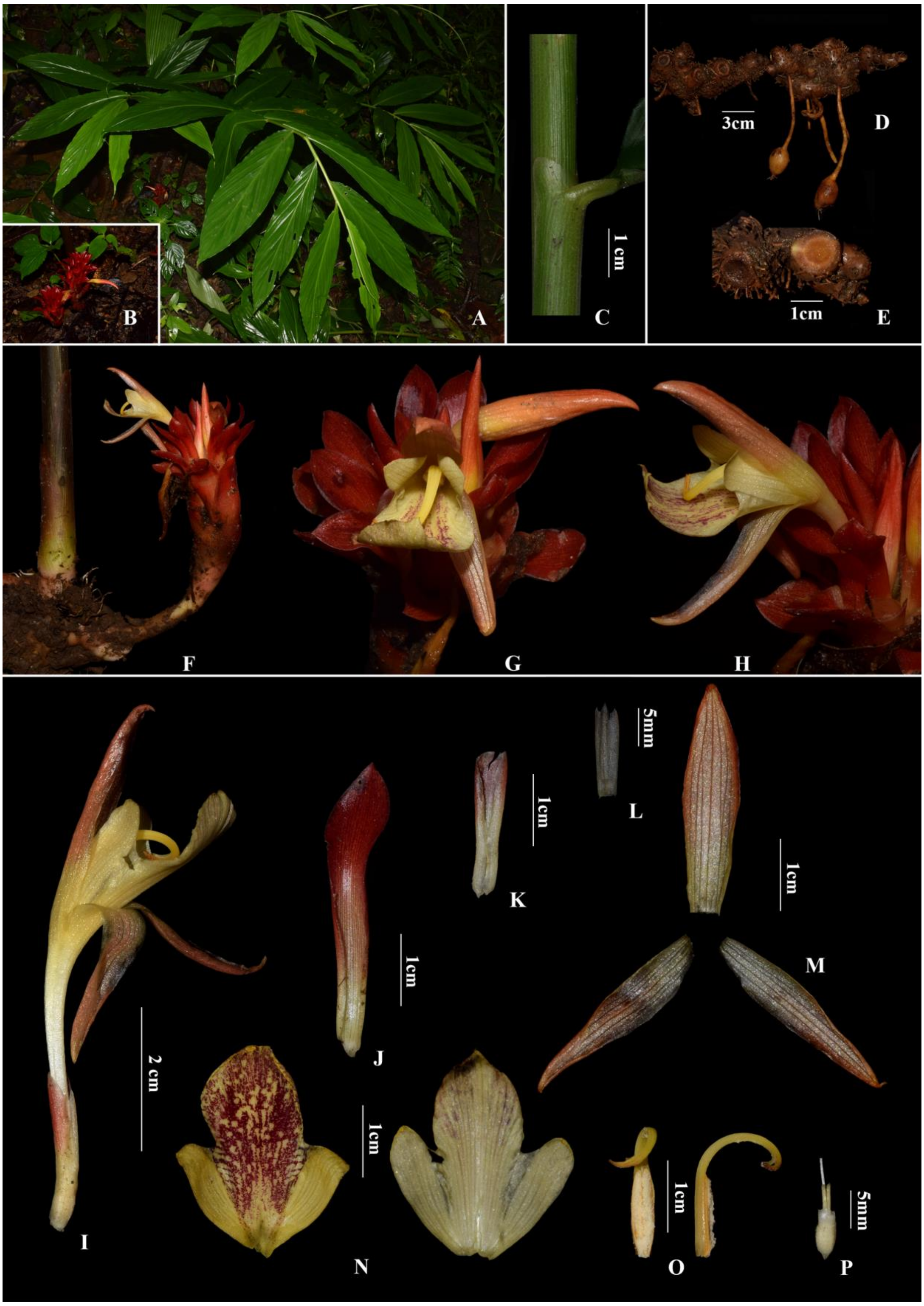


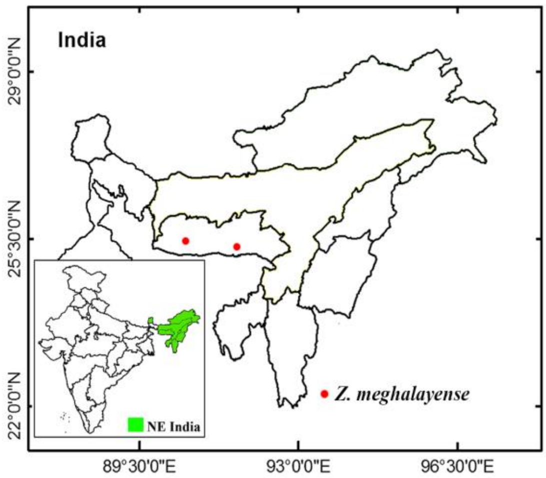
Fig. **17.** ***Zingiber meghalayense*** Sushil K.Singh, Ram.Kumar & Mood. **A.** habit; **B.** inflorescence; **C.** a portion of leaf base showing ligule; **D. & E.** rhizome; **F.** inflorescence with flower; **G. & H.** flower front & side view; **I.** single flower; **J.** bract; **K.** bracteole; **L.** calyx; **M.** corolla lobes; **N.** labellum adaxial & abaxial view; **O.** stamen front & side view; **P.** ovary with epigynous glands.

cylindrical, cream, 0.4–0.6 × 0.3–0.4 cm, trilocular with axile placentation, densely pubescent; epigynous glands linear, cream, 0.4–0.8 cm long; Fruit not seen.

***Distribution*:** Currently known from Meghalaya only (**Map 17**).

***Phenology*:** Flowers from August through September.

***Etymology*:** Named after the Indian state "Meghalaya".



Map 17. Distribution of *Z. meghalayense.*

***Habitat & Ecology*:** *Z. meghalayense* grows on sandy soils along the margins of mixed evergreen forests at c. 800 m elevation in association with *Globba multiflora, Curcuma* sp. etc.

***IUCN status*:** Least Concerned (LC)

***Notes*:** *Z. meghalayense* is similar to *Z. rubens* both having tall clumping plants, but *Z. meghalayense* shows much longer and wider leaves with a short ligule. In the flowering stage, both species produce a radical inflorescence on short peduncles emerging from the rhizome at the base of the stem (typical character of Sect. *Cryptanthium* Horan.). In *Z. meghalayense* the bracts are loosely imbricating, linear and dull red with a rounded reflexed apex, whereas in *Z. rubens* the bracts are closely imbricating, ovate and bright to pale red with an acuminate apex. The flower of *Z. rubens* is characterised by maroon blotched labellum and totally adnate yellow lateral staminodes. Whereas the flower of the *Z. meghalayense* is light yellow with purple stripes prominent, acute lateral staminodes.

***Specimen examined*:** **India**, **Meghalaya**, East Khasi Hills District, Sohra, on the way to Thangrang Park, 830 m, 08 July 2017, *Jayakrishnan & Nikhil 153503* (CALI).

18. *Zingiber mekongense* Gagnep., Bull. Soc. Bot. France 54: 168. 1907; Triboun *et al.*, Thai J. Bot. 6: 57. 2014; Cho *et al.*, Checklist Seed Pl. Cambodia: 209. 2016; Souvannakhoummane & Leong-Škorničková, Edinburgh J. Bot. 75: 16. 2018; Aung & Tanaka, Bull. Natl. Sci. Mus., Ser. B. 45: 4. 2019; Huong *et al.*, VNU J. Sci. 36: 3. 2020. ***Type***: **Laos**, De Stung Streng à Kong, Luang-prabang, *Thorel 2198* (holo P!). **Fig. 18**

Perennial, rhizomatous herbs. Rhizome brown externally, pale yellow internally, mildly aromatic. Leafy shoots 50–150 m tall, leaves 10–12 nos. when flowering; basal sheaths 3–4 in number, green with reddish tinge; ligules bilobed, 2.2–3.4 mm long, membranous, translucent white, sparsely hairy, rounded at apex; petiole 2–3 cm long, green, pulvinate; laminae oblong, 35–62 × 5.5–12 cm, dark green on adaxial surface, light green on abaxial surface, glabrous or slightly pubescent on the upper surface, glabrous on lower surface, base cuneate, apex acuminate, margin undulate. Inflorescence two to three, 1–2 flowers at a time, radical spicate, 5–10 cm long; peduncle procumbent with inflated sheathing bract 4–7 cm long, cream or greenish with reddish tinge at apex; spikes ovate, 5.5–8.5 × 2.3–4.5 cm; fertile bracts, ovate, 3.5–4.1 × 0.5–1.8 cm, cream or pale red or greenish, apex acute, glabrous internally and sparsely pubescent externally; bracteoles narrowly ovate, 3.5–3.8 × 0.5–0.8 cm, pinkish white or pale cream, glabrous, apex acute. Flowers 5–7 cm long; calyx tubular with unilateral split, c. 2.5 × 0.5 cm, white, apex tri-lobed, outer sparsely pubescent, inner glabrous; floral tube 3.5–3.8 cm long, glabrous, white; dorsal corolla lobe narrowly ovate, 2.5–2.7 × 0.9–1 cm, red with translucent veins, acuminate at apex; lateral corolla lobes narrowly ovate, 2.2–2.5 × 0.5–0.7 cm, pale red with translucent veins, apex acute, incurved soon after opening of flower; labellum oblong, 2.2–2.6 × 1.5–2.2 cm, light yellow at middle, maroon or violet at margin with creamy yellow spots, apex rounded, emarginated, margin crispy; lateral staminodes, 1.5–2.2 × 0.5–1 cm, $^{1}/_{4}{}^{th}$ adnate to labellum, creamy yellow at base maroon or violet with yellow spots at middle and apex, apex rounded. Stamen c. 2.3 × c. 0.3 cm; filament reduced to c. 2 mm long, connective tissue glabrous or sparsely hairy, cream or white; anther crest (beak) 1–1.5 cm long, pale white, wrapped around the stigma, glabrous. Style filiform, white, stigma cup-shaped, ostiole ciliate.

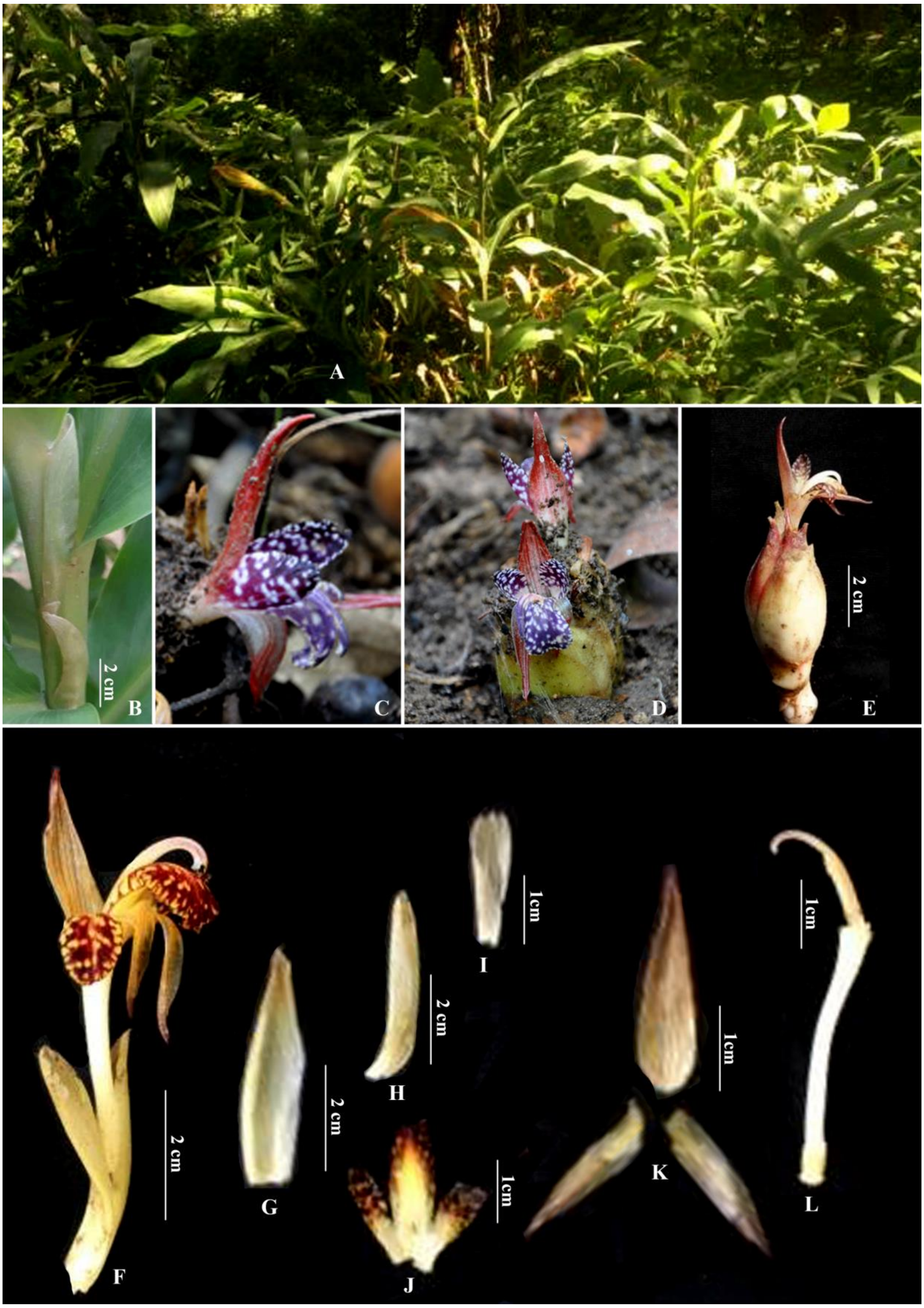
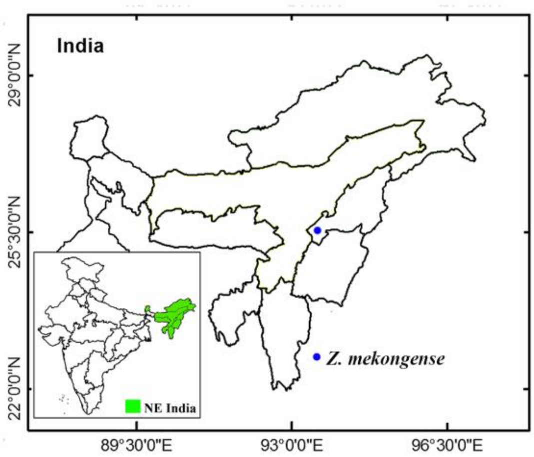


Fig. 18. ***Zingiber mekongense*** Gagnep. **A.** habit; **B.** a portion of leaf base showing ligule; **C. & D.** inflorescence with flowers (Indian specimen); **E.** Spike with flower; **F.** single flower; **G.** bract; **H.** bracteole; **I.** calyx; **J.** labellum adaxial view; **K.** corolla lobes; **L.** floral tube with ovary and stamen. (**E–F** Thailand specimen) Photos by Tanaka and Lê Thị Hương. (**Reproduced with permission)**

Ovary cylindrical, cream, c. 0.5 × c. 0.3 cm, trilocular with axile placentation, villous; epigynous glands two, linear, c. 6 mm long, cream. Fruit capsule, cream, glabrous, 3.5–5 × 1.3–1.5 cm; seeds globose, 4–5 × 3–4 mm, red, glabrous, arilate, aril white. (Taken from Huong *et al.* (2020)).

Distribution: Cambodia, India, Myanmar, Laos, Thailand and Vietnam (**Map 18**).

Phenology: Flowers from July to August, fruiting from August to October.



Map 18. Distribution of *Z. ligulatum*.

Habitat & Ecology: They prefer to grow under the cover of a secondary mixed bamboo forest, in a dry open space. Plants were found in patches with a distance of around 150–200 m between them, growing in a population of about 20–30 individuals.

IUCN status: Data Deficient (DD)

Notes: Gagnepain (1907) described *Zingiber mekongense* from Laos and it has lately been discovered in Thailand, Myanmar and Vietnam (Triboun *et al.*, 2014; Aung & Tanaka, 2019; Huong *et al.*, 2020). This species was reported in Cambodia by Chou *et al.* (2016). Recently Moaakum *et al.* (2022) reported this plant from Nagaland as a new distributional record to Indian flora. *Z. mekongense* is related to *Z. flavomaculosum* S.Q. Tong, but has densely imbricate inflorescence bracts with convex, sharp, brown hairy tip (Aung & Tanaka, 2019). Bracts range in color from red to green and in Indian plants, they were green.

Specimens examined: **India**, **Nagaland**, Peren District, Intangki Reserve Forest, 550 m elev., 25°31′80.0″N, 93°25′36.2″E, 8 June 2016, *Moaakum & Santanu Dey MOAZ 074* (ASSAM).

19. *Zingiber mizoramensis* Ram.Kumar, Sushil K.Singh & S.Sharma, Phytotaxa 233 (1): 83. 2015; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. Nor. Re. Ind. 1: 152, 2021. ***Type*: India**. **Mizoram**, Champhai District, Murlen National Park, 93°18′48.07″E 23°34′37.12″N, 19 September 2014, *Ramesh Kumar et al., 131495* (holo ASSAM). **Fig. 19**

Perennial, rhizomatous herbs. Rhizome fleshy, clump forming, externally dark brown, internally cream, 1.6–1.9 cm in diameter; roots thick, with long spine-like root hairs, tubers not seen. Leafy shoots 90–100 cm tall, leaves 16–18 numbers when flowering; pseudostem 48–55cm long, green purplish near the base, puberulent or farinose; basal sheaths 4–5 in number, purplish towards the apex, green towards base, glabrous or sparsely pubescent; ligules 3–4 mm long, green with brownish tinge, pubescent, apex truncate, hairy; Leaves subsessile, pulvinate; laminae narrowly ovate, 25–35 ×5–6.5 cm, adaxially green glabrous, abaxially light green, pubescent, base cuneate, apex acuminate, margin undulate. Inflorescence 2–3 per plant, one or two flower at a time, radical spicate, 14.5–17 cm long; peduncle 9–12 cm long, creamy white with reddish tinge, covered with creamy white sterile bracts with reddish tinge; spikes broadly ovate, 5.5–6.2 × 4.1–4.8 cm; sterile bracts broadly ovate, dark red, apex acute, glabrous both internally and externally; fertile bracts enclosing a single flower, narrowly ovate, 3.5–3.8 × 1.3–1.8 cm, dark red at apex, cream with reddish tinge at middle and base, apex slightly notched with long hairs; bracteoles narrowly obovate, 3.1 × 1.2–1.4 cm, red at apex and creamy with reddish tinge at middle and base, apex truncate, glabrous externally and internally, pubescent at margin at apex; Flowers 5.9–6.5 cm long (from tip of labellum to base of ovary); calyx tubular with unilateral split, 1.5–1.6 × 0.7–0.8 cm (split opened), translucent white, apex bi-lobed with reddish tinge, externally pubescent at base, inner glabrous; floral tube 3.4–3.6 × c. 0.3 cm, wide near the mouth of flower, cream with pinkish lines, sparsely pubescent; dorsal corolla lobe narrowly ovate, 3.2–3.3 × 1–1.2 cm, pinkish cream at apex creamy towards base, hairiness glabrous internally and sparsely pubescent externally, apex acute, deflexed at anthesis; lateral corolla lobes narrowly ovate, 2.8–3 × 0.7–0.8 cm, pinkish cream at apex creamy towards

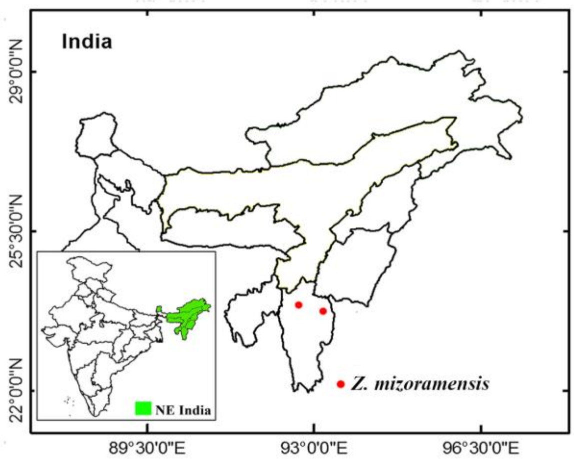
Fig. 19. ***Zingiber mizoramensis*** Ram.Kumar, Sushil K.Singh & S.Sharma. **A.** habit (Inset: Basel portion of the plant); **B, C. & D.** inflorescence with flowers; **E.** a portion of leaf base showing ligule; **F. & G.** rhizome; **H.** single flower; **I.** bract; **J.** bracteole; **K.** calyx; **L.** corolla lobes; **M.** labellum adaxial & abaxial view; **N.** stamen front & side view; **O.** ovary with epigynous glands.

base, glabrous internally and sparsely pubescent externally, deflexed at anthesis; labellum obovate, 2.9–3.2 × 1.4–1.6 cm, creamy white at base, creamy white with purple blotches at apex and middle, acute at apex, margin entire, glabrous both externally and internally; lateral staminodes narrowly ovate, c. 2.2 × c. 0.7 cm, ¾th portion adnate to labellum, creamy white with purple lines and spots at apex, apex acute. Stamen 3–3.4 × 0.2–0.4 cm; filament size c. 2 mm long, connective tissue glabrous, creamy white; anther thecae 1.5 × c. 0.4 cm, creamy yellow; anther crest 1.5–1.7 cm long (straightened), cream with pinkish purple lines and spots, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-shaped, with purple spots; ostiole ciliate. Ovary cylindrical, cream with purple stripes, c. 0.9 × c. 0.4 cm, trilocular with axile placentation, pubescent; epigynous glands two, linear, size 3–4 mm long, cream. Fruit not seen.

Distribution**:** Currently known only from Mizoram (**Map 19**).

Phenology**:** Flowers from September to October.

Etymology**:** Named after the State of Mizoram from where the type was collected.



Map 19. Distribution of *Z. mizoramensis*.

Habitat & Ecology**:** It grows on moist dark humus-rich soil in evergreen forest edge at an elevation between 1200 and 1400 m in association with *Leea indica* (Burm.f.) Merr., *Impatiens* sp., *Pteris* sp., *Globba multiflora* Wall. ex Baker etc.

IUCN status **(Proposed here):** Least concerned (LC)

Notes**:** *Z. mizoramensis* is very much allied to *Z. nimmonii* and *Z. arunachalensis*, but differs from the former in its odorless, pale creamy rhizome, oblong-obovate, glabrous bracts, obtuse labellum and much broader lateral staminodes whereas *Z. nimmonii* has purplish lilac rhizomes which are strongly aromatic, lancelolate bracts and pubescent calyx, corolla, bifid labellum and comparatively narrower lateral staminodes. It differs from *Z. arunachalensis* in having red, ovate spikes with short peduncles, oblong bracts with truncate apices, purplish pink with white base corolla lobes and adnate, ovate–lanceolate lateral staminodes.

***Specimens examined*: India**, **Mizoram,** Aizawl District., Durtlang, Siphira village, 1100–1200 m, 15 July 2017, *Jayakrishnan & Nikhil 153522* (CALI); Champhai District, Murlen National Park, 25 July 2017, *Jayakrishnan & Nikhil 153527* (CALI).

20. *Zingiber murlenica* Ram.Kumar, Sushil K.Singh & S.Sharma, Phytotaxa 233 (1): 80. 2015; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 1: 152, 2021. ***Type***: **India, Mizoram**, Champhai District, Murlen National Park, 93°15′30.49″E 23°38′42.12″N, 11 August 2014, *Ramesh Kumar et al., 128821* (holo ASSAM). **Fig. 20**

Perennial rhizomatous herbs. Rhizome thick, branched, externally brown, internally grayish brown, 1.5– 2 cm diam. Leafy shoot 1–2.5 m tall, leaves 14–18 in number when flowering; pseudostem 30–40 cm long, glabrous; Basal sheath without blade, 3–4, dark green, glabrous; ligules bilobed, 4–5 mm long, membranous, green, margin hyaline, glabrous, apex rounded; petiole absent or sub-sessile, pulvinate; laminae elliptic-lanceolate, 25–52 × 10–15 cm, apex acuminate, base cuneate, adaxially dark green, glabrous, abaxially light green, pubescent. Inflorescence 1–2, basal, radical spicate, spikes ovate or sub-globose, 5–7 × 3–4.5 cm, single flower opening at a time; peduncle 7–11 cm long, procumbent, pinkish white, sheathing bracts pinkish white; sterile bracts broadly ovate, apex acuminate, deflexed, cream with greenish tinge pink at apex, glabrous internally and externally; fertile bracts narrowly ovate, 5–7 × 2–2.5 cm, apex acuminate, deflexed, pinkish or creamy white with reddish tinge at apex, gives a stellar appearance to spike, each enclosing a single flower; bracteoles narrowly ovate, 3–3.2 × 0.7–0.8 cm, apex notched, white, glabrous. Flowers 7–9 cm long; calyx tubular with unilateral split, 1.8–2 × c. 0.4 cm, apex tri-lobed, creamy white, membranous, glabrous; corolla tube creamy white, 5.5–6 cm long, glabrous; dorsal corolla lobe narrowly ovate, 2.8–3 × 0.8–1 cm, apex

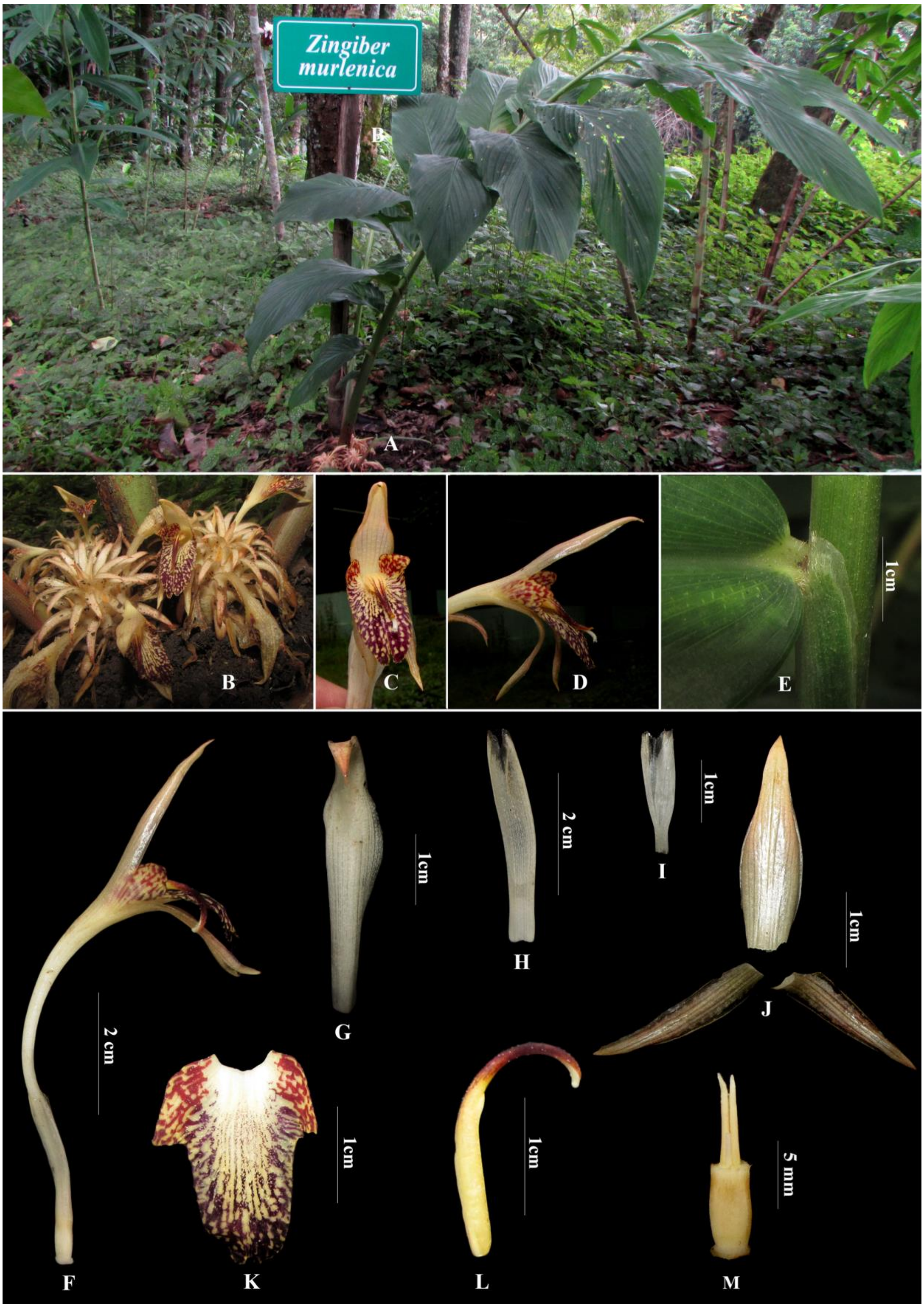


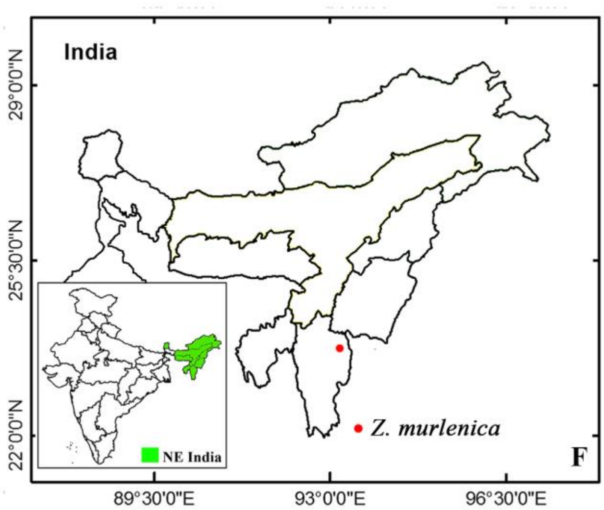
Fig. 20. ***Zingiber murlenica*** Ram.Kumar, Sushil K.Singh & S.Sharma. **A.** habit; **B.** inflorescence with flowers; **C.** flower front view; **D.** flower side view; **E.** a portion of leaf base showing ligule; **F.** single flower; **G.** bract; **H.** bracteole; **I.** calyx; **J.** corolla lobes; **K.** labellum; **L.** stamen; **M.** ovary with epigynous glands.

acute, curved, creamy white with translucent veins, pinkish tinge at apex, glabrous; lateral corolla lobes triangular or narrowly ovate, 2.5–2.8 × c. 0.4 cm, apex acute, creamy white with translucent veins, pinkish tinge at apex, glabrous on both sides; labellum broadly ovate, 2–2.3 × 1.5–1.7 cm, apex truncate, margin entire, creamy white with deep purple blotches and stripes, glabrous; lateral staminodes triangular, 0.8–0.9 × c. 0.3 cm, apex acute, maroon with yellow stripes, ¾th portion adnate to labellum. Stamen 2–2.3 × c. 0.2 cm; filament reduced to c. 1 mm long, connective tissue creamy yellow, glabrous; anther thecae cream, c. 1.5 × c 0.3 cm; anther crest deep purple, c. 0.8 cm long, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-shaped; ostiole ciliate. Ovary cylindrical, 0.5–0.6 × c. 0.4 cm, cream, trilocular with axile placentation, pubescent; epigynous glands two, 6–7 mm long, cream, linear. Fruit not seen.

Distribution**:** Currently known only from the type locality (Murlen National Park, Mizoram). (**Map 20**).

Phenology**:** Flowers from June to August.

Etymology**:** Named after Murlen National Park.



Map 20. Distribution of *Z. murlenica*.

Habitat & Ecology: The plants are growing on sandy, moist soil in exposed forest margins at an elevation of 900 m in association with *Z. mizoramensis*.

IUCN status**:** Data deficient (DD)

Notes**:** *Z. murlenica* is similar to *Z. callianthus* and *Z. cernuum* but differs from the former in having greenish brown rhizomes, short petioles, pinkish-white peduncles, oblong-obovate, pinkish-green, glabrous, creamy-white bracteoles and a labellum with maroon mottling and from the latter in having deflexed bracts with acuminate apices. The occurrence of this taxon in the type locality is also very rare, we couldn't find a single population from the Murlen National Park and the descriptions are based on live specimens growing in the experimental garden of BSI Meghalaya. Also, the distribution of this taxon is in question because we have observed a similar kind of plant in the fruiting stage from the Andaman Islands. It shares many morphological characteristics with *Z. cernuum* and *Z. wrayi*, a detailed study is required to confirm its identity.

***Specimen examined*: India, Meghalaya,** Bharapani, BSI experimental garden, 12 September 2014, *Rameshkumar 128822* (ASSAM).

Zingiber neotruncatum T.L.Wu, K.Larsen & Turland

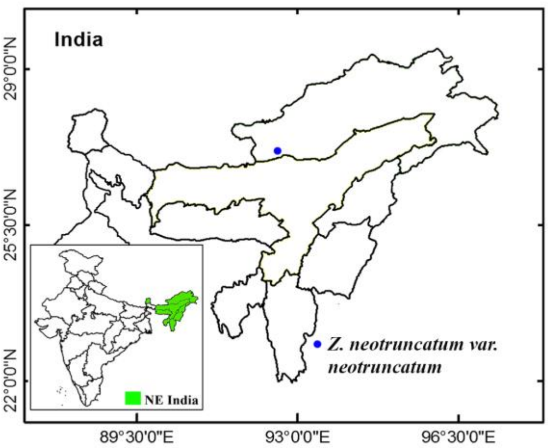
The plant was first collected and described by S.Q. Tong in 1987 from Jinghong in South Yunnan, China and named as *Z. truncatum* S.Q.Tong. But the name was a later homonym of *Z. truncatum* Stokes. Subsequently, Wu *et al.* (2000) proposed a new name, *Zingiber neotruncatum*. Sabu *et al.* (2013) reported the occurrence of *Z. neotruncatum* from the state of Arunachal Pradesh, Northeast India as a new addition to the flora of India.

Key to the varieties

1. Bracteoles and corolla lobes are creamy white, bracts light green.......................... .... **1. *Z. neotruncatum* var. *neotruncatum***
1. Bracteoles and corolla lobes with reddish tinge at apex, bracts bright red… .... **2. *Z. neotruncatum* var. *ramsawmii***

21. *Zingiber neotruncatum* var. *neotruncatum* T.L.Wu, K.Larsen & Turland, Novon. 10(1): 91. 2000; M.Sabu *et al.,* Rheedea 23: 47. 2013; Triboun *et al.,* Thai Journ. Bot. 6: 53–77. 2014; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt.Assem. Veg. Fl. Nor. Re. Ind. 1: 152, 2021. ***Type*: China**, Yunan, Jinghong, 810 m, 12 August 1984, *S. Q. Tong & S. Liu 24935* (holo HITBC!). **Fig. 21**

Perennial, non-stoloniferous rhizomatous herbs. Rhizome thick, rhizome pleasantly aromatic, creeping, externally brown, internally yellowish, 1.5–2 cm diam.; tubers not seen. Leafy shoot 90–168 m tall, leaves 13–31 in number when flowering; pseudostem 70–153 cm long, hairy; basal sheath without blade, 5–6, purplish-red and upper one reddish green with red margins, pubescent; ligules bilobed, 0.3–0.5 cm long, green, pubescent, apex truncate; petiole subsessile, pulvinate; laminae linear–lanceolate, 30–45 × 3.5–5.8 cm, apex acuminte, base obovate, margin, adaxially dark green, glabrous, abaxially pubescent at base and along the mid vein. Inflorescence 1–2 per plant, spikes oblong–ovate on separate leafless peduncle, 6–8 cm long single flower opening at a time; peduncle 6–13 × 1.5–2 cm, enclosed by greenish brown sheathing bracts; sterile bracts narrowly ovate, 3.8–4.1 × 2–2.3 cm, apex pointed, pubescent internally and glabrous externally; fertile bracts ovate, 3–4 × 2–3 cm, apex acute, green to greenish white, margin hyaline, each enclosing a single flower; bracteoles narrowly ovate, 2.7–2.8 × 1.9–2.2 cm, apex obtuse and split, translucent white, glabrous both internally and externally. Flowers 7–7.5 cm long; calyx tubular with unilateral split, c. 2.5 cm long, apex bi-lobed, hyaline, glabrous; corolla tube creamy white, 4–4.3 cm long, pubescent; dorsal corolla lobe narrowly ovate, 2.3–2.5 × 1.3– 1.5 cm, apex acute and beaked, creamy white with translucent veins, sparsely pubescent externally; lateral corolla lobes narrowly ovate, 2.3–2.5 × c. 0.8 cm, apex acute, creamy white with translucent veins, sparsely pubescent; labellum obovate, 3.2–3.5 × 2.4 cm, apex truncate, slightly notched, margin folded back, creamy white with yellowish tinge at the center, yellowish tinge at periphery, glabrous; lateral staminodes narrowly obovate, c. 1 × 0.4 cm, apex truncate, creamy white, $^{3}/_{4}$th portion adnate to the labellum. Stamen 2.2–2.5 × 0.2–0.3 cm; filament reduced to c. 1 mm long, connective tissue creamy white, glabrous; anther thecae creamy white, c. 1.3 × c. 0.3 cm; anther crest creamy white, 1.2–1.3 cm long, wrapped around the stigma, glabrous. Style



Map 21. Distribution of *Z. neotruncatum* var. *neotruncatum*.

Fig. 21. *Zingiber neotruncatum* var. *neotruncatum* T.L.Wu, K.Larsen & Turland. **A.** habit; **B.** ligule; **C.** rhizome inflorescence at young stage; **D.** C. S. of rhizome; **E.** inflorescence with flower; **F.** flower front view; **G.** single flower; **H.** bract; **I.** bracteole; **J.** calyx; **K.** corolla lobes; **L.** labellum adaxial & abaxial view; **M.** stamen front & side view; **N.** ovary with epigynous glands.

filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, 4–5 × c. 3 mm, creamy white, trilocular with axile placentation, pubescent; epigynous glands two, c. 3 mm long, creamy white, linear. Fruit not seen.

Distribution**:** *Z. neotruncatum* is distributed in South China, Thailand, India and Vietnam. In India, it grows in Arunachal Pradesh (**Map 21**).

Phenology**:** Flowers from July to October. Flower opening in the afternoon and lasts up to 24 hrs; fruiting October onwards.

Etymology**:** The plant was first named as *Z. truncatum* and it was a later homonym of *Z. truncatum* Stokes. later a new name, *Z. neotruncatum* was proposed by Wu *et al.* (2000) which means “new truncatum”.

Habitat & Ecology**:** It prefers to grow in forest margins above 1000 feet along the foothills of Himalayas. Plants are also found deep inside the evergreen forest in dark soil with plenty of organic matter. The plants prefer shady habitats and flowers get fully open after the sunset, so nocturnal insects may be the possible pollinators (flowers are yellowish white). The associated angiosperms are *Costus speciosus* (Koenig) J.E. Smith and *Ophiorrhiza* sp.

IUCN Status **(Proposed here):** Near Threatened (NT)

Notes**:** *Z. neotruncatum* shows some similarities with the Thailand species *Zingiber phumiangense* A. Chaveerach & P. Mokkamul in having green bracts with translucent margins, basifixed anthers and glabrous ovary but differs from it in having narrowly lanceolate leaves, calyx tube hyaline with truncate tip, inconspicuous lateral corolla lobes and anther sessile or subsessile exceeding the labellum.

Specimens examined**: India**, **Arunachal Pradesh**, West Kameng District, way to Bomdila, Drupong, 07 August 2003, *M. Sabu & A.K. Pradeep 92535* (CALI); way to Bomdila, Tippi forest, 15 July 2016, *Jayakrishnan & Nikhil Krishna 150202* (CALI). **Kerala,** Calicut, Olavanna (Transplanted from Arunachal Pradesh), 30 July 2012, *M. Sabu 105832* (CALI). **Meghalaya**, East Khasi Hill District, Shillong, experimental garden Botanical Survey of India (Cultivated), 28 July 2017, *Jayakrishnan 153529* (CALI).

22. *Zingiber neotruncatum* T.L.Wu, K.Larsen & Turland **var. *ramsawmii*** Lalramngh., M.Sawmliana, T.Jayakr. & M.Sabu, J. Jpn. Bot. 96(6): 321. 2021. ***Type*: India**, **Mizoram**, Aizawl District, Tamdil, 1 km from Tamdil lake towards Dilkan village, 29 July 2017, *Jayakrishnan T & Nikhil Krishna 153524* (holo CALI; iso CAL). **Fig. 22**

Perennial, nonstoloniferous rhizomatous herbs. Rhizome fleshy with pleasant aroma, not so much branched, externally light brown, internally yellow with an outer brown circle, 1.5–3 cm in diameter. Leafy shoots 1–1.5 m tall, leaves 20–24 when flowering; pseudostem 40–70 cm long, purplish brown, pubescent; ligules bilobed, 3–4 mm long, green, pubescent, apex truncate; petiole subsessile, pulvinate; laminae linear to narrowly ovate, 5–45 × 1–6.5 cm, adaxially green, glabrous and shiny, abaxially light green, pubescent, base cuneate, apex acuminate, margin entire. Inflorescence radical, one to two per plant, spicate, narrowly ovate, one flower at a time, 6–12 × 4.5–6.8 cm; peduncle 5–12 cm long, purplish brown; sterile bracts 4–5 nos., broadly ovate, bright red up to the middle cream with reddish tinge at base, apex round, internally pubescent towards the margin, externally glabrous; fertile bracts enclosing a single flower, ovate, 3–3.5 × 2–2.5 cm, bright red up to the middle cream with reddish tinge at base apex acute, internally pubescent towards the margin, externally glabrous; bracteoles narrowly ovate, 3–3.2 × 1–1.2 cm, creamy yellow with reddish tinge at apex, pubescent both internally and externally, apex acute. Flowers 7–8 cm long; calyx tubular with unilateral split, 2–2.3 × 1.5–1.7 cm, cream, hyaline with reddish teeth, apex tri-lobed, glabrous; floral tube 4.5–5 cm long, creamy yellow, externally glabrous; dorsal corolla lobe narrowly ovate, 3.2–3.5 × 0.5–0.7 cm, creamy yellow with reddish tinge at apex, glabrous both internally and externally, apex acute; lateral corolla lobes triangular ovate, 3.2–3.3 × 0.5–0.7 cm, creamy yellow with reddish tinge at apex, glabrous; labellum ovate, 3–3.2 × 1–1.3 cm, creamy yellow, apex slightly notched margin wavy, glabrous; lateral staminodes obovate, 1.8–2 × 0.5–0.7 cm, adnate half by length, cream with

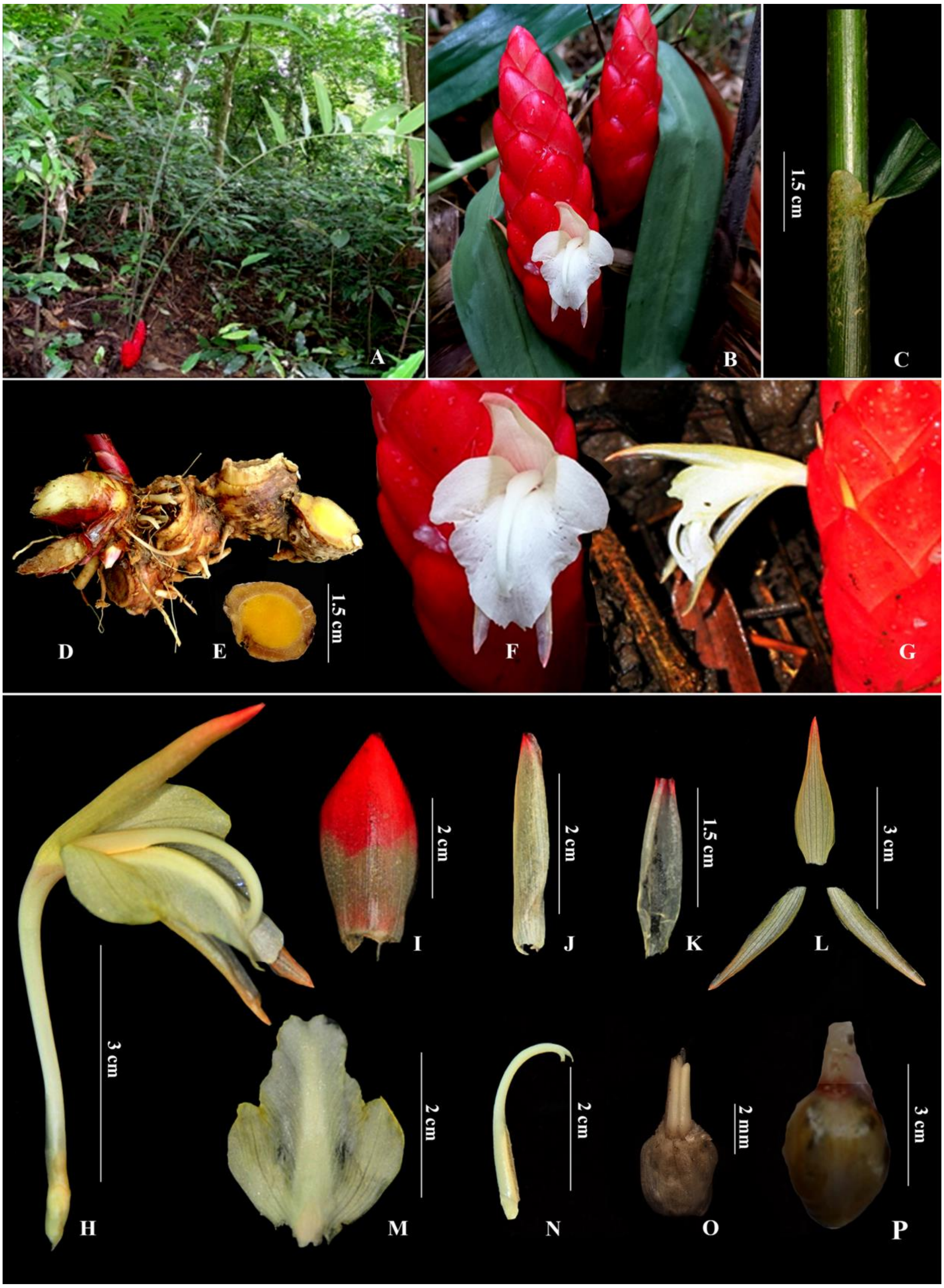


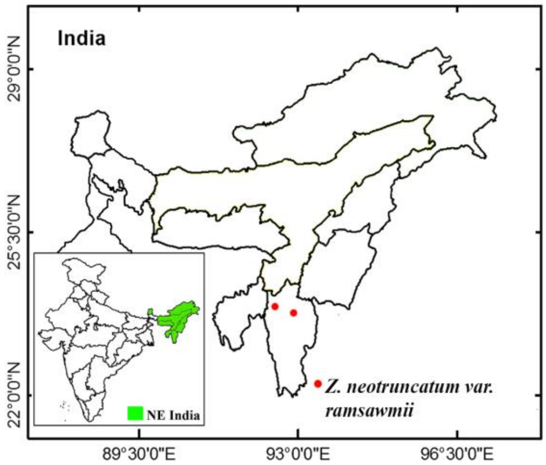
Fig. 22. ***Zingiber neotruncatum*** T.L.Wu, K.Larsen & Turland **var.** ***ramsawmii*** Lalramngh., M.Sawmliana, T.Jayakr. & M.Sabu. **A.** habit; **B.** inflorescence; **C.** a portion of pseudostem showing leaf base and ligule; **D.** rhizome; **E.** C. S. of rhizome; **F.** close up of inflorescence with front view of flower; **G.** inflorescence with side view of flower; **H.** single flower; **I.** bract; **J.** bracteole; **K.** calyx; **L.** corolla lobes; **M.** labellum; **N.** side view of stamen; **O.** ovary with epigynous glands; **P.** mature fruit.

yellowish tinge at apex, apex acute to round; Stamen 2.7–3.2 × c. 0.6 cm; connective tissue glabrous, cream; anther thecae 1.2–1.5 × 0.4–0.6 cm, cream; anther crest 0.9–1.2 cm long, creamy white with purple markings, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-shaped; ostiole ciliate. Ovary cylindrical, cream, 0.4–0.5 × 0.3–0.4 cm, trilocular with axile placentation, glabrous; epigynous glands linear, 0.3–0.5 × c. 0.1 cm, cream. Fruit capsule, 2–4 × c. 2 cm, cream.

Distribution: *Zingiber neotruncatum* var. *ramsawmii* is endemic to Mizoram (**Map 22**).

Phenology: Flowering July to August, fruiting August to October. Flowers open in the evening and last for 12 hrs.

Etymology: The varietal epithet denotes the combination of the two names of the collectors, Lalramnghinglova and Sawmliana.



Map 22. Distribution of *Z. neotruncatum* var. *ramsawmii*

Habitat & Ecology: The plants grow in the bamboo mixed forest in the sandy clayey soil in Tamdil forest and very damp humus clayey yellow-brown soil in Dampui forest in association with *Archidendron bigeminum* (L.) I. C. Nielsen, *Phrynium pubinerve* Blume, *Thysanolaena latifolia* (Roxb. ex Hernem), Honda *Stemona tuberosa* Lour., *Leea asiatica* (L.) Ridsdale, *Cheilocostus speciosus* (J.Koing) C. Specht. etc.

***IUCN status* (Proposed here):** Based on the available data collected within three years here proposed as Critically Endangered (CR) (IUCN criteria: CR C1+2a(ii)).

Notes: *Z. neotruncatum* var. *ramsawmii* differs from the typical variety in having narrowly ovate, bright red spike, bright red bracts, narrowly ovate bracteoles with reddish tinge at apex, calyx tri-lobed at apex with reddish tinge and *Zingiber* *neotruncatum* var. *neotruncatum* posses oblong–ovate, light green spike, green bracts, ovate–obovate bracteoles with cream apex and bi-lobed, hyaline calyx.

***Specimens examined*: India, Mizoram**, Aizawl District, Tamdil, 1 km from Tamdil lake towards Dilkan village, 21 July 2016, *H.Lalramnghinglova & M.Sawmliana 0208, 0254* (ASSAM); Mamit District, Dampui forest, 6 km away from Dampui village, 3 Oct. 2016, *H. Lalramnghinglova* and *M. Sawmliana 02056* (ASSAM).

23. *Zingiber officinale* Roscoe Trans. Linn. Soc. London 8: 348. 1807; Roxb., Asiat. Res. 11: 345. 1810, Fl. Indica i: 46. 1820; Dalzell & A. Gibson, Bombay Fl. Suppl. 87.1861; Baker in Hook.f., Fl. Brit. India 6: 246. 1892; K.Schum. in Engler, Pflanzenr. 4 (46): 170. 1904; T.Cooke, Fl. Bombay 2: 736. 1907; C.E.C.Fisch, Rec. Bot. Surv. India 9: 178. 1921 in Gamble, Fl. Madras 8: 1489. 1928; Holttum, Gard. Bull. Singapore 13: 54. 1950; Mitra, Fl. Pl. East. India 1: 253. 1958; A.S.Rao & D.M.Verma, Bull. Bot. Surv. India 14: 137, 1972; B.L.Burtt & R.M.Sm., Notes. Roy. Bot. Gard. Edinburgh 31: 180. 1972, in Dassan. Rev. Handb. Fl. Ceylon 4: 498. 1983; Deb, Fl. Tripura 379. 1983; B.L.Burtt in Manilal, Bot. His. Hort. Malab. 144. 1980; Nicolson *et al.,* Interpret. Rheede Hort. Malab. 318. 1988; R.M.Sm., Notes Roy. Bot. Gard. Edinburgh 45: 412. 1989; Kumar in Hajra *et al.,* Fl. Sikkim 1: 134. 1996; Kumar, Zingib. Sikkim 71. 2001; K.G.Bhat, High. PI. Indian Subcont. 4: 69.1993, Fl. Udupi, 635.2003; M.Sabu & Mangaly. Proc. 2nd Symp. Fam. Zingiberaceae 21. 1996; M. Sabu, Folia Malaysiana 4(1): 39. 2003; M. Sabu, Zingiberaceae and Costaceae South India, 243. 2006; A.A.Mao *et al.,* Checkl. Fl. Nagaland 1: 143. 2017; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 1: 152, 2021. ***Lectotype***: (designated by Janson 1981) Habitat in "Indus inter tropicos" in: Rheede tot Draakestein, H. A. van, Hortus indicus malabaricus, 11: 22–23, Figure 12. 1692. **Fig. 23**

Zingiber sianginensis Tatum Mibang & A.K.Das, Pleione 10 (1): 169–173. (2016).

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

Inschi Rheede, Hort. Malab. 11: 23–25, t. 12. 1692.

***Vernacular names*:** Mal. Inji; Tam. Sukku; Tel. Allamu.

Perennial rhizomatous herbs. Rhizome thick, pungent odor, branching sympodial, externally brown, internally grayish yellow, 1.5–2 cm diameter. leafy shoot 0.8–1.15 m tall, leaves 24–26 in number when flowering; pseudostem 60–95 cm long; basal sheath without blade 2–3 nos., dark green, sparsely pubescent; ligules bilobed, 2–4 mm long, membranous, sparsely pubescent; leaves subsessile, pulvinate; laminae linear to lanceolate, 25–30 × 1.5–3 cm, apex acuminate, base cuneate, margin entire, adaxially dark green, glabrous, abaxially light green, pubescent. Inflorescence 2–3 nos., basal, separate from the leafy shoot, spikes narrowly ovate, 4–7 × 1.5–2 cm, 1–2 flowers opening at a time; peduncle 15–26 cm, green, sheathing bracts dark green; sterile bracts broadly ovate, apex mucronate, light green with greenish yellow at apex, pubescent internally and glabrous externally; fertile bracts each enclosing a single flower, broadly ovate, 2.3–2.5 × 1.3–2 cm, apex mucronate, light green with greenish yellow at the apex, green changes to dark red when mature, closely imbricating; bracteoles narrowly ovate, 2–2.3 × 0.7–0.9 cm, apex truncate, creamy white, inner glabrous, externally pubescent. Flowers 4.2–4.5 cm long; calyx tubular with unilateral split, 1–1.2 × c. 0.8 cm, teeth not prominent, white, hyaline, membranous, glabrous; corolla tube pale yellow, c. 2.5 cm long, glabrous; dorsal corolla lobe ovate, 2.1–2.3 × 0.6–0.7 cm, apex acute, creamy yellow with translucent veins, glabrous; lateral corolla lobes triangular or narrowly ovate, 1.8–2 × c. 0.4 cm, apex acute, creamy yellow with translucent veins, glabrous; labellum orbicular, 1.5–2 × 0.9–1.2 cm, apex rounded, margin wavy, deep maroon with yellow blotches, glabrous; lateral staminodes ovate, c. 0.8 × c. 0.6 cm, apex rounded, deep maroon with yellow spots, free from labellum. Stamen 1.7–1.8 × 0.1–0.3 cm; filament reduced to c. 1 mm long, connective tissue cream, glabrous; anther thecae cream, 1 × 0.3 cm; anther crest deep purple, c. 0.8 cm long, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary globose, c. 3 × c. 2.5 mm, cream, trilocular with axile placentation, glabrous; epigynous glands two, linear, c. 7 mm long, cream. Fruit not seen.

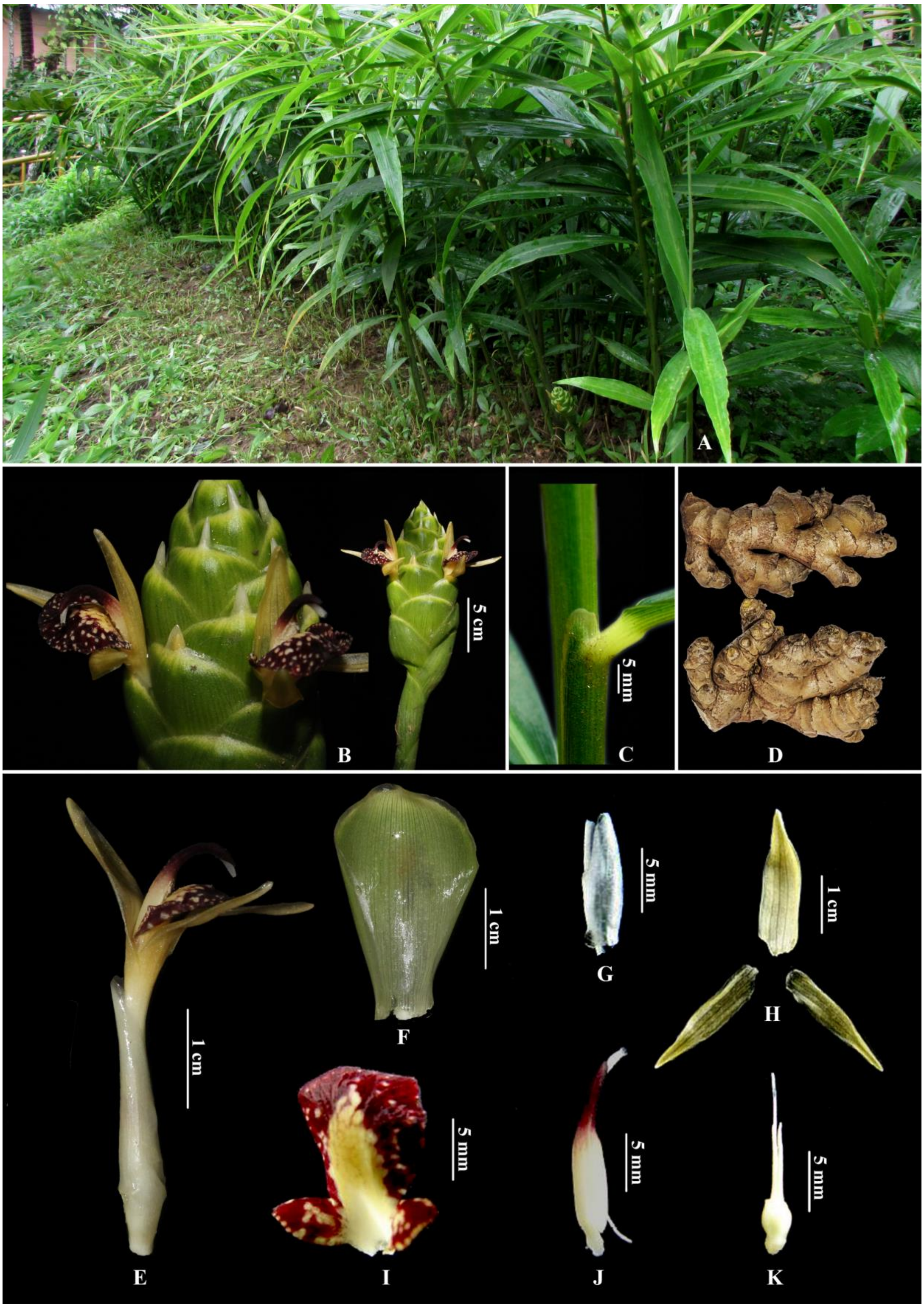
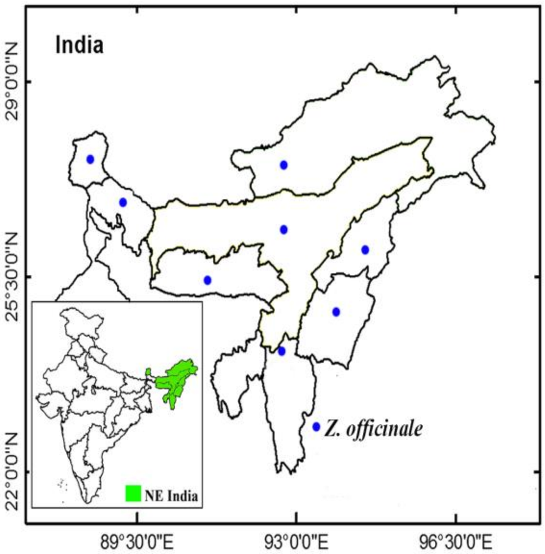


Fig. **23.** ***Zingiber officinale*** Roscoe. **A.** habit; **B.** inflorescence with flower; **C.** a portion of pseudostem showing ligule; **D.** rhizome; **E.** single flower with bracteole; **F.** bract; **G.** calyx; **H.** corolla lobes; **I.** labellum; **J.** stamen with style and stigma; **K.** ovary with epigynous glands.

***Distribution*:** Widely cultivated throughout the world, especially in tropical countries. The native country of origin is still in confusion. Dahlgren *et al.* (1985) considered it to be originated in eastern India. But Wu (1985) suggested that it might have originated somewhere between the Yaugtze Kiang and Huaugho and due to great variability in natural environments, wild ginger disappeared from its original range. In Northeast India, it is widely cultivated in all states (**Map 23**).



Map 23. Distribution of *Z. officinale*.

***Phenology*:** August to October.

***Etymology*:** The specific epithet is derived from officinalis meaning used in medicine, referring to its wide spectrum of medicinal properties.

***Habitat & Ecology*:** Widely cultivated species. The wild population prefer to grow in evergreen forest and semi-evergreen forest.

***IUCN status*:** Least concerned (LC)

***Notes*:** The plant was first mentioned in the monumental work "Hortus Malabaricus" by Rheede (1678–1693) as 'inschi', later Linnaeus treated it under the genus *Amumum* as *A. zingiber* in his work "*Species plantarum*" (1753). In 1807 Roscoe transferred this plant to the genus *Zingiber* as *Z. officinale*. Recently Tatum Mibang and Das (2016) described a new species *Z. sianginensis* based on the collection from Siang valley of Arunachal Pradesh. The specimen was extensively cultivated by the Adi community of Siang Valley and these specimens have similarities with *Z. officinale*. In Zingiberaceae, the development of abnormal flowers is quite common (Song *et al.*, 2004). From the photographs of *Z. sianginensis*, we concluded that the distinguishing floral characters are due to abnormal flower development and the vegetative characters are overlapping. The genus *Zingiber* is characterized by the presence of a single anther with beak-like appendage wrapped around the style, but the specimen has two fertile anthers, larger lateral corolla lobes and development of external staminodes. These abnormal characters are quite common in many genera like *Alpinia* and *Amomum*. As all the remaining characters except the number of stamens exactly match with *Z. officinale*, we have treated *Z. sianginensis* as a synonym of *Z. officinale* Roscoe.

Z. officinale resembles *Z. purpureum* in having narrow leaves and short ligules but it can be easily distinguished by the dark purple labellum with yellow blotches while *Z. purpureum* has yellowish white labellum with pale purple markings. This is a unique spice used in the preparation of condiments, curries, pickles and syrups. It is one of the important drugs of Ayurveda and is used in local systems of medicine. The pungent, hot, anodyne, antirheumatic, carminative, cooling, diuretic and aphrodisiac properties make it a unique spice. It enhances the digestive power, cleanses the throat and tongue, reduces the risk of cardiac disorders and cures cough, vomiting, anemia, fever, elephantiasis and constipation. In traditional medicine, ginger is extensively used for its specific action in rheumatism and inflammation of the liver.

Specimens examined**: Andhra Pradesh**, East Godavari District, Maradumilli Cocoa plantation, 23 November 1980, *Subba Rao 68528* (MH). **Karnataka**, Bangalore District, Experimental garden, Indian Horticultural Research Institute, Hassarghat, 25 October 1983 *Subramaniayan 4392* (FRC); South Karnataka District, Mangalore, 12 July 1980, *Bhat 1980* (PPCH). **Kerala**, Calicut District, Peruvannamuzhi, *s.d. Sabu 39155* (CALI); *s.loc.*, 28 July 2009, *Julia John 123721*; Idukki District, Nagampara R.F., *s.d.*, *Subramaniyan 8689* (FRC); Thenkachi, 23 November 1972, *Sharma 40876* (MH); Kottayam District, Changanaserry, Vazhapally, 25 January 1988, *V. T. Antony 1495* (CAL); Malappuram District, Mangaly's garden, Thenhipalam, *s.d.*, *Sabu 37332* (CALI); Palakkad District, Thunakadavu Submergible area, Parambikulum, 24 July 1964, *Sebastine 20914*

(MH); Thiruvananthapuram District, *s.loc*, *s.d.*, *Calder & Ramaswami 468* (CAL); Thrissur District, Thalikulam, *s.d.*, *Sabu 37334* (CALI); Thunakadavu, Submergible area, 667 m, 24 July 1964, *K. M. Sebastine 20914* (MH); Kannamkuzhi, 12 November 1976, *Ramamoorthy 48473* (MH); Enamakkal, 28 September 1983, *Sheela Francis K 1247* (CALI); Enamakkal, 17 January 1984, *K. V. Asa 1222* (CALI). **Mizoram**, Kolasib, 21 September 1997, *Sunil Tripathi 21819*-C (CDRI). **Nagaland**, *s loc.*, *s.d.*, *D. M. Verma 34650* (CALI). **Tamil nadu**, Coimbatore District, Between Olliar and Thorakadavu, Anamalais, 9 August 1968, *Barbar 3678* (MH); Kanyakumari District, Upper Kodayar, 400 m, 11 September 1976, *Henry 48339* (MH). Nilgiri District, Ayyankolli forest, 900 m, 22 November 1972, *Vajravelu 42887* (MH). **Uttar Pradesh**, Lucknow, Garden, 1963, *P. Joshi 2454* (CDRI).

24. *Zingiber pherimaense* Biseshwori & Bipin. Phytotaxa 178 (3): 221–224. 2014; A. A.Mao *et al.*, Checkl. Fl. Nagaland, 1: 134. 2017; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U. Shankar, Eco. Patt. Assem. Veg. Fl. Nor. Re. Ind. 1: 152, 2021. ***Type***: **India**, **Manipur,** Imphal, cultivated at IBSD, 4 August 2012, *Bipin K. IBSD/Z-105*, (holo ASSAM; iso IBSD). (Originally from India, Nagaland, Pherima, c. 870 masl, 25º45.426'N 93º57.223'E). **Fig. 24**

Perennial, rhizomatous herbs. Rhizome thick, branched and forms small clumps, covered by numerous thin roots along the entire length, externally tan white, internally divided into two circular zones, both creamy yellow, 2 cm diameter; tubers absent. Leafy shoot 1.7–2 m tall, leaves 20–22 in number when flowering; pseudostem 80–90 cm long; basal sheaths 3–4 in number, purplish green, pubescent; ligules 5 mm long, bilobed, light green, pubescent, apex rounded; petiole subsessile, pulvinate; laminae oblong-lanceolate, 30–35 × 6.8–7.5 cm, adaxially dark green, glabrous, abaxially light green, pubescent, base cuneate, apex acuminate, margin wavy. Inflorescence one to two, one flower at a time, radical spicate; peduncle 6–13 cm long, red, sheathing bracts bright red; spikes capitates, 2−3 × 5−7 cm; sterile bracts broadly ovate, loosely imbricating, dark red, apex acute, glabrous internally and sparsely pubescent externally; fertile bracts many, each enclosing a single

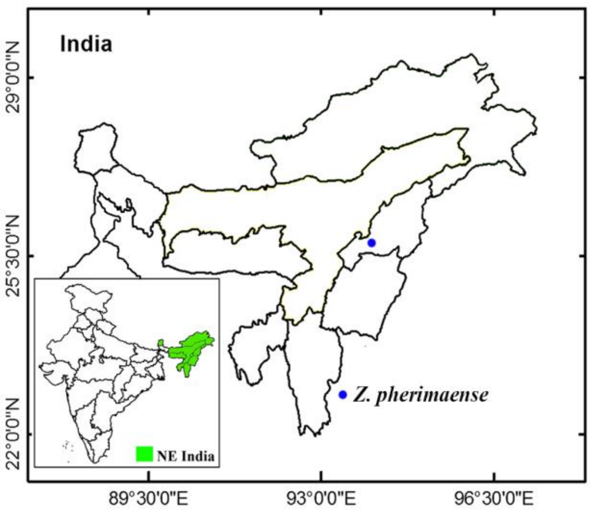
Fig. 24. ***Zingiber pherimaense*** Biseshwori & Bipin. **A.** habit; **B.** inflorescence with flower buds; **C.** single flower; **D.** young inflorescence; **E.** bract; **F.** bracteole; **G.** calyx; **H.** corolla lobes; **I.** labellum; **J.** stamen; **K.** ovary with epigynous glands.

flower, narrowly ovate, 3–4 × 0.8–1.0 cm, bright red, apex acute; bracteoles linear to lanceolate, 2.2–3.0 × 0.4 cm, white at base red at apex, glabrous internally, pubescent externally, apex rounded. Flowers 6–6.5 cm long; calyx tubular with unilateral split, 1 × 0.4 cm, white, apex tri-lobed, apex sparsely pubescent; floral tube white, 3–3.2 cm long, glabrous; dorsal corolla lobe narrowly ovate, 3–3.5 × c. 0.5 cm, white at base pink towards the apex, glabrous, apex acute, curved; lateral corolla lobes triangular–narrowly ovate, 2–2.4 × c. 0.5 cm, white at base pink towards the apex, glabrous on both sides; labellum obovate, broad at apex narrow towards the base, 3.2–3.8 × 1.2 cm, creamy white with reddish pink blotches, apex round emarginate, margin slightly wavy, glabrous; lateral staminodes 2.2–2.4 × c. 0.8 cm, adnate up to middle of the labellum, white with reddish pink markings, apex acute.Stamen 2–2.3 × c. 0.3 cm; filament c. 1mm long, connective tissue glabrous, cream; anther thecae 1.2–1.4 × c. 0.3 cm, creamy white; anther crest 0.6–0.8 cm long, cream with purple markings at apex, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, creamy white, c. 0.6 × 0.4–0.5 cm, trilocular with axile placentation, pubescent; epigynous glands two, linear, c. 0.7 cm long, cream. Fruit not seen.

***Distribution*:** Currently known only from the Pherima village of Nagaland from where the taxon was first collected (**Map 24**).

***Phenology*:** Flowers occur from July through August, opening in the evening and senescing within 24 hours.

***Etymology*:** Named after the village Pherima of Nagaland.



Map 24. Distribution of *Z. pherimaense*.

***Habitat & Ecology*:** This species was growing in a dense and tall bamboo thicket at c. 800 m. alongside the margin of blended evergreen woodland on loose, grey-brown clay soils included with humus and leaf litter. Rainfall in this place is 1800−2000 mm/year. The plant is dormant from December to March at some point in the cool, dry season.

***IUCN status*:** Data Deficient (DD)

***Notes*:** *Z. pherimaense* shows similarities with *Z. meghalayense*, *Z. rubens* and *Z. roseum* but the very long peduncle, shape of the labellum and tightly clumping rhizomes make it distinct from the allied taxa.

Specimens examined: **India**. **Meghalaya**, Barapani, BSI experimental garden, 2 August 2017, *Roy 153206* (ASSAM). **Nagaland**, Dimapur District, Pherima village, 800 m, 26 July 2016, *Jayakrishnan & Nikhil 150208* (CALI).

25. *Zingiber purpureum* Roscoe, Trans. Linn. Soc. London 8: 348. 1807; Alston in Trimen, Handb. Fl. Ceylon 6: 283. 1931; Balakrishnan, Fl. Jowai 2: 522. 1983; B.L.Burtt & R.M.Sm., in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 4: 494. 1983; R.M.Sm., Notes Roy. Bot.Gard. Edinburgh 45: 418. 1989; Kumar & Raju in Gupta, High. Pl. Ind. Subcont.2: 254.1991; R.R.Jha & S.K.Varma, Taxo. Biodiversity 1: 110. 1995; M.Sabu & Mangaly, Prod. 2nd Symp. Fam. Zingiberacae 21. 1996; Kumar in Hazra *et al.*, Fl. Sikkim 1: 133. 1996; S. Kumar, Zing. Sikkim 72. 2001; Lin Bai *et al.*, Taxon 68(6): 1334-1349. 2019. ***Neotype***: Liverpool Botanic Garden (cultivated), 1824, *J. Shepherd s.n.* (LINN!). **Fig. 25**

Zingiber cliffordiae Andrews, Bot. Repos. 9: pl. 555. 1809. ***Lectotype***: [illustration] "*Zingiber cliffordiae*" in Bot. Repos. 9: pl. 555. 1809.

Zingiber cassumunar Roxb., Asiat. Res. 11: 347. 1810, Fl. Indica 1: 48. 1820; Dalzell & Gibson, Bombay Fl. 272. 1861; Baker in Hook.f., Fl. Brit. India 6: 243. 1892; K.Schum. in Engler, Pflanzenr. 4(46): 179. 1904; T. Cooke, Fl. Bombay 2: 734. 1907; C.E.C.Fisch. in Gamble, Fl. Madras 8: 1490. 1928; Holttum, Gard. Bull. Singapore 13: 58. 1950; Mitra, Fl. Pl. East. India 1: 253. 1958; A.S.Rao & D.M.Verma, Materials Monocot Fl. Assam, Bull. Bot. Surv. India 14: (1–4). 114–143. 1972. *Amomum cassumunar* (Roxb.) Donn, Hortus Cantabrig.,ed. 7: 1. 1812 *nom. illeg*; *Zingiber luridum* Salisb.,Trans. Hort.Soc. London 1: 284. 1812.

Lectotype: [illustration] "*Zingiber cassumunar*" in Asiat. Res. 11: t. 5 [= pl. 7]. 1810.

Zingiber cassumunar var. *subglabrum* Thwaites, Enum. Pl. Zeyl.: 315. 1861. ***Lectotype***: **Srilanka**, Central province, Kandy District, Hantani, *s.coll.*, *s.n.* C.P. 3727 (PDA [without accession number; sheet with two inflorescences]).

Zingiber pubisquamum Ridl., Philipp. J. Sci., C. 4: 169. 1909. ***Lectotype***: **Philippines,** Mindanao, Lake Lanao, Camp Keithley, September 1907, *M.S. Clemens 1163a* (K barcode K000255204 [digital image!]).

Zingiber paucipunctatum D.Fang, Guihaia 16(1): 6. 1996. ***Holotype***: **China,** Guangxi Province, Nanning Shi, Maoqiao Medical Botanical Garden [Guangxi Medical Botanical Garden] (cultivated), 27 July 1994, *D. Fang 78614* (GXMI barcode GXMI 051074!).

Amomum xanthorhiza Roxb. ex Steud., Nomencl. Bot., ed. 2, 1: 78. 1840, not validly published, pro syn. (ICN, Art. 36.1(b)).

Zingiber xantorrhizon Steud., Nomencl. Bot. ed. 2, 2: 799. 1841, not validly published, pro syn. (ICN, Art. 36.1(b)).

Zingiber anthorrhiza Horan., Prodr. Monogr. Scitam. 27. 1862, not validly published, pro syn. (ICN, Art. 36.1(b)).

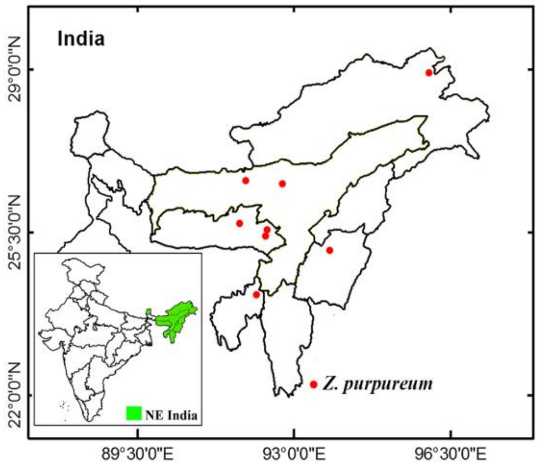
Zingiber montanum auct.non (J.Koenig) Link ex A. Dietr.: B.L.Burtt & R.M.Sm., Notes Roy. Bot. Gard. Edinburgh 31: 194. 1972; Ramamoorthy in C.J. Saldanha & Nicolson, Fl. Hassan Dist. 769. 1976; Theilade, Nordic J. Bot. 19: 396. 1999; M. Sabu, Fol. Malaysiana 4: 31. 2003; M. Sabu, Zingiberaceae and Costaceae South India, 225–250. 2006; Tripathi & Singh, J. Econ. Taxon. Bot. 30: 526. 2006; V.A. Vasantha, Biosystematic studies on the genus *Zingiber* Boehm. in South India 221–224. 2009; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India 1: 152. 2021.

Zingiber montanum auct. non (Koenig) Theilade: Theilade in Gard. Bull. Singapore 48: 25. 1998.

Perennial, rhizomatous herbs. Rhizome slender, aromatic, externally brown, internally bright yellow, 1.5–2 cm diameter. Leafy shoot 100–116 cm tall, leaves 28–34 in number when flowering; pseudostem 75–95 cm long, sparsely pubescent; basal sheaths 3–4 in number, green, pubescent; ligules 2–3 mm long, bilobed, green, pubescent, acute; petiole subsessile, pulvinate; laminae linear-lanceolate, 23–41.5 × 3–3.5 cm, adaxially dark green, glabrous, abaxially light green, pubescent, base rounded, apex acute, margin entire. Inflorescence separate, lateral spike from rhizome; peduncle 10–25 cm long, sheathing bracts brownish red with green tinge; spikes ovate; sterile bracts broadly ovate, brownish-red with a greenish tinge, apex acute, glabrous internally and pubescent externally; fertile bracts each enclosing a single flower, broadly ovate, 3.5–3.8 × 2.8–3 cm, brownish-red with a greenish tinge, apex acute; bracteoles ovate-lanceolate, 2.2–2.7 × 1.9–2.5 cm, white at base, red towards distal half, glabrous internally, pubescent externally, apex trilobed. Flowers 6–6.5 cm long; calyx tubular with unilateral split, c. 1.8 × c. 0.7 cm, white, apex bi-lobed, pubescent; floral tube creamy white, 3–3.3 cm long, glabrous; dorsal corolla lobe ovate, 2.5–2.9 × 0.6–0.8 cm, creamy white with translucent veins, apex acute, curved; lateral corolla lobes triangular-lanceolate, 2.3–2.8 × c. 0.5 cm, creamy white with translucent veins, glabrous on both sides; Labellum sub-orbicular, 3.0–3.2 × 2–2.4 cm, pale yellow, yellow at center, unspotted, apex deeply notched, emarginate with crisped margin, glabrous; lateral staminodes triangular–ovate, c. 9 × c. 7.2 mm, adnate ¼th to the labellum, creamy yellow, apex nearly acute. Stamen c. 2.3 × c. 0.4 cm; filament reduced to c. 1 mm long, connective tissue glabrous, cream; anther thecae c. 1.3 × c. 0.4 cm, creamy white; anther crest 1–1.2 cm long, cream, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, cream, c. 0.5 × c. 0.4 cm, trilocular with axile placentation, ovules many, pubescent; epigynous glands two, linear, 0.4–0.5 cm long, cream. Fruit not seen.

Fig. **25.** ***Zingiber purpureum*** Roscoe. **A.** habit; **B.** a portion of stem showing ligule; **C.** inflorescence with flower; **D.** & **E.** flowers lateral & front view; **F.** single flower; **G.** bract; **H.** bracteole; **I.** calyx; **J.** corolla lobes; **K.** labellum; **L.** stamen front & side view; **M.** ovary with epigynous glands.

Distribution: It is widely distributed and cultivated in South and southeast Asia (India, Malaysia, Myanmar, Sri Lanka and Thailand). In Northeast India this plant is cultivated in local fields and various Botanical gardens associated with institutions. Natural populations of this plant are found in Sikkim, Meghalaya, Assam, Arunachal Pradesh, Tripura and Manipur. In South India, it shows a wide distribution; large populations were found in Andhra Pradesh, Tamil Nadu, Kerala, Karnataka and Maharashtra (**Map 25**).



Map 25. Distribution of *Z. purpureum*.

Phenology: Flowering from July to September, fruiting from September to November. Flowers open in the morning and last for 24 hrs, 2–3 flowers open simultaneously in an inflorescence.

Etymology: The specific epithet "purpureum" is a reference to the purple colored bracts of the plant.

Habitat & Ecology: These plants are usually found in forest margins and open grass fields at an altitude of 300–1500 m in association with *Oxalis corniculata* L., *Sida acuta* Burm. f., *Pennisetum* sp. and other Poaceae members.

IUCN status: Least concerned (LC)

Notes: *Z. purpureum* was originally published by Roscoe in 1807, based on an introduced plant of unknown origin cultivated at the Liverpool Botanic Garden, England and later *Z. cassumunar* was discovered by Roxburgh in 1810, based on plants collected from India.

Roscoe (1815), proposed that *Z. purpureum* was conspecific with *Z. cassumunar* Roxb and he incorrectly adopted Roxburgh's name *Z. cassumunar*, instead of the earlier *Z. purpureum*. Dietrich (1831) treated *Z. cassumunar* as a distinct species and cited *Z. purpureum* as its synonym. The nomenclatural issues of cassumunar ginger were started by Steudel (1840) and he also considers *Z. cassumunar* as the correct name for “cassumunar ginger”, but he listed both (as *A. montanum*) and *Z. purpureum* as synonyms of it and subsequently *Z. montanum* was treated conspecific with “cassumunar ginger”. Several authors like, Baker (1892), Schumann (1904) and Ridley (1907) followed the same mistake, whereas several authors treated *Z. montanum* and *Z. purpureum* as distinct taxa (Horaninow, 1862; Valeton, 1917, 1918; Burtt & Smith, 1983).

Burtt and Smith in 1972 raised the issue that if *Z. montanum* and *Z. cassumunar* were conspecific, then the earliest name, *Z. montanum*, should be adopted and in 1983 they treated *Z. montanum* and *Z. pupureum* as distinct species based on morphological features.

Later, in 1998, Theilade revised genus *Zingiber* of Peninsular Malaysia, in this work a recently discovered specimen at C (C10018484) (which was thought to be Koenig’s gathering from Phuket) was treated as the holotype of *Amomum montanum* (Basiyonim of *Z. montanum*) and based on that specimen Theilade proposed *Z. montanum* as the correct name for cassumunar ginger and reduced both *Z. casssumunar* and *Z. purpureum* as its synonyms. This treatment was followed by Sabu (1996, 2003) and Tripathi and Singh (2006).

Bai *et al.* (2019) identified a specimen at C, which was not matching with the protologue of *A. montanum* and they suggested that the specimen was not the original materials of Koenig which represents *Z. purpureum*. Their investigation to find out the original specimens of *A. montanum* was in a vein. However, critical exploration of the type localities of *A. montanum* made them conclude that no specimens identical to the specimen at C were growing there, instead, *Zingiber* populations which are matching with the protologue of *A. montanum* were collected. These findings lead them to conclude *Z. purpureum* as the original name for “cassumunar ginger” and *Z. montanum* as a distinct species.

***Specimens examined*: India. Andhra Pradesh,** E. Godavari District, Kutravada, Alt. 425 m, 24 September 1980, G. V. *Subb*a *Rao, s.n.* (CAL). **Arunachal Pradesh,**

Dibang Valley District, 13 August 2000, *Manas Bhaumik 2741* (CAL). **Assam,** Kamrup District, Chandrapur, 18 July 2009, *Thomas & Prabhu 127037* (CALI); Nawgong District, 24 December 1950, *G.K. Deka 23000* (ASSAM). **Bihar,** *s.loc*., 10 June 1865, K.C. Kanodia 1142 (CAL). **Goa,** 20 August 2009, *Julia John 123725* (CALI). **Jharkhand,** Ranchi District, Barapchar, alt. 815 m, 8 August 2004, *Jana Skornickova 73458* (CALI); Gangaghat vicinity, Alt. 694 m, 9 August 2004, *Jana Skornickova 73459* (CALI). **Kerala,** Kannur District, Thirunelli Reserve forest, 9 August 1979, *s.n. 62778* (CAL); Palakkad District, Kaikatty to Pothundy, 30 December 1976, *E. Vajravelu. 48786* (CAL); Thadikkundu, 9 November 1976, *E. Vajravelu 48897* (CAL); Pathanamthitta District, Pamba to Ayyapan temple, 9 November 1977, *N.C. Nair 50816* (CAL). **Maharashtra,** Chankala Village, 25 July 2009, *Thomas & Prabhu 127115* (CALI). **Manipur,** Saitu, c. 4000 m, November 1907 *A. Meebold 6638* (CAL); *s.loc., Wallich 6563* (CAL). **Meghalaya**, Khasi Hillls, Rebhoi Hills, Nongpho, 22 July 1918, *Upendra Nath Kanjilal 7384* (ASSAM); *s.loc.* 04 August 1935, *G.K. Deka 21847* (ASSAM); Jainthia Hills, Lumshonong, 21 November 1969, *N. P. Balakrishnan50107* (ASSAM); Shangpung, 4 August 2007, *Sanoj* & *Rajesh Kumar 95185* (CALI). **Orissa,** Bhatipattar, 4 November 1959, *Panigrahi 201704* (CAL); Chota Nagpur, *s.d., J.S. Gamble 8841* (CAL). **Tamil Nadu,** Madras, Ramp Hills, *s.d., V. Narayana Swami 87* (CAL). **Tripura**, North Tripura, Zaithang, 28 July 2009, *Thomas & Prabhu 127115* (CALI). **West Bengal,** Hazarbagh, Chotu Megpur, 11 October 1883, C.B. Clarke 33827 (CAL). Kamdahi, 15 September 1964, *K.K. Grarh 2451* (CAL); Sundarbans, 7 August 1802, *D. Prain 468020* (CAL); Some specimens at CALI without collection details also observed (Accession no. 468035, 46815, 468020, 468042, 468021, 468024, 468028 & 468030).

26. *Zingiber roseum* (Roxb.) Roscoe, Trans. Linn. Soc. London 8: 348. 1807; Roxb., Asiat. Res. 11: 347. 1810, FI. Indica 1: 49. 1820; Baker in Hook.f., Fl. Brit. India 6: 244. 1892; K. Schum. in Engler, Pflanzenr. 4(46): 184. 1904; C.E.C.Fisch. in Gamble, Fl. Madras 8: 1489. 1928; B.D.Naithani, Fl. Chamoli 2: 640. 1984; A.K.Mukharjee, Fl. Pachmarhi 1: 299. 1984; P. C. Pant, Fl. Corbett National Park 1:153. 1986; Manilal, Fl. Silent Valley 314. 1988; Sabu, Folia Malaysiana 4(1): 25–

52. 2003; Sabu, Zingiberaceae and Costaceae of South India, 225–250, 2006; A.A.Mao *et al.*, Checkl. Fl. Nagaland 1: 143. 2017; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 1: 152, 2021. ***Type*****:** *Zingiber roseum* (Roxb.) Roscoe. Iconotype-Icones Roxburghianae. t. 502. (CAL). **Fig. 26**

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

Zingiber perenense Odyu, D. K. Roy, Lyngwa & A. A. Mao, Thailand Nat. Hist. Mus. J. 13 (1): 3, 2019. ***syn. nov.***

Perennial, stoloniferous rhizomatous herbs. Rhizome thick, branched, externally white, internally creamy white, 1.5–2 cm in diameter; tubers absent. Leafy shoot 95–150 cm tall. Leaves 13–18 in number. when flowering; pseudostem 60–70 cm long, pubescent; basal sheaths 4–5 in number, dark green, pubescent; ligules 1.7–2.3 cm long, hyaline, bilobed, pubescent, apex acute; sub-sessile, pulvinate; laminae lanceolate, 30–35 ×6.5–7.6 cm, adaxially light green, glabrous, abaxially light green, densely pubescent, base acute, apex acuminate, margin undulate. Inflorescence very dense, 1–2 flower at a time, radical spicate; peduncle 10–15 cm, creamy white, covered with creamy white or greenish white sterile bracts with reddish tinge at apex; spikes half immersed in soil, ovate or globose; sterile bracts broadly ovate, creamy white with reddish tinge, apex acute, internally glabrous and pubescent externally; fertile bracts enclosing a single flower, narrowly ovate, 3.4–3.8 × 1–1.3 cm, creamy white at base and red at middle and apex, apex acute; bracteoles linear–lanceolate, 2.6–3 × 1.2–1.3 cm, red with creamy white at the center, apex notched or bilobed, glabrous internally, sparsely pubescent externally. Flowers 6.4–7 cm long; calyx tubular with unilateral split, c. 1.7 × c. 0.9 cm (open), membranous, white, three tri-lobed, hairy towards the base; floral tube slender, 3.5–4 cm long, sparsely pubescent; dorsal corolla lobe narrowly ovate, 3.2–3.4 × c. 0.5 cm, red color is prominent along the veins, glabrous internally and pubescent externally, apex acute and pointed; lateral corolla lobes narrowly ovate, 2.4–2.7 × c. 0.3 cm, red, glabrous internally and pubescent externally, incurved soon after opening of flower; Labellum orbicular, oblong-cuneate, 3.2–3.3 × 1.1–1.3 cm, white at the centre

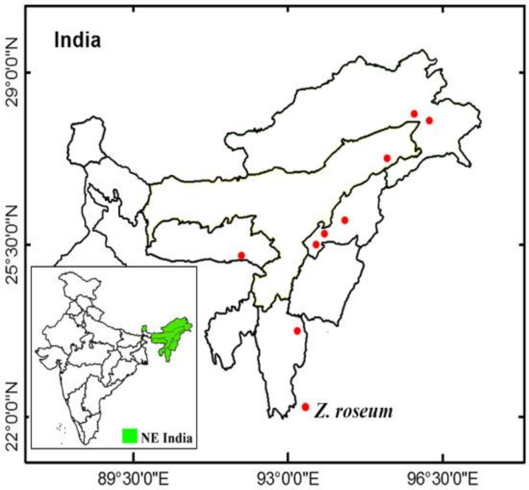
Fig. 26. ***Zingiber roseum*** (Roxb.) Roscoe. **A.** habit; **B. & C.** inflorescence with flower; **D.** flower front view; **E.** basal part of plant showing rhizome & inflorescence; **F.** C. S. of rhizome; **G.** a portion of leaf base showing ligule; **H.** single flower; **I.** fruit; **J.** infructascence; **K.** bract; **L.** bracteole; **M.** calyx; **N.** corolla lobes; **O.** labellum; **P.** stamen side & front views; **Q.** ovary with epigynous glands.

yellow with red spots towards margin, apex round margin recurved, crisped; lateral staminodes orbicular, narrowly ovate, 0.5–0.8 × c. 0.3 mm, adnate half to the length, yellow with orange spots, apex pointed. Stamen arching over and equaling labellum; filament *c.* 1 mm long, connective tissue glabrous, white; anther thecae c. 1.4 × c. 0.3 cm, yellow; anther crest size 0.8–0.9 cm long, red, wrapped around the stigma, glabrous. Style long, filiform, white, glabrous, stigma cup-shaped; ostiole ciliate. Ovary cylindrical, cream, 0.4–0.6 × c. 0.2 cm, trilocular with axile placentation, pubescent; epigynous glands two, linear, 0.2–0.3 cm long, cream. Fruit capsule, reddish white at base, red at apex, 3–3.5 cm long, seeds many.

***Distribution*:** In India, this plant is reported from Andhra Pradesh, Assam, Mizoram, Goa, Karnataka, Maharashtra, Arunachal Pradesh, Meghalaya, Nagaland orissa and Uttar Pradesh (**Map 26**).

***Phenology*:** Flowering takes place from June to August, fruiting from August to December.

***Etymology*:** In Latin, the specific epithet "roseum" means pink, which refers to the reddish pink inflorescence of the plant.



Map 26. Distribution of *Z. roseum*.

***Habitat & Ecology*:** These plants grow well in the forest margins along the roadsides, on vertical cuttings, on open fields, along the sides of streams etc. They usually form large populations with more than 10 individuals in a single population because of their running rhizomes. The plants are observed at an altitude of 100 to 800 m from the sea level in clayey soil rich in organic matter and found associated with *Impatiens lohitensis* R. Gogoi & S. Borah, *Lobelia zeylanica* L., *Commelina communis* Wall., *Bauhinia tenuiflora* Walt ex Clarke, *Mikania micrantha* Kunth. etc.

***IUCN status* (Proposed here):** Widely distributed from central India to North and Northeast India, hence we propose it as Least Concerned (LC).

***Notes*:** *Z. roseum* closely resembles *Z. rubens* and *Z. ligulatum* but differs in long bifid ligule, small white labellum with yellow at margins with red spots. Haines (1961) treated *Z. roseum* and *Z. rubens* as distinct species and he also suggested that *Z. roseum* may be a form of *Z. rubens* with a more robust inflorescence. Later Basbu (1977) studied these species and suggested that they share many characteristics and differ only in the colour of the bracts and purple streaked tip. Jha and Varma (1995) suggested that these two are distinct species. Recently Vasantha (2006) revived and added more clarity to the identity of both the species. According to her *Z. roseum* is characterized by oblong, cuneate, recurved, labellum white at centre and yellow with red spots towards margin.

Recently Odyuo *et al.* (2019) described a new species of *Zingiber* from Nagaland *Z. perenense,* which shares many characters with *Z. roseum*. The distinguishing characters like shape of lamina, length of peduncle, color of bracts, etc. are continues and overlap within the species. *Z. roseum* shows a wide distribution from South India to Northeast India and we have observed many ecotypes with many variations in floral and vegetative characters. As per our critical examination, *Z. perenense* can only be considered as a variation of *Z. roseum* hence here reduced as a synonym.

Specimens examined: **India, Andhra Pradesh**, East Godavari District, Maradumalli to Kakure, 21 September 1966, *Subba Rao 67589* (MH), Maradumalli, 23 July 2005, *Prasanth & Prabhu 106001* (CALI). *Ibid.,* 25 July 2005, *Prasanth & Prabhu 106005*, *106023* (CALI); Visakhapatnam District, Forest near Sankarimetta, 30 August 1960, *Balakrishnan 10944* (MH); Barmakonda R.F, 9 December 1923, *Jacob 17165* (MH); Cherukonda, 26 October 1972, *Subba Rao 42753* (MH). **Arunachal Pradesh,** Dimphe village, Tezu, 26 July 2016, *Jayakrishnan & Nikhil 150206* (CALI); Lower Dibang Valley District, Iduli, 26 km from Roing to Iduli, elev. 152 m, 21 July 2016, *T. Jayakrishnan* and *Nikhil krishna 150205* (CALI). **Assam,** Sivsagar District, Amguri, 19 July 2009, *Thomas & Prabhu 127035, 127036*

(CALI). **Meghalaya,** Dawki, 25 July 2017, *Jayakrishnan & Nikhil 153541* (CALI). **Mizoram**, Murlen National Park, 24 August 2008, *Prasanth & Shameer 115407* (CALI). **Nagaland**, Lumami, 22 June 2005, *Sanoj 92116* (CALI); Peren District, Tesen village, 16 July 2018, *N. Odyuo* & *D.K. Roy 138352* (ASSAM); Pherima, 26 July 2016, *Jayakrishnan & Nikhil, 150220* (CALI).

27. *Zingiber rubens* Roxb., Asiat. Res. 11: 348. 1810 & Fl. Indica 1:53.1820; Baker in Hook.f. Fl. Brit. India 6: 243. 1892; Prain, Ben Pl. 1045.1903; Mitra, Fl. PL. East. India 253. 1958; Rao & Verma in Bull.Surv. India 14: 137. 1972; Balakrishnan, Fl. Jowai 2: 522. 1983; Deb, Fl. Tripura 380. 1983; Smith in Fl. Bhu. 17: 187. 1987; Kumar in Hajra *et al.*, Fl. Sikkim 1: 134. 1996; Theilade, Nord. J. Bot. 19 (4): 406. 1999; Tripathi & Singh, J. Econ. Taxon. Bot. 30: 526. 2006; S.K.Singh & S.K.Srivast. in A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. Monocot. 133. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India 1: 152, 2021. ***Type*****:** **India**, **West Bengal,** *s.d, Roxburgh s.n.* (K). **Fig. 27**

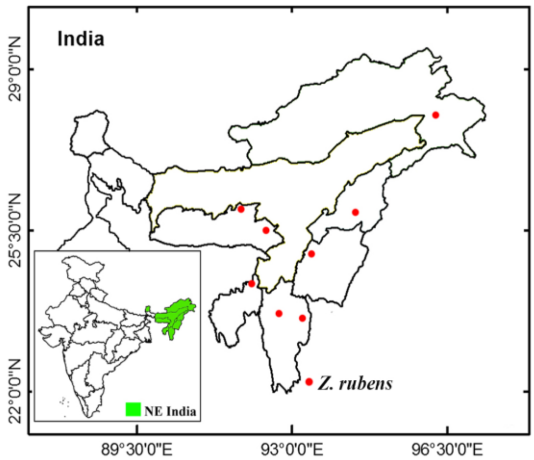
Vernacular name**:** Sarg-mang in Khasi**,** Murga-gach in Tripura

Perennial, rhizomatous herbs. Rhizome thick, tight clumber, branches are short, externally brown, internally creamy white, 1.5–2 cm diameter; tubers fusiform. Leafy shoot 0.9–2 cm tall, leaves 12–16 in number when flowering; pseudostem 40–60 cm long; basal sheaths 3–4 in number, purplish green, glabrous; ligules 5–6 mm long, pale green with reddish tinge, glabrous, rounded; petiole subsessile, pulvinate; laminae elliptic-lanceolate, 30–60 × 8–12 cm, adaxially dark green, glabrous, abaxially light green, pubescent cuneate, apex acuminate, margin entire. Inflorescence two to three per plant, one to two flower at a time, radical spicate, half immersed in soil, 9–10 cm long; peduncle 3–4 cm long, sheathing bracts red; spikes ovate, 6–7 × 3–5 cm; sterile bracts ovate, red, apex acute, glabrous internally and pubescent externally; fertile bracts many, each enclosing a single flower, broadly ovate, 4–4.2 × 1.3 cm, red at apex pale red at base, apex acute; bracteoles ovate-lanceolate, 3–3.2 × 0.4–0.6 cm (closed), cream with reddish tinge, glabrous internally, pubescent externally, apex tri-lobed. Flowers 6.5–7.3 cm long; calyx tubular with unilateral split, 1.3 × 0.6 cm, hyaline with reddish tinge, apex tri-lobed,

Fig. **27.** ***Zingiber rubens*** Roxb. **A.** habit; **B.** a portion of stem showing ligule; **C.** rhizome; **D.** inflorescence with flower; **E. & F.** flowers front & lateral view; **G.** single flower; **H.** bract; **I.** bracteole; **J.** calyx; **K.** corolla lobes; **L.** labellum adaxial & abaxial view; **M.** stamen front & side view; **N.** ovary with epigynous glands.

glabrous; floral tube white, 5 cm long, glabrous; dorsal corolla lobe narrowly ovate, 3–3.4 × c. 1.2 cm, creamy red with translucent veins, apex acute, curved; lateral corolla lobes narrowly ovate, 3–3.2 × c. 0.6 cm, creamy red with translucent veins, glabrous on both sides; labellum ovate, 2.6–2.8 × c. 1.5 cm, creamy white with maroon blotches, apex notched, margin crisped, glabrous; lateral staminodes linear, c. 0.8 × c. 3 cm, totally adnate to labellum, yellow with red markings. Stamen 3–3.2 × c. 0.3 cm; filament reduced to c. 1 mm long, connective tissue glabrous, yellow; anther thecae c. 1.8 × c. 0.3 cm, creamy white; anther crest 1–1.3 cm long, yellow with red spots at apex, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, creamy white, 0.8–0.9 × c. 0.3 cm, trilocular with axile placentation, pubescent; epigynous glands two, linear, 0.3–0.4 cm long, cream. Fruit not seen.

***Distribution*:** India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Sikkim and Tripura (**Map 27**).



Map 27. Distribution of *Z. rubens*.

***Phenology*:** Flowering and fruiting July to October.

***Etymology*:** The specific epithet "rubens" refers to the red colored inflorescence of the plant.

***Habitat & Ecology*:** The plants are growing at an elevation of 100–1500 m in the understory of evergreen forest and forest margins, many populations are observed along the roadsides and on vertical cutting. They grow well in black soil and clayey soil. Usually, 2 to 3 individual plants are observed in a single population.

***IUCN status*:** Least Concered (LC)

***Notes*:** *Z. rubens* is characterized by a yellow lateral staminode blotched with maroon which is totally adnate to the labellum. *Z. rubens* resembles *Z. squarrosum* in overall habitat, red spikes, white labellum with maroon spots. But the former can be easily distinguished by its adnate lateral staminodes.

***Specimens examined*: India**, **Arunachal Pradesh**, Lohit District, Town, 21 December 1969, *J. Joseph 48814* (ASSAM). **Manipur,** Bataklh, November 1907*, A. Meebold 5966* (CAL); Itong Mauip, *A. Meebold 6396* (CAL); *s.loc.*, 1881-82, *G. Watt 7460* (CAL). **Meghalaya**, Jainthia Hills, Raliong, ca 1600 m, 23 August 1968, *N.P. Balakrishnan 47031* (ASSAM); Rebhoi District, Nongpho, 16 September 1997, *Sunil Tripahti 21803* (CDRI). **Mizoram,** Aizawl District, on the way to Tamdil, 18 July 2017, *Jayakrishnan & Nikhil 153523* (CALI); Champai District, Longfong Wild Life Sanctuary, 27 August 2008, *Prasanth & Shameer 115444* (CALI). **Nagaland**, Neichoogond, 18 October 1885, *C.B. Clarke 41214* (CAL). **Tripura**, Kailashahar, 16 August 1960, *D.B. Deb 2646* (CAL).

28. *Zingiber zerumbet* (L.) Roscoe ex Sm., Exot. Bot. 2: 105. 1806; Roxb., Asiat. Res. 11: 346. 1810; Rosc.In Trans. Linn. Soc. London 8: 348. 1817; Roxb., Fl. Indica 1: 47.1820; Rosc., Monandr. Pl. Scitam. 35. 1828; Dalzell & Gibson, Bombay Fl. 272. 1861; Thwaites, Enum. Pl. Zeyl. 315. 1861; Baker in Hook.f., F Brit. India 6: 267. 1892; Trimen, Handb. Fl. Ceylon 4: 259. 1898; Prain, Bengal Pl. 2: 1044. 1903; K.Schum in Engler, Pflanzenr. 4(46): 172. 1904; T.Cooke, Fl. Bombay 2: 73 1907; C.E.C.Fisch., Rec. Bot. Surv. India 9: 178. 1921, in Gamble, Fl. Madras 8: 1490. 1928; Holttum, Gard. Bull. Singapore 13: 59. 1950; Mitra, Fl. Pl. East. India 1; 253. 1958; A.Rao & D.M.Verma, Bull. Bot. Surv. India 14: 137. 1972; B.L.Burtt & R.Sm. Notes Roy. Bot. Gard. Edinburgh 31: 182. 1972, in Dassan., F Handb. Fl. Ceylon 4: 495. 1983; Deb, Fl. Tripura 2: 380. 1983; Nicolson *et al.,* Interpret. Rheede Malab. 319. 1988; R.M.Sm. Notes Roy. Bot. Gard. Edinburgh 45: 418. 1989; Kumar & Raju in Gupta, High. Pl. Ind. Subcont. 2: 253. 1991; Theilade in Gard. Bull. Singapore 48: 227. 1996; Kumar in Hajra *et al.*, Fl. Sikkim 1: 134. 1996; Sabu, Folia Malaysiana 4(1): 25–52. 2003; Sabu, Zingiberaceae and Costaceae of South India, 225–250, 2006; Tripathi & Singh, J. Econ. Taxon. Bot. 30: 526. 2006; A.A.Mao *et al.,* Checkl. Fl. Nagaland, 1: 114. 2017; A.A.Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. 1: 134. 2020; U.Shankar, Eco. Patt. Assem. Veg. Fl. North. Reg. India. 1: 152, 2021. ***Type***: **Myanmar, Pegu,** 1826, *C. W. s.n.* (lecto K, designated by Theilade, 1996) **Fig. 28**

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

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

Zingiber spurium Koenig in Retz. Obs. 3: 60. 1783.

Amomum spurium (Koenig) G. Mel. Syst. 1: 6. 1791; A. *Sylvestre* Poir. In Lamk. Encycl. Suppl. 5: 548. 1817.

Zingiber aromaticum Valeton, Bull.Jard. Bot. Buitenzorg, ser. 2, 27: 131. 1918.

***Vernacular name*:** Mal: *Malan Kua.*

Perennial rhizomatous herbs. Rhizome thick, profusely branched, branching sympodial, fleshy, externally light brown, internally pale yellow or creamy yellow, 1–3 cm diameter; tubers present, fusiform, 2–4 × 1.5. Leafy shoot 1.5–2 m tall, leaves 14–18 in number when flowering; pseudostem 30–60 cm long, sparsely pubescent; basal sheaths, green, pubescent; ligules 2.5–3 mm long, green, membranous, pubescent, rounded at apex; petiole green, glabrous, 4–5 mm long, pulvinate; laminae lanceolate, 12–36 × 4–12 cm, adaxially dark green, glabrous, abaxially light green, pubescent, base cuneate, apex acuminate, margin entire. Inflorescence lateral spike, arising from the rhizome, 23–52 cm long; peduncle 20–50 cm long, green, sheathing bracts pale green at base dark green at apex; spikes broadly ovate; sterile bracts obovate, green, pale green towards the base, turn red at maturity, apex rounded or sub-acute, glabrous internally and pubescent externally; fertile bracts many, each enclosing a single flower, broadly obovate, 3–3.7 × 2–2.9 cm, green, pale green towards the base, turn red at maturity, closely imbricating, apex rounded or sub-acute; bracteoles ovate-oblong, 2.6–3.0 × 1.2–1.5 cm, white, membranous, glabrous internally, pubescent externally, apex tri-lobed. Flowers 5.5–5.8 cm long; calyx tubular with unilateral split, c. 1.5 × c. 2 cm (open), white, membranous, apex tri-lobed, pubescent towards apex; floral tube creamy white with yellow towards the tip, 2.5–3.3 cm long, glabrous; dorsal corolla lobe narrowly

Fig. **28.** ***Zingiber zerumbet*** (L.) Roscoe ex Sm. **A.** habit; **B. & C.** inflorescence with flower; **D.** corolla tube with stamen; **E.** bract; **F.** bracteole; **G.** calyx; **H.** corolla lobes; **I.** labellum; **J.** stamen front & side view; **K.** ovary with epigynous glands.

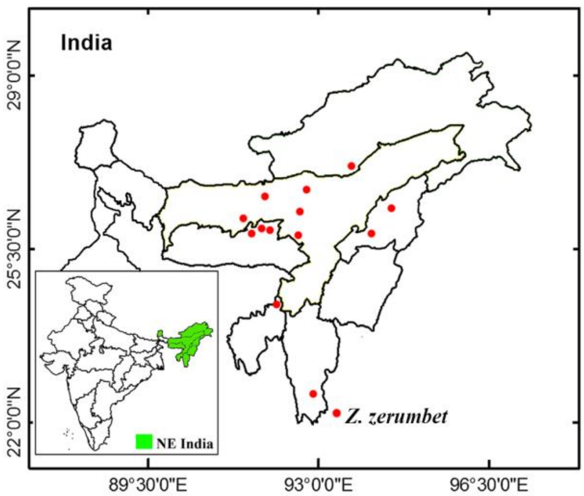
ovate or lanceolate, 2.3–2.5 × 1–1.2 cm, creamy yellow with translucent veins, apex acute, curved, glabrous; lateral corolla lobes triangular-lanceolate, c. 1.9 × c. 0.6 cm, creamy yellow with translucent veins, glabrous on both sides; Labellum sub-orbicular, 2.5–2.9 × 1.9–2.4 cm, creamy yellow at periphery, yellow towards middle, margin wavy, emarginate, glabrous; lateral staminodes, 1.5–1.6 × c. 0.4 cm, ¼th portion adnate to labellum, creamy yellow, margin crisped or wavy. Stamen 1.8–2 × 0.2–0.4 cm; filament reduced to c. 1 mm long, connective tissue glabrous, cream; anther thecae c. 1 × c. 0.4 cm, creamy white; anther crest 0.7–0.9 cm long, creamy white, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, creamy white, c. 0.5 × c. 0.3 cm, trilocular with axile placentation, pubescent; epigynous glands two, cream, 0.4–0.6 cm long, linear. Fruit dehiscent capsule, 1.7 × 1.3 cm, ellipsoid, glabrous. Seeds 9–12, oval.

Distribution**:** Widely cultivated in South East Asia. In India this species is distributed in most of the states, mainly Assam, Meghalaya, Manipur, Tripura, Arunachal Pradesh, West Bengal, Bihar orissa, Uttar Pradesh, Sikkim, Maharashtra, Kerala and Tamil Nadu. Also known from Sri Lanka, Malaysia and China etc. (**Map 28**)

Phenology**:** Flowering June to August, fruits from August to October.

Habitat & Ecology**:** It can be found in evergreen forests on hillsides and rocky ground, moist deciduous forests. It is cultivated species as home garden in local area.

IUCN status**:** Least concerned (LC)



Map 28. Distribution of *Z. zerumbet.*

Notes**:** *Z. zerumbet* resembles *Z. ottensii* in overall habit, whereas *Z. purpureum* and *Z. capitatum* shares an unspotted, yellow or pale yellow labellum with *Z. zerumbet*.

The aromatic spike and internally yellow rhizome make *Z. zerumbet* distinct from *Z. ottensii* whereas *Z. purpureum* can be easily identified by looking at the linear narrow leaves and brown red spikes. It can be also easily distinguished from *Z. capitatum* in having a lateral globose spike (vs. terminal spike). Rhizome of *Z. zerumbet* is used in treating cough, stomach ache, asthma, leprosy, vermifuge and other skin diseases and also used as a substitute for true gingers (Prakash & Mehrotra, 1996). The plant is known as shampoo ginger because of the mucilage present in the inflorescence of *Z. zerumbet* is used as shampoo.

***Specimens examined*: India andamans**, Nayashir Reserve Forest, *s.d.*, *Thomas & Shameer 113508* (CALI). **Arunachal Pradesh,** Papum pare District, Chessa, 12 October 1996, *Sunil Tripathi 20380* (CDRI). **Assam,** Jaintia Hills District, Kumturai, 27 September 1960, V.N.Naik 18185 (ASSAM); Kamrup District, Kulsi Forest, 20 June 1964, *A.S. Rao 39000* (ASSAM); *Ibid.*, 9 December 1945, *G. K. Deka 39744* (ASSAM); Nawgong District, Kholahat Reserve Forest, 19 August 1938, *R.N. De 18377* (ASSAM); Rangulu, 5 km from Jakhala Bandha towards Kaziranga National Park, 17 July 2009, *Thomas & Prabhu 127001* (CALI); Sucha to Bulpuri, 10 July 1963, *R.M. Dutta 33845* (ASSAM). **Jharkhand,** West Singhbhum District, Kurika, 12 November 2003, *Jana Skornickova & Prasanth Kumar 73434* (CALI). **Karnataka**, South Kanara, District, Mangalore, *Bhat 1912* (PPCH); Udupi, *s.d.*, *Bhat 1939* (PPCH). **Kerala,** Kannur District, Kannoth R.F., 8 December 1913, *Ramach*andr*an 66967* (MH); Kollam, Chalakkayam, 2 November 1977, *N.C. Nair 50829* (MH); Iritty, Kunnampally, 22 July 2004, *Vasantha 94870* (CALI); Kasarkode District Cheruvathur, 30 June 1980, *Ansari 67927* (MH); Kollam District, Sangilapalam, Kulathupuzha, *Venketasubramaniyam & Sasidharan 1115* (FRC); Kallar, *s.d.*, *Sabu 86159* (CALI); Thiruvanathapuram District, Ponmudi, *Sabu 103203* (CAL); Kottayam District, Illikal, Palai, *s.d.*, *Mangaly 6726* (CALI); Thrisur District, Kodasseri Reserve Forest, 14 November 1876, *K. Ramamurthy 48523* (MH); Thrissur District Parambikulam, 29 July 1962, *K. M. Sebastine 14700* (MH). **Meghalaya,** Rebhoi District, Nongpho, 27 September 1960, *Deka 18185* (ASSAM); Nongpoh, Bulaiba Tilla, 29 July 1967, *J. Joseph 37422* (ASSAM); *s.loc*., Umsaw, 10 September 1981, *Ved Prakash 12808* (CDRI); *s.loc*., 26 September

1985, *Ved Prakash 14839* (CDRI); l.c., 11 November 1987, *Ved Prakash 17155* (CDRI); Lailad, 3 October 1996, *Sunil Tripahti 20363* (CDRI); Nongpho, 15 May 2008, *Thomas & Prasanth 94924*, *94981* (CALI). **Mizoram,** Saiha to Bualpui, 10 July 1963, *R.M. Dutta 33845* (ASSAM). **Nagaland,** Lumami, Nagaland University Campus, 18 May 2006, *Sabu & Pradeep 103602* (CALI); Pherima Village, 26 July 2016, *Jayakrishnan & Nikhil Krishna 150207* (CALI). **Tripura**, Churachandpur Reserve Forest, 29 August 1957, *R.S. Rao 8977* (ASSAM); Chandarpur Reserve, 29 September 1957, *D.B. Deb 1118* (CAL); Magapnokarami, 29 August 1957, *R.S. Rao 8977* (ASSAM). **West Bengal**, Burdwan District, Mankundu, 30 June 1976, *B.G. 4483, 2759* (CDRI); *s.loc, s.d., Wallich 6560* (CAL); Howrah District, 26 August 1964, *S.S. Hennet 958* (CAL).

COMPARATIVE MORPHOLOGY

The genus *Zingiber* is having medium-sized herbs about 0.6–2.5 m tall, bearing long, stoloniferous or tight clump-forming and fleshy subterranean, aromatic or non-aromatic rhizomes. Each branch of the rhizome bears a terminal bud, which after the dormant stage develops into an erect leafy shoot. The base of the leafy shoot forms a leafless stem covered by 3 to 4 bladeless leaf sheaths, followed by distichously arranged normal leaves. Each leaf sheath at its apex develops a membranous bilobed ligule and continues upward as a short petiole-like portion and finally terminates in the leaf blade. The plane of distichy of leaves is parallel to the rhizome. The petiole has a swollen base which forms the pulvinus. The inflorescence is produced on a lateral shoot developed directly from the rhizome, with a short or long peduncle, rarely terminal or emerging through the leaf sheath also occurs. The peduncle is protected by sterile sheathing bracts. The entire inflorescence forms a cone and each bract encloses a single flower. The bracts are green or with a yellow tinge or red when young, turning red to a deep purple at maturity. Flowers are usually short living, last up to a few hours. Labellum is a 3-lobed structure with two lateral staminodes which are adante or free from the mid lobe. Labellum and staminodes are the most beautiful part of the flowers. The diagnostic character of the genus is the single stamen with a long, curved beak or horn-like appendage which embraces the upper part of the style.

Rhizome

The rhizome is a type of subterranean stem that has been adapted for the vegetative propagation and storage of food. Rhizomes can be short, long or underground. A sequence of interwoven rhizomes is known as a sympodium. The rhizome is divided into nodes and inter-nodes. It has scale leaves and axillary buds on its nodes. Axillary buds and rhizome is protected by scale leaves. The apical bud has produced an aerial shoot which also divides into nodes and internodes. Rhizome forms two, three or four major branches. Secondary, tertiary and quaternary branches were developed as a result of the further growth of axillary buds. Rhizomes are fleshy, remain dormant during the dry season and sprout back to life following rain. Rhizomes are aromatic and occur in a variety of colors. Basically, two types of rhizomes were observed in the genus *Zingiber* viz., Stoloniferous or running and Non-stoloniferous or clump-forming. Rhizome is tight or short clump forming in *Z. arunachalensis*, Z. *bipinianum*, *Z. campanulatum*, *Z. capitatum*, *Z. chrysanthum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. kerrii*, *Z. ligulatum*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. officinale*, *Z. pherimaense*, Z. *pupureum*, *Z. rubens* and *Z. zerumbet*, whereas in *Z. bipinianum*, *Z. caudatum*, *Z. clarkeii*, *Z. cornigerum*, *Z. flavofusiforme* and *Z. roseum* the rhizome is stoloniferous and horizontally elongated. The rhizome is deep yellow inside in *Z. capitatum*, *Z. chrysanthum*, *Z. neotruncatum* var. *ramsawmii* and Z. *pupureum* it is pale yellow in *Z. zerumbet*, creamy yellow in *Z. pherimaense*, grayish-yellow in *Z. officinale*, yellowish-brown in *Z. neotruncatum* var. *neotruncatum* and rest of the species rhizome is cream or creamy white. In *Z. campanulatum* rhizome is cream with a bluish tinge in some areas, in *Z. cornigerum* internally rhizome is divided into three circular zones, inner cream, middle creamy yellow and outer dark brown but in *Z. murlenica* the rhizome is unique in having internally grayish-green color. Rhizomes are pleasant and fruity smelled in *Z. neotruncatum* var. *ramsawmii*, *Z. neotruncatum* var. *neotruncatum* and *Z. kerrii* and it is pungent and strongly aromatic in *Z. zerumbet*, *Z. officinale*, Z. *pupureum*, *Z. murlenica*, Z. *arunachalensis*, *Z. chrysanthum* and *Z. rubens*. Rhizomes with slight or without any characteristic aroma were found in the rest of the species.

Root

The primary roots are thin and soft they develop as tufts from the base of new sprouts. These roots have many root hairs and are ephemeral. As the rhizome gets matured the primary roots are replaced by stout, thick fibrous roots developing from the lower nodes, they grow deep into the soil and give better anchorage to the growing areal shoot system. The rhizomes are covered with spine-shaped root hairs in *Z. mizoramensis*. In *Z. cornigerum* and *Z. clarkei* the rhizome is covered with thin root hairs throughout its length. In species like *Z. zerumbet*, *Z. rubens*, Z. *pupureum*, *Z. meghalayense*, *Z. flavofusiforme*, *Z. capitatum* and *Z. campanulatum* the roots end in ovoid, fusiform or spindle-shaped structures called root tubers which are storage in function and rich in starch. They are 1 to 4 cm long, cream or dirty white, internally cream or creamy yellow. In *Z. flavofusiforme* the tubers are grayish-blue internally.

Aerial shoot

The aerial shoot system is developing from the apical bud of lateral branches of the rhizome andthey grow up to the length of 1 to 2.5 m. The size of the leafy shoot depends on the age of the rhizome, the older rhizome forms longer shoots whereas the younger one forms a robust shoot system. The areal shoot is divided into nodes and the internodes basal region is covered with leafless sheaths which form the pseudostem and the rest of the shoot possess leaf blades at each node which are alternately placed and more or less horizontally oriented. The basal blades are usually smaller and from the middle onwards develop larger leaves. As the plant grows in length new leaves are produced. A mature plant bears 12 to 22 leaves when flowering and upon growth the leafy shoot arch over to one side. In *Z. capitatum*, *Z. marginatum* and *Z. flavofusiforme* the inflorescence is produced terminally on the leafy shoot. In such species, the inflorescence development limits vegetative growth. In *Z. clarkei* the inflorescence is arising through the leaf sheath, usually, from the middle of the leafy shoot and in all other species, the inflorescence is separate and develops directly from the base of the pseudostem.

Leaves

Leaves are alternate, distichously arranged and the plane of distichy is parallel to the rhizome. Leaves are usually subsessile. The short petiole forms a fleshy, bulged pulvinus at its base which forms the unique feature of the genus. Ligules are formed at the upper margin of the leaf sheath which is a bilobed membranous structure. It may be shortly or deeply bilobed, acute or round at apex, usually hyaline and sometimes tinged with green or red. The size of the ligule also varies and it ranges from 0.2–4 cm. The smallest ligule was observed in *Z.*

capitatum with a size of 1 mm and the largest was in *Z. ligulatum* which grows up to 4 cm long and flap-like. The shape of the lamina varies from linear-lanceolate to ovate or elliptic-lanceolate. Lamina is linear in *Z. capitatum*, *Z. kerrii*, *Z. officinale*, *Z. purpureum*, *Z. neotruncatum* var. *ramsawmii* and *Z. neotruncatum* var. *neotruncatum* whereas in the rest of the species the lamina is broad. In *Z. campanulatum* the lamina is oblong and oblong-lanceolate in *Z. chrysanthum* and *Z. pherimaense*. The size of lamina also varies among species, the largest lamina was observed in *Z. murlenica* and the smallest in *Z. meghalayense*. Each leaf has a sheathing base that partially or fully encircles the stem with a unilateral split. It is usually thin, fleshy and hairy. Lamina may be pubescent or glabrous. Hairs are unicellular and distributed mainly on the abaxial side of the lamina and rarely along the abaxial side of the midrib. The venation pattern is parallel with a prominent midvein and slightly oblique convergent lateral veins.

Inflorescence

The genus *Zingiber* is characterized by spike inflorescence which may be terminal or produced separately from the rootstalk or rhizome and rarely arising through the leaf sheath. In *Z. capitatum*, *Z. flavofusiforme* and *Z. marginatum* the spike is terminal whereas in *Z. clarkei* the spike is arising through the leaf sheath and in the rest of the species the spike is on a separate shoot or peduncle developing from the rootstalk or rhizome. The spike is ovate, globose or sub-globose and produced on the procumbent peduncle in *Z. arunachalensis*, Z. *bipinianum*, *Z. callianthum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. ligulatum*, *Z. mekongense*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. pherimaense*, *Z. rubens*, *Z. caudatum*, *Z. cornigerum* and *Z. roseum*, whereas in *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. officinale*, *Z. intermedium*, Z. *pupureum* and *Z. zeumbet* the spike is produced on a separate eruct peduncle. The peduncle may be short or very long and the size ranges from 10–100 m. Peduncle are ensheathed by two ranked sterile bracts. The longest peduncle was observed in *Z. purpureum*, *Z. officinale* and *Z. zerumbet*. The shortest was in *Z. roseum*, *Z. rubens* and *Z. ligulatum*. Spikes are sessile in *Z. capitatum*, *Z. flavofusiforme* and *Z. marginatum*. In *Z. roseum*, *Z. mizoramensis* and *Z. rubens* the spike is half immersed in soil. The inflorescence is variously colored usually light to dark green, pinkish to dark red, yellow, brown, cream or purple. Green-colored spikes may turn dark red or purple at maturity. In *Z. flavofusiforme* the spike is fusiform and bright yellow. Purplish brown spike are observed in *Z. arunachalanensis*, *Z. bipinianum* and *Z. purpureum*. In *Z. roseum, Z. rubens, Z. neotruncatum* var. *ramsawmii*, *Z. mizoramensis*, *Z. pherimaense* and *Z. meghalayense* the spike is red-colored. Green or light green spikes are found in *Z. zerumbet, Z. officinale, Z. kerrii*, *Z. neotruncatum* var. *neotruncatum* and *Z. capitatum* and all other species have a white or cream-colored spike. The bracts on the spike may be closely imbricating or loosely imbricating. In *Z. pherimaense, Z. callianthum* and *Z. meghalayense* the bracts are loosely imbricating, whereas in the rest of the species the bracts are closely imbricating. The flowers last for only a few hours or up to 24 hours. They are very delicate and fragile.

Shape of the spike varies considerably, cylindrical with tapering narrow apex in *Z. neotruncatum* var. *ramsawmii*, ovate with acute apex in *Z. purpureum*, *Z. kerrii*, *Z. mizoramensis* and *Z. neotruncatum* var. *neotruncatum* and ovoid with rounded apex in *Z. zerumbet*. Spike is narrowly ovate or lanceolate with acuminate or caudate apex in *Z. arunachalensis* and *Z. caudatum*. The size of the spike varies from 4-6 cm in *Z. roseum* and 10–20 cm in *Z. campanulatum* and *Z. neotruncatum* var. *ramsawmii*. In *Z. officinale, Z. bipinianum*, *Z. neotruncatum* var. *neotruncatum, Z. meghalayense* and *Z. capitatum*, the flower opens in the evening about 3–5 pm. One to two flowers are produced at a time in *Z. officinale, Z. meghalayense, Z. pherimaense*, *Z. dimapurense, Z. mizoramensis* and *Z. murlenica,* whereas 4–6 flowers are seen in *Z. capitatum*. In others like *Z. zerumbet, Z. rubens, Z. kerrii, Z. cornigerum, Z. callianthum, Z. roseum, Z. arunachalensis, Z. caudatum, Z. clarkei, Z. dimapurense, Z. mekongense, Z. flavofusiforme, Z. kangleipakense, Z. ligulatum, Z. mizoramensis, Z. murlenica*, *Z. pherimaense* and *Z. purpureum* 1–2 flowers occur and opens early in the morning i.e., about 5–7 am. The number of inflorescences produced may vary from 2 to 4 in most of the species. Holttum (1950) believed that the basic inflorescence unit in Zingiberaceae consists of axillary monochasial cymes and each branch with a terminal flower. A single flower in each bract is considered as derived.

Bracts

The inflorescence has a central axis or rachis which bears the bracts. There are two kinds of bracts in the inflorescence the outer sterile (without flower) and the fertile or flowering bracts. Bracts are broadly ovate to narrowly ovate and rarely obovate, brightly colored and the color intensifies as the bracts get older. Bracts are loosely imbricating in *Z. callianthum* with a visible inflorescence rachis. In *Z. meghalayense* and *Z. pherimaense* bracts are loosely imbricating and, in the rest, they are closely imbricating and spirally arranged. In *Z. callianthum* bract is linear. It is oblong–obovate in *Z. clarkei*, spathulate with reflexed apex in *Z. meghalayense*. In *Z. murlenica* bract is reflexed at apex which gives a stellar appearance to the spike, whereas in *Z. meghalayense* the apex is acuminate and twisted with a wavy margin. The apex of the bract is slightly notched in *Z. mizoramensis.* Long caudate bracts are found in *Z. caudatum.* A single flower is present at the axils of each bract and their size ranges from 2.3–2.5 × 1.3–2 cm in *Z. officinale* to 5–7 × 2–2.5 cm in *Z. murlenica*. In *Z. kerrii, Z. zerumbet* and *Z. officinale* the color of bracts turns red as the inflorescence matures. Bracts are bright yellow in *Z. flavofusiforme*. The bracts of *Z. kerrii* are characterized by a large red spot at apex similarly a white marking is found at the tip of the bracts in *Z. officinale*. *Z. marginatum* is characterized by bracts with membranous margins. **Fig. 29**

Bracteole

The bracteoles are protected by the fertile bracts. They face the inner side of bracts; each encloses a single flower bud. They are persistent and enclosing the fruit and unilaterally split up to the base. The shape varies with species usually narrowly ovate, linear, lanceolate or ovate-lanceolate. They are variously colored usually creamy white, white, red and light green. In all the species, the apices are acute with the exceptions of *Z. chrysanthum*, *Z. kangleipakense*, *Z. murlenica*, *Z. neotruncatum* var. *neotruncatum* and *Z. roseum*, in which the apices are notched or bilobed, whereas in *Z. rubens*, *Z. purpureum* and *Z. zerumbet* the apices are trilobed. A truncate apex was found in *Z. clarkei*, *Z. kerrii* and *Z. officinale*. Bracteoles with horned apex (one small lobe and one long acuminate lobe) were observed in *Z. cornigerum*. **Fig. 30**

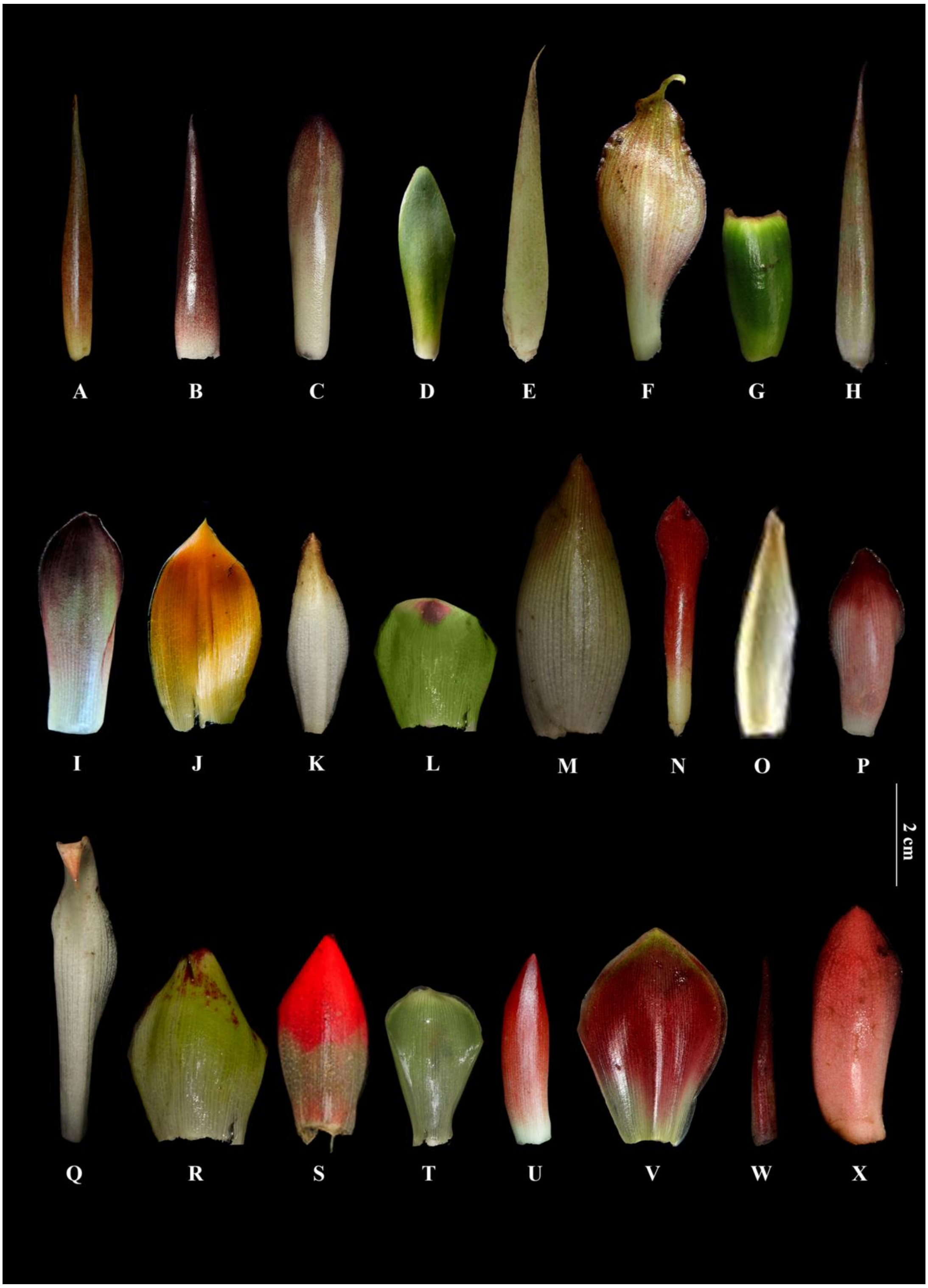


Fig. 29. Bracts of *Zingiber* sp.: **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*; **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

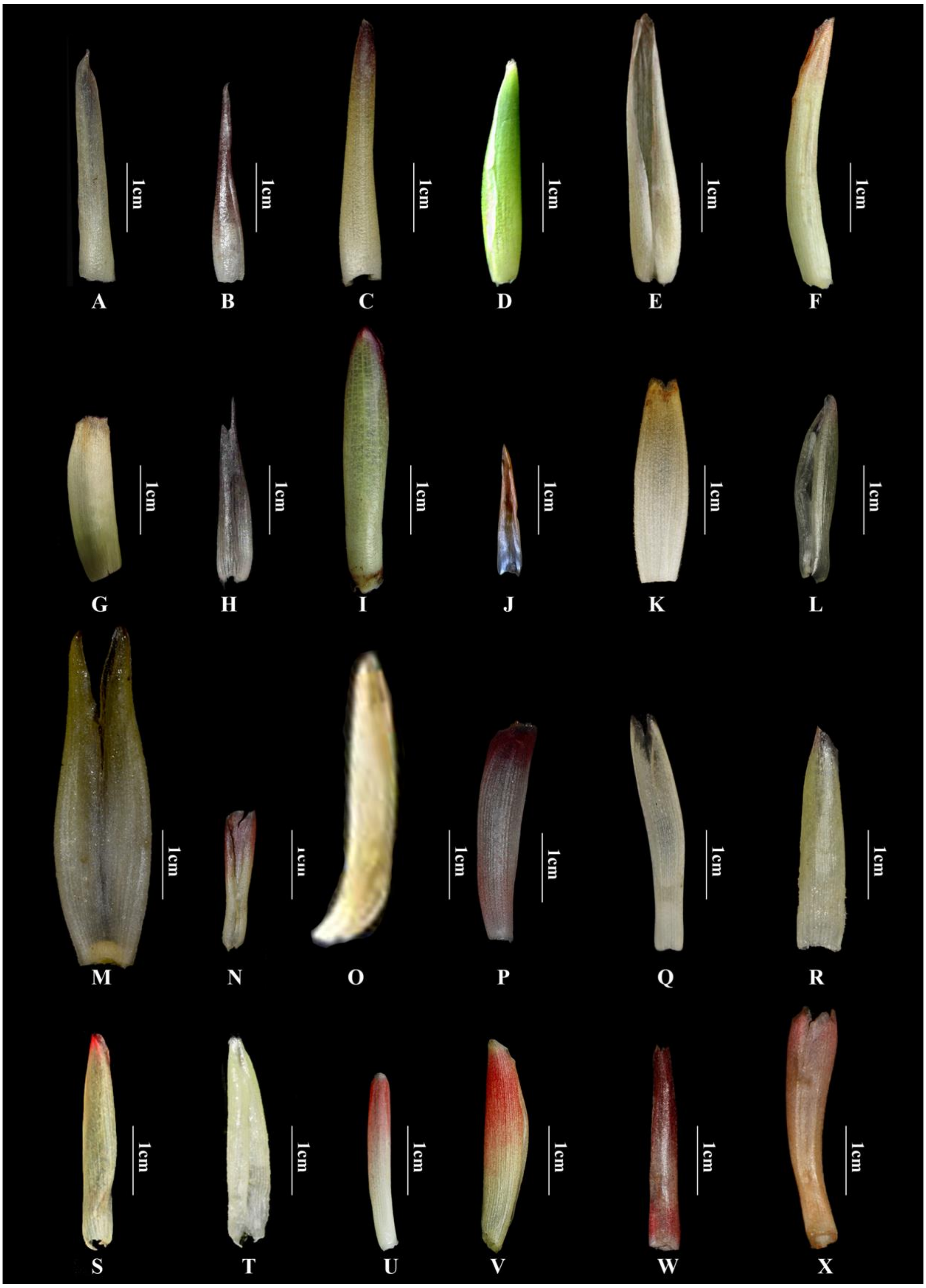


Fig. 30. Bracteoles of *Zingiber* sp.: **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*; **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

Fig. 31. Flowers of *Zingiber* sp. (inset: flower front view) : **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*.

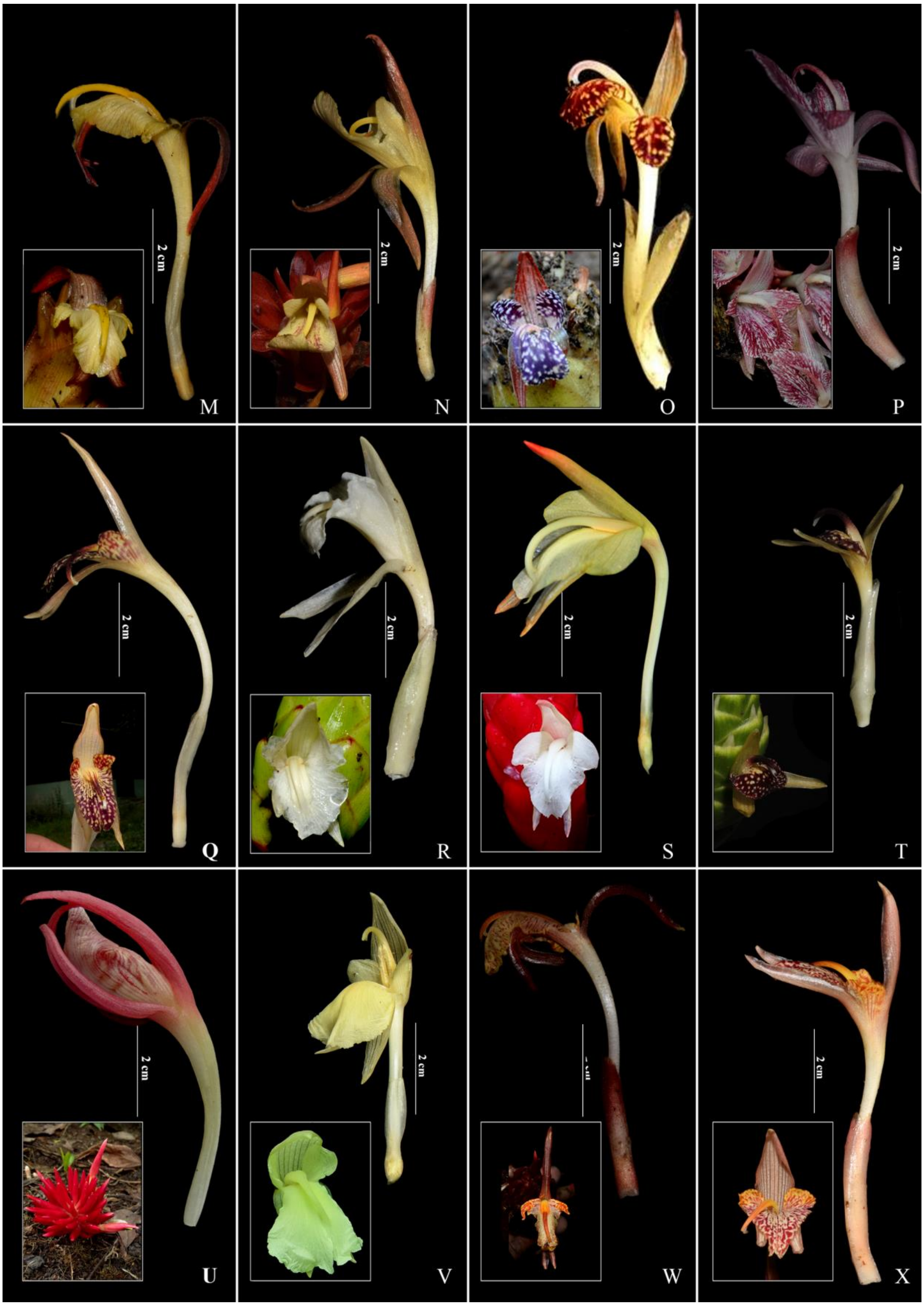


Fig. 32. Flowers of *Zingiber* sp. (inset: flower front view): **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

Flower

Flowers are bisexual, zygomorphic, trimerous, dichlamydeous and epigynous. Each flower is enclosed by a bracteole. They are fragile and ephemeral. *Z. clarkei* and *Z. officinale* have the smallest flowers (4–4.5 cm), whereas *Z. chrysanthum* and *Z. cornigerum* have the longest flowers (8–10 cm). **Fig. 31, 32**

Calyx

Calyx is a membranous structure that rises above the ovary. They are smaller than bracteoles. Calyx forms a tubular structure with a unilateral split. The apex is unsplit and may be bilobed or trilobed. Apices are bilobed in *Z. bipinianum*, *Z. clarkei*, *Z. cornigerum*, *Z. dimapurense*, *Z. flavofusiforme*, *Z. mizoramensis*, *Z. neotruncatum* var. *neotruncatum* and *Z. purpureum*. In *Z. officinale* teeth are not prominent whereas in other species calyx is trilobed at apex. They are usually white-colored in all species but in *Z. neotruncatum* var. *ramsawmii* and *Z. rubens* the apices are red-tinged and it is purple-tinged in *Z. mizoramensis*. **Fig. 33**

Corolla

Corolla of genus *Zingiber* consists of three lobes all of them characterized by 4-5 translucent veins on their entire length, the largest lobe is placed above the labellum which forms the dorsal corolla lobe and two small narrow lateral corolla lobes are situated below the labellum. They are arranged at the distal end of the corolla tube. The corolla tube in most of the species was found to be longer than both bract and bracteole except in *Z. clarkei*, *Z. officinale* and *Z. capitatum*, here the corolla tube is as long as the bract and bracteole. The orientation and size of the dorsal corolla lobes are somewhat different from the lateral one. The dorsal lobes are normally narrowly ovate in all species but it is broadly ovate in *Z. capitatum*, *Z. flavofusiforme*, *Z. kerrii* and *Z. zerumbet*. The lateral corolla lobes are arranged in pairs and in most species, will get curled backward soon after the opening of the flower. The apices of the lobes are acute and it is curved in dorsal corolla lobes. The color is usually cream or white with a pink or reddish tinge at the apices. Corolla lobes are cream or creamy white with pinkish tinged at the apex in *Z. dimapurense*, *Z. mizoramensis*, *Z. pherimaense*, *Z. callianthum* and *Z. meghalayense*, whereas in *Z. chrysanthum* and *Z. kangleipakense* corolla lobes are bright yellow with or without a reddish tinge at the apex. It is cream with reddish tinged at the apex in *Z. roseum*, *Z. ligulatum*, *Z. rubens*, *Z. mekongense* and *Z. neotruncatum* var. *ramsawmii*. White lobes are found in *Z. cornigerum*, *Z. bipinianum* and Z. *caudatum* whereas in the rest of the species it is cream or creamy yellow.

Fig. 34

Labellum

Labellum is the most attractive part of the flower. The color patterns, shape and size of labellum vary with species, hence it has a great role in distinguishing among species. It is a trilobed structure with a large mid lobe and two lateral lobes (staminodes) placed on either side of the mid lobe. The degree of fusion between staminodes and mid lobe varies from species to species. Labellum is variously colored. Color is white or creamy white with purple markings and blotches in *Z. bipinianum* and *Z. caudatum*, white with pinkish blotches in *Z. cornigerum*. It is bright yellow in *Z. chrysanthum*, *Z. kangleipakense* and *Z. capiatatum* whereas it is pale yellow with white at the center in *Z. ligulatum*, pale yellow with deep yellow at the center in *Z. zerumbet* and *Z. purpureum*, yellow with purple mottled in *Z. meghalayense* and yellow with red at the margin in *Z. clarkei*. In *Z. arunachalensis*, *Z. mizoramensis* and *Z. campanulatum* the labellum is deep purple with creamy white spots and blotches, whereas in *Z. rubens*, *Z. callianthum* and *Z. pherimaense* it is creamy white with red or purplish-red (or maroon) blotches. In *Z. mekongense* labellum is violet or maroon with yellow at the middle, deep maroon with yellow spots in *Z. officinale* and *Z. flavofusiforme*, creamy white and unspotted in *Z. kerrrii*, creamy yellow in *Z. neotrncatum* var. *neotruncatum* and *Z. neotrncatum* var. *ramsawmii*. In *Z. dimapurense* the labellum is purplish-pink with white botches. The margin is recurved and crispy in *Z. roseum, Z. ligulatum*, *Z. mekongense*, *Z. kangleipakense*, *Z. capitatum* and *Z. purpureum*. The apices are notched in *Z. capitatum*, *Z. chrysanthum*, *Z. kerrii*, *Z. ligulatum*, *Z. meghalayense*, *Z. purpureum*, *Z. rubens*, Z. *neotrncatum* var. *neotruncatum* and *Z. neotrncatum* var. *ramsawmii* whereas in others the apices are acute or round. **Fig. 35**

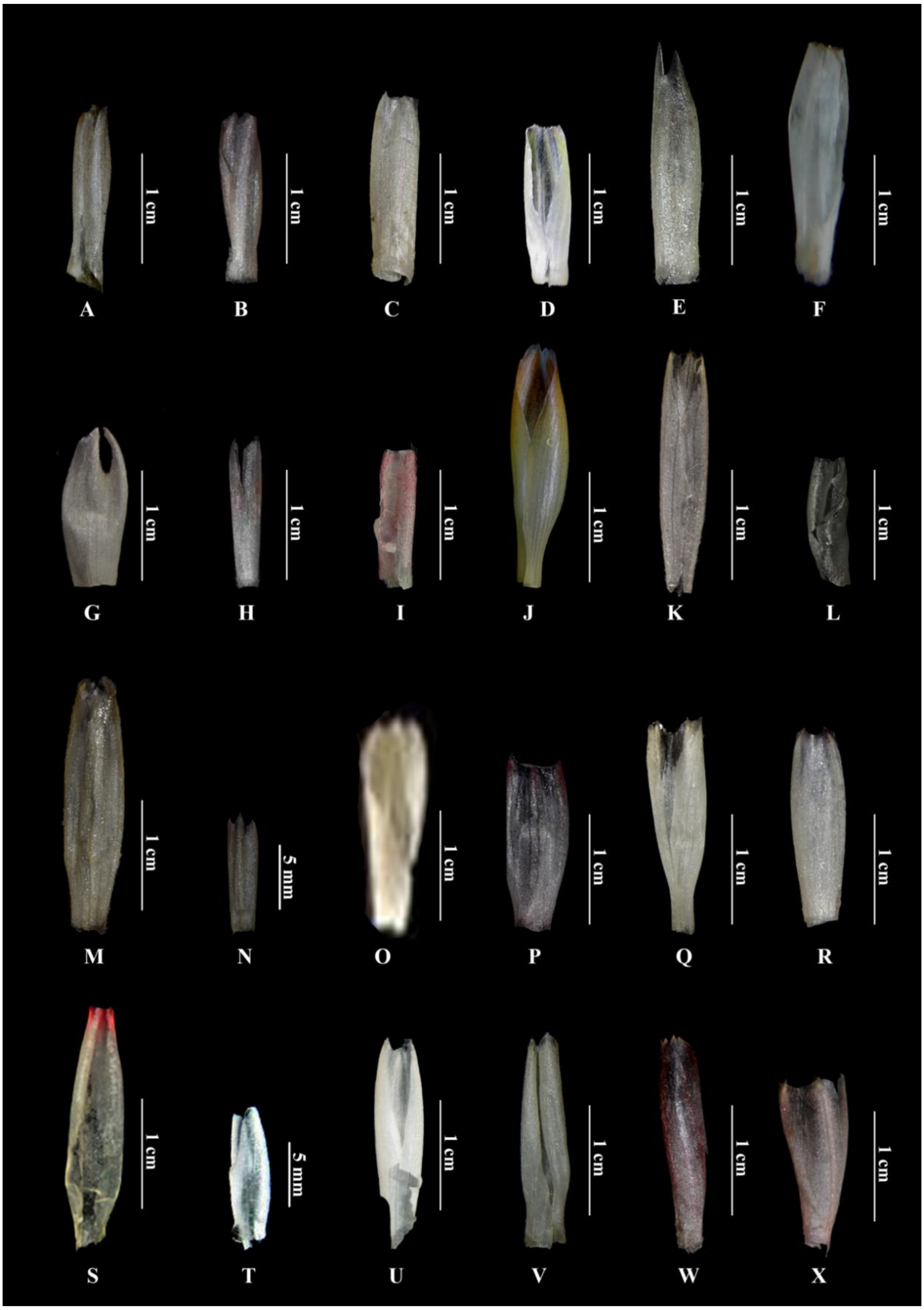


Fig. 33. Calyx of *Zingiber* sp.: **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*; **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

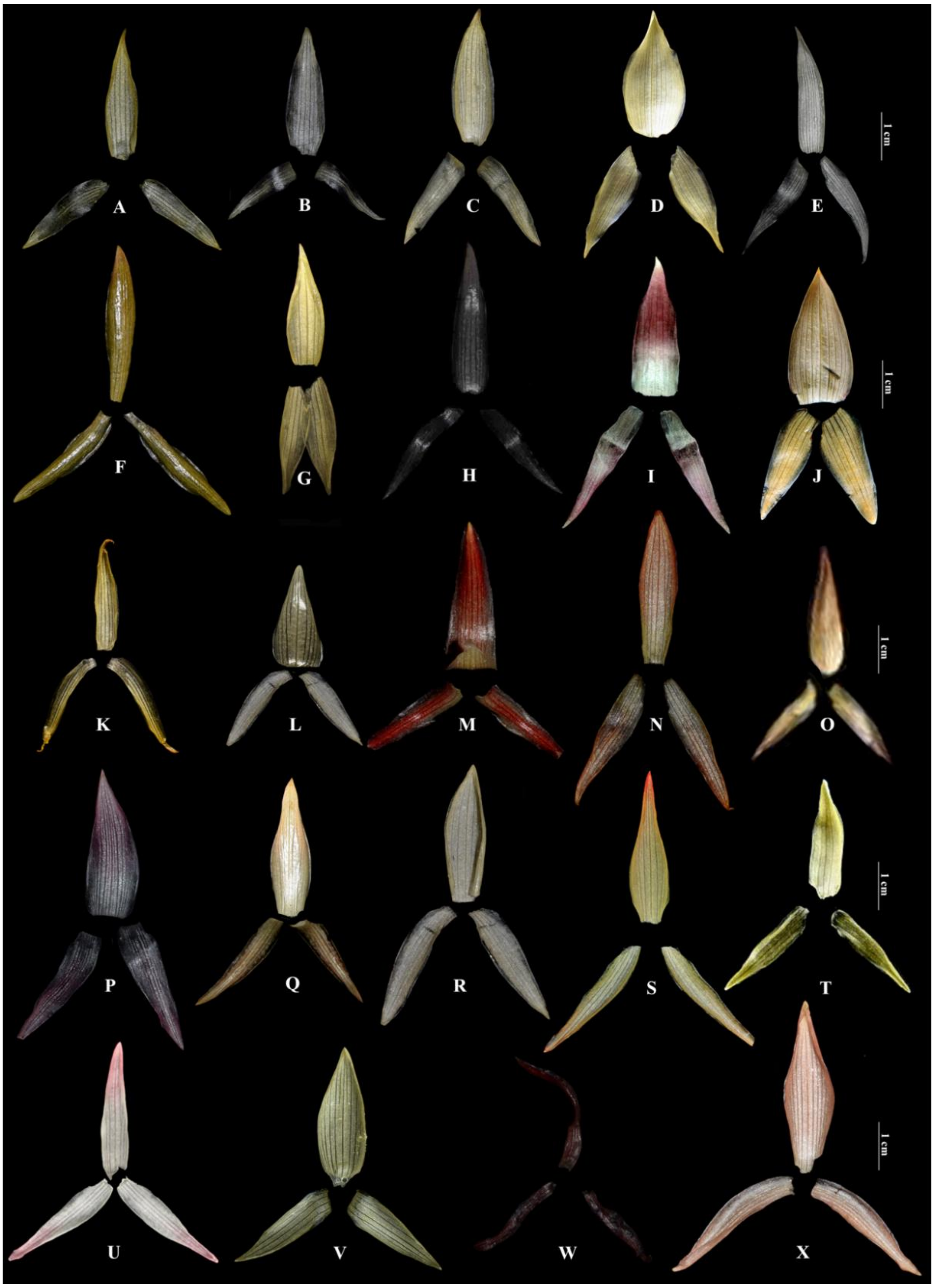


Fig. 34. Corolla lobes of *Zingiber* sp.: **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*; **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

Fig. 35. Labellum and Lateral staminodes of *Zingiber* sp.: **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*; **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

Lateral staminodes

In *Zingiber* species, the two lateral stamens are modified into petal-like structures which is connate to the labellum. The degree of fusion between labellum and lateral staminodes varies with species. In *Z. rubens*, *Z. kangleipakense* and *Z. flavofusiforme* the lateral staminodes are almost adnate to the labellum, whereas in *Z. clarkeii*, *Z. kerrii*, *Z. arunachalensis*, *Z. bipinianum* and *Z. officinale* lateral staminodes are almost free from labellum (attached at the base only). Staminodes are attached half by length to the labellum in *Z. roseum*, *Z. pherimaense*, *Z. cornigerum*, *Z. capiatum*, Z. *chrysanthum* and *Z. caudatum*, $^{3}/_{4}{}^{th}$ length attached to labellum in *Z. callianthum*, *Z. campanulatum*, *Z. dimapurense*, *Z. neotrncatum* var. *neotruncatum*, *Z. murlenica*, *Z. mizormensis* and *Z. ligulatum*, ¼th length attached to labellum in *Z. purpureum* and *Z. mekongense.* The longest staminodes are observed in *Z. meghalayense* (2–2.5 cm) and *Z. pherimense* (2.2–2.4 cm) and the smallest in *Z. kangleipakense* (0.2 × c. 0.2 cm). Color varies from white to cream with purple or reddish spots and bright yellow to pale yellow or creamy yellow with purple spots. It is white unspotted in *Z. bipinianum*, *Z. cornigerum*, *Z. caudatum* and *Z. dimapurense*. Creamy white in *Z. kerrii*, *Z. neotrncatum* var. *neotruncatum* and *Z. neotrncatum* var. *ramsawmii*. Purple with cream dots in *Z. arunachalensis*, *Z. mekongense* (in Indian specimen violet with cream spots) and *Z. officinale*. Cream with pinkish blotched in *Z. campanulatum* and *Z. mizoramensis*. bright yellow in *Z. capitatum*, *Z. chrysanthum*, *Z. meghalayense*, Z. *clarkei* (Creamy yellow) and *Z. kangleipakense*, whereas pale yellow color in *Z. ligulatum*, *Z. purpureum* and *Z. zerumbet*, yellow with purple or red spots in *Z. roseum* and *Z. rubens* cream or white with reddish-pink spots in *Z. callianthum* and *Z. pherimaense*. **Fig. 35**

Fertile stamen

A single fertile anther with a long-curved beak-like appendage (Anther crest) which embraces the upper part of the style is the characteristic feature of the genus *Zingiber*. The anther crest is seen as a continuation of the connective tissue which is short or as long as the anther thecae. The crest is mostly protective in its function it avoids the slender style from breakage and provides support to the stigma by placing it in an upright position. The cup-shaped stigma is projecting below the apex of the crest, with ciliate margins. In most of the species color pattern of anther and anther crest are like that of the labellum. **Fig. 36**

Ovary

Ovary is inferior, trilocular with axile placentation. Ovules are many in each locule. Ovary may be cylindrical or barrel-shaped, glabrous or hairy. Ovary is glabrous in *Z. officinale*, *Z. neotrncatum* var. *ramsawmii*, *Z. kerrii* and *Z. flavofusiforme*. Usually cream or creamy white rarely with purple stripes. The size of the ovary ranges from 9–10 × 3 mm in *Z. callianthum* and 2.5–2.7 × 2.4–2.5 mm in *Z. kerrii*. **Fig. 37**

Epigynous glands

At the apex of the ovary, two stylodial nectariferous glands are enclosing the lower portion of the style. In most of the species, it is creamy white or creamy yellow, equal or unequal in length. The longest epigynous gland was observed in *Z. arunachalensis* (0.8–1.6 cm long) and the smallest one in *Z. kerrii* (2.5–2.7 mm long). **Fig. 37**

Style and stigma

The style is long, thin, linear and white. It is situated in a cavity inside the filament and the anther and protrudes above the anther. It passes through the corolla tube cavity. The long curved anther appendage embraces the upper part of the style. Stigma is cup-shaped and with ciliate margins which project just below the apex of the crest.

Fruits and seeds

Fruit is a fleshy loculicidal capsule with three longitudinal slits that can dehisce. When dried, the fruit wall is soft and fleshy, somewhat ridged, leathery and encircled by persistent bract and bracteole. Usually green or creamy white when young, but as they mature, they turn dark crimson or dark purple. A thin, saccate, white aril with unevenly lacerate edges covers the ellipsoid, black or dark brown seeds.

Fig. 36. Fertile stamens of *Zingiber* sp.: **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*; **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

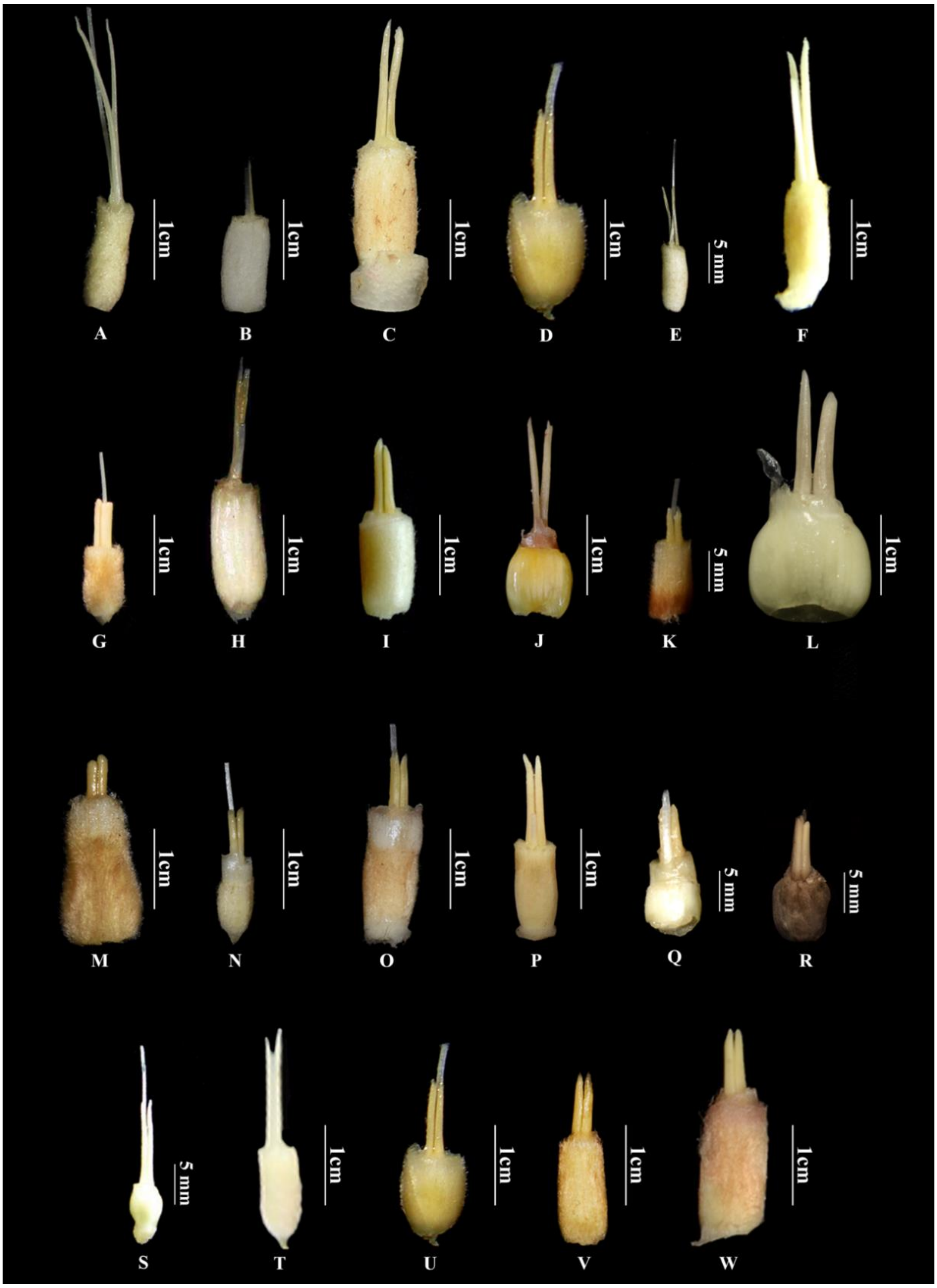


Fig. 37. Ovary with epigynous glands of *Zingiber* sp.: **A.** *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. caudatum*; **F.** *Z. chrysanthum*; **G.** *Z. clarkei*; **H.** *Z. cornigerum*; **I.** *Z. dimapurense*; **J.** *Z. flavofusiforme*; **K.** *Z. kangleipakense*; **L.** *Z. kerrii*; **M.** *Z. ligulatum*; **N.** *Z. meghalayense*; **O.** *Z. mekongense*; **P.** *Z. mizoramensis*; **Q.** *Z. murlenica*; **R.** *Z. neotruncatum* var. *neotruncatum*; **S.** *Z. neotruncatum* var. *ramsawmii*; **T.** *Z. officinale*; **U.** *Z. pherimaense*; **V.** *Z. purpureum*; **W.** *Z. roseum*; **X.** *Z. rubens*.

ANATOMY

Anatomy has been regarded as important in plant systematics since the time of Linnaeus. Many following taxonomists incorporated anatomical factors as well. In their book 'Die Natürlichen Pflanzenfamilien,' Engler and Prantl (1887-1915) analyzed the anatomical features. The rhizome structure of Zingiberaceae was observed by Schumann (1904). Later, Tomlinson (1962) studied the order Scitamineae with the use of anatomy and floral morphology, claiming that the knowledge from anatomy and floral morphology is effective in categorizing and explaining the order's putative phylogeny. Paliwal and Anand (1978) discovered anatomical features as a valuable technique for identifying herbarium specimens and determining evolutionary patterns in taxonomic interrelationships. In Pharmacognosy, anatomical features were shown to be beneficial in plant identification (Datta & Mukerji, 1950; Banerjee & Mukerjee, 2001; Das *et al.,* 2004) and also in plant-insect relationship (Schoonhoven *et al.,* 2005) Palaeobotany (Bandulska, 1924; Dilcher, 1974), forensic science (Bhatia *et al.,* 1973, 1988) etc.

Many scientist studied the anatomy of *Zingiber* sp. e.g., (Remashree *et al*., 1997, 1999; Jayasree, 2007; Vasantha, 2009; Uma & Muthukumar, 2014; Das *et al*., 2018; Liu *et al.,* 2020).

In the present work we have attempted to study the foliar anatomy of some selected species of genus *Zingiber* in Northeast India. A total of 17 species and one variety were included in the study, which ensures the participation from all four infrageneric sections. The study investigated the ability of anatomical characters in species identification and sectional delimitation. The work includes the foliar parts, viz., midrib, lamina, margin and sheath.

Results

General Anatomy **Fig. 38**

Vascular bundles

Arrangements: The vascular bundles of various parts like midrib, petiole and sheath are symmetrically arranged in the form of several arcs. There are usually I to IV arc bundles (Tomlinson, 1956). The arc I bundles form the main vascular bundles which are situated near the abaxial surface. The bundle arc II is arranged abaxially to arc I, which are arranged alternatively with arc I bundles and are smaller than arc I bundles. Arc III bundles are positioned near the adaxial region of arc I bundles, they are medium-sized and more or less irregularly arranged. A group of small bundles close to the adaxial surface forms the arc IV bundles.

Vascular bundles Structure: The vascular bundles in the main arc (bundle arc I) are designated as 'Musa-type' (Solerender & Meyer, 1930). The bundles are usually pear-shaped due to the widening of their abaxial region. They are made up of one or two large metaxylem components with one to three protoxylem elements placed adaxially. A uniform concentric arrangement of parenchyma cells surrounds the metaxylem element. An angular xylem layer separates the xylem from the phloem, which is organized towards the abaxial surface. Sieve tubes, companion cells and parenchyma make up phloem. Each bundle is enclosed by an incomplete sclerenchymatous bundle cap that can only be observed on the adaxial and abaxial ends of the bundle.

Bundles of arc II are surrounded by a continuous sclerenchymatous bundle cap and each bundle consists of a single metaxylem element (protoxylem are very rare or absent) and a small group of phloem. Xylem parenchyma may or may not be present.

The arc III bundles contain a single large metaxylem element with or without protoxylem. The sclerenchymatous bundle caps are incomplete in most bundles and they may be complete in the marginal bundles.

Midrib

The midrib region consists of a single-layered epidermis on both adaxial and abaxial surfaces. The ground tissue is composed of parenchymatous cells which are smaller towards the epidermal region and gradually enlarge towards the central portion. The arc bundles are embedded in the ground tissue which are arranged into I, III and IV arc bundles and arc II is absent in all the species. Air canals bounded by a layer of chlorenchyma cells are present in between the arc I bundles.

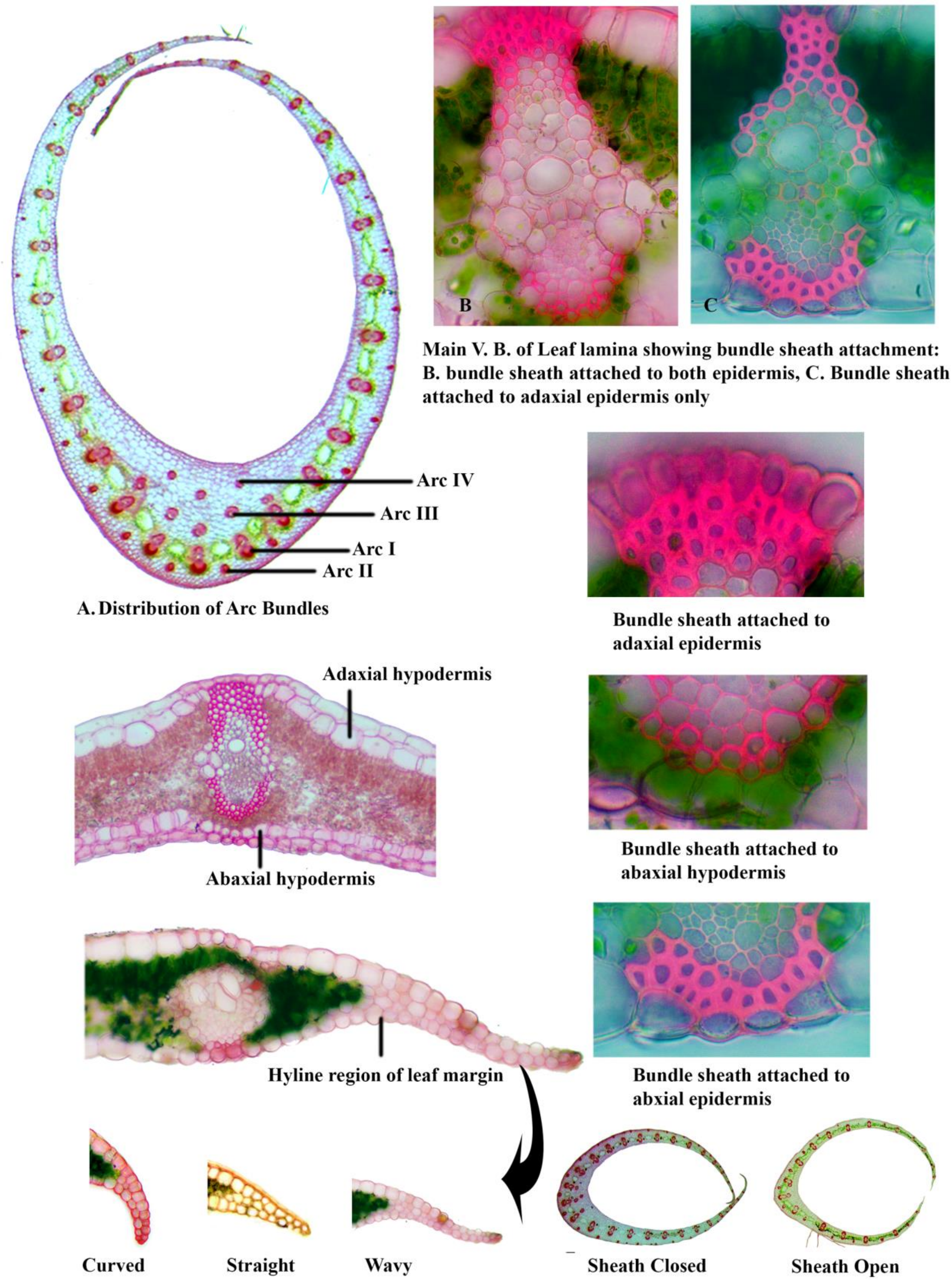


Fig. 38. General anatomy of *Zingiber*.

Lamina

The lamina is bounded by a single-layered epidermis on both adaxial and abaxial surfaces. Adaxial hypodermis is absent in all the species except in *Z. clarkei*. Abaxial hypodermis is sometimes replaced with aerenchyma tissue in some species. The mesophyll is composed of both palisade and spongy cells. The vascular bundles are oblong to ovate, embedded in the mesophyll tissue and partially surrounded by sclerenchymatous bundle sheath on both surfaces.

Margin

The marginal region of the lamina is composed of a group of smaller epidermal cells that forms the hyaline region of the margin. Margin is tapering and beak-shaped in all species. The length and number of layers of the hyaline region vary with species. Hypodermis is absent in all species. Mesophyll consists of palisade and spongy cells. Vascular bundles are absent near the margin.

Sheath

Sheath consists of a single-layered epidermis surrounding broad parenchymatous ground tissue. The bundle arc arrangement is similar to that of midrib except in the presence of arc II bundles.

Key to the species using foliar anatomical characters

1. Adaxial hypodermis present in lamina .... **6. *Z. clarkei***
1. Adaxial hypodermis absent in lamina.. **2**
2. Lamina: bundle cap is not attached to either of the epidermis .... 7. ***Z. cornigerum***
2. Lamina: bundle cap is attached to adaxial epidermis or both epidermis............ **3**
3. Bundle cap of lamina is attached to both adaxial and abaxial epidermis… **4**
3. Bundle cap of lamina is attached to adaxial epidermis only **12**
4. Leaf margin: bundle cap is attached to both the epidermis….**5. *Z. chrysanthum***
4. Leaf margin: bundle cap is attached to abaxial epidermis only.......................... **5**
5. Mid rib: Abaxial surface wide V-shaped... .**6**
5. Mid rib: Abaxial surface wide U-shaped... **7**

6. Leaf margin hyaline region biseriate and ends up uniseriate ....**18. *Z. roseum***

6. Leaf margin hyaline region initially triseriate and ends up uniseriate…………. ....**4. *Z. capitatum***

7. Lamina: palisade and spongy bilayered.. **8**

7. Lamina: palisade single layered spongy bilayered **9**

8. Lamina near main V. B. bends upward; sheath open… ...... **12. *Z. mizoramensis***

8. Lamina near main V. B. bends downward; sheath closed................................... ....**14. *Z. neotruncatum* var. *ramsawmii***

9. Sheath: bundle arcs I, II and III present; adaxial bundle sheath of lamina attached to 5 epidermal cells… **10**

9. Sheath: bundle arcs I and II present; adaxial bundle sheath of lamina attached to 2 epidermal cells **11**

10. Midrib: adaxial surface wide U-shaped; sheath closed ....**10. *Z. kerrii***

10. Midrib: adaxial surface wide V-shaped; sheath opened. ...... **16. *Z. pherimaense***

11. Leaf margin straight; main V. B. of lamina cylindrical...........**17. *Z. purpureum***

11. Leaf margin bends downward; main V. B. of lamina bottle-shaped .. **15. *Z. neotruncatum* var. *neotruncatum***

12. Mid rib bundle arc I and III present.. **13**

12. Mid rib bundle arc I, III and IV present.. **15**

13. Main V. B. of lamina ventricose; margin: hyaline region initially 4 seriate ends up uniseriate… ....**9. *Z. kangleipakense***

13. Main V. B. of lamina ovate; margin: hyaline region initially biseriate ends up uniseriate **14**

14. Leaf margin bend downwards; sheath closed, adaxial surface wide W-shaped or bulged at the middle...**2. *Z. bipinianum***

14. Leaf margin straight; Sheath open, adaxial surface wide U-shaped..................... ....**3. *Z. campanulatum***

15. Sheath: bundle arcs I, II and III present; margin: length of hyaline region less than 150 µm **16**

15. Sheath: bundle arcs I, II and III present; margin: length of hyaline region greater than 150 µm **17**

16. Lamina: aerenchymatous layer present below the abaxial epidermis; midrib adaxial surface wide U-shaped... .**1. *Z. arunachalensis***

16. Lamina: aerenchymatous layer absent below the abaxial epidermis; midrib adaxial surface wide V-shaped…....................................... **11. *Z. meghalayense***

17. Leaf margin: 4-layered initially ends up uniseriate; midrib adaxial surface wide V-shaped… .... **8. *Z. dimapurense***

17. Leaf margin: biseriate initially ends up uniseriate; midrib adaxial surface wide U-shaped… ....**13. *Z. murlenica***

1. *Zingiber arunachalensis* **Fig. 39**

Lamina: 217–240 µm thick. Adaxial surface near the main vascular bundle bends upward, adaxial epidermal cells are as broad as high. Abaxial epidermal cells broader than high. Adaxial hypodermis absent. Mesophyll tissue consists of 2-layered palisade and single-layered spongy cells. Vascular bundles are embedded in the mesophyll tissue. Sclerenchymatous bundle cap is in contact with the adaxial epidermis. Main vascular bundle ovate, 183–190 × 79–85 µm, adaxial bundle cap 2 to 3-layered, abaxial bundle cap single-layered. Metaxylem elliptical, 20–22 × 38–43 µm. protoxylem 6–11 × 7–14 µm. Abaxial hypodermis replaced with aerenchymatous layer.

Margin: Tapering and beaked. Hypodermis is completely absent. Bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 239–244 µm long. Hyaline region 118–128 µm long, biseriate and ends up uniseriate.

Midrib: Adaxial, as well as abaxial surfaces are wide U-shaped. Bundle arcs I, III and IV are present and arc III is represented by two bundles at the centre and arc III by a single bundle. Arc II is absent. The diameter of metaxylem of arc l bundle is 37.49–39.30 µm. Air canals are seen alternating with arc l bundles, air canals and vascular bundles are in turn surrounded by Chlorenchyma. Hairs are absent on both sides.

Leaf sheath: Closed, adaxial surface is wide V-shaped and abaxial surfaces is U-shaped. Bundle arcs I, II and III are present. Arc I and II are alternating throughout the sheath. Arc III is represented by five bundles. The diameter of metaxylem of arc 1 bundle at the median region ranges from 30–51 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are present on the abaxial surface. Rectangular crystals are present.

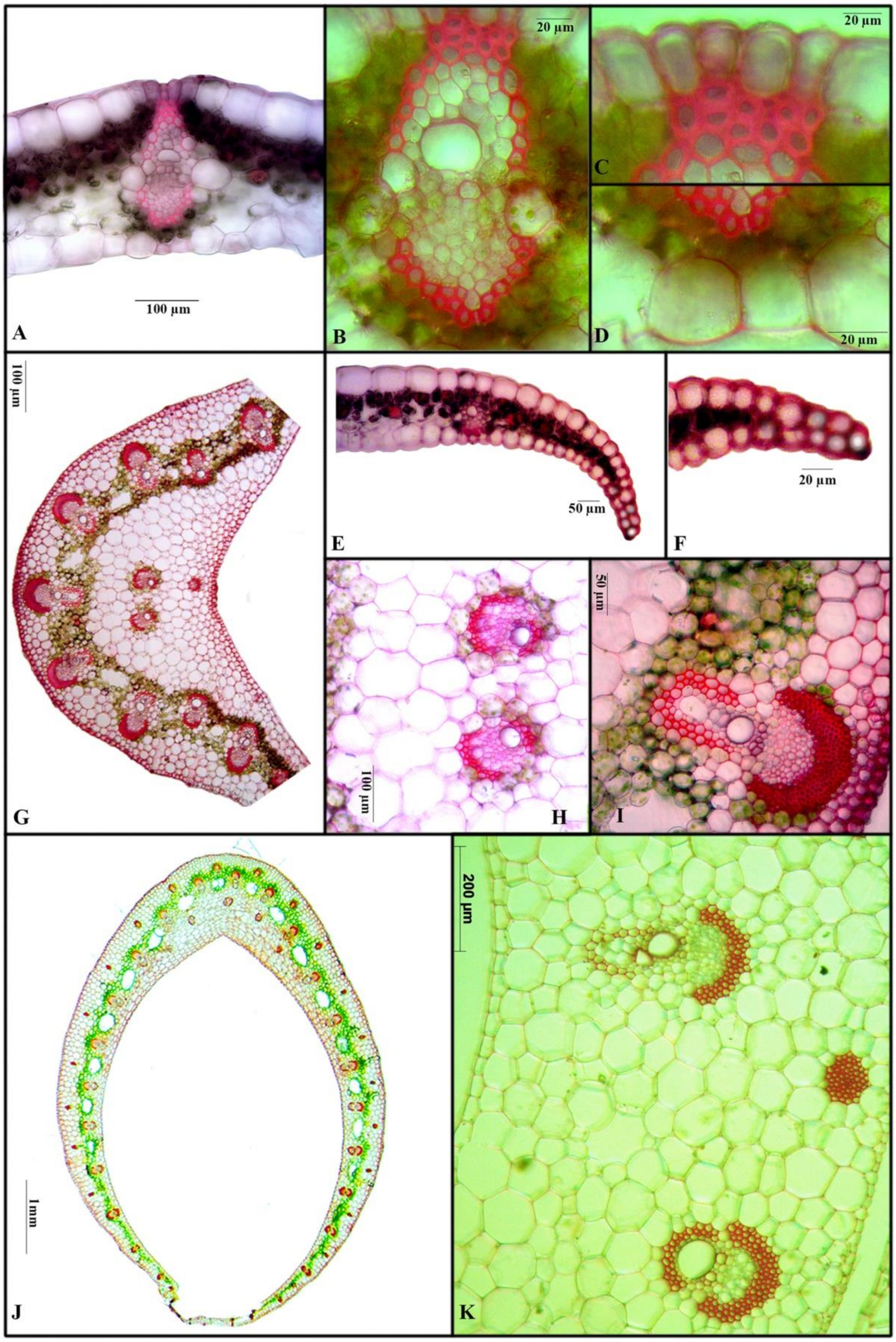


Fig. 39. ***Zingiber arunachalensis***. C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

2. *Zingiber bipinianum* **Fig. 40**

Lamina: 245–255 µm thick. Slightly bends upward, Abaxial both adaxial and abaxial epidermal cells are broader than high. Adaxial hypodermis absent. Mesophyll tissue 92–98 µm thick, palisade single-layered, 29–31 × 8–11 µm, spongy cells bilayered 13–17 × 11–13 µm. Vascular bundles are embedded in the mesophyll tissue. The sclerenchymatous cap of the bundle is in contact with adaxial epidermis only. Main vascular bundle ovate to elliptic, 176–179 × 99–104 µm, adaxial bundle cap 3–4 layered, 6 epidermal cells are in direct contact with adaxial bundle cap, abaxial bundle cap 1–2 layered. Abaxial hypodermis absent.

Margin: Margin tapering and slightly bends downwards. Hypodermis is completely absent. Bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 271–286 µm long. Hyaline region 93.94–102.08 µm long, bilayerd and ends up uniseriate.

Midrib: Adaxial surface is U-shaped and abaxial surface is wide U- shaped. Bundle arcs I and III are present and arc III is represented by 2 bundles just above the arc I bundles. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma.

Leaf sheath: Closed, adaxial surface wide W-shaped and abaxial surfaces U-shaped. Bundle arcs I, II, III and IV are present. Arc I and II are alternating throughout the sheath. Arc III is represented by three bundles in the middle and arc IV is represented by a single bundle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 36–51 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are present on the abaxial side.

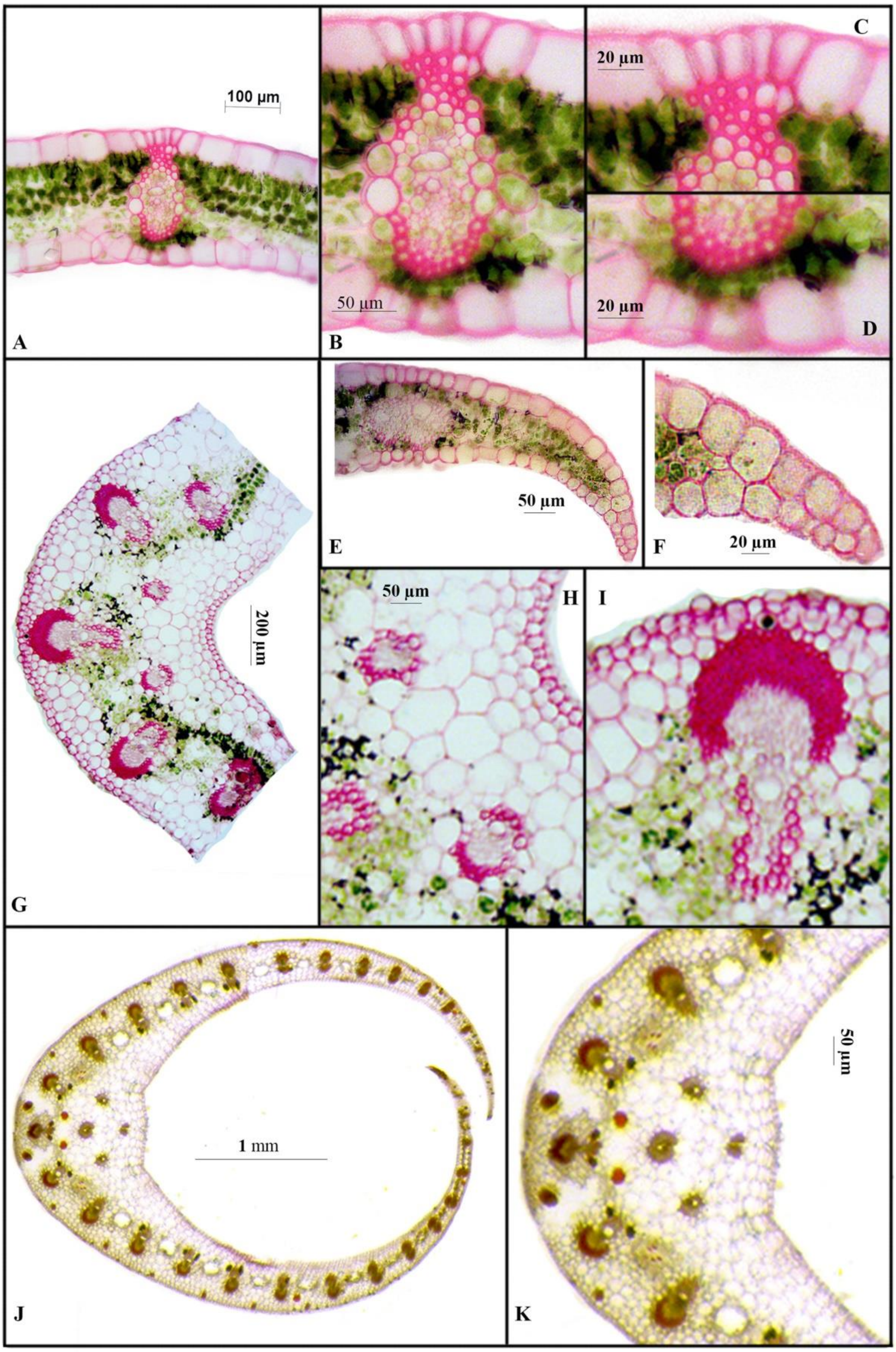


Fig. 40. ***Zingiber bipinianum***. C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

3. *Zingiber campanulatum* **Fig. 41**

Lamina: Lamina straight, 264–288 µm thick. Adaxial epidermal cells are as broad as high. Abaxial epidermal cells are broader than high, 42–62 × 31–43 µm. Adaxial hypodermis absent. Mesophyll tissue 111–124 µm thick, palisade 2-layered, spongy cells 1–2-layered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous cap of the bundle is in contact with adaxial epidermis only. Main vascular bundle ovate, 215–217 × 118–130 µm, adaxial bundle cap 4–5 layered, 3 epidermal cells are in direct contact with adaxial bundle cap, abaxial bundle cap single layered. Abaxial hypodermis single layered.

Margin: Margin is tapering, hyaline region straight. Hypodermis is completely absent. Bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 265–271 µm long. Hyaline region biseriate and ends up uniseriate, 116–124 µm long.

Midrib: Adaxial side concave and abaxial surfaces wide U-shaped. Bundle arcs I and III are present and arc III is represented by 4-bundles at the center alternating with arc I bundles. Arc II and IV are absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma.

Leaf sheath: Sheath open, both adaxial and abaxial surfaces are wide U-shaped. Bundle arcs I, II, III and IV are present. Arc I and II are alternating throughout the sheath. Arc III is represented by three bundles at the middle and arc IV is represented by four bundles. The diameter of metaxylem of arc 1 bundle at the median region ranges from 24–32 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are present on the abaxial and adaxial sides.

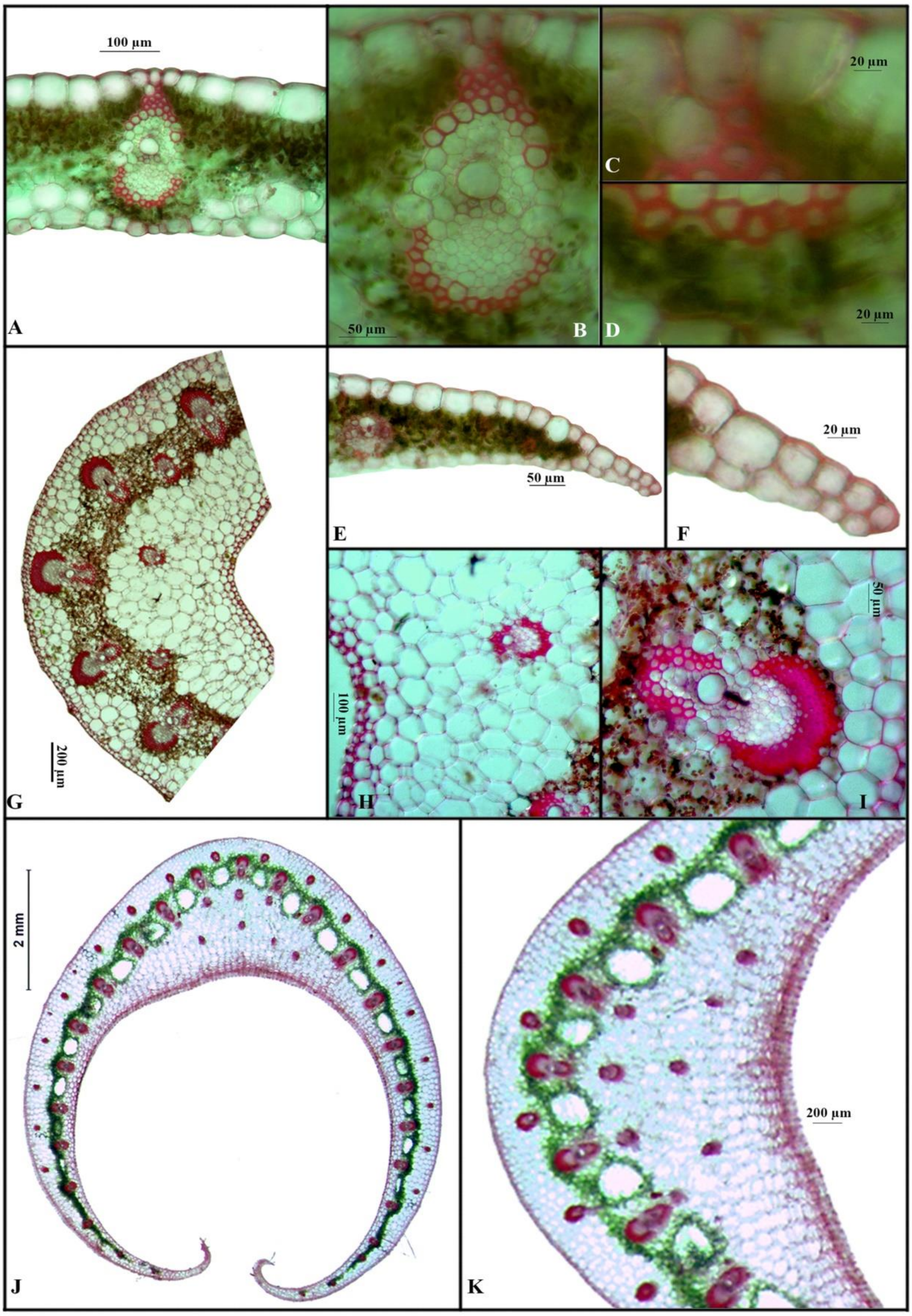


Fig. 41. ***Zingiber campanulatum***. C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

4. *Zingiber capitatum* **Fig. 42**

Lamina: Lamina straight, 147–165 µm thick. Adaxial and abaxial epidermal cells are as broad as high. Adaxial hypodermis absent. Mesophyll tissue 93–107 µm thick, palisade bilayered, spongy cells bilayered. Vascular bundles are embedded in the mesophyll. The sclerenchymatous cap of the bundle is in contact with both adaxial and abaxial epidermis. Main vascular bundle cylindrical and very narrow, 146–149 × 40–49 µm, adaxial bundle cap 5–6 layered, in contact with two epidermal cells, abaxial bundle cap 2-layered, in contact with 3 epidermal cells. Metaxylem Circular, 20–25 µm diam. Protoxylem 7–9 µm diam. Abaxial hypodermis absent.

Margin: Margin is tapering, slightly constricted above the vascular bundle, hyaline region beaked. Hypodermis is completely absent. Bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 128–130 µm long. Hyaline region 3 layered initially and ends up uniseriate, 165–181 µm long.

Midrib: Adaxial side concave and abaxial surfaces wide V- shaped. Bundle arcs I and III are present and arc III is represented by 2-bundles at the center. Arc II and IV are absent. Air canals absent, a patch chlorenchyma is seen in between arc I bundles. Oil cells and rectangular crystals are present.

Leaf sheath: Sheath closed, both adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Arc I and II are alternating throughout the sheath. Arc III is represented by three bundles in the middle and arc IV is absent. The diameter of metaxylem of arc 1 bundle at the median region ranges from 42–46 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are present on the abaxial side.

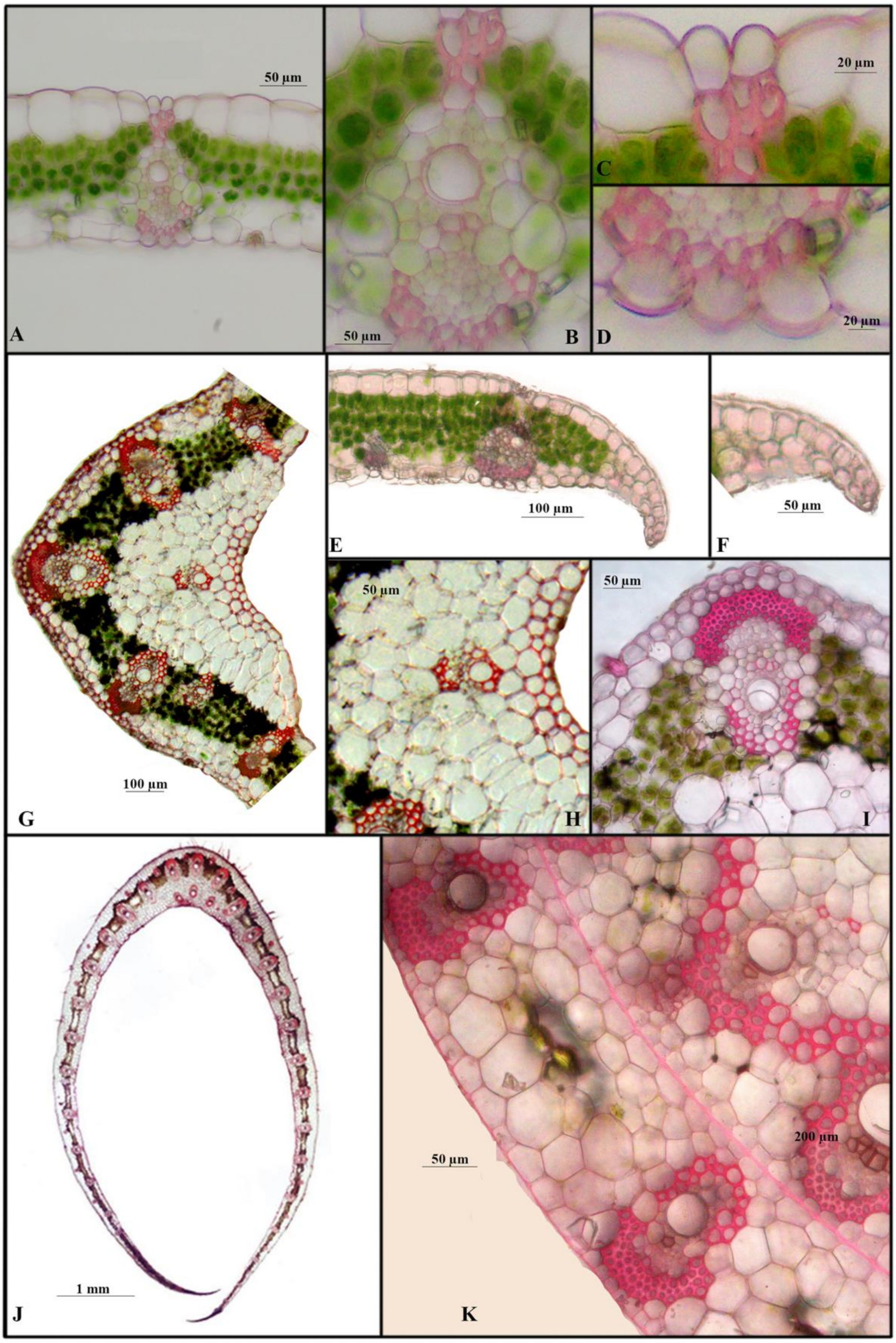


Fig. 42. ***Zingiber capitatum***. C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

5. *Zingiber chrysanthum* **Fig. 43**

Lamina: Lamina straight, 224–243 µm thick. Both epidermal cells are almost same size except in the region of vascular bundle (smaller epidermal cells) and broader than high. Adaxial hypodermis absent. Mesophyll tissue 80–98 µm thick, palisade bilayered, spongy cells single layered. Vascular bundles are embedded in the mesophyll. The sclerenchymatous bundle cap is in contact with both adaxial and abaxial epidermis. Main vascular bundle oblong, 198–203 × 45–52 µm, adaxial bundle cap 4-layered and in contact with seven epidermal cells, abaxial bundle cap bilayered, in contact with two epidermal cells. Metaxylem circular, 28–35 µm diam. Protoxylem 9–12 µm diam. Abaxial hypodermis absent, aerenchyma present just above the abaxial epidermis.

Margin: Margin is tapering, hyaline region curved downward and beaked. Hypodermis is completely absent. Bundle is connected to both adaxial and abaxial epidermis. Relative length between margin and marginal bundle is 198–202 µm long. Hyaline region initially 2–3 layered and ends up uniseriate, 116–118 µm long, oil cells present.

Midrib: Adaxial side wide V-shaped and abaxial surfaces U- shaped. Bundle arcs I, III and IV are present and arc III is represented by 4-bundles at the center and are alternating with arc I bundles. Arc II absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Calcium oxalate crystals are observed in a few cells in between arc III-bundles.

Leaf sheath: Sheath closed. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II, III and IV are present. Arc I and II are alternating throughout the sheath. Arc III is represented by three bundles and are lying parallel to arc I bundles. Arc IV is presented by a single bundle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 64–75 µm diam. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are absent. Rectangular crystals are present.

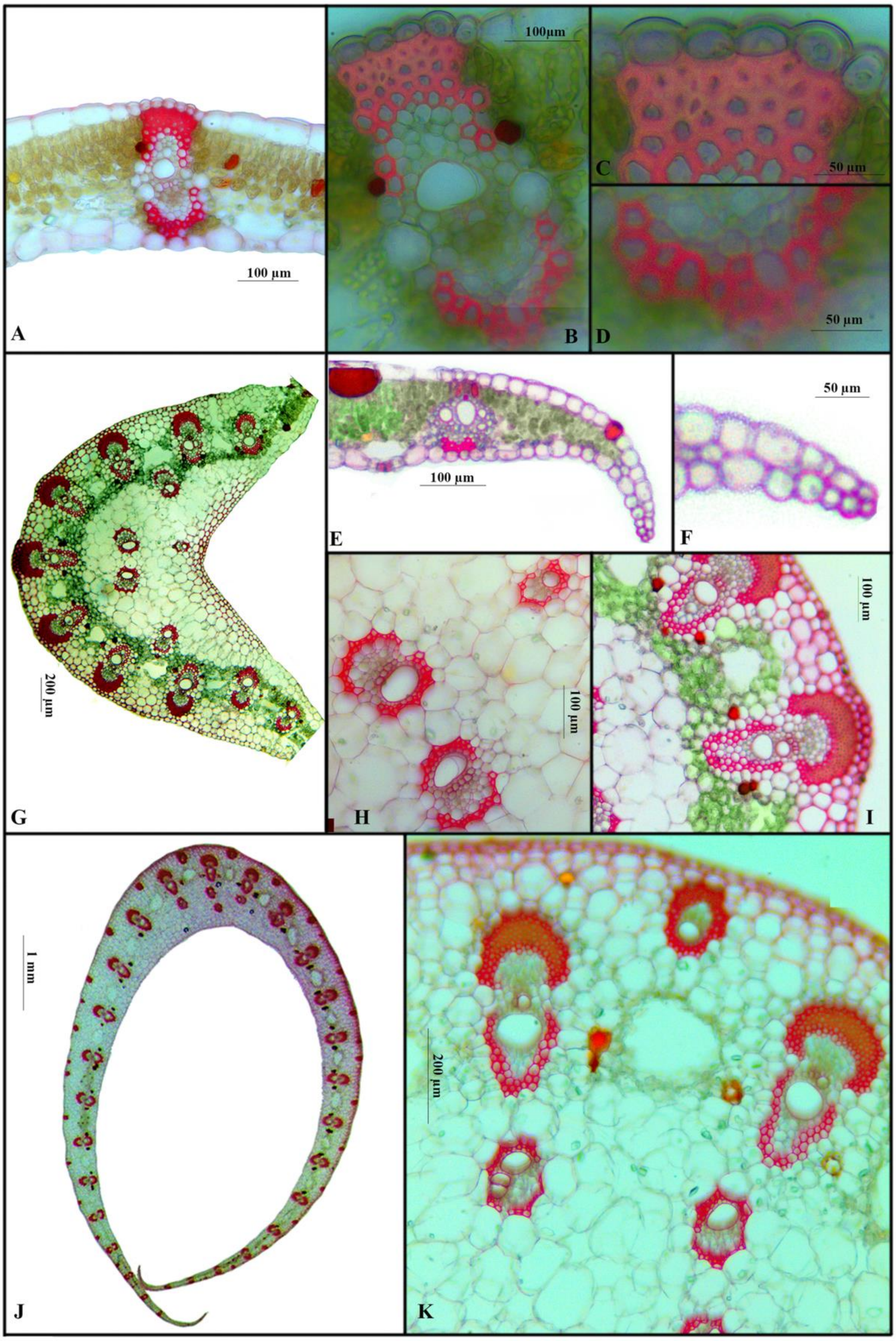


Fig. 43. ***Zingiber chrysanthum***. C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

6. *Zingiber clarkei* **Fig. 44**

Lamina: lamina bends upward, 295–380 µm thick. Both epidermal cells are almost same size except in the region of vascular bundle (smaller epidermal cells in the main vascular bundle) and broader than high. Abaxial epidermal cells are smaller than adaxial epidermal cells. A prominent adaxial hypodermis present throughout the lamina. Mesophyll tissue 169–202 µm thick, palisade 2-layered, spongy cells 5-layered. Vascular bundles are embedded in the mesophyll. The sclerenchymatous bundle cap is in contact with adaxial epidermis only. Main vascular bundle oblong, 298–302 × 120–132 µm, adaxial bundle cap 3–6 layered and in contact with seven epidermal cells. Abaxial bundle cap 2 to 3 layered, attached to abaxial hypodermis. Metaxylem circular, 29–34 µm diam. Protoxylem 19 µm diam. Smaller vascular bundles are attached to both hypodermis. Abaxial hypodermis present. Rectangular crystals are present in both mesophyll and abaxial hypodermal cells.

Margin: Margin is tapering, hyaline region curved downward and beaked. Hypodermis is completely absent. Main vascular bundle is connected to both adaxial and abaxial epidermis. Relative length between margin and marginal bundle is 400–437 µm long. Hyaline region initially 2–3 layered and ends up uniseriate, 165–171 µm long, oil cells present. Crystals are seen in both epidermis.

Midrib: Both adaxial and abaxial surfaces are concave-shaped. Bundle arcs I, III and IV are present and arc III is represented by 6-bundles at the center and are alternating with arc I bundles. Arc IV is represented by a single bundle. Arc II absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Calcium oxalate crystals are observed in a few cells in between arc I bundles.

Leaf sheath: Sheath open. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II, III and IV are present. Arc I and II are alternating throughout the sheath. Arc III is represented by three bundles. Arc IV is presented by a single bundle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 57–65 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are present on the abaxial surface. Rectangular crystals are present.

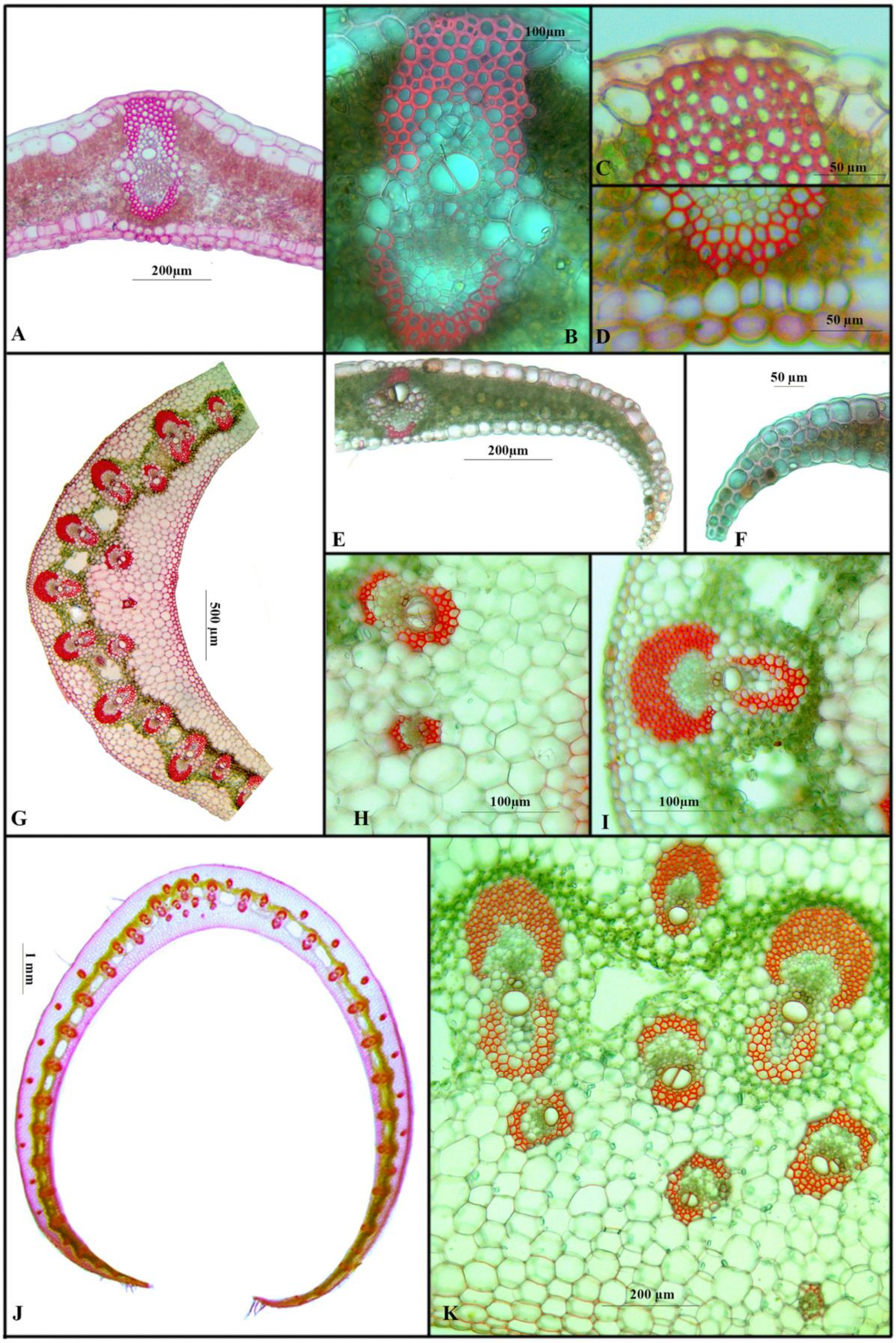


Fig. 44. ***Zingiber clarkei***. C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

7. *Zingiber cornigerum* **Fig. 45**

Lamina: Lamina bends upward, 265–339 µm thick. Adaxial epidermal cells are as broad as high, Abaxial epidermal cells are as high as broad. Adaxial hypodermis present only above primary vascular bundle. Mesophyll tissue 81–88 µm thick, palisade 2-layered, spongy cells single layered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous cap of the bundle is not in contact with either of the epidermis. Main vascular bundle ovate, 218–220 × 141–147 µm, adaxial bundle cap 4–5 layered, abaxial bundle cap 1–2 layered. Metaxylem circular, 33–35 × 31–34 µm. Protoxylem 7–12 × 7–16 µm. Abaxial hypodermis single layered.

Margin: Margin tapering and slightly bends downwards. Hypodermis is completely absent. Bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 227–228 µm long. Hyaline region 2–4 seriate, 150–153 µm long.

Midrib: Both adaxial and abaxial surfaces are U-shaped. Bundle arcs I, III and IV are present and arcIII is represented by 2-bundles at the center. ArcIV is represented by single bundle just below adaxial epidermis. Air canals are seen alternating with arcI bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma.

Leaf sheath: Closed, adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present and alternating throughout the sheath. Arc III is represented by a single bundle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 24–50 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are absent. Rectangular crystals are present.

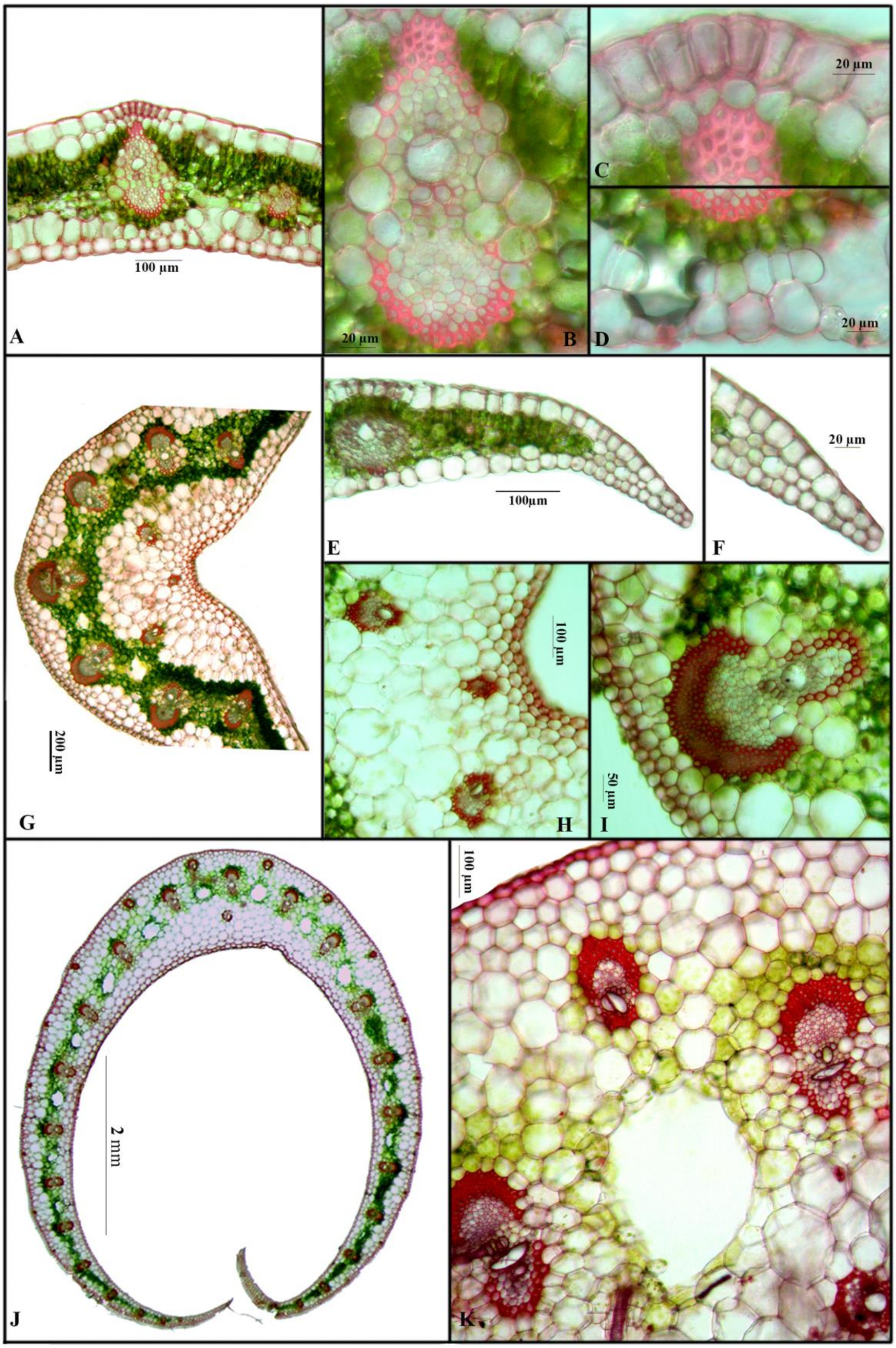


Fig. 45. ***Zingiber cornigerum***. C. S. of leaf parts: **A.** Lamina. **B.** Main vascular bundle of lamina. **C.** Adaxial bundle cap attachment. **D.** Abaxial bundle cap attachment. **E.** Leaf margin. **F.** Hyaline region of leaf margin. **G.** Midrib. **H. & I.** Midrib: a portion enlarged. **J.** Sheath. **K.** Sheath: a portion enlarged.

8. *Zingiber dimapurense* **Fig. 46**

Lamina: lamina straight, 299–303 µm thick. Adaxial epidermal cells are as broader than high. Abaxial epidermal cells are as high as broad and smaller than adaxial epidermis. Adaxial hypodermis absent. Mesophyll tissue 137–142 µm thick, palisade bilayered, spongy cells bilayered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with adaxial epidermis only. Main vascular bundle elliptic, 243–246 × 98–112 µm, adaxial bundle cap 4–5 layered, abaxial bundle cap 2–3 layered. Metaxylem circular, 32–35 µm. Protoxylem 12–14 µm. Abaxial hypodermis single layered.

Margin: Margin is tapering, hyaline region curved downward and beaked. Hypodermis is completely absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 220–229 µm long. Hyaline region initially 3–4 layered and ends up uniseriate, 217–241 µm long, oil cells present. Oil cells present. Crystals are seen in both epidermis.

Midrib: Adaxial surface wide V-shaped and abaxial surfaces are wide U-shaped. Bundle arcs I, III and IV are present and arc III is represented by 4-bundles at the center and are alternating with arc I bundles. Arc IV is represented by two bundles. Arc II is absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals are observed in a few cells in between arc I bundles.

Leaf sheath: Sheath closed. Both adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II, III and IV are present. Arc I and II are alternating throughout the sheath. Arc III and IV are represented by three bundles. The diameter of metaxylem of arc1 bundle at the median region ranges from 53–58 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs absent. Rectangular crystals are present.

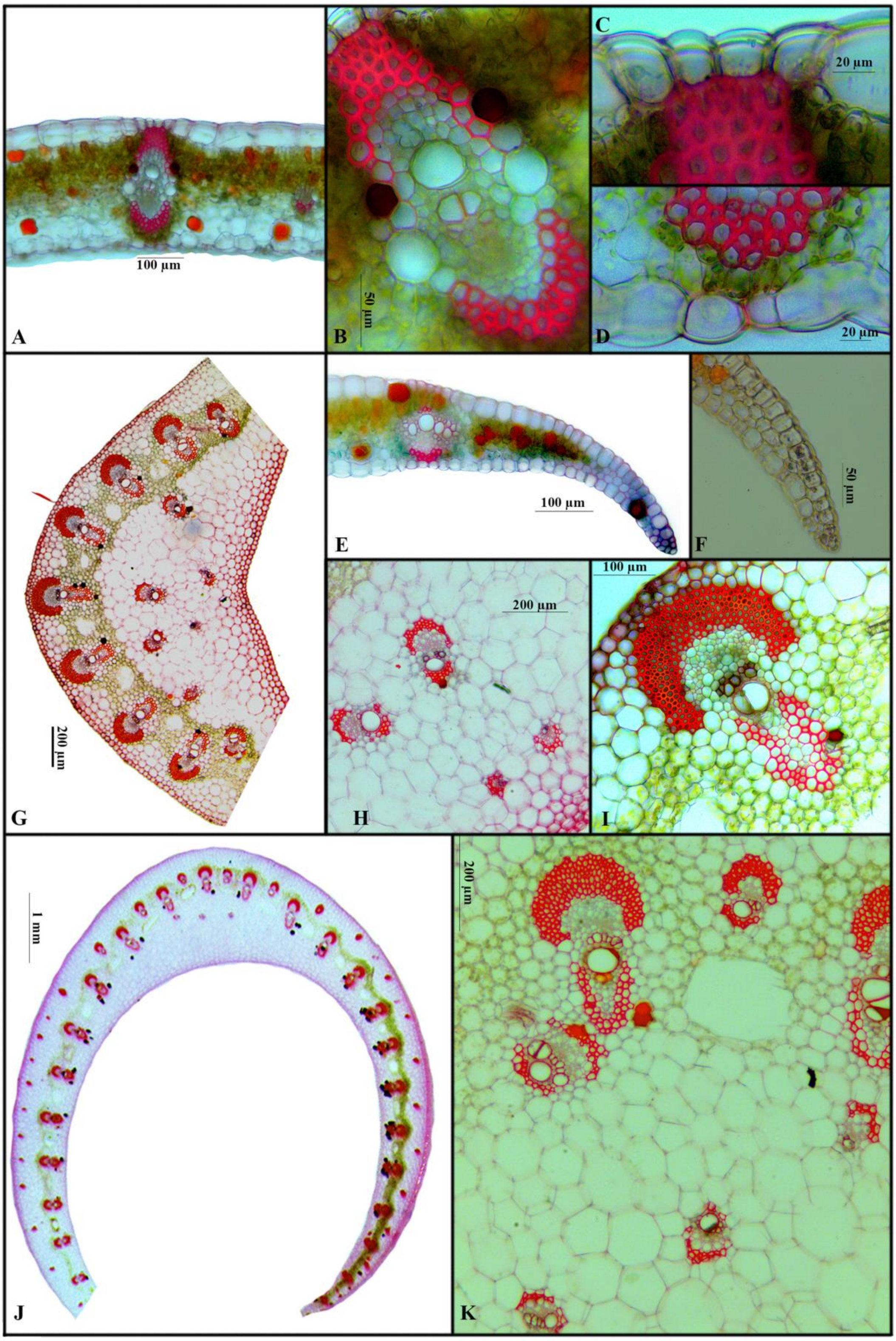


Fig. 46. ***Zingiber dimapurense.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

9. ***Zingiber kangleipakense*** **Fig. 47**

Lamina: lamina bends upward, 211–258 µm thick. Adaxial epidermal cells are as broad as high, Abaxial epidermal cells are broader than high and smaller than adaxial epidermis. Adaxial hypodermis absent. Mesophyll tissue 90–96 µm thick, palisade bilayered, spongy cells single layered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with adaxial epidermis only. Main vascular bundle ventricose, 206–220 × 76–97 µm, adaxial bundle cap 3–4 layered, adaxial bundle cap is attached to eight epidermal cells. abaxial bundle cap single layered. Metaxylem angular, 14–25 µm diam. Protoxylem 11–12 µm. Abaxial hypodermis absent instead air cavities or arenchyma present.

Margin: Margin is tapering, slightly constricted above the vascular bundle, hyaline region straight and wavy, beaked. Hypodermis is completely absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 80–84 µm long. Hyaline region initially 3–4 layered, 3-layered up to the middle, 2-layerd up to the apex and ends up uniseriate, 260–268 µm long, oil cells and crystals are not seen.

Midrib: Adaxial surface wide V-shaped and abaxial surfaces are wide U-shaped. Bundle arcs I and III are present and arc III is represented by 5-bundles at the center, among these 3 bundles were fused at the centre. Arc II and IV are absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals are observed in a few cells in between arc I bundles.

Leaf sheath: Sheath closed. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II, III and IV are present. Arc I and II are alternating throughout the sheath. Arc III is represented by six bundles. Arc IV are represented by three bundles. The diameter of metaxylem of arc 1 bundle at the median region ranges from 57–59 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs present on the abaxial surface. Rectangular crystals are present.

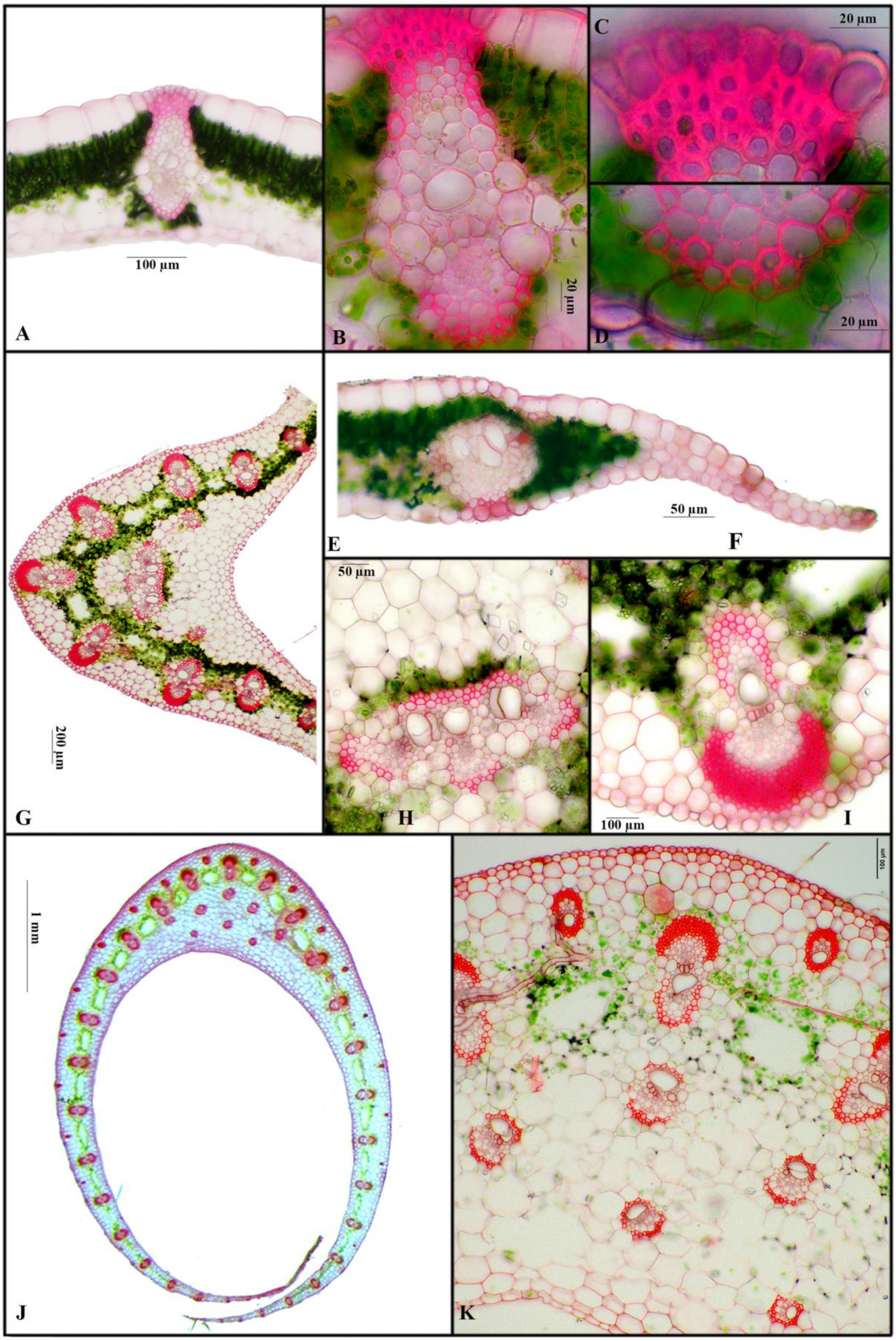


Fig. 47. *Zingiber kangleipakense.* C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

10. *Zingiber kerrii* **Fig. 48**

Lamina: lamina straight, 162–165 µm thick. Both adaxial and abaxial epidermal cells are broader than high, Adaxial hypodermis absent. Mesophyll tissue 85–90 µm thick, palisade single-layered, spongy cells bi-layered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with both adaxial and abaxial epidermis. Main vascular bundle cylindrical, 144–148 × 70–76 µm, adaxial bundle cap 3–4 layered, adaxial bundle cap is attached to five epidermal cells. abaxial bundle cap 1–2 layered. Metaxylem circular, 23–25 µm diam. Protoxylem 6–9 µm. A well-defined abaxial hypodermis absent instead air cavities or aerenchyma present. Rectangular crystals are present.

Margin: Margin is tapering, hyaline region straight or slightly bend downward and beak is not tapering or uniform in thickness. Hypodermis is completely absent. Main vascular bundle is connected to abaxial epidermis only via two sclerenchyma cells. Relative length between margin and marginal bundle is 130–136 µm long. Hyaline region initially 2-layerd up to the apex and ends up uniseriate, 102–105 µm long. Oil cells absent, crystals are present in some cells near the vascular bundle.

Midrib: Both adaxial and abaxial surfaces are wide U-shaped. Bundle arcs I and III are present and arc III is represented by 2-bundles at the center. Arc II and IV are absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals are observed in a few cells in between arc I bundles and arc III bundles and some oil cells are observed.

Leaf sheath: Sheath closed. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Arc I and II are alternating throughout the sheath. Arc IV absent. Arc III is represented by two bundles at the middle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 45–47 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs absent. Rectangular crystals and oil cells are present.

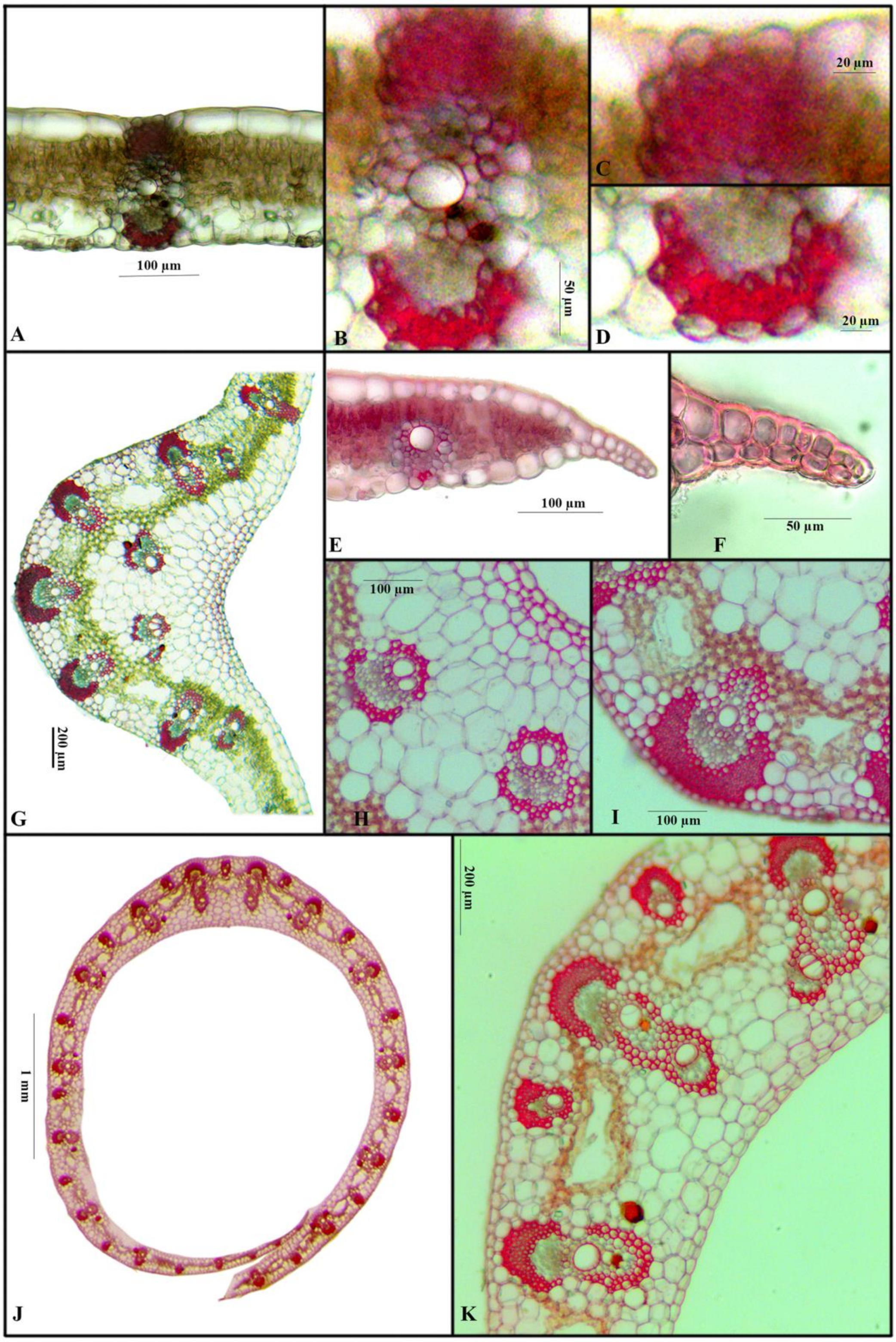


Fig. 48. ***Zingiber kerrii.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

11. ***Zingiber meghalayense*** **Fig. 49**

Lamina: lamina bends upward near main vein, 219–280 µm thick. Adaxial epidermal cells are as broader than high, abaxial epidermal cells are as high as broad and smaller than adaxial epidermal cells. Adaxial hypodermis absent. Mesophyll tissue 92–120 µm thick, palisade bi-layered, spongy cells bi-layered. Vascular bundles are embedded in the mesophyll tissue. Sclerenchymatous bundle cap is in contact with adaxial epidermis only. Main vascular bundle ventricose, 213–230 × 64–105 µm, adaxial bundle cap 4–5 layered, abaxial bundle cap single layered. Metaxylem circular, 26–37, Protoxylem 9–12 µm. Abaxial hypodermis absent.

Margin: Margin is tapering, hyaline region bends downward at right angle to the lamina and beak or uniform in thickness, tapering towards the tip. Hypodermis is completely absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 310–315 µm long. Hyaline region bi-layered up to the apex and ends up uniseriate, 137–148 µm long. Oil cells absent, crystals are present in some cells near the vascular bundle.

Midrib: Adaxial surface wide V-shaped and abaxial surface wide U-shaped. Bundle arcs I, III and IV are present and arc III is represented by 3-bundles at the center. Arc IV is represented by a single bundle. Arc II absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals are absent.

Leaf sheath: Sheath closed. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Arc I and II are alternating throughout the sheath. Arc IV absent. Arc III is represented by three bundles in the middle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 39–45 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs present on the abaxial epidermis. Rectangular crystals and oil cells are not seen.

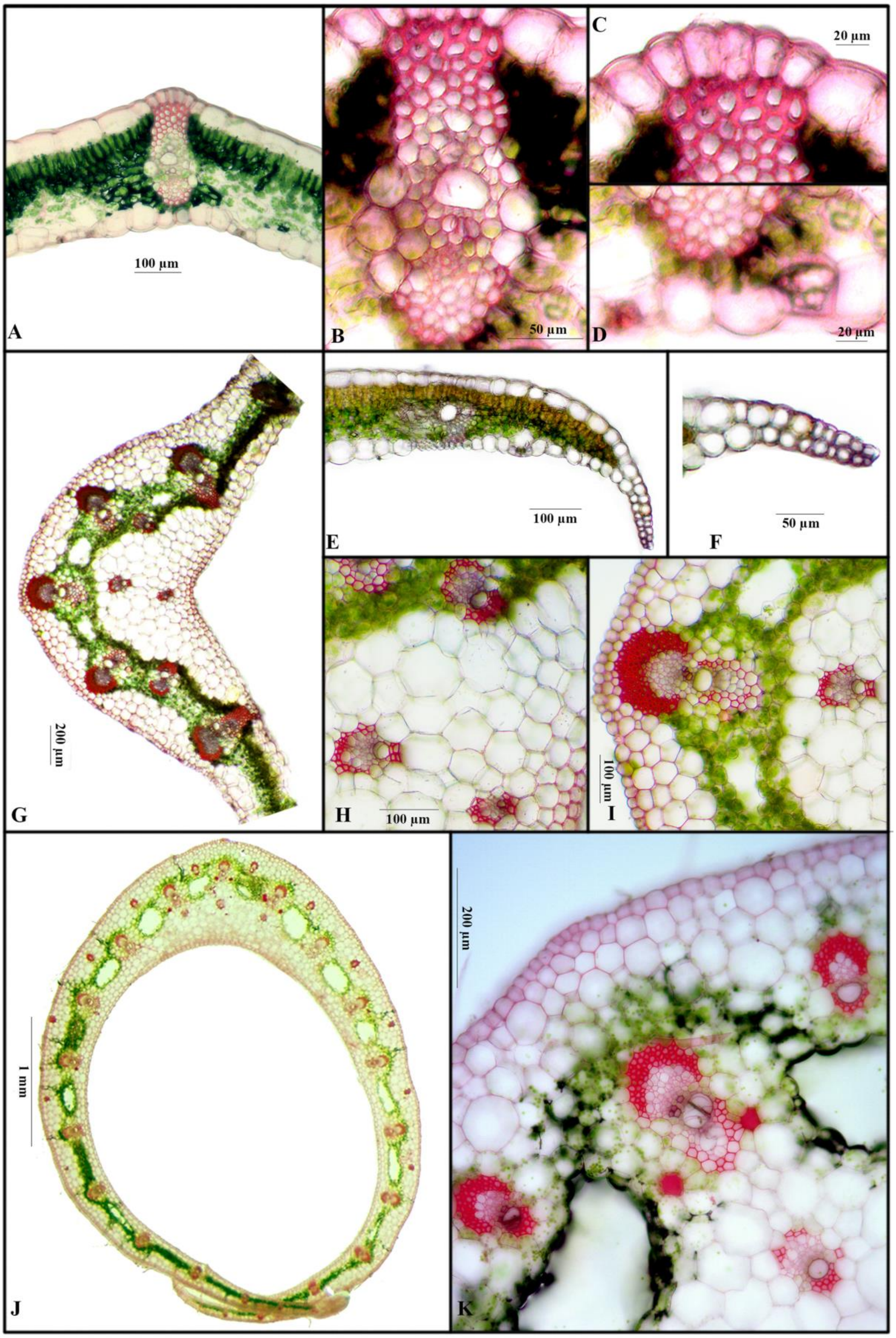


Fig. 49. ***Zingiber meghalayense.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

12. *Zingiber mizoramensis* **Fig. 50**

Lamina: lamina bends upward, 167–200 µm thick. Adaxial epidermal cells are as broader than high. Abaxial epidermal cells are as high as broad. Adaxial hypodermis absent. Mesophyll tissue 56–60 µm thick, palisade bilayered, spongy cells single layered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with both adaxial and abaxial epidermis. Main vascular bundle bottle-shaped, 174–176 × 89–90 µm, adaxial bundle cap 4–5 layered, attached to five epidermal cells, abaxial bundle cap 1–2 layered, attached to two epidermal cells. Metaxylem elliptic, 17–29 µm diam, Protoxylem 7–9 µm diam. Abaxial hypodermis absent. Rectangular crystals present in the mesophyll tissue.

Margin: Margin is tapering, hyaline region slightly bends downward, beak uniform in thickness, tapering towards the tip. Hypodermis absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 400–416 µm long. Hyaline region bi-layered up to the apex and ends up uniseriate, 170–179 µm long. Oil cells absent, crystals are present.

Midrib: Both adaxial surface and abaxial surface are wide U-shaped. Bundle arcs I and III are present. Arc III is represented by 2-bundles at the center and surrounded by chlorenchyma. Arc IV and II are absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals absent.

Leaf sheath: Sheath open. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Arc I and II are alternating throughout the sheath. Arc IV absent. Arc III is represented by a single bundle in the middle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 32–43 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Rectangular crystals and oil cells are not seen.

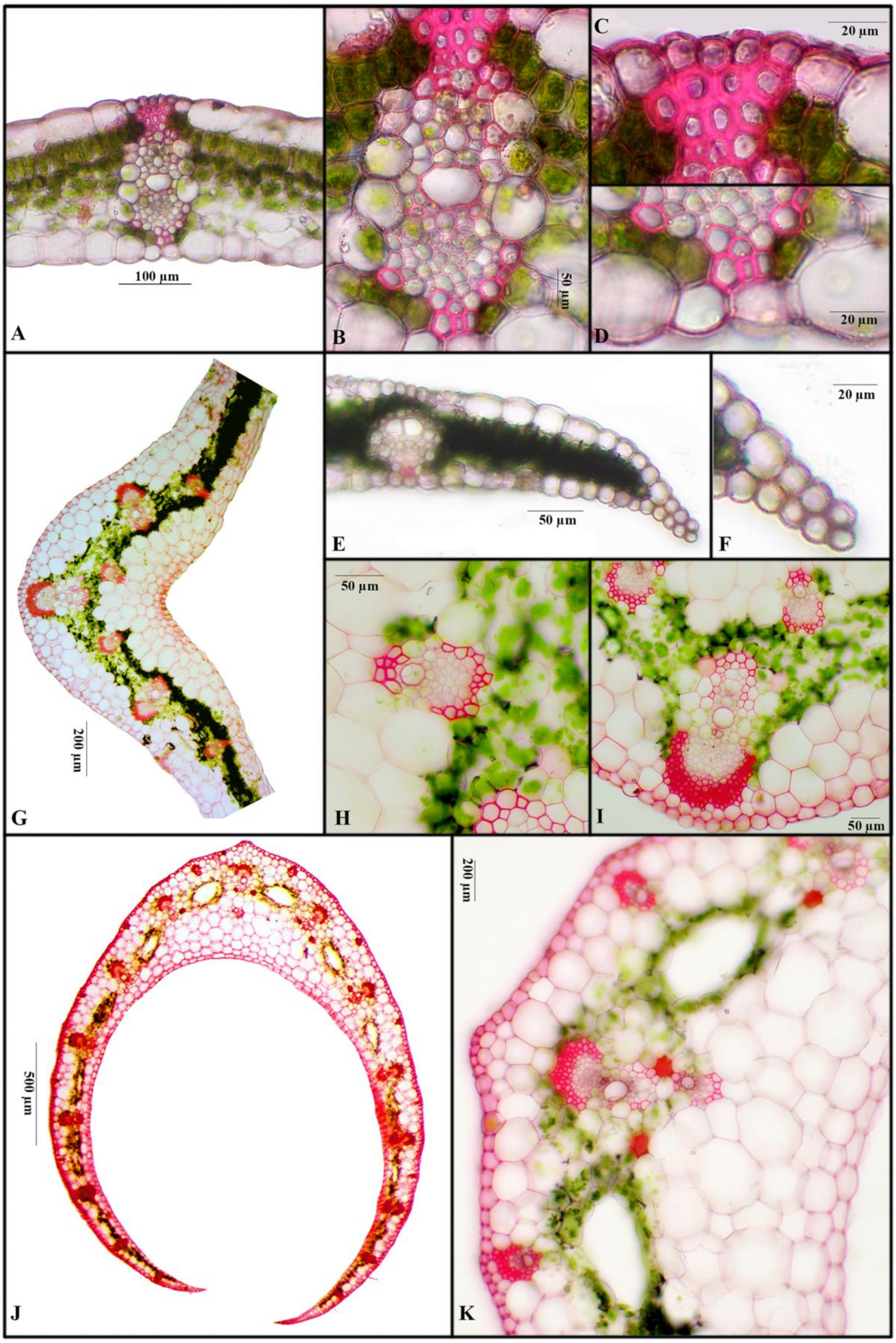


Fig. 50. ***Zingiber mizoramensis.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

13. *Zingiber murlenica* **Fig. 51**

Lamina: lamina bends upward, 180–220 µm thick. Adaxial and abaxial epidermal cells are as broader than high. Adaxial hypodermis absent. Mesophyll tissue 104–108 µm thick, palisade bilayered, spongy cells bilayered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with adaxial epidermis only. Main vascular bundle ventricose, 174–180 × 100–110 µm, adaxial bundle cap 3-layered, attached to five epidermal cells, abaxial bundle cap 1–2 layered. Metaxylem elliptic, 35–60 µm diam., Protoxylem 16–20 µm diam. Abaxial hypodermis present. Rectangular crystals present in the mesophyll tissue. Oil cells present.

Margin: Margin is tapering, hyaline region bends downward, beak uniform in thickness, tapering towards the tip. Hypodermis absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 283–290 µm long. Hyaline region bi-layered up to the apex and ends up uniseriate, 198–204 µm long. Oil cells and crystals absent.

Midrib: Both adaxial surface and abaxial surface are wide U-shaped. Bundle arcs I, III and IV are present. Arc III is represented by 3-bundles at the center and surrounded by chlorenchyma. Arc IV is represented by 2 bundles. Arc II absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals present.

Leaf sheath: Sheath closed. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II, III and IV are present. Arc I and II are alternating throughout the sheath. Arc III is represented by 3–4 bundles in the middle and Arc IV is represented by a single bundle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 43–50 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Rectangular crystals and oil cells are not seen.

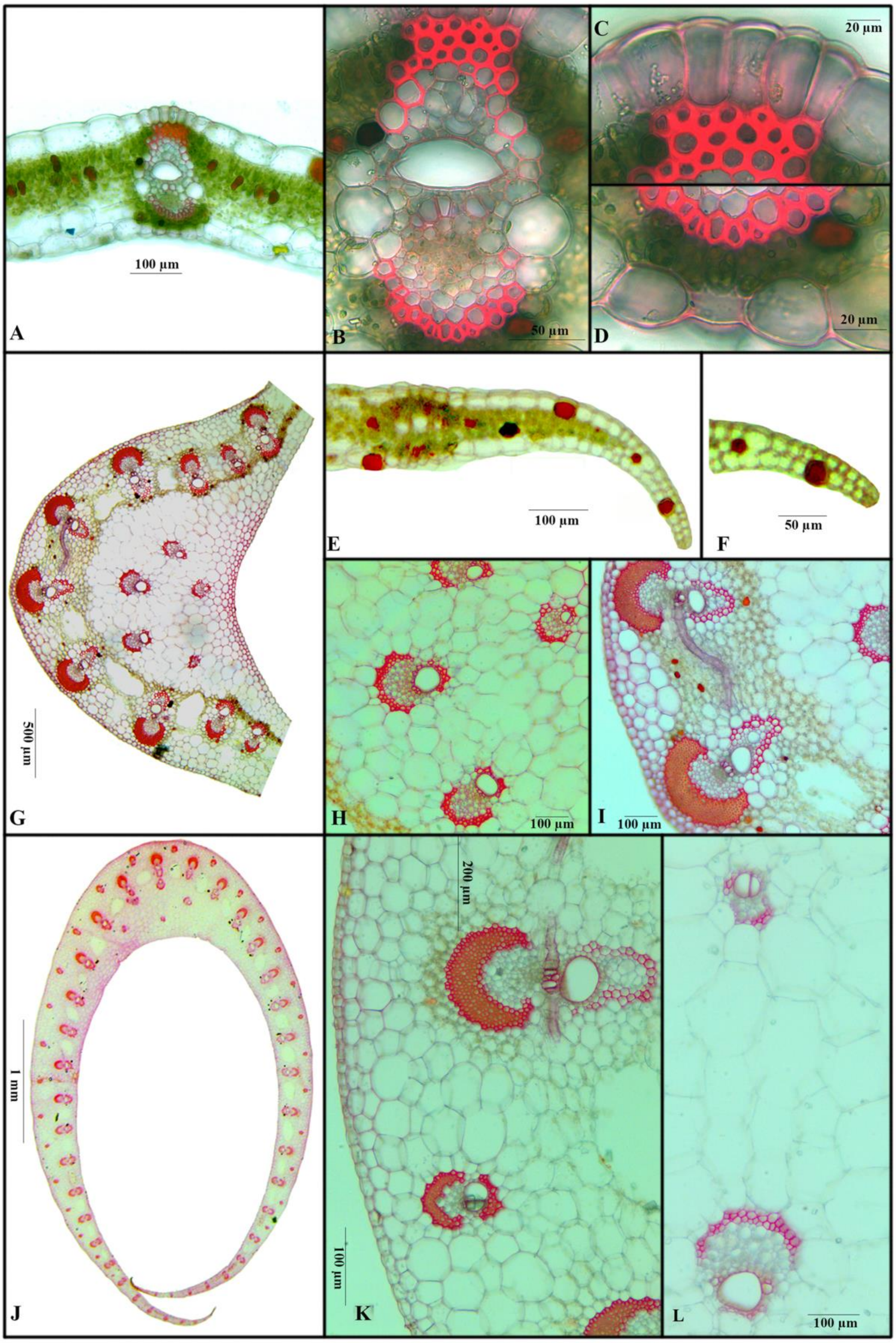


Fig. 51. ***Zingiber murlenica.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

14. *Zingiber neotruncatum* var. *neotruncatum.* **Fig. 52**

Lamina: lamina bends downward, 169–188 µm thick. Adaxial and abaxial epidermal cells are as broader than high. Adaxial hypodermis absent. Mesophyll tissue 120–140 µm thick, palisade single-layered, spongy cells bilayered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with adaxial epidermis and abaxial epidermis. Main vascular bundle bottle-shaped, 162–168 × 67–72 µm, adaxial bundle cap 3–4 layered, attached to two epidermal cells, abaxial bundle cap 1–2 layered, attached to five epidermal cells. Metaxylem elliptic, 25–28 µm diam, Protoxylem 10–13 µm diam. Abaxial hypodermis present. Rectangular crystals present in the mesophyll tissue and hypodermis. Oil cells absent.

Margin: Margin is tapering, hyaline region bends downward, beak uniform in thickness, tapering towards the tip. Hypodermis absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 225–230 µm long. Hyaline region bi-layered up to the apex and ends up uniseriate, 123–125 µm long. Oil cells and crystals present.

Midrib: Both adaxial surface and abaxial surface are wide U-shaped. Bundle arcs I and III present. Arc III is represented by 3-bundles at the center and lateral bundles are surrounded by chlorenchyma. Arc IV and II are absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals present. Hairs absent.

Leaf sheath: Sheath closed. Both the adaxial and abaxial surfaces are U-shaped. Bundle arcs I and II are present. Arc I and II are alternating throughout the sheath. The diameter of metaxylem of arc 1 bundle at the median region ranges from 35–37 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Rectangular crystals present. Oil cells absent, hairs present on both surfaces.

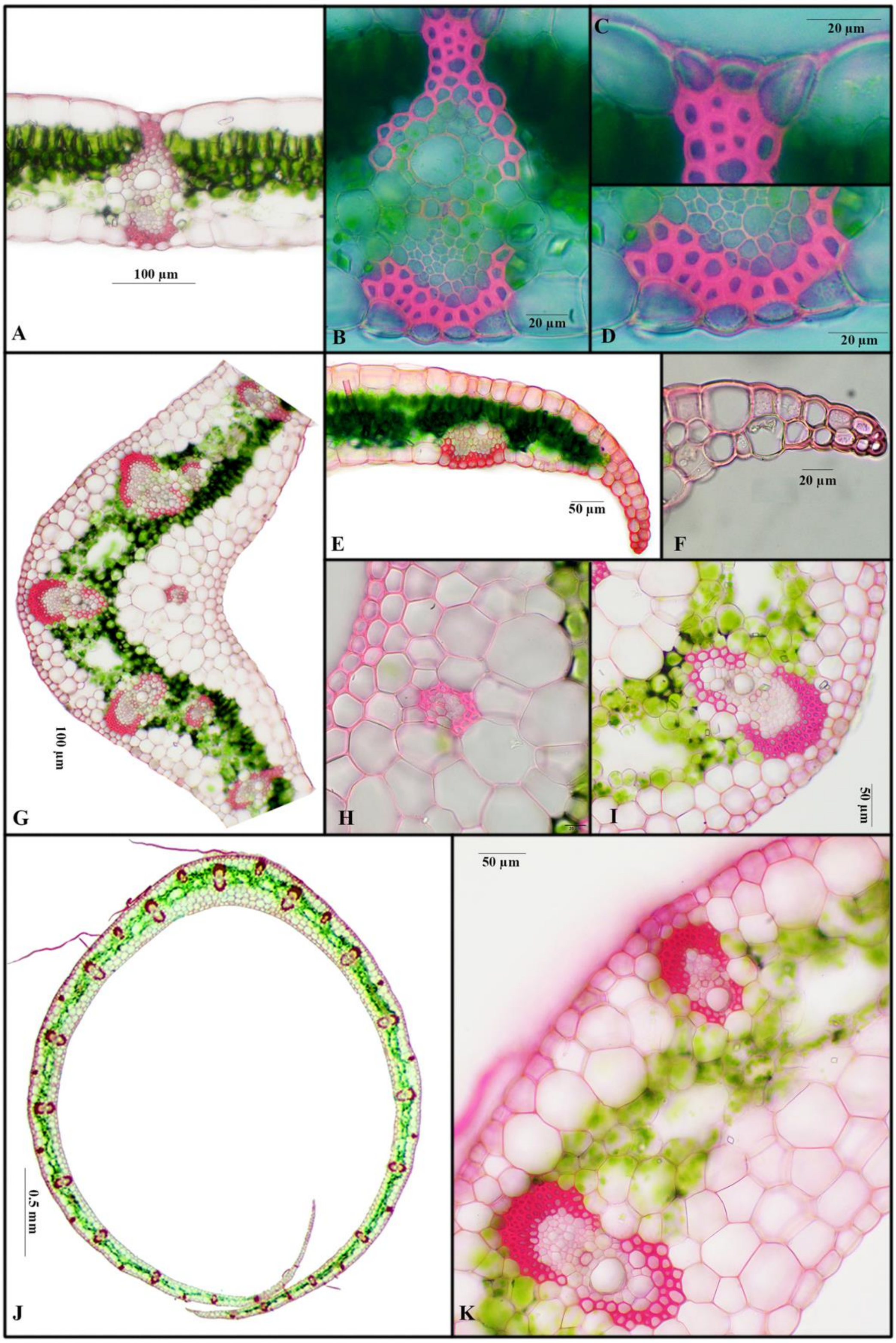


Fig. 52. ***Zingiber neotruncatum*** **var.** ***neotruncatum.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

15. *Zingiber neotruncatum* var. *ramsawmii.* **Fig. 53**

Lamina: Lamina bends downward, 185–195 µm thick. Adaxial and abaxial epidermal cells are as broader than high. Adaxial hypodermis absent. Mesophyll tissue 82–83 µm thick, palisade bilayered, spongy cells bilayered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with adaxial epidermis and abaxial epidermis. Main vascular bundle bottle-shaped, 180–182 × 71–85 µm, adaxial bundle cap 3–4 layered, attached to five epidermal cells, abaxial bundle cap 1–2 layered, attached to 5 epidermal cells. Metaxylem elliptic, 23–27 µm diam and protoxylem 12–14 µm diam. Abaxial hypodermis present. Rectangular crystals present in the mesophyll tissue and hypodermis. Oil cells absent.

Margin: Margin is tapering, hyaline region bends downward, beak uniform in thickness, tapering towards the tip. Hypodermis absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 232–238 µm long. Hyaline region bi-layered up to the apex and ends up uniseriate, 110–112 µm long. Oil cells absent, crystals present.

Midrib: Both adaxial surface and abaxial surface are wide U-shaped. Bundle arcs I and III present. Arc III is represented by 3-bundles at the center and lateral bundles are surrounded by chlorenchyma. Arc IV and II are absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals present. Hairs absent.

Leaf sheath: Sheath closed. Adaxial surface V-shaped and abaxial surface U-shaped. Bundle arcs I, II and III are present. Arc III is represented by two bundles. Arc I and II are alternating throughout the sheath. The diameter of metaxylem of arc 1 bundle at the median region ranges from 32–34 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Rectangular crystals present. Oil cells absent, hairs present on the abaxial epidermis.

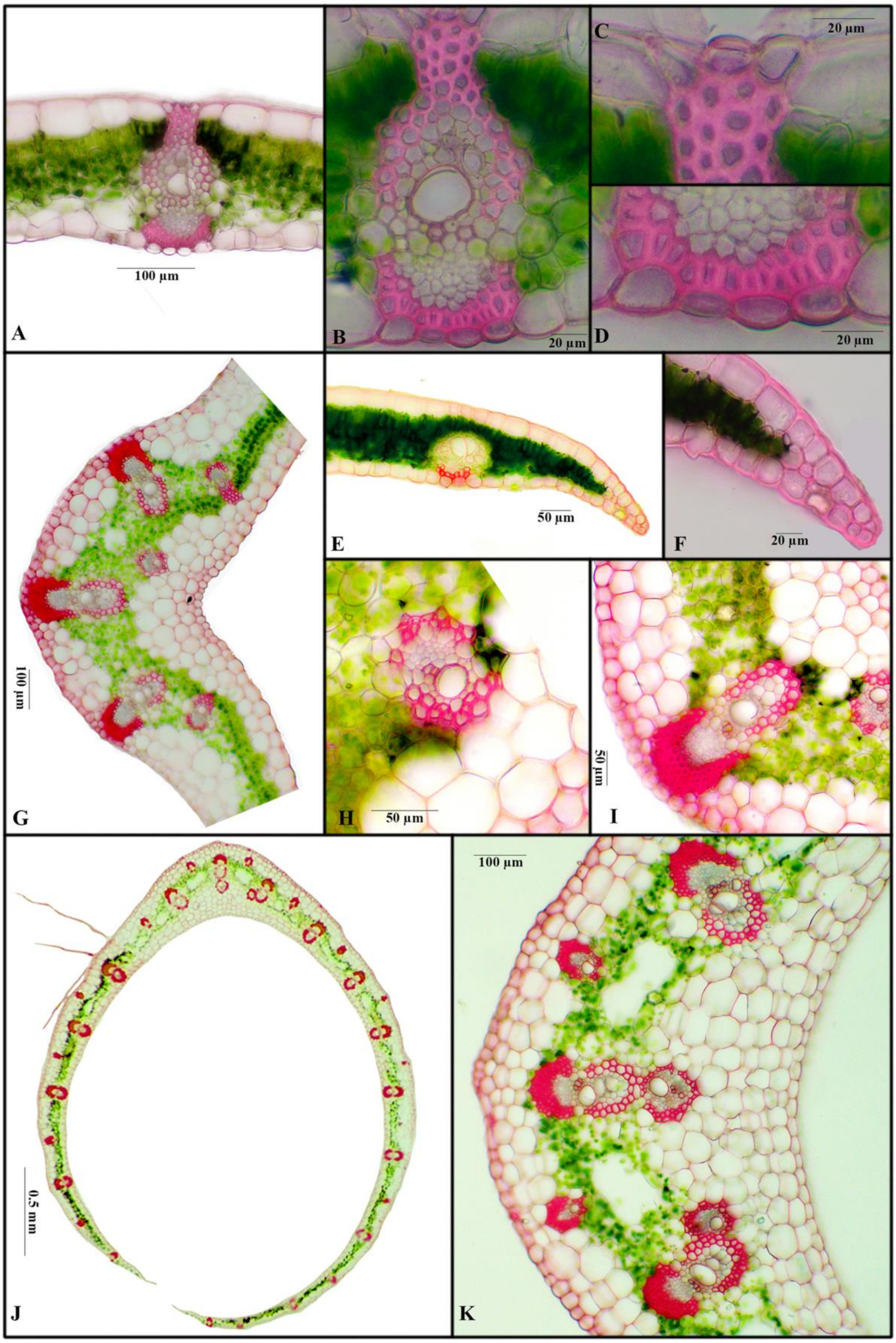


Fig. 53. ***Zingiber neotruncatum*** **var.** ***ramsawmii.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

16. *Zingiber pherimaense* **Fig. 54**

Lamina: lamina bends upward, 223–230 µm thick. Adaxial epidermal cells broader than high. Abaxial epidermal cells are isodiametric. Adaxial hypodermis absent. Mesophyll tissue 102–104 µm thick, palisade single-layered, spongy cells bilayered. Vascular bundles embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with both adaxial and abaxial epidermis. Main vascular bundle oblong, 210–213 × 95–98 µm, adaxial bundle cap 3–4 layered, attached to five epidermal cells, abaxial bundle cap single layered. Metaxylem angular, 34–38 µm diam, Protoxylem 13–16 µm diam. Abaxial hypodermis present. Rectangular crystals present in the mesophyll tissue. Oil cells absent.

Margin: Margin tapering, hyaline region bends downward, beak uniform in thickness, tapering towards the tip. Hypodermis absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 234–246 µm long. Hyaline region bi-layered up to the apex and ends up uniseriate, 100–103 µm long. Oil cells absent, crystals present.

Midrib: Adaxial surface wide V-shaped and abaxial surface wide U-shaped. Bundle arcs I and III present. Arc III is represented by a single bundle at the center. Arc IV and II are absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals and oil cells present. Hairs absent.

Leaf sheath: Sheath open. Both adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Arc III is represented by a single bundle. Arc I and II are alternating throughout the sheath. The diameter of metaxylem of arc 1 bundle at the median region ranges from 37–39 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Rectangular crystals present. Oil cells and hairs absent.

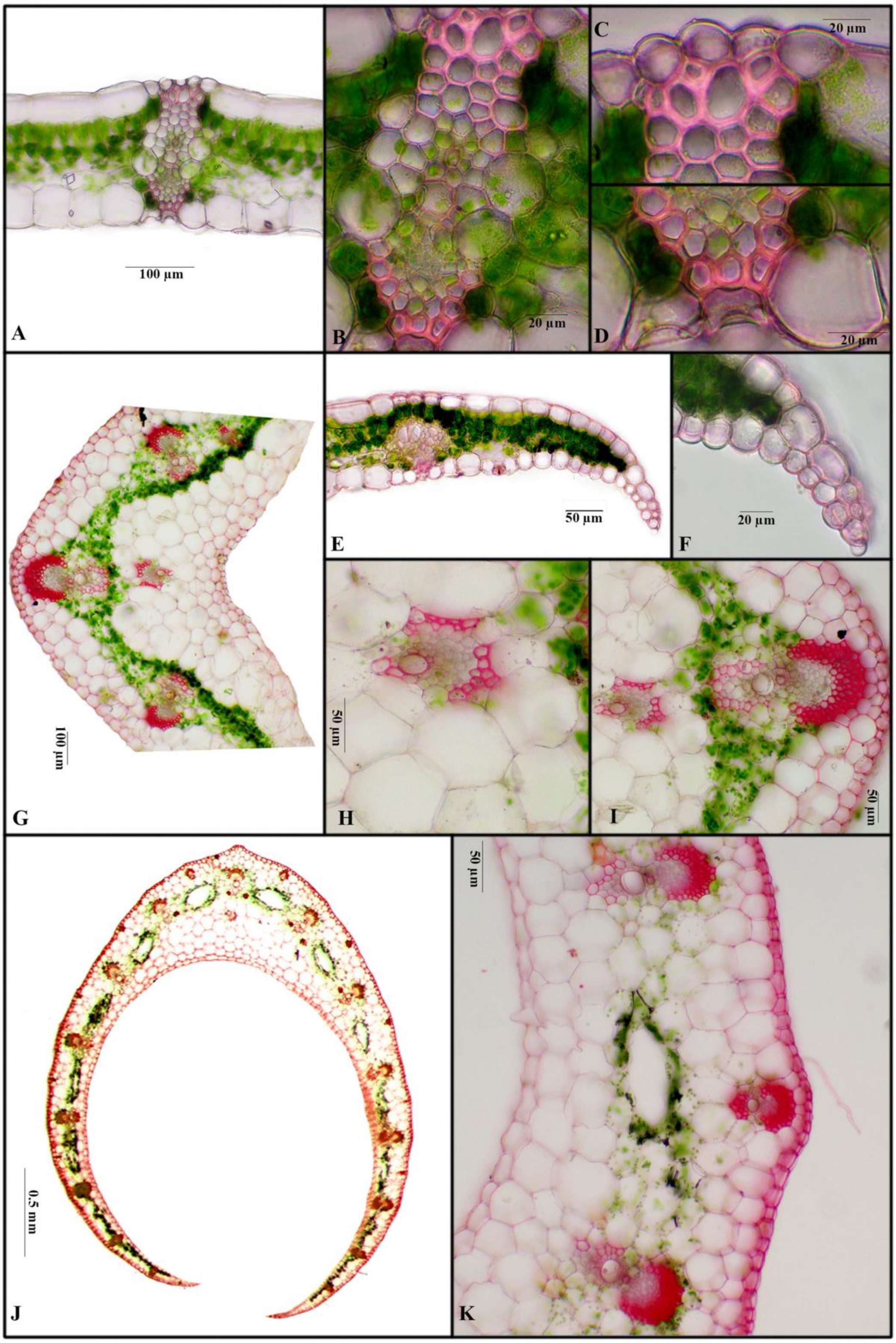


Fig. 54. *Zingiber pherimaense.* C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

17. *Zingiber purpureum* **Fig. 55**

Lamina: lamina straight, 164–169 µm thick. Both adaxial and abaxial epidermal cells as high as broad, Adaxial hypodermis absent. Mesophyll tissue 56–72 µm thick, palisade single-layered, spongy cells bi-layered. Vascular bundles embedded in the mesophyll. Sclerenchymatous bundle cap is in contact with both adaxial and abaxial epidermis. Main vascular bundle cylindrical, 128–131 × 30–50 µm, adaxial bundle cap 2-layered, adaxial bundle cap is attached to two epidermal cells. abaxial bundle cap 1–2 layered. Metaxylem circular, 11–18 µm diam. Protoxylem 5–8 µm. abaxial hypodermis absent instead air cavities or aerenchyma present. Rectangular crystals are present.

Margin: Margin is tapering, hyaline region straight and beak is not tapering. Hypodermis is completely absent. Main vascular bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 118–120 µm long. Hyaline region initially 3-layered up to the middle, from middle to tip bi-layered and ends up uniseriate, 213–218 µm long. Oil cells absent, crystals are present in some cells near the vascular bundle.

Midrib: Both adaxial and abaxial surfaces are wide U-shaped. Bundle arc I present, with middle large bundle and two small lateral bundles. Arc II, III and IV absent. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma. Rectangular crystals are observed in a few cells, oil cells are not observed.

Leaf sheath: Sheath closed. Both the adaxial and abaxial surfaces are V-shaped. Bundle arcs I and II are present. Arc I and II are alternating throughout the sheath. Arc III, IV absent. The diameter of metaxylem of Arc 1 bundle at the median region ranges from 35–40 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs on abaxial side. Rectangular crystals present.

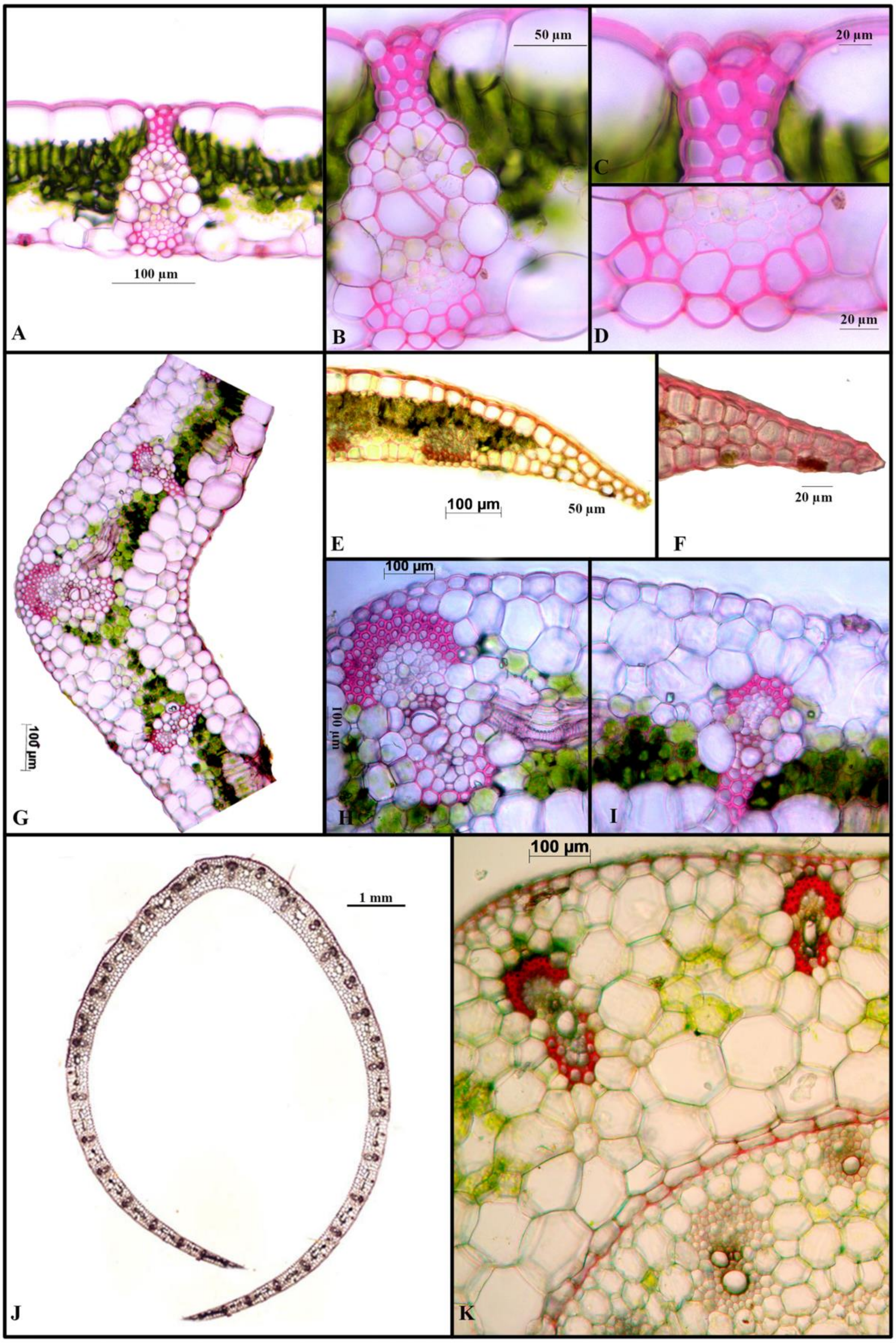


Fig. 55. ***Zingiber purpureum.*** C. S. of leaf parts: **A.** Lamina; **B.** Main vascular bundle of lamina; **C.** Adaxial bundle cap attachment; **D.** Abaxial bundle cap attachment; **E.** Leaf margin; **F.** Hyaline region of leaf margin; **G.** Midrib; **H. & I.** Midrib: a portion enlarged; **J.** Sheath; **K.** Sheath: a portion enlarged.

18. *Zingiber roseum* **Fig. 56**

Lamina: Lamina bends upwards, 153–175 µm thick. Both adaxial epidermal cells and abaxial epidermal cells are as broad as high. Adaxial hypodermis absent. Mesophyll tissue 68–78 µm thick, palisade single-layered, spongy cells bilayered. Vascular bundles are embedded in the mesophyll. Sclerenchymatous cap of the bundle is in contact with both adaxial and abaxial epidermis. Main vascular bundle bottle-shaped, 105–110 × 41–50 µm, adaxial bundle cap 3-layered, 2 epidermal cells are in direct contact with adaxial bundle cap, abaxial bundle cap single-layered, attached to 5 epidermal cells. Abaxial hypodermis absent.

Margin: Margin tapering, bulged near vascular bundle, hyaline region bends downwards. Hypodermis is completely absent. Bundle is connected to abaxial epidermis only. Relative length between margin and marginal bundle is 193–200 µm long. Hyaline region bi-layered and ends up uniseriate, 167–175 µm long.

Midrib: Adaxial surface is wide U-shaped and abaxial surface is wide V-shaped. Bundle arcs I and III are present and arc III is represented by 2-bundles just above the arc I bundles. Air canals are seen alternating with arc I bundles, air canals and vascular bundles are in turn surrounded by chlorenchyma

Leaf sheath: Sheath closed, Adaxial and abaxial surfaces are U-shaped. Bundle arcs I, II and III are present. Arc I and II are alternating throughout the sheath. Arc III is represented by a single bundle in the middle. The diameter of metaxylem of arc 1 bundle at the median region ranges from 43–51 µm. Air canals are seen in between arc l bundles and air cavities are in turn surrounded by chlorenchyma. Hairs are present on the abaxial side.

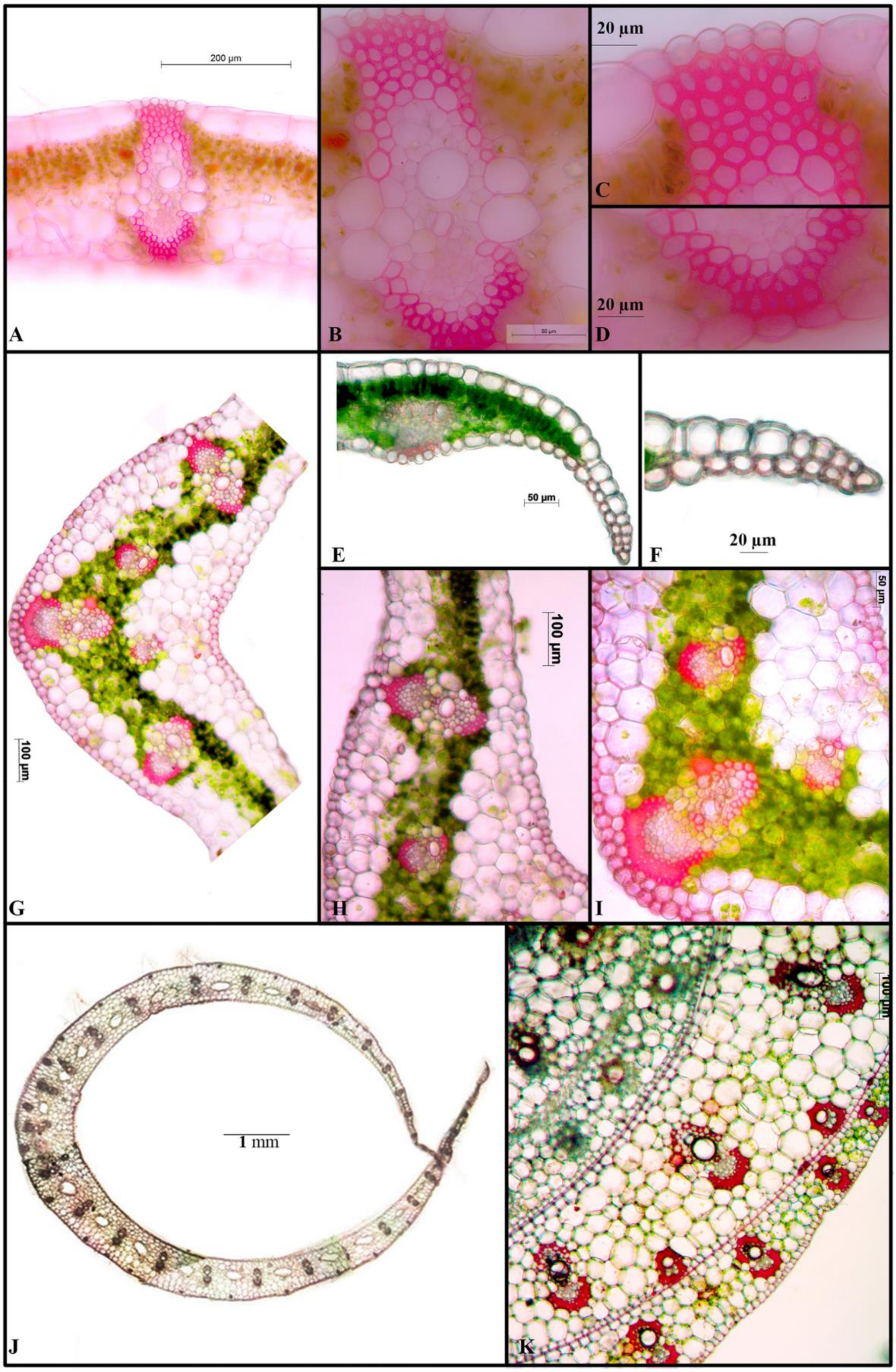


Fig. 56. *Zingiber roseum.* C. S. of leaf parts: **A.** Lamina. **B.** Main vascular bundle of lamina. **C.** Adaxial bundle cap attachment. **D.** Abaxial bundle cap attachment. **E.** Leaf margin. **F.** Hyaline region of leaf margin. **G.** Midrib. **H. & I.** Midrib: a portion enlarged. **J.** Sheath. **K.** Sheath: a portion enlarged.

Comparative Anatomy

Lamina

The thickness of lamina in the genus *Zingiber* ranges from 147 to 380 µm. Thickest laminae were found in *Z. clarkei* (295–380 µm), *Z. cornigerum* (265–339 µm) and *Z. pherimaense* (299–303 µm) and thinnest was found in *Z. capitatum* (147–165 µm). The epidermal cells on both surfaces are almost the same size except near the vascular bundles (Smaller cells near the bundle cap attachment). In most of the taxa studied, the epidermal cells are broader than high. The exceptions are *Z. purpureum* and *Z. roseum* (both adaxial and abaxial epidermal cells are as broad as high), *Z. arunachalensis, Z. campanulatum, Z. cornigerum* and *Z. kangleipakense* (with adaxial epidermal cells as broad as high and abaxial epidermis broader than high) and *Z. dimapurense*, *Z. meghalayense* and *Z. mizoramensis* (with abaxial epidermal cells as broad as high and adaxial epidermal cells broader than high). In majority of the *Zingiber* sp. the lamina near main vascular bundle bend upward but in *Z. campanulatum*, *Z. capitatum*, *Z. chrysanthum*, *Z. dimapurense, Z. kerri* and *Z. purpureum* it is straight and in *Z. neotruncatum* var. *neotruncatum* and *Z. neotruncatum* var. *ramsawmii* lamina bends slightly downward at adaxial side. The genus *Zingiber* in India is characterized by leaf lamina devoid of a distinct adaxial hypodermis. The exception is *Z. clarkei* with a single layer of parenchymatous hypodermis on both adaxial and abaxial surfaces. *Z. clarkei* is the only representative of the Sect. *Pleuranthesis* in India, hence this character can be utilized as a diagnostic character for Sect. *Pleuranthesis*. *Z. cornigerum* is characterized by a small patch of the parenchymatous layer below the adaxial epidermis but only above the main vascular bundle. In *Z. bipinianum*, *Z. capitatum*, *Z. meghalayense, Z. mizoramensis* and *Z. roseum* the lamina do not have a hypodermis whereas in *Z. arunachalensis*, *Z. chrysanthum*, *Z. dimapurense, Z. kangleipakense, Z. kerrii* and *Z. purpureum* a single layered aerenchymatous layer is present below the abaxial epidermis. A single layer of well-defined hypodermal parenchymatous layer was observed below the abaxial epidermis of *Z. campanulatum*, *Z. clarkeii*, *Z. cornigerum, Z. murlenica, Z. neotruncatum* var. *neotruncatum* and *Z. neotruncatum* var. *ramsawmii* and *Z. pherimaense*. The number of palisade and spongy layers in the mesophyll varies with species. *Z. bipinianum*, *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum, Z. pherimaense* and *Z. purpureum* are with a single layer of palisade

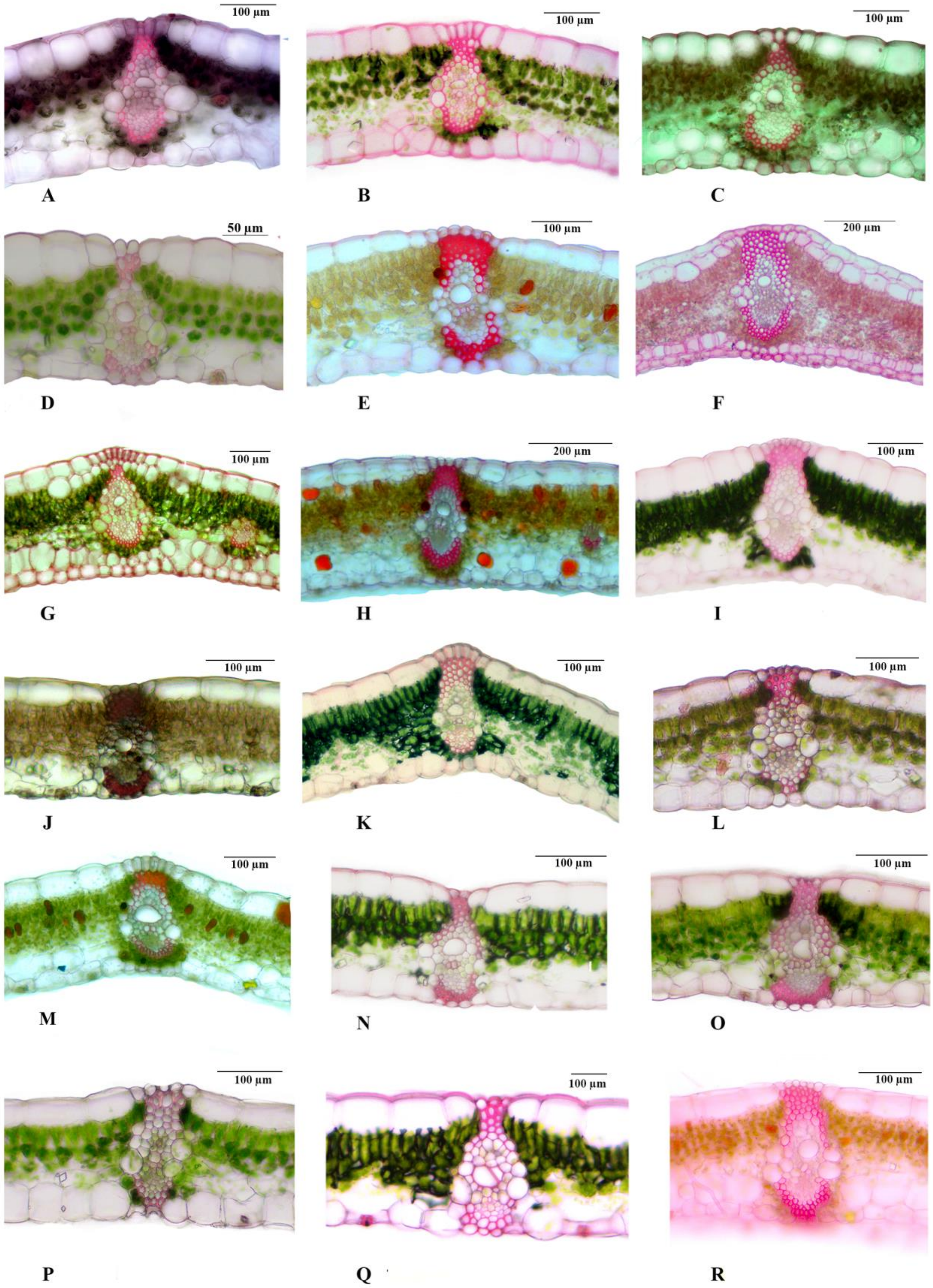


Fig. 57. Cross section of lamina: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmi*; **P.** *Z. pherimaense*; **Q.** *Z. purpureum*; **R.** *Z. roseum*.

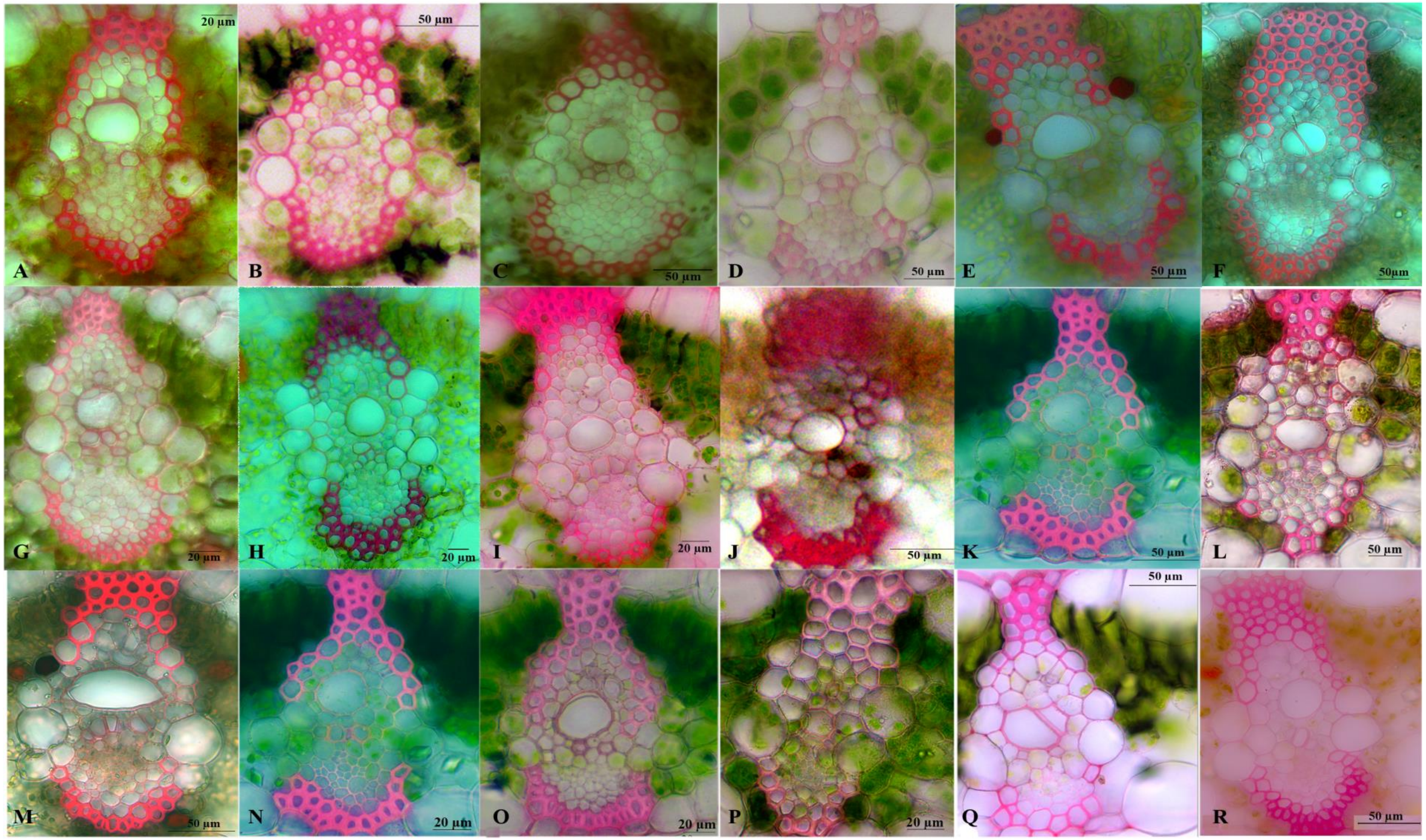


Fig. 58. Vascular bundle lamina: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmi*; **P.** *Z. pherimaense*; **Q.** *Z. purpureum*; **R.** *Z. roseum*.

whereas in all others it is bilayered. One or two layers of spongy cells are found in this genus. One of the important characteristics noted in anatomy of lamina in *Zingiber* is the attachment of bundle cap. In *Z. capitatum, Z. chrysanthum*, *Z. kerrii*, *Z. mizoramensis*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. pherimaense*, *Z. purpureum* and *Z. roseum* the sclerenchymatous bundle cap are in contact with both adaxial and abaxial epidermis, whereas in *Z. arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. clarkei*, *Z. dimapurense*, *Z. kangleipakense, Z. meghalayense* and *Z. murlenica* the sclerenchymatous bundle cap are in contact with adaxial epidermis only. In *Z. cornigerum* the sclerenchymatous bundle cap are not in contact with either of the epidermis. **Fig. 57 & 58**

Margin

Towards the margin, the leaves have epidermis followed by a mesophyll on both surfaces. The mesophyll comprises one or bi-layered palisade and one or two-layered spongy cells in most species. Oil cells are observed in *Z. clarkei*, *Z. chrysanthum, Z. dimapurense* and *Z. murlenica* and rectangular crystals in most of the species studied. The bundle cap is in contact with both adaxial and abaxial epidermis in *Z. chrysanthum* and in the rest of the taxa bundle cap is in contact with abaxial epidermis only. The relative length between margin and marginal bundle varies from species to species and it ranges from 84–437 µm. The smallest distance was found in *Z. kangleipakense* (80–84 µm) and the longest was found in *Z. clarkei* (400–437 µm). The length of the hyaline region also varies among species and it ranges from 93–268 µm. The longest hyaline regions were observed in *Z. purpureum* (234–246 µm) and *Z. kangleipakense* (260–268 µm). The smallest region was found in *Z. bipinianum* (93–102 µm). The hyaline region bends downward in all species except in *Z. purpureum* and *Z. campanulatum* (hyaline region straight), whereas in *Z. kangleipakense* it is straight and wavy. The number of layers in the hyaline region varies among different species, it is triseriate initially and ends up uniseriate in *Z. capitatum*, *Z. chrysanthum* and *Z. clarkei.* In *Z. cornigerum*, *Z. dimapurense* and *Z. kangleipakense* hyaline region is 4-seriate initially and ends up uniseriate, whereas in the rest of the species it is biseriate which ends up uniseriate. **Fig. 59**

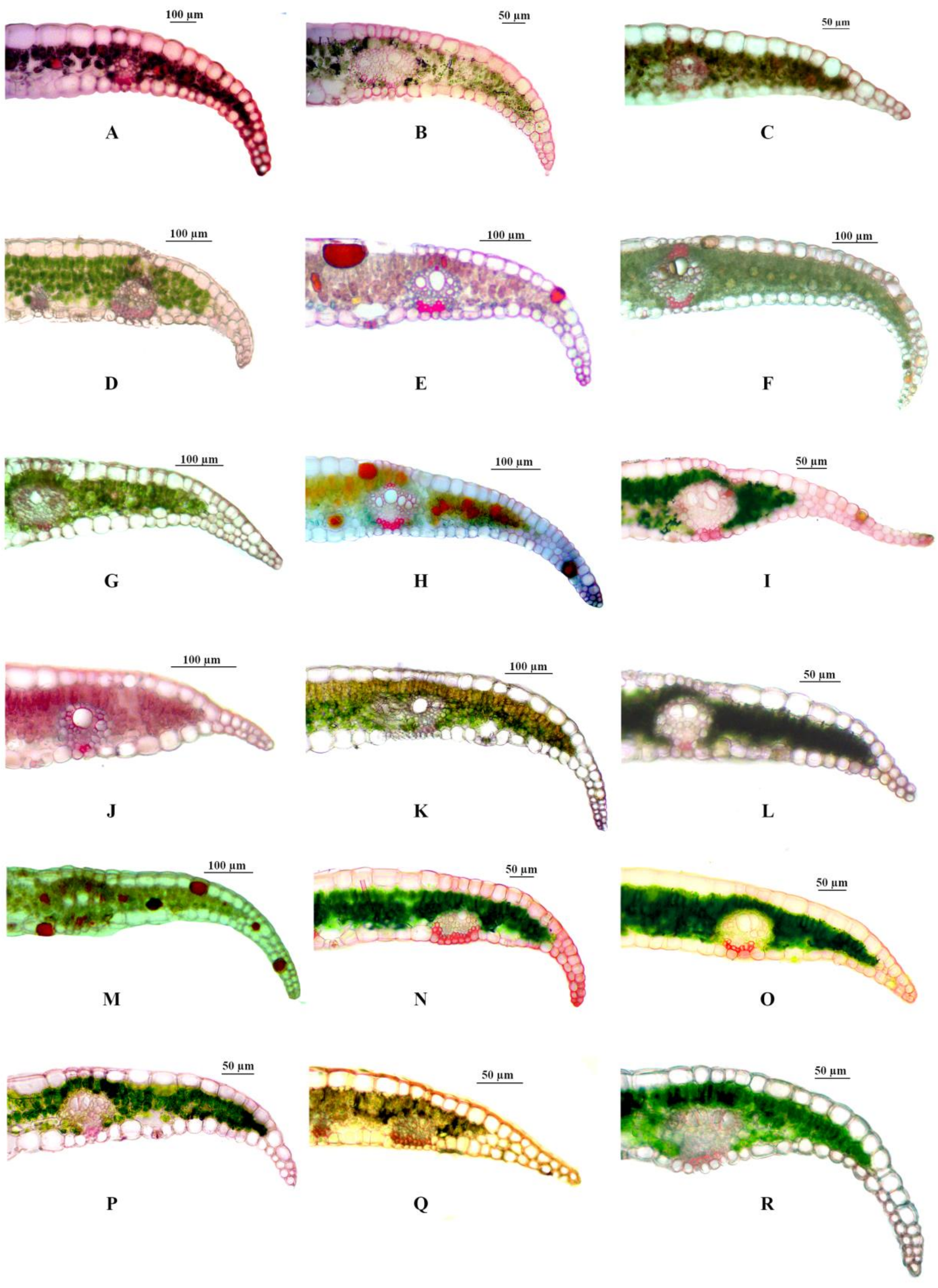


Fig. 59. Cross section of leaf margin: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmi*; **P.** *Z. pherimaense*; **Q.** *Z. purpureum*; **R.** *Z. roseum*.

Midrib

The shape of the midrib on the adaxial and abaxial surfaces varies with species. The shape of the adaxial and abaxial surfaces ranges from wide V-shaped to concave-shaped. It is U- shaped in *Z. bipinianum* and *Z. cornigerum* only, whereas it is wide U-shaped in *Z. arunachalensis*, *Z. kerrii*, *Z. mizoramensis*, *Z. murlenica*, *Z. neotruncatum* var. *neotruncatum Z. neotruncatum* var. *ramsawmii*, *Z. purpureum* and *Z. roseum*. Wide V-shaped adaxial surface was observed in *Z. chrysanthum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense* and *Z. pherimaense*, whereas concave-shaped adaxial surfaces were found in *Z. campanulatum*, *Z. capitatum* and *Z. clarkei.* The abaxial surface is wide V-shaped in *Z. capitatum* and *Z. roseum*, it is U-shaped in *Z. chrysanthum* and *Z. cornigerum*, a concave shaped abaxial surface was found in *Z. clarkei* and in the rest of the taxa it was wide U-shaped. The arc bundles I, III and IV were observed in the midrib of genus *Zingiber* and arc II fails to develop or absent in all the taxa studied. The occurrence of different arc bundle varies among species. Arc I, III and IV were found in *Z. arunachalensis*, *Z. chrysanthum*, *Z. clarkei*, *Z. cornigerum*, *Z. dimapurense*, *Z. meghalayense* and *Z. murlenica*, whereas in the rest of the taxa bundle arcs I and III are present except in *Z. purpureum* (Arc I only). **Fig. 60 & 61**

Sheath

The mouth of the sheath is closed in most of the taxa studied except in *Z. campanulatum*, *Z. clarkei*, *Z. mizoramensis* and *Z. pherimaense*. The sheath is U-shaped in most of the *Zingiber* species studied, whereas it is wide U-shaped in *Z. campanulatum*, wide V-shaped in *Z. arunachalensis*, wide W-shaped in *Z. bipinianum* and V-shaped in *Z. purpureum*. The abaxial surface of the sheath is U-shaped in all the species except in *Z. purpureum* (V-shaped). Arc bundles I, II, III and IV were observed in the sheath of genus *Zingiber*. The occurrence of Arc bundles varies among different species. Presence of arc bundles I and II observed in *Z. neotruncatum* var. *neotruncatum* and *Z. purpureum* (Arc III and IV absent), arc bundles I, II, III and IV were present in *Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. clarkei*, *Z. dimapurense*, *Z. kangleipakense* and *Z. murlenica*, whereas in rest of the taxa arc bundles I, II and III were observed and arc IV is absent. **Fig. 62 & 63**

Fig. 60. Cross section of leaf midrib: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmi*; **P.** *Z. pherimaense*; **Q.** *Z. purpureum*; **R.** *Z. roseum*.

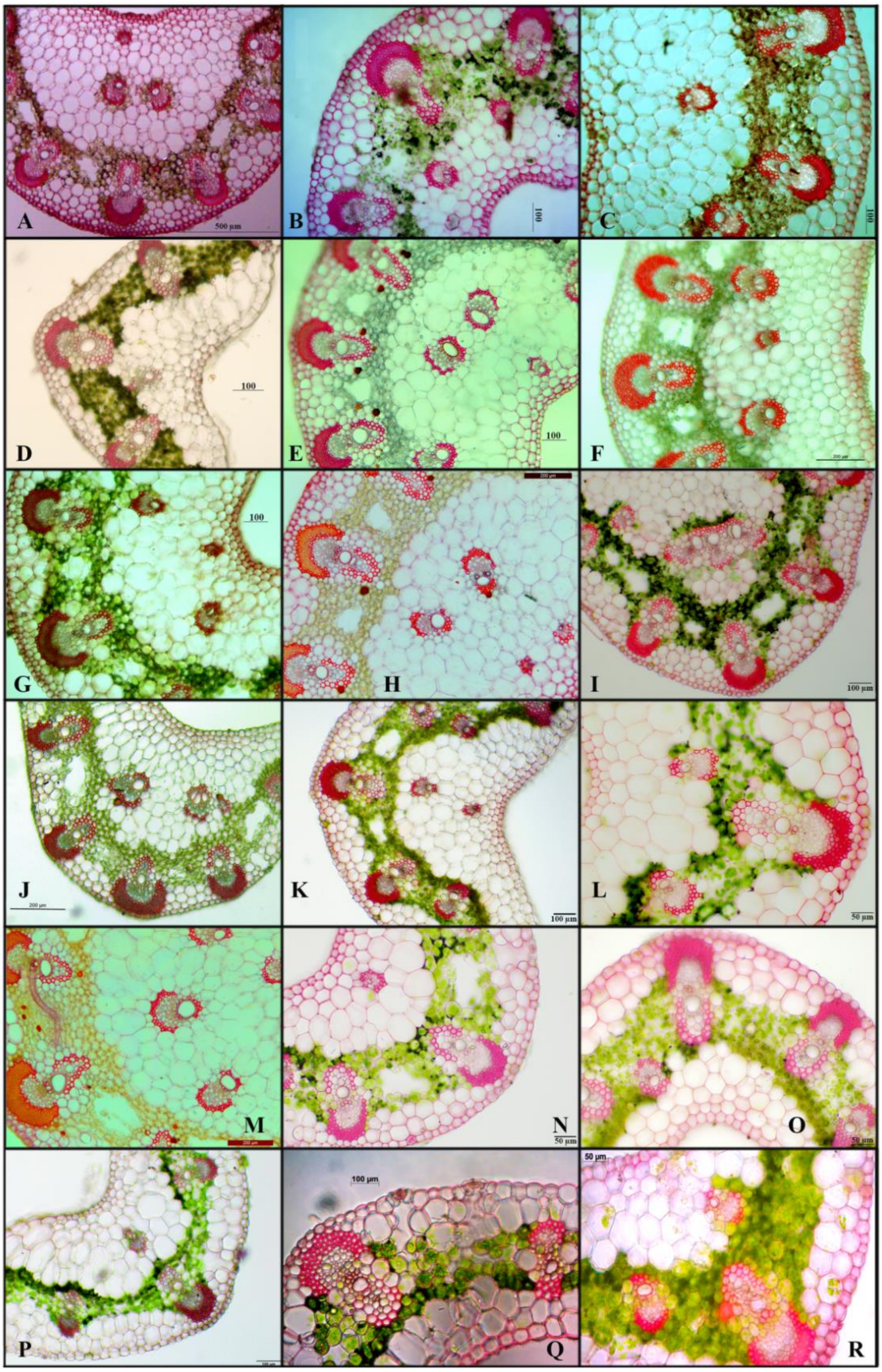


Fig. 61. Midrib: portion enlarged: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmi*; **P.** *Z. pherimaense*; **Q.** *Z. purpureum*; **R.** *Z. roseum*.

Fig. 62. Cross section of leaf sheath: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmi*; **P.** *Z. pherimaense*; **Q.** *Z. purpureum*; **R.** *Z. roseum*.

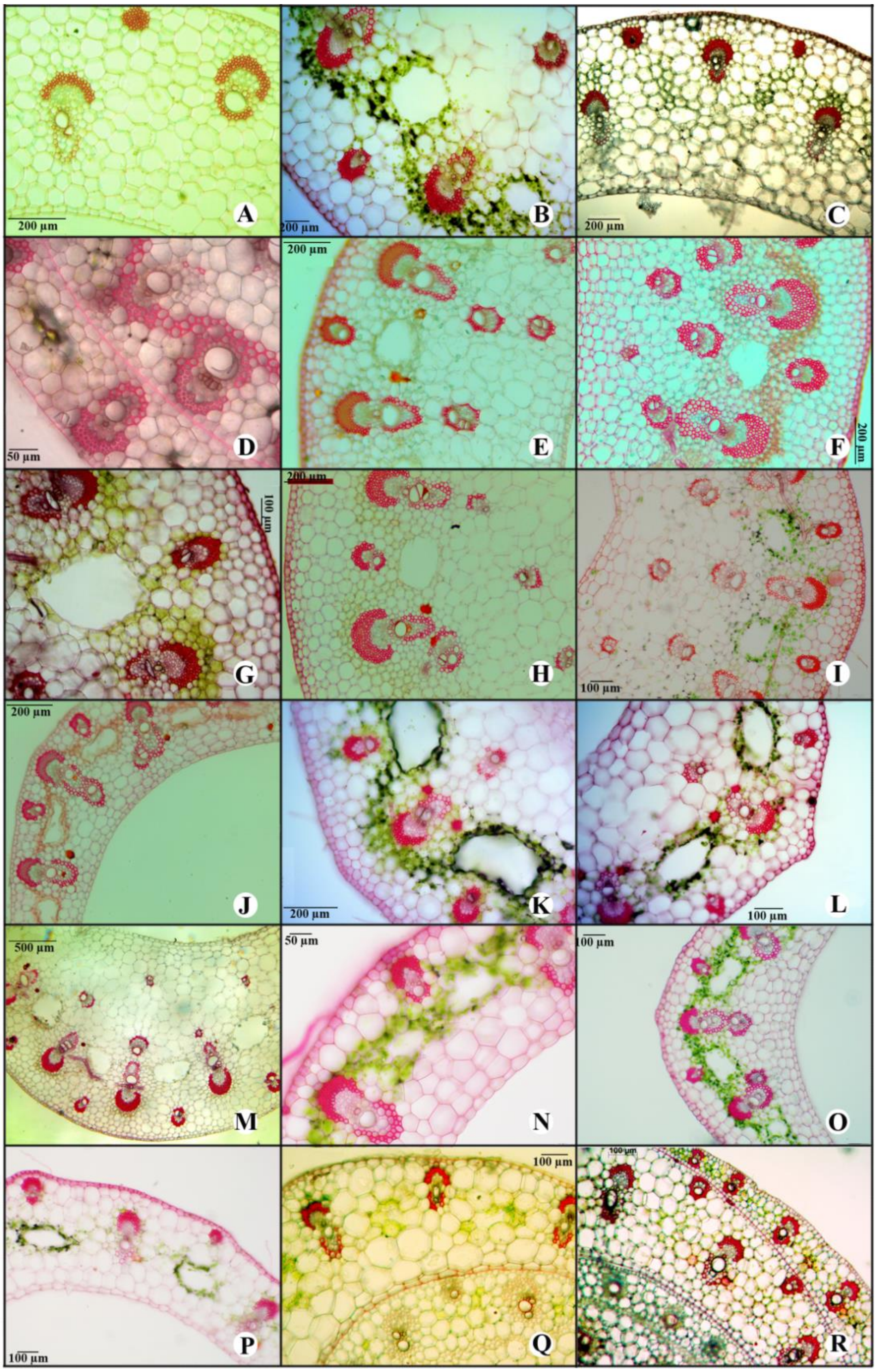


Fig. 63. Comparitive anatomy of leaf sheath: portion enlarged: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmi*; **P.** *Z. pherimaense*; **Q.** *Z. purpureum*; **R.** *Z. roseum*.

Table 5. Comparison of anatomical characters of genus *Zingiber*.

Attributes	***Z. arunachalensis***	***Z. bipinianum***	***Z. campanulatum***	***Z. capitatum***	***Z. chrysanthum***	***Z. clarkei***	***Z. cornigerum***	***Z. dimapurense***	***Z. kangleipakense***
Lamina: shape near main V. B.	Bends upward	Slightly bends upward	Straight	Straight	Straight	Bends upward	Bends upward	Straight	Bends upward
Lamina: thickness (µm)	217–240	245–255	264–288	147–165	224–243	295–380	265–339	299–303	211–258
Lamina: hypodermis	An aerenchymatous layer above abaxial epidermis	Absent	Single layer of abaxial hypodermis	Absent	An aerenchymatous layer above abaxial epidermis	A parenchymatous layer on both surface	A small patch of parenchyma layer below adaxial epidermis and a parenchymatous layer above abaxial epidermis	An aerenchymatous layer above abaxial epidermis	An aerenchymatous layer above abaxial epidermis
Lamina: mesophyll	Palisade- two layer Spongy- single layer	Palisade- single layer Spongy- two layer	Palisade- two layer Spongy- two layer	Palisade- two layer Spongy- two layer	Palisade- two layer Spongy- single layer	Palisade- two layer Spongy- five layer	Palisade- two layer Spongy- single layer	Palisade- two layer Spongy- two layer	Palisade- two layer Spongy- single layer
Lamina: Main V. B. (µm)	Ovate 183–190 × 79–85	Ovate to elliptic, 176–179 × 99–104	Ovate, 215–217 × 118–130	Cylindrical, 146–149 × 40–49	Oblong, 198–203 × 45–52	Oblong, 298–302 × 120–132	Ovate, 218–220 × 141–147	Elliptic, 243–246 × 98–112	Ventricose, 206–220 × 76–97
Lamina: bundle cap attached to	Adaxial epidermis only	Adaxial epidermis	Adaxial epidermis only	Adaxial and abaxial	Adaxial and abaxial	Adaxial epidermis only	Bundle cap is not in contact	Adaxial epidermis only	Adaxial epidermis only

		only		epidermis	epidermis		with either of the epidermis		
adaxial bundle cap	4 epidermal cells	6 epidermal cells	3 epidermal cells	3 epidermal cells	7 epidermal cells	7 epidermal cells	Absent	4 epidermal cells	8 epidermal cells
Bundle cap: Adaxial	2–3 layered	3–4 layered	4–5 layered	5–6 layered	4 layered	3–6 layered	4–5 layered	4–5 layered	3–4 layered
Bundle cap: Abaxial	Single layer	1–2 layered	Single layer	2 layered	2 layered	2–3 layered	2 layered	2–3 layered	Single layer
Margin: shape	Bend downwards	Bend downwards	Straight	Bend downwards	Bend downwards	Bend downwards	Bend downwards	Bend downwards	Straight and wavy
Margin: length of hyaline region (µm)	118–128	93–102	116–124	165–181	116–118	165–171	150–153	217–241	260–268
Margin: relative length between V.B. and hyaline region (µm)	239–244	271–286	265–271	128–130	198–202	400–437	227–228	220–229	80–84
Margin: hyaline region number of layers	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	3 seriate initially ends up uniseriate	3 seriate initially ends up uniseriate	3 seriate initially ends up uniseriate	4 seriate initially ends up uniseriate	4 seriate initially ends up uniseriate	4 seriate initially ends up uniseriate
Margin: bundle cap attached to	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Adaxial and abaxial epidermis	Adaxial and abaxial epidermis	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only
Midrib: adaxial Surface	Wide U-shaped	U-shaped	Concave-shaped	Concave-shaped	Wide V- shaped	Concave-shaped	U-shaped	Wide V-shaped	Wide V-shaped
Midrib: abaxial surface	Wide U-shaped	Wide U-shaped	Wide U-	Wide V-	U-shaped	Concave-	U-shaped	Wide U-shaped	Wide U-shaped

			shaped	shaped		shaped			
Midrib: bundle arcs	I, III and IV	I and III	I and III	I and III	I, III and IV	I, III and IV	I, III and IV	I, III and IV	I and III
Sheath: closed or open	Closed	Closed	Open	Closed	Closed	Open	Closed	Closed	Closed
Sheath: adaxial surface	Wide V-shaped	Wide W-shaped	Wide U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped
Sheath: abaxial surface	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped
Sheath: bundle arcs	I, II and III	I, II, III and IV	I, II, III and IV	I, II and III	I, II, III and IV	I, II, III and IV	I, II and III	I, II, III and IV	I, II, III and IV

Attributes	***Z. kerrii***	***Z. meghalayense***	***Z. mzoramensis***	***Z. murlenica***	***Z. neotruncatum* var. *neotruncatum***	***Z. neotruncatum* var. *ramsawmii***	***Z. pherimaense***	***Z. purpureum***	***Z. roseum***
Lamina: shape near main V. B.	Straight	Bends upward	Bends upward	Bends upward	Bends downward	Bends downward	Bends upward	Straight	Bends upward
Lamina: thickness (µm)	162–165	219–280	167–200	180–220	169–188	185–195	223–230	164–169	153–175
Lamina: hypodermis	An aerenchymatous layer below abaxial epidermis	Absent	Absent	A Parenchymatous layer below abaxial epidermis	A Parenchymatous layer below abaxial epidermis	A Parenchymatous layer below abaxial epidermis	A Parenchymatous layer below abaxial epidermis	An aerenchymatous layer below abaxial epidermis	Absent
Lamina: mesophyll	Palisade- single layer Spongy- two layer	Palisade- two layer Spongy- two layer	Palisade- two layer Spongy-	Palisade- two layer Spongy-	Palisade- single layer Spongy-	Palisade- two layer Spongy-	Palisade- single layer Spongy-	Palisade- single layer Spongy-	Palisade- single layer

			single layer	two layer	two layer	two layer	two layer	two layer	Spongy-two layer
Lamina: Main V. B.	Cylindrical, 144–148 × 70–76 µm	Ventricose, 213–230 × 64–105 µm	Bottle-shaped, 174–176 × 89–90 µm	Ventricose, 174–180 × 100–110 µm	Bottle shaped, 162–168 × 67–72 µm	Bottle shaped, 180–182 × 71–85 µm	Oblong, 210–213 × 95–98 µm	Cylindrical, 128–131 × 30–50 µm	Bottle shaped, 105–110 × 41–50 µm
Lamina: bundle cap attached to	Adaxial and abaxial epidermis	Adaxial epidermis only	Adaxial and abaxial epidermis	Adaxial epidermis only	Adaxial and abaxial epidermis	Adaxial and abaxial epidermis	Adaxial and abaxial epidermis	Adaxial and abaxial epidermis	Adaxial and abaxial epidermis
Adaxial bundle cap attached to	5 epidermal cells	7 epidermal cells	5 epidermal cells	5 epidermal cells	2 epidermal cells	5 epidermal cells	5 epidermal cells	2 epidermal cells	5 epidermal cells
Bundle cap: Adaxial	3–4 layered	4–5 layered	4–5 layered	3 layered	3–4 layered	3–4 layered	3–4 layered	2 layered	3 layered
Bundle cap: Abaxial	1–2 layered	Single layer	1–2 layered	1–2 layered	1–2 layered	1–2 layered	Single layer	1–2 layered	Single layer
Margin: shape	Bend downward	Bend downward	Bend downward	Bend downward	Bend downward	Bend downward	Bend downward	Straight	Bend downward
Margin: length of hyaline region (µm)	102–105	137–148	170–179	198–204	123–125	110–112	100–103	213–218	167–175
Margin: relative length between V.B. and hyaline region (µm)	130–136	310–315	400–416	283–290	225–230	232–238	234–246	118–120	193–200

Margin: hyaline region number of layers	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate	Biseriate and ends up uniseriate
Margin: bundle cap attached to	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only	Abaxial epidermis only
Midrib: adaxial Surface	Wide U-shaped	Wide V-shaped	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide V-shaped	Wide U-shaped	Wide U-shaped
Midrib: abaxial surface	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide U-shaped	Wide V-shaped
Midrib: bundle arcs	I and III	I, III and IV	I and III	I, III and IV	I and III	I and III	I and III	I only	I and III
Sheath: closed or open	Closed	Closed	Open	Closed	Closed	Closed	Open	Closed	Closed
Sheath: adaxial surface	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	V-shaped	U-shaped
Sheath: abaxial surface	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	U-shaped	V-shaped	U-shaped
Sheath: bundle arcs	I, II and III	I, II and III	I, II and III	I, II, III and IV	I and II	I, II and III	I, II and III	I and II	I, II and III

Cluster analysis

The dendrogram derived from the anatomical characters generated two main clades shown in **Fig. 64.** Clade I is a monoclade represented by *Z. clarkei* which is the only representative of the Sect. *Pleuranthesis* and anatomically this section is characterized by the presence of adaxial and abaxial hypodermis and the rest of the taxa clustered together in the second clade which is characterized by the absence of adaxial hypodermis. The clade II is bifurcated to form two subclades, subclade I and subclade II. The sub clade I is represented by the members of the Sect. *Cryptanthium* which includes *Z. arunachalensis, Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. cornigerum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis, Z. murlenica*, *Z. pherimaense* and *Z. roseum*. They are characterized by a bundle sheath attached to adaxial epidermis only and the remaining taxa clustered together in sub clade II represented by members of the Sect. *Zingiber* (*Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. kerrii* and *Z. purpureum*) and *Z. capitatum* of the Sect. *Dymczewiczia*. Sub clade II is characterized by the presence of bundle sheath attached to both adaxial and abaxial epidermis. The clustering of Sect. *Dymczewiczia* along with Sect. *Zingiber* strongly suggests the amalgamation of Sect. *Dymczewiczia* with Sect. *Zingiber*.

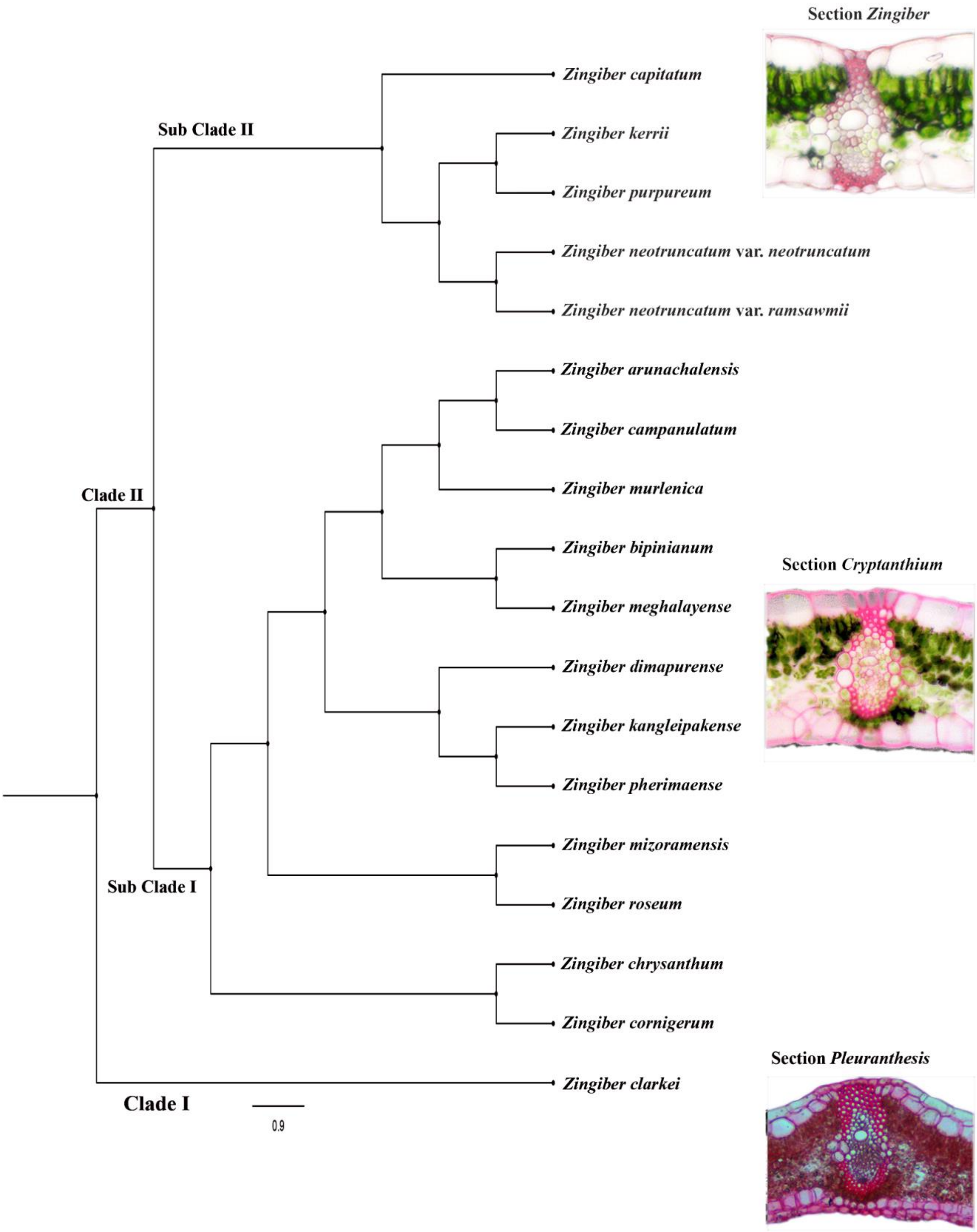


Fig. 64. UPGMA dendrogram of *Zingiber* sp. based on anatomical characters

PALYNOLOGY

A total of 20 species and 1 variety of *Zingiber* from North East India were selected for the present palynological study (**Fig. 72**). Pollen samples *Z. flavofusiforme*, *Z. marginatum*, *Z. ligulatum*, *Z. intermedium* and *Z. caudatum* were omitted from the study because of the non-availability of samples.

Pollen grains were found mostly aggregated and tightly packed in both the anther thecae. Generally, occurs in creamy white color. In the genus *Zingiber,* we have observed two major types of pollens; spheroidal and ellipsoidal. Spheroidal pollens are observed in *Z. capitatum* var. *elatum*, *Z. clarkei*, *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. kerrii*, *Z. officinale*, *Z. purpureum* and *Z. zerumbet* which exhibit cerebroid ornamentation. Ellipsoidal pollen grains present in *Z. arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. cornigerum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica, Z. pherimaense*, *Z. roseum* and *Z. rubens* with spiro-striate ornamentation.

Pollens are protected by a characteristic double-layered wall with an outer exine and an inner intine, which gives its distinctive morphology. The exine is composed of sporopollenin, a nonliving layer and a secretary product, which is resistant to acetolysis (Erdtman, 1952), Heslop Harrison (1968). The thickness of the wall ranges from 1–5 µm with characteristic ornamentation. Erdtman (1952) reported the occurrence of an ellipsoid with tubercled ornamentation in *Z. officinale,* ellipsoid pollens with striate sculpturing in *Z. roseum* and sub Spheroidal pollen with areoles in *Z. zerumbet*. Theilade *et al.* (1993) and Liang (1988) reported cerebroid sculpturing in Spheroidal pollens and spiro-striate in ellipsoidal pollens. Vasantha (2009) studied the pollen morphology of 9 species of *Zingiber* from South India and found that spheroid pollens with cerebroid sculpturing found in *Z. capitatum* var. *elatum*, *Z. purpureum, Z. neesasnum*, *Z. officinale* and *Z. zerumbet*, whereas ellipsoid pollen with spiro-striate ornamentation in *Z. cernuum*, *Z. nimmonii*, *Z. roseum* and *Z. wightianum*.

The important characteristics studied in pollen morphology are pollen size and shape. In the case of Spheroidal pollen grains the diameter of the pollen was taken as the size and in the case of ellipsoid pollen grains diameter along the longest equatorial axis is taken, followed by the diameter along the shortest equatorial axis (Theilade *et al.*, 1993).

Our study shows that the exine is very thin and prone to acetolysis. Treatment with acetone only removes the external sculpturing. Even dehydration of pollens for SEM analysis shatters the shape and ornamentation which shows that the exact shape and pollens can be observed in hydrated conditions. The exine ornamentation is generally cerebroid in spheroidal grains and spiro-straite in ellipsoidal grains (Vasantha, 2009). The exine is characterized by ridges and grooves. The ridges are called muri and grooves are known as lumen. Lumens are very narrow or even absent and muri are very closely placed in spheroidal pollens with cerebroid sculpturing. Muri are found pebble-like, rectangular, elongated, irregular or sinuous. In ellipsoid pollens muri are elongated, noodle-shaped, parallelly arranged, sometimes show sparse branching or frequent bifurcations and extended from one end to the other end. Lumens in ellipsoidal grains are much wider as compared to Spheroidal grains and are parallelly arranged.

According to Mangaly and Jyothi (1990) aperture is found in *Z. zerumbet*, *Z. roseum* and *Z. officinale*. Theilade *et al.* (1993) also observed aperture-like depressions on pollen wall and they suggest that pollen of *Zingiber* are found to be inaperturate as well as the aperture-like structures observed in some grains are most probably artifacts caused by the SEM preparation procedures. They also suggested that *Zingiber* belongs to a group of pollen having a pollen wall offering an infinite number of germination sites. A recent SEM study by Vasantha (2009) on South Indian *Zingiber* suggests the occurrence of aperture-like structures or furrows on the pollen wall. But the present SEM study doesn't support the occurrence of any aperture-like regions on pollen wall depressions are seen on some parts of pollen in various taxa but it was not found in all grains we have observed. While germination, the pollen wall ruptures and the pollen tube comes out through the pore.

Results

Key to the species

1. Pollen grains spherical with cerebroid sculpturing 2
1. Pollen grains ellipsoid with spirostriate sculpturing 9
2. Muri wringled...3
2. Muri pebble-like **4**
3. Ridges on the pollen as tri-radiate mark, muri narrow and diffused or not prominent… ....**14. *Z. neotruncatum* var. *neotruncatum***
3. Ridges absent, muri broad and prominent. ....**15. *Z. neotruncatum* var. *ramsawmii***
4. Lumen absent or very narrow...**5**
4. Lumen 1.3 to 1.6 µm wide **7**
5. Pollen size 50 to 75 µm **6**
5. Pollen size 80 to 95 µm .... **21. *Z. zerumbet***
6. Muri Size 1 to 2 µm..**16. *Z. officinale***
6. Muri size 3 to 7 µm ....**18. *Z. purpureum***
7. Puncta absent **8**
7. Puncta present..**4. *Z. capitatum***
8. Ridge is present between the distal and proximal half ....**6. *Z. clarkei***
8. Ridge absent .... **10. *Z. kerrii***
9. Muri ribbon-shaped .... **13. *Z. murlenica***
9. Muri noodle-shaped...**10**
10. Pollen length greater than 100 µm..**11**
10. Pollen length less than 90 µm...**18**
11. Muri frequently branched ....**9. *Z. kangleipakense***
11. Muri Occasionally branched...**12**
12. Cap-like structure at both ends **14**
12. Cap absent or present at one lateral end **13**

13. Muri obliquely oriented from one lateral end to other .... **8. *Z. dimapurense***
13. Muri straight .... **20. *Z. rubens***
14. Pollen both end tapering **15**
14. Pollen both end broad or one end tapering **16**
15. Ridge along the polar axis .... **12. *Z. mizoramensis***
15. Ridge absent .... **19. *Z. roseum***
16. Pollen both lateral ends broad or rounded .... **7. *Z. cornigerum***
16. Pollen one lateral end broad and other tapering **17**
17. Muri widely arranged .... **17. *Z. pherimaense***
17. Muri closely arranged .... **1. *Z. arunachalensis***
18. Branching of muri frequent .... **2. *Z. bipinianum***
18. Branching of muri occasional **19**
19. Lumen narrow .... **5. *Z. chrysanthum***
19. Lumen wide **20**
20. Muri margin rough and closely placed .... **3. *Z. campanulatum***
20. Muri margin smooth and widely placed .... **11. *Z. meghalayense***

1. *Zingiber arunachalensis*: Pollen grains are ellipsoidal, with a cap at both ends in some pollens one end is tapering towards the end the other end is somewhat Spheroidal. Size of the grain, 116.5–165.7 × 52.6–57.9 µm, exine 1.8 µm, hyaline and ornamentation spiro-striate, with prominent muri and lumen, muri slightly wavy, noodle-shaped, parallel arranged, branching absent, obliquely oriented from one lateral end to the other, converging into a cap at both ends. Muri 85.2–112 × 2–2.24 µm thick and lumen parallel, 2.20–2.79 µm. exine got distorted or shed when desiccated and maintains the original shape when hydrated. Intine is nearly hyaline, 1.6 µm thick. Aperture and puncta are absent. **Fig. 65 A & B**

2. *Zingiber bipinianum*: Pollen grains are sub-spheroidal to ellipsoidal and inaperturate with a cap at one end. Equatorial diameter 80.5–90 µm. Exine is very thin 1.5 µm thick. Intine thick 3–5 µm. Ornamentation is spiro-striate, with closely packed muri and very narrow lumen, muri noodle shaped, parallel arranged, frequently branched, obliquely oriented from one lateral end to the other, converging into a cap at one end. Muri 2.45–2.62 µm thick, lumen very narrow and irregular.

Fig. 65 C & D

3. *Zingiber campanulatum*: Pollen grains are ellipsoidal, with a cap at both ends. tapering towards both ends. Size of the grain 111–113 × 48.47–49.90 µm, exine 1.6 µm, hyaline and ornamentation spiro-striate, with prominent muri and lumen, muri noodle-shaped, parallel arranged, margin not smooth, occasionally branched, obliquely oriented from one lateral end to the other, converging into a cap at both ends. Muri 2.06–3.05 µm thick and lumen parallel, 2.34–2.81 µm. exine got distorted or shed when desiccated and maintains the original shape when hydrated. Intine is nearly hyaline, 1.6 µm thick. Aperture and puncta are absent. **Fig. 65 E & F**

4. *Zingiber capitatum*: Pollen grains are spheroidal, more or less ovate in distal view. Equatorial diameter 64.93–76.64 µm. Aperture is absent. Exine is 2 µm thick, consists of an outer thin layer and ornamentation is cerebroid. Muri are compactly arranged and made up of pebble-like structures, length varies from 3.5–4.2 × 1.7 µm and puncta sparse, branching irregular and frequent. Lumen narrow, 1.3 µm and irregular. **Fig. 66 A & B**

5. *Zingiber chrysanthum*: Pollen grains are ellipsoidal, with a cap at both ends in some pollen one end is tapering towards the end the other end is hemi spherical. Size of the grain 114.6–119.4 × 52.57–56.43 µm. Exine 1.6 µm, hyaline and ornamentation spiro-striate, with prominent muri and lumen, muri slightly wavy, noodle-shaped, parallel arranged, occasionally branched, obliquely oriented from one lateral end to the other, converging into a cap at both ends. Muri 25.2–28.6 × 1.8–1.9 µm thick and lumen parallel, 1.4–1.5 µm. some crystal-like structures are present in the lumen. Intine nearly hyaline, 1.8 µm thick. Aperture and puncta are absent. **Fig. 66 C & D**

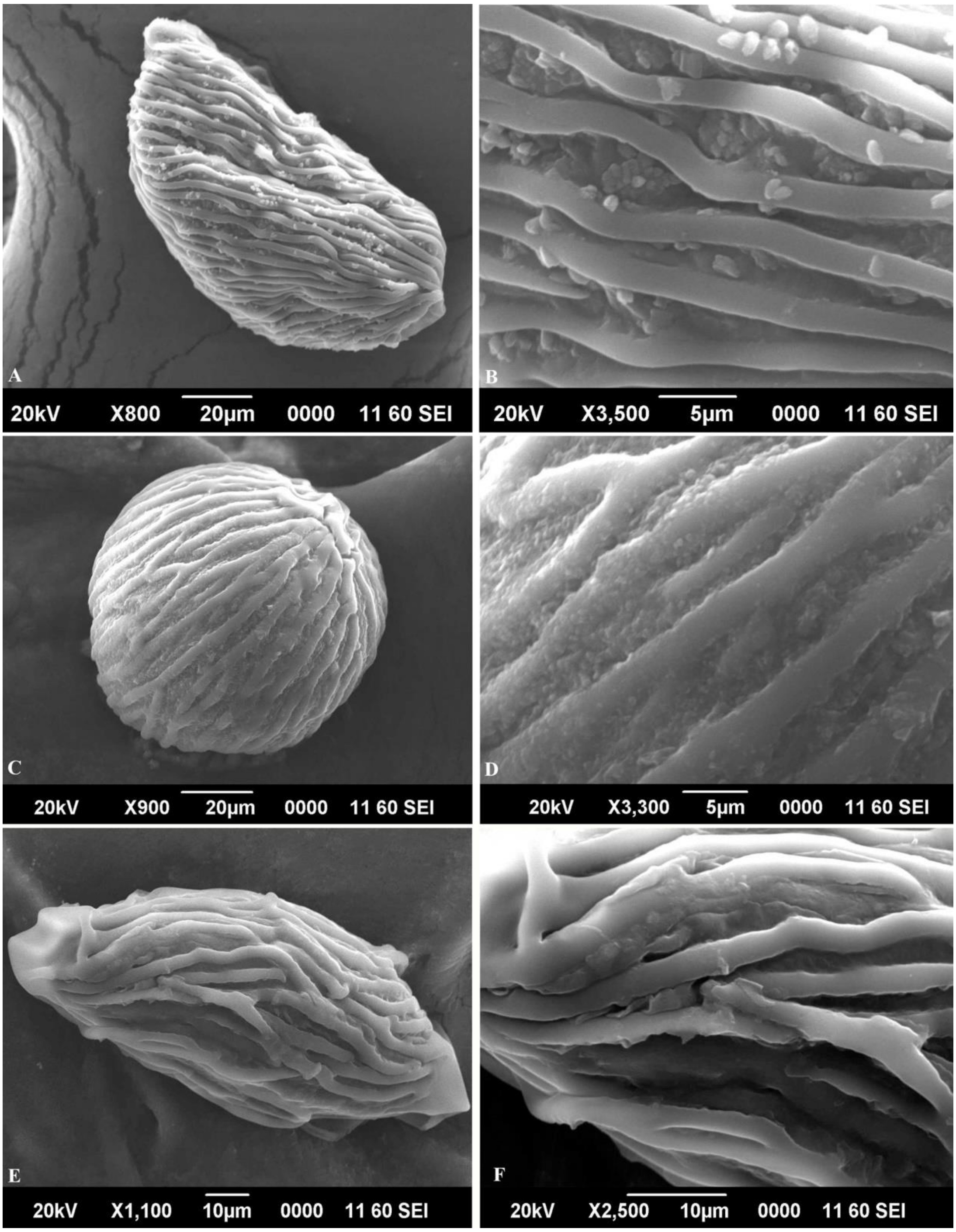


Fig. 65. Pollen granis of *Zingiber* sp.: A–B. *Z. arunachalensis*; **C–D.** *Z. bipinianum*; **E–F.** *Z. campanulatum.*

6. *Zingiber clarkei*: Pollen grains are Spheroidal in shape, A ridge is seen between the distal and proximal half. The equatorial diameter is, 46.3–52.7 µm, exine 1.2 µm consisting of an outer thin layer and ornamentation cerebroid, Muri and lumen present, Muri are compactly arranged, pebble-like and elongated ones are seen at the ridge. Length of muri ranges from 7.90–10.23× 2.10–3.21 µm, frequently and irregularly branched. Lumen is very narrow and irregular, 1.10–1.66 µm. Aperture and puncta are absent. **Fig. 66 E & F**

7. *Zingiber cornigerum*: The pollen grains are ellipsoid, with a cap at both ends, proximal and distal ends are not tapering somewhat rounded, inaperturate and with spiro-striate sculpturing, size of the pollen grains 122–155 × 47–80 µm, P/E ratio 1.78, muri are loosely and parallel arranged, noodle-shaped, occasionally branching, branching present only at proximal and distal ends, muri obliquely oriented from one lateral end to other and converging at both ends, 2.03–2.28 µm width. Lumen (between muri) broad, 4.14–5.20 µm width. **Fig. 67 A & B**

8. *Zingiber dimapurense*: Pollen grains are ellipsoid in shape, with a cap at one end and other end spheroidal in shape, inaperturate and with spiro-striate sculpturing, size of the pollen grains 120.3–148.20 × 49.27–55.64 µm, P/E ratio 2.6, muri are parallel arranged, noodle-shaped, occasionally branching, muri obliquely oriented from one lateral end to other and converging at both ends, 2.58–3.03 µm width. Lumen narrow, 2.10–2.20 µm width. **Fig. 67 C & D**

9. *Zingiber kangleipakense*: Pollen grains are ellipsoidal with both end tapering. Proximal end more tapering than distal end. Both lateral ends form a cap. Pollen size 122.30–140.62 × 50.32–54.73 µm. P/E ratio 2.56 ornamentation is spiro-striate, muri are noodle shaped, parallelly arranged and slightly obliquely oriented from one lateral end to the other, converging into a cap at both ends. They frequently bifurcate at the middle of the pollen grain and converge at two lateral ends with a narrow lumen. Average thickness of muri ranges from 2.27–2.37 µm. and lumen 2.68–3.83 µm. **Fig. 67 E & F**

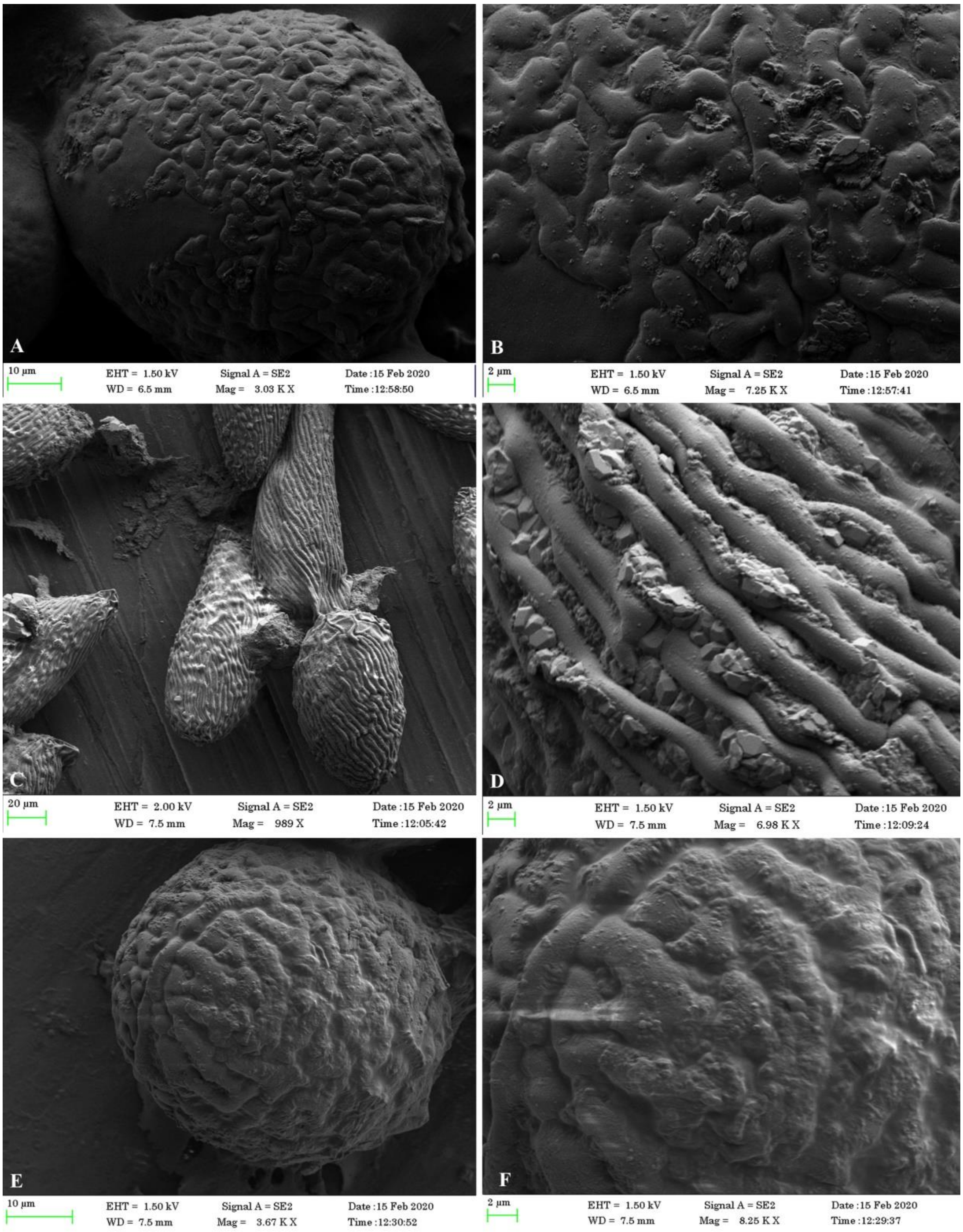


Fig. 66. Pollen granis of *Zingiber* sp.: A–B. *Z. capiatum*; **C–D.** *Z. chrysanthum*; **E–F.** *Z. clarkei.*

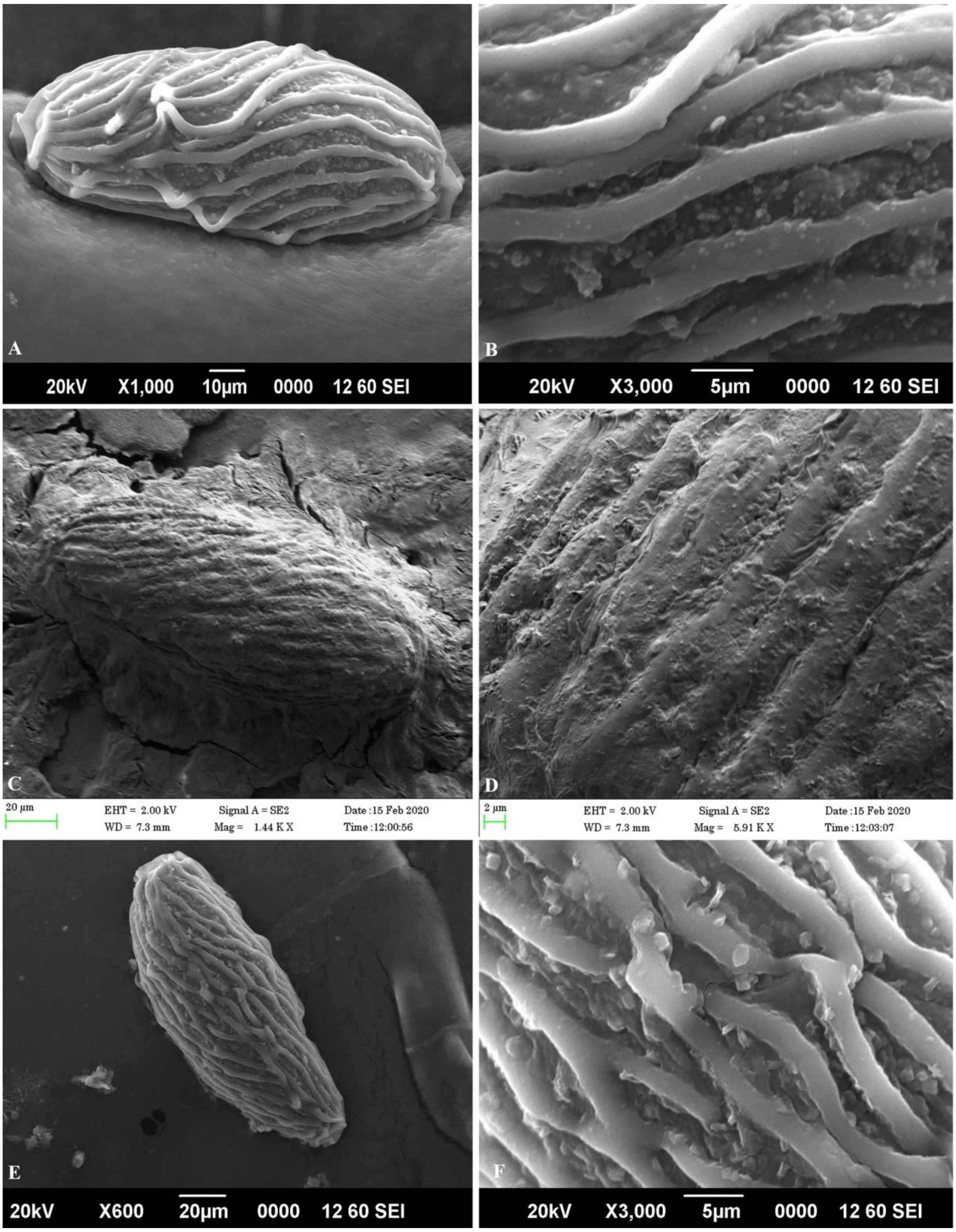


Fig. 67. Pollen granis of *Zingiber* sp.: A–B. *Z. cornigerum*; **C–D.** *Z. dimapurense*; **E–F.** *Z. kangleipakense.*

10. *Zingiber kerrii*: Pollen grains are sub-spheroidal. Equatorial diameter 85–87 µm. Aperture is absent. Exine is 1.9 µm thick, consists of an outer thin layer and ornamentation is intermediate type or sprio-straite to cerebroid, Muri are compactly arranged and frequently branched, muri form cap-like structure at the distal end of the grain. muri length varies from 14–25 µm and puncta absent, branching irregular and frequent. Muri 2.45–2.65 µm in width. Lumen narrow 1.3 µm and irregular.

Fig. 68 A & B

11. *Zingiber meghalayense*: Pollen grains are ellipsoidal, with a cap at both ends. Size of the pollen grain is 98.56–99 × 48–54.30 µm, exine 2.3 µm, nearly hyaline and ornamentation spiro-straite. Muri oriented from one lateral end to another, converging into a cap at each ends. Muri are widely arranged, occasionally branched and form a reticulate appearance in some areas. Muri 2.58–4.60 µm. Lumen in between muri is very wide, 2.58–4.60 µm and irregular. Intine hyaline, 2.58 µm thick, consists of an outer and an inner layer. **Fig. 68 C & D**

12. *Zingiber mizoramensis*: Pollen grains are ellipsoidal; both ends are tapering with a cap at both ends. Size of the grain 120.25–133.76 × 47.50– 50.59 µm, exine 1.8 µm, hyaline and ornamentation spiro-striate, with prominent muri and lumen, muri noodle-shaped, parallel arranged, occasionally branched, obliquely oriented from one lateral end to the other, converging into a cap at both ends. A prominent ridge is present along the polar axis, new branches are arising from the ridge and each branch again forms dichotomies. Muri 88.2–109 × 2.28–3.39 µm thick and lumen parallel, 3.71–4.05 µm. Intine nearly hyaline, 1.5 µm thick. Aperture and puncta are absent. **Fig. 68 E & F**

13. *Zingiber murlenica*: Pollen grains are ellipsoidal, with a cap at both ends. Size of the pollen grain is 127.54–137.20 × 50–59.21 µm, exine 1.93 µm, nearly hyaline and ornamentation spiro-straite. Exine got distorted or shed when desiccated in some areas and maintains the original shape when hydrated. Muri oriented from one lateral end to another, converging into a cap at each end. Muri are widely arranged, ribbon-shaped, occasionally branched, branching is irregular and forms a reticulate appearance in some areas. Muri 2.58–2.92 µm. Lumen in between muri is very wide, 3.46–5 µm and irregular. Intine hyaline, 2.2 µm thick, consists of an outer and an inner layer. **Fig. 69 A & B**

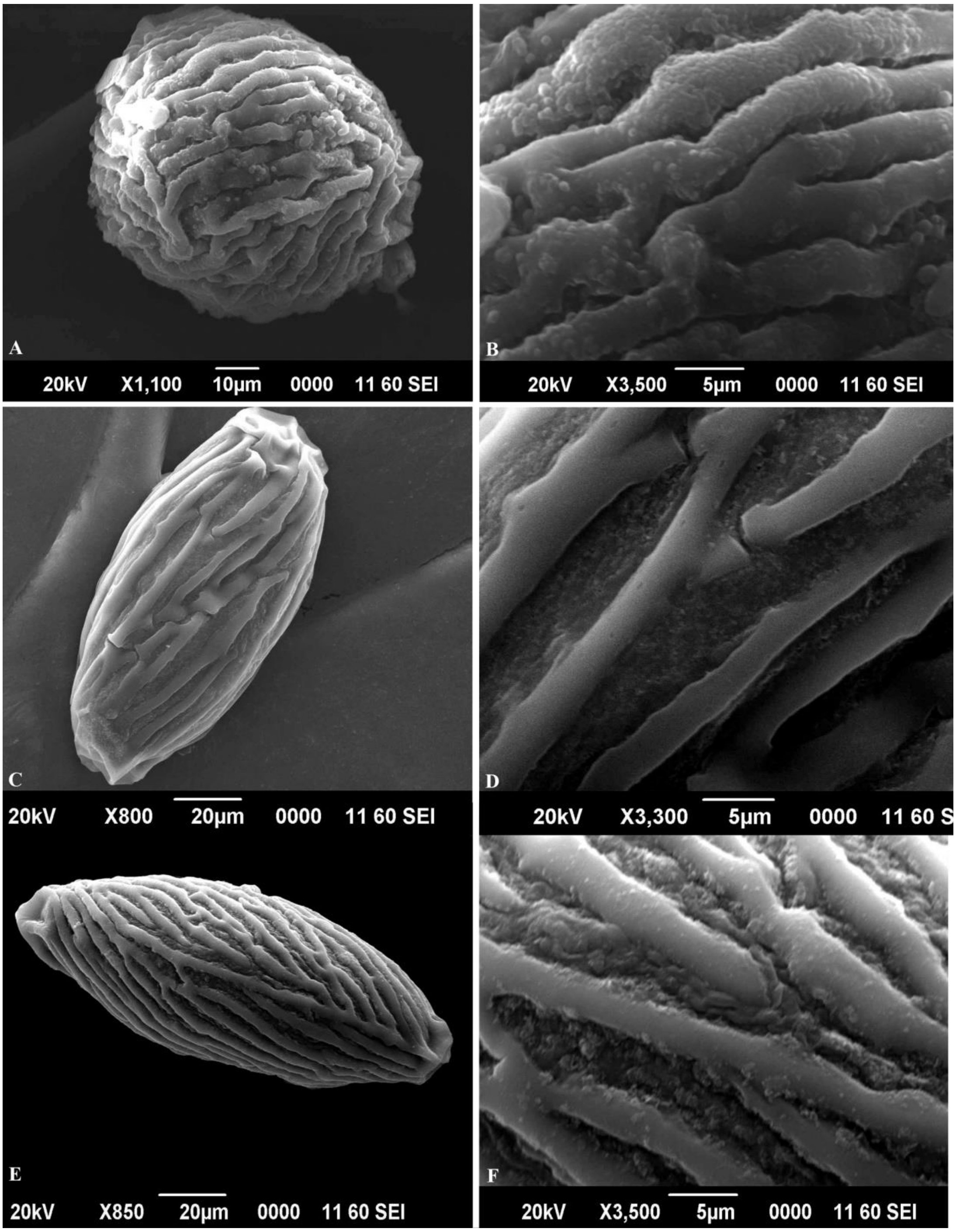


Fig. 68. Pollen granis of *Zingiber* sp.: A–B. *Z. kerrii*; **C–D.** *Z. meghalayense*; **E–F.** *Z. mizoramensis.*

14. *Zingiber neotruncatum* var. *neotruncatum*: Pollen grains are spheroidal. Equatorial diameter 68.21–71.09 µm. Aperture absent. Exine is 1.3 µm thick, consists of an outer thin layer and ornamentation is cerebroid, muri are very compactly arranged and, muri forms small cap-like projection at the distal end of the grain. muri length varies from 6–10 µm and puncta absent, muri 1.45–1.65 µm in width, wriggled in shape, an elongated and small pebble or spike-like muri is also there it gives a jackfruit like texture. Lumen very narrow and irregular.

Fig. 69 C & D

15. *Zingiber neotruncatum* var. *ramsawmii*: Pollen grains are spheroidal. Three ridges are seen as a tri-radiate mark along the polar axis of the grain. Equatorial diameter 66.75–68.99 µm. Aperture absent. Exine is 1.3 µm thick, consists of an outer thin layer and ornamentation are cerebroid, muri are very compactly arranged and much smaller than typical variety *Z. neotruncatum var. neotruncatum*, muri length varies from 2–6 µm and puncta absent, muri 0.8–0.9 µm in width, wriggled in shape, an elongated and small pebble or spike-like muri is also there it gives a jackfruit like texture. Lumen is very narrow and irregular. Small depressions are also present in some parts of the grain. **Fig. 69 E & F**

16. *Zingiber officinale*: Pollen grains are spheroid. Equatorial diameter 52–55 µm. Exine is thin, 1.5 µm thick forming a continuous layer. Ornamentation is cerebroid. Muri compactly arranged, sinuous, pebble-like or elongated, bifurcated in some areas, 6.43–22.87 × 3.18–4.26 µm and puncta sparse. Lumen is very narrow and irregular. Depressions are present on the grain. Exine is 2 µm thick; intine consists of an outer thick layer of 3 µm and an inner thin layer of 1.5 µm. **Fig. 70 A & B**

17. *Zingiber pherimaense*: Pollen grains are ellipsoidal, with a cap at both ends. Size of the pollen grain is 119.17–127.40 × 55.95–59.34 µm, exine 1.63 µm, nearly hyaline and ornamentation spiro-straite. exine got distorted or shed when desiccated in some areas and maintains the original shape when hydrated. Crystal-like structures are present on the surface. Muri oriented from one lateral end to another, converging into a cap at each end. Muri are widely arranged, noodle-shaped, occasionally branched, branching is dichotomous and branches converge at the opposite end. Muri 2.77–3.11 µm long. Lumen in between muri is very wide, 2.55–7.39 µm and irregular. Intine hyaline, 2.2 µm thick, consists of an outer and an inner layer. **Fig. 70 C & D**

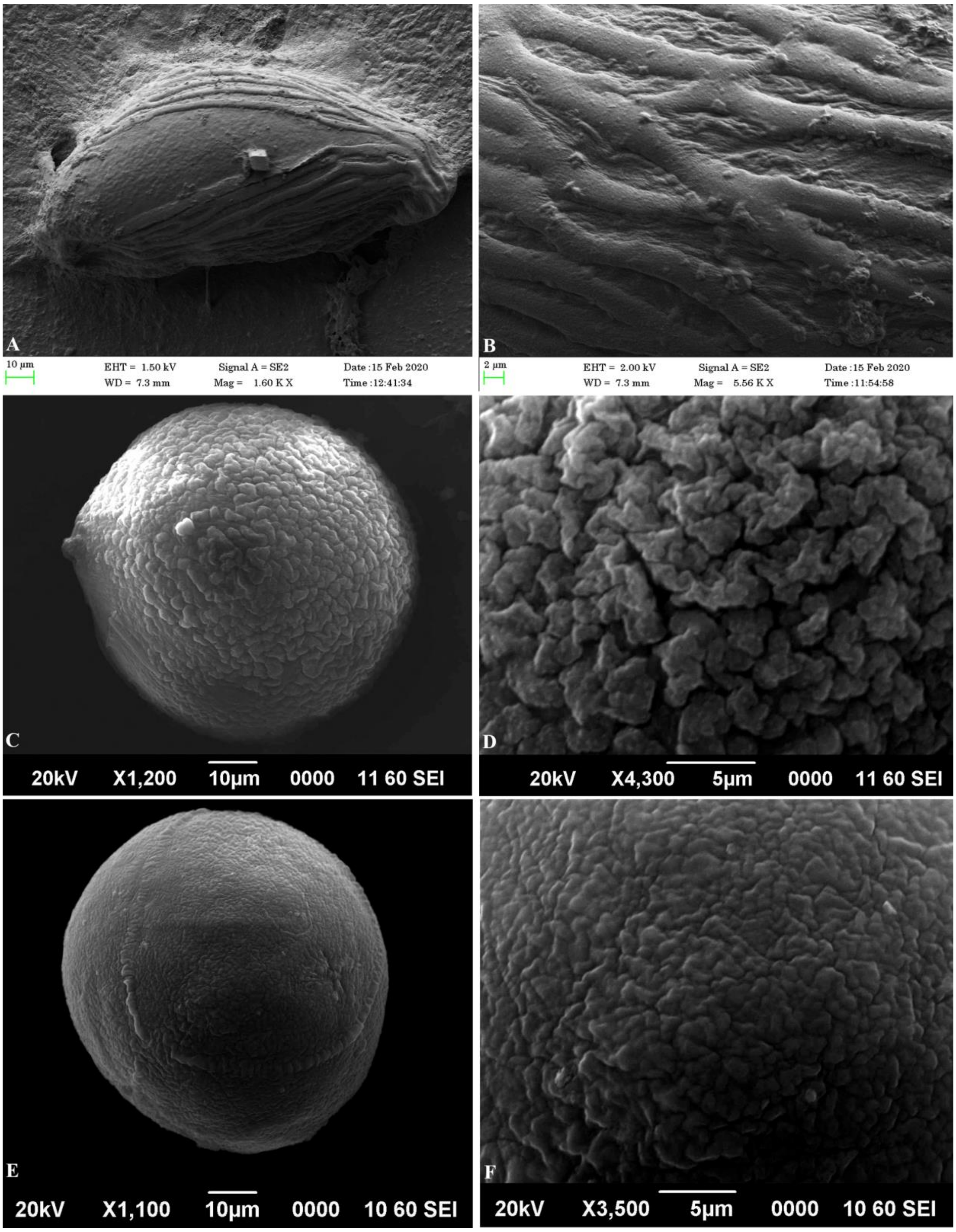


Fig. 69. Pollen granis of *Zingiber* sp.: A–B. *Z. murlenica*; **C–D.** *Z. neotruncatuum* var. *neotruncatum*; **E–F.** *Z. neotruncatuum* var. *ramsawmii.*

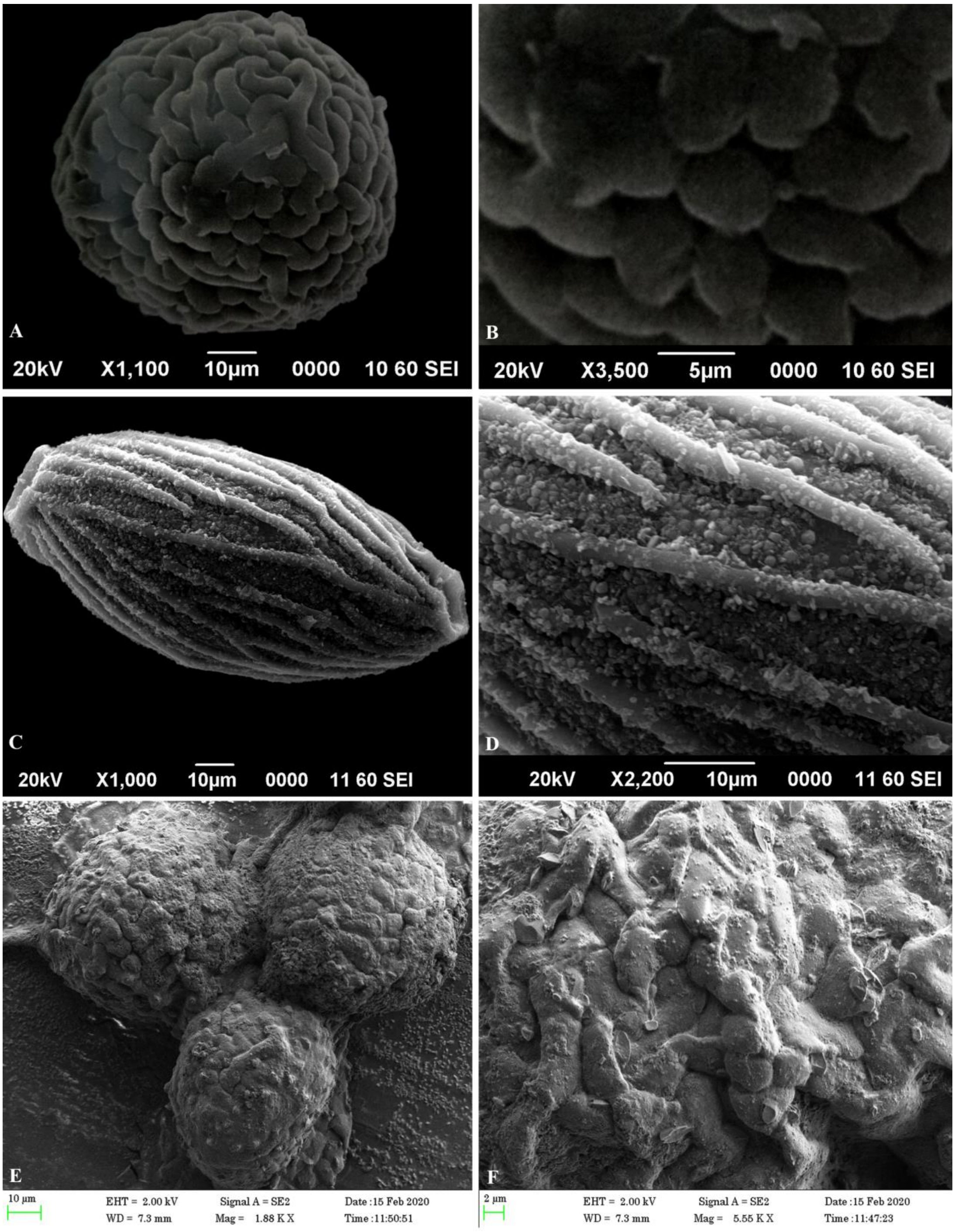


Fig. 70. Pollen granis of *Zingiber* sp.: A–B. *Z. officinale*; **C–D.** *Z. pherimaensе*; **E–F.** *Z. purpureum.*

18. ***Zingiber purpureum*****:** Pollen grains are spheroidal and inaperturate. Equatorial diameter 67.33–75.17 µm. Exine is very thin, 1.5 µm thick, Intine consists of two layers, outer 5 µm thick and inner 2–3 µm. Ornamentation is cerebroid. Muri are compactly arranged, not much prominent and made up of rectangular-shaped and pebble-like structures, length varies from 3.75–6.6 × 2.5–3.19 µm. Lumen is very narrow and irregular. Large depressions are seen on the pollen surface.

Fig. 70 E & F

19. ***Zingiber roseum*****:** Pollen grains are ellipsoidal with both end tapering. Proximal end more tapering than the distal end. Both lateral ends form a cap. Pollen size 125.43–135.72 × 48.42–4.83 µm. P/E ratio 2.47 ornamentation is spiro-striate, muri are noodle shaped, sinuous, parallelly arranged and slightly obliquely oriented from one lateral end to the other, converging into a cap at both ends. Occasionally branching. Average thickness of muri ranges from 2.32–2.89 µm. Lumen 2.58–3.45 µm. **Fig. 71 A & B**

20. ***Zingiber rubens*****:** Pollen grains are ellipsoidal or barrel-shaped, size of the pollen grain is 114.23–125.05× 55.04–59.40 µm, exine 1.43 µm, nearly hyaline and ornamentation spiro-straite. Exine got distorted or shed when desiccated in some areas and maintains the original shape when hydrated. Muri oriented straight from one lateral end to another. Muri are widely arranged, noodle-shaped, occasionally branched, branching is dichotomous and branches converge at the opposite end. Muri 3.51–4.28 µm. Lumen in between muri is wide, 2.21–3.49 µm and irregular. Intine hyaline, 2.3 µm thick, consists of an outer and an inner layer. **Fig. 71 C & D**

21. ***Zingiber zerumbet*****:** Pollen grains are spheroidal and inaperturate. Equatorial diameter 91.10–92.97 µm. Exine is very thin, 2 µm thick, Intine consists of two layers, outer 5 µm thick and inner 2–3 µm. Ornamentation is cerebroid. Muri are compactly arranged, not much prominent and made up of rectangular-shaped and pebble-like structures, length varies from 1.25–6.23 × 2.11–3.71 µm. Lumen is very narrow and irregular. Starch depositions are present on the pollen surface.

Fig. 71 E & F

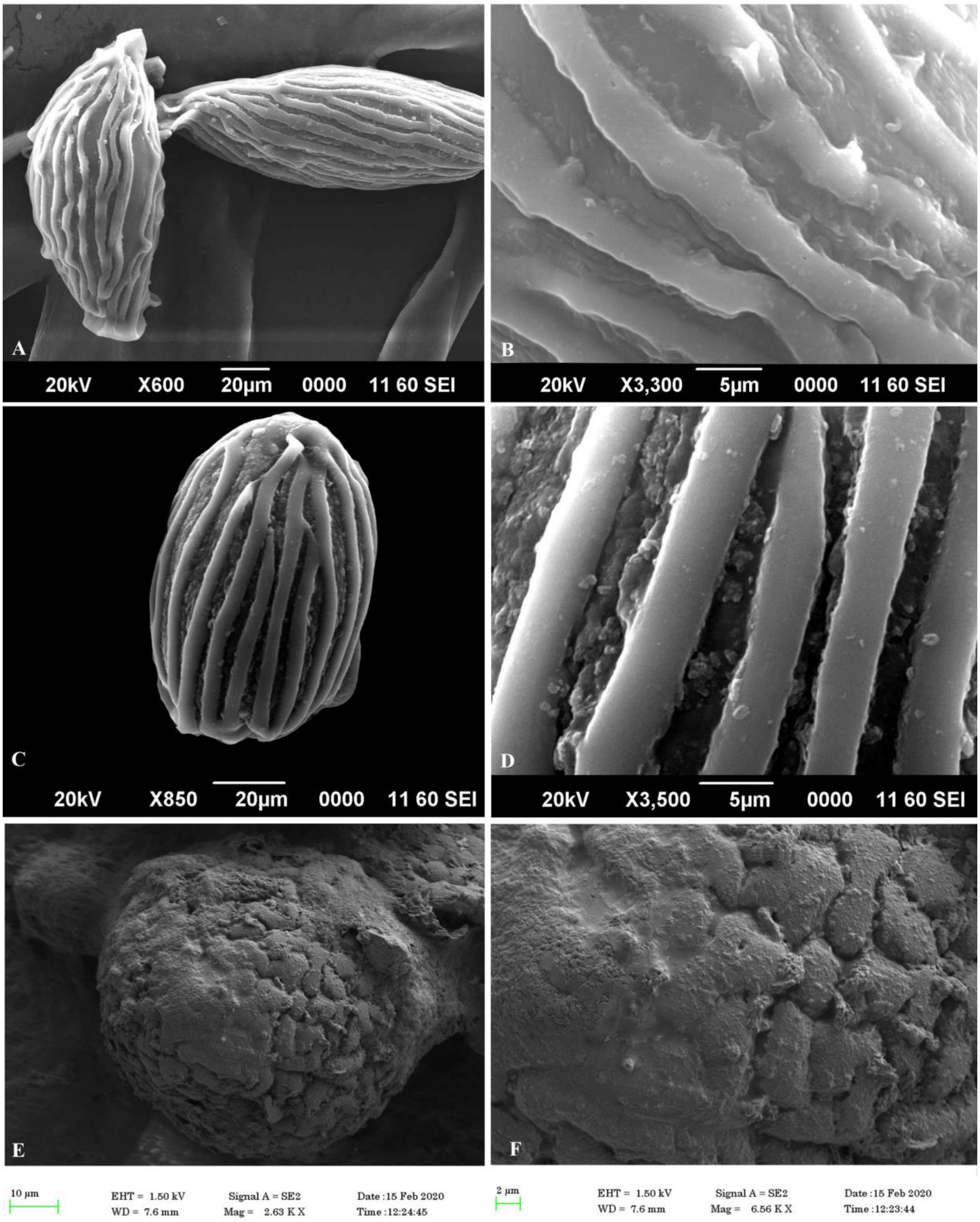


Fig. 71. Pollen granis of *Zingiber* sp.: A–B. *Z. roseum*; **C–D.** *Z. rubens*; **E–F.** *Z. zerumbet.*

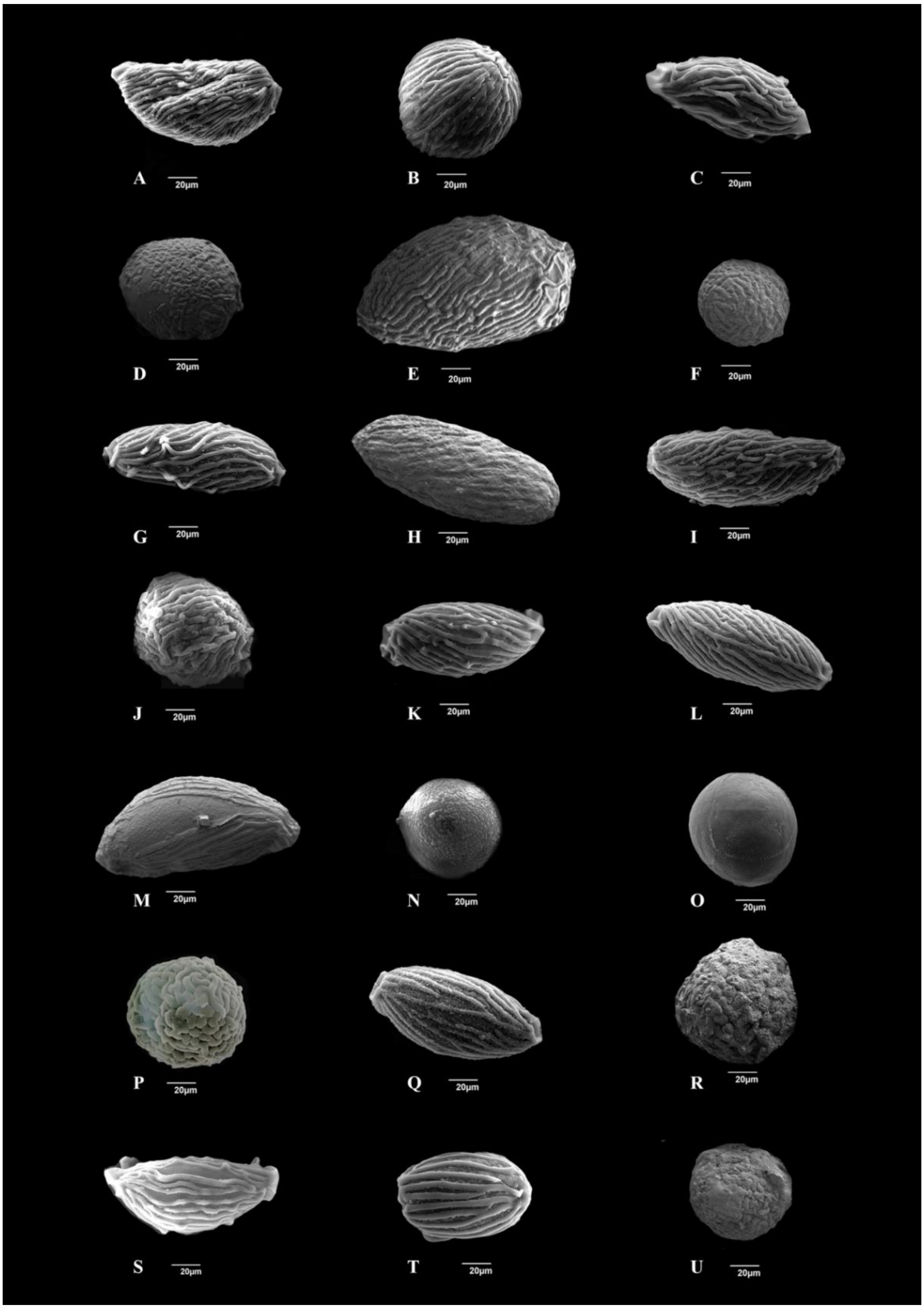


Fig. 72. Comparitive pollen morphology of genus *Zingiber*: A. *Z. arunachalensis*; **B.** *Z. bipinianum*; **C.** *Z. campanulatum*; **D.** *Z. capitatum*; **E.** *Z. chrysanthum*; **F.** *Z. clarkei*; **G.** *Z. cornigerum*; **H.** *Z. dimapurense*; **I.** *Z. kangleipakense*; **J.** *Z. kerrii*; **K.** *Z. meghalayense*; **L.** *Z. mizoramensis*; **M.** *Z. murlenica*; **N.** *Z. neotruncatum* var. *neotruncatum*; **O.** *Z. neotruncatum* var. *ramsawmii*; **P.** *Z. officinale*; **Q.** *Z. pherimaense*; **R.** *Z. purpureum*; **S.** *Z. roseum*; **T.** *Z. rubens*; **U.** *Z. zerumbet.*

Cluster analysis

The dendrogram derived from the palynological characters generated two main clades and the main clades were again sub-divided into sub-clades shown in **Fig. 73**. Clade I consists of *Z. arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. cornigerum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. pherimaense*, *Z. roseum* and *Z. rubens*. Clade I represents the Sect. *Cryptanthium* characterized by ellipsoidal pollen with spirostraite sculpturing. Clade II is represented by *Z. capitatum*, *Z. clarkei*, *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. kerrii*, *Z. officinale*, *Z. purpureum* and *Z. zerumbet* which represents Sect. *Pleuranthesis*, Sect. *Zingiber* and Sect. *Dymczewiczia* all of them are characterized by spherical pollen with cerebroid sculpturing.

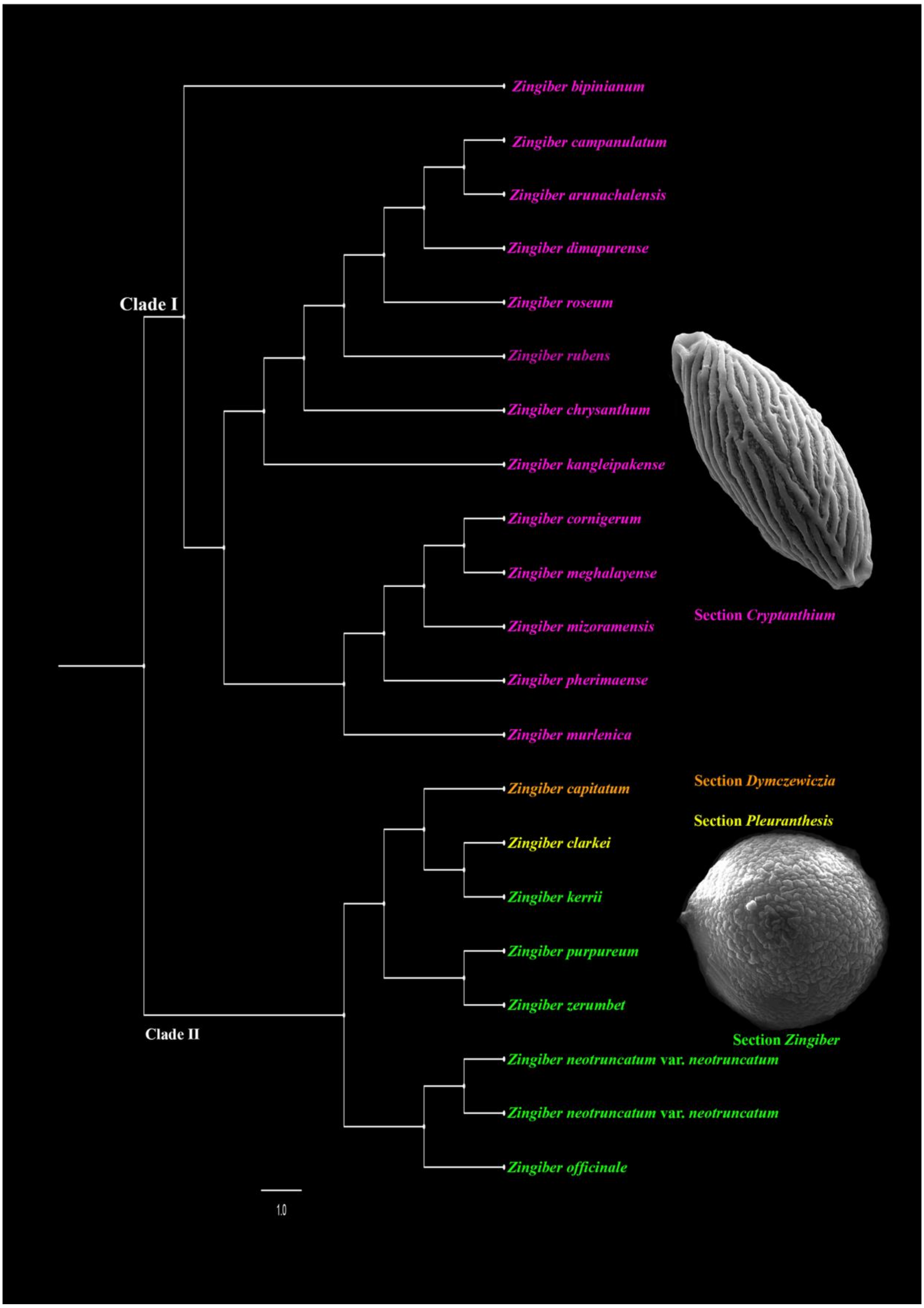


Fig. 73. UPGMA dendrogram of *Zingiber* sp. based on palynological characters.

Table 6. Comparison of palynological characters of genus *Zingiber*.

Characters	Shape	Srnamentation	Size (µm)	Muri size (µm)	Muri shape	Mrui branching	Lumen breadth (µm)
Zingiber arunachalensis	Ellipsoidal	Spiro-striate	116.5–165.7 × 52.6– 57.9	85.2–112 × 2–2.24	Noodle-shaped	Occasionally branched	2.20–2.79
Z. campanulatum	Ellipsoidal	Spiro-striate	111–113 × 48.47–49.90	89–115 × 2.06–3.05	Noodle-shaped	Occasionally branched	2.34–2.81
Z. bipinianum	Ellipsoidal	Spiro-striate	80.5–90	2.45– 2.62	Noodle-shaped	Frequently branched	Very narrow
Z. capitatum	Spherical	Cerebroid	64.93–76.64	3.5–4.2 × 1.7	Pebble-like	Irregular and frequent	1.3
Z. chrysanthum	Ellipsoidal	Spiro-striate	52.57–56.43 ×114.6– 119.4	25.2–28.6 × 1.8–1.9	Noodle-shaped	Occasionally branched	1.8
Z. clarkei	Spherical	Cerebroid	46.3–52.7	7.90–10.23× 2.10–3.21	Pebble-like	Irregular and frequent	1.10–1.66
Z. cornigerum	Ellipsoidal	Spiro-striate	122–155 × 47–80	2.03–2.28	Noodle-shaped	Occasionally branched	4.14–5.20
Z. dimapurense	Ellipsoidal	Spiro-striate	120.3–148.20 × 49.27–55.64	2.58–3.03	Noodle-shaped	Occasionally branched	2.10–2.20
Z. kangleipakense	Ellipsoidal	Spiro-striate	122.30–140.62 × 50.32–54.73	2.27–2.37	Noodle-shaped	Frequently branched	2.68–3.83
Z. kerrii	Spherical	Cerebroid	85–87	2.45– 2.65	Pebble-like	Frequently branched	1.3

Z. meghalayense	Ellipsoidal	Spiro-striate	98.56–115.48 × 48–54.30	2.58–4.60	Noodle-shaped	Occasionally branched	2.58–4.60
Z. mizoramensis	Ellipsoidal	Spiro-striate	120.25–133.76 × 47.50– 50.59	88.2–109 × 2.28–3.39	Noodle-shaped	Occasionally branched	3.71–4.05
Z. murlenica	Ellipsoidal	Spiro-striate	127.54–137.20 × 50–59.21	2.58–2.92	Ribbon–shaped	Occasionally branched	3.46–5
Z. neotruncatum* var. *neotruncatum	Spherical	Cerebroid	68.21–71.09	1.45– 1.65	Wriggled	Frequently branched	Very narrow
Z. neotruncatum* var. *ramsawmii	Spherical	Cerebroid	66.75–68.99	0.8– 0.9	Wriggled	Frequently branched	Very narrow
Z. officinale	Spherical	Cerebroid	52–55	1.2– 1.7	Pebble-like	Frequently branched	Very narrow
Z. pherimaense	Ellipsoidal	Spiro-striate	119.17–127.40 × 55.95–59.34	2.77–3.11	Noodle-shaped	Occasionally branched	2.55–7.39
Z. purpureum	Spherical	Cerebroid	67.33–75.17	3.75–6.6	Pebble-like	Frequently branched	Very narrow
Z. roseum	Ellipsoidal	Spiro-striate	125.43–135.72 × 48.42–54.83	2.32–2.89	Noodle-shaped	Occasionally branched	2.58–3.45
Z. rubens	Ellipsoidal	Spiro-striate	114.23–125.05× 55.04–59.40	3.51–4.28	Noodle-shaped	Occasionally branched	2.21–3.49
Z. zerumbet	Spherical	Cerebroid	91.10–92.97	1.25–6.23	Pebble-like	Frequently branched	Very narrow

Discussion

A previous study by Vasantha (2009) supports the role of pollen as a useful character for identifying and classifying the genus *Zingiber* in South India at the interspecific level, the present study describes the pollen morphology of 21 taxa from North East India also supports the use of pollen characters for species-level delimitation. Characters like length, breadth, shape and branching pattern, the orientation of muri, arrangement of muri, the shape of lateral ends, presence or absence of puncta, presence of ridge and depressions on pollen, etc. can be used as diagnostic characters and tools for species-level delimitation.

We have recognized two broad groups based on the pollen micro-morphology viz. ellipsoidal pollens and spheroidal pollen-bearing plants. Both the groups show their distinct micro-morphological characters which are listed in the **Table 6.** Spheroidal pollens are found in *Z. capitatum*, *Z. clarkei*, *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. kerrii*, *Z. officinale*, *Z. purpureum*, *Z. zerumbet* and ellipsoidal pollens in ***Z.** arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. cornigerum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. pherimaense*, *Z. roseum* and *Z. rubens*. In spheroidal pollens, the exine ornamentation is cerebroid, whereas in ellipsoidal pollens it is spiro-straite. Pollen grains of *Zingiber* provide many characters that have diagnostic value so the morphological characters of pollen grains can be utilized for the delimitation of species.

The pollen characters can be utilized for the delimitation of infrageneric sections of the genus *Zingiber*. Baker (1892) recognized four infrageneric sections (1) Z. Sect. *Cryptanthium* Horaninow (1862), having a radical inflorescence with procumbent peduncle; (2) Z. Sect. *Zingiber* with long erect peduncle; (3) Z. Sect. *Pleuranthesis* Benth. characterized with a spike emerging through the leaf sheath and (4) Z. Sect. *Dymczewiczia* with a terminal inflorescence. Spheroidal grains with cerebroid sculpturing are the characteristic feature of section *Dymczewiczia* and Sect. *Zingiber*. A previous study by Theilade *et al.* (1993) proposed the amalgamation of both Sect. *Dymczewiczia* and Sect. *Zingiber* based on the pollen characters. Our present study supports the proposal by Theilade as the pollen characters of both the sections are found to match.

Liang (1998) studied pollen morphology of Chinese *Zingiber*, placed pollen grains with spheroidal shape and cerebroid sculpturing in Section *Zingiber* and spiro-straite pollen grains in Sect. *Cryptanthium*.

Vasantha (2009) worked on the pollen morphology of South Indian *Zingiber*, placed pollen grains with spheroidal shape and cerebroid sculpturing in Sect. *Zingiber* and Sect. *Dymczewiczia* and plants with spiro-straite pollen grains in Section *Cryptanthium*

In *Z. arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. cornigerum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. pherimaense*, *Z. roseum* and *Z. rubens* the pollen grains are ellipsoidal with spiro-striate ornamentation. They are characterized by a spike with a procumbent short peduncle which is produced directly from the rhizome. In *Z. bipinianum*, pollen grain is sub-spheroidal to ellipsoidal this shape is an intermediate one which was not been reported in any other *Zingiber* sp. so far. These taxa included under Sect. *Cryptanthium*.

The pollen grains are spheroidal with cerebroid sculpturing in *Z. capitatum*, *Z. clarkei*, *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. kerrii*, *Z. officinale*, *Z. purpureum* and *Z. zerumbet*. *Z. capitatum* comes under the Sect. *Dymczewiczia*, characterized by a terminal spike, which also shows cerebroid ornamentation. Recently *Z. flavofusiforme*, another member of the section was reported from Assam as a new distributional record to India, but we failed to collect the pollen samples, so excluded them from the study. *Z. clarkei* is the only representative of the Sect. *Pleuranthesis* characterized by inflorescence emerging through the leaf sheath and spheroidal pollen with cerebroid sculpturing. *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. kerrii*, *Z. officinale*, *Z. purpureum* and *Z. zerumbet* belong to the Sect. *Zingiber* in which spikes produced separately from the rootstock on more or less elongated peduncles, show pollen grains with cerebroid sculpturing.

Ellipsoidal grains show great variation in the pattern of arrangement of muri and lumen within different species and have important taxonomic value. Ellipsoidal grains are characterized by noodle-shaped muri which are obliquely oriented from one lateral end to the other and parallelly arranged but in *Z. rubens* muri is straightly oriented. Muri fuse to form a cap-like structure at both ends in most of the grains but in *Z. dimapurense* cap is present at one lateral end only and in *Z. rubens* cap is absent at both lateral ends.

Characters like the size of grains, thickness, branching pattern and packing of muri are found consistent among ellipsoidal grains. Largest pollens were observed in *Z. arunachalensis* (116.5–165.7 × 52.6–57.9 µm) and *Z. cornigerum* (122–155 × 47–80 µm) and the smallest was observed in *Z. bipinianum* (80.5–90 µm) and *Z. campanulatum* (111–113 × 48.47–49.90 µm). The thickness of muri ranges from 1.8–4.60 µm, the thickest muri was observed in *Z. meghalayense* with 2.58–4.60 µm and *Z. rubens* with 3.51–4.28 µm. The thinnest muri were found in *Z. chrysanthum* (1.8–1.9 µm). Muri are closely packed in *Z. bipinianum* and *Z. chrysanthum* and widely placed in *Z. cornigerum*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis* and *Z. murlenica*. Muri are occasionally branched in all species of the section *Cryptathium* except in *Z. kangleipakense*. In ***Z.*** *arunachalensis* and *Z. roseum* muri are slightly wavy and in *Z. murlenica* the muri are ribbon-shaped. In *Z. mizoramensis* a prominent ridge is present along the polar axis of the pollen and new branches are arising from the ridge. Vasantha (2009) studied the pollen morphology of 4 species of the Sect. *Cryptanthium* and according to her Z. *nimmonii* is having closely arranged muri with prominent bracket-shaped, widely arranged branches and *Z. cernuum* is characterized by a sinuous, noodle-shaped muri which are obliquely oriented from one end to the other and lumen is wide and parallelly arranged. Muri are occasionally branched and closely arranged in *Z. wightianum*.

In spheroidal pollen grains, the largest pollen was observed in *Z. zerumbet* (91.10–92.97 µm) and *Z. kerrii* (85–87 µm) in *Z. kerrii* the sculpturing was an intermediate type (cerebroid to spiro-straite). The smallest grains were observed in

Z. clarkei (46.3–52.7 µm) and *Z. officinale* (52–55 µm) Vasantha (2009) noted a well distinct depression on all spheroidal grains but we could locate such depressions in *Z. neotruncatum* and *Z. purpureum* only. Muri of all spheroidal grains are very tightly packed, frequently branching, pebble-like and rectangular or triangular. In *Z. neotruncatum* var. *neotruncatum* and *Z. neotruncatum* var. *ramsawmii* the muri don't have any characteristic shape, they are wriggled structures and in Z. *neotruncatum* var. *ramsawmii* three ridges are seen as a tri-radiate mark along the polar axis of the grain. In *Z. officinale* and *Z. zerumbet* puncta are observed and are very sparse.

Walker (1976) regarded the large boat-shaped pollen grains as primitive and smaller globose forms as derived. But considering the molecular phylogeny of *Zingiber,* the Sect. *Cryptanthium* is the recently evolved Section and Sect. *Zingiber* and *Dymczewiczia* are evolved later. Sect. *Pleuranthesis* is the most primitive section and the rest are evolved from it so the spheroidal grains may be the primitive and larger ellipsoid pollens are advanced.

PHYTOCHEMISTRY

The rhizomes of 19 taxa of genus *Zingiber* were subjected to GC-MS headspace analysis. Out of the 19 taxa studied the volatile characterization of *Z. arunachalensis, Z. bipinianum, Z. campanulatum, Z. capitatum, Z. clarkei, Z. cornigerum, Z. dimapurense, Z. kangleipakense, Z. meghalayense, Z. mizoramensis* , *Z. murlenica, Z. kerrii, Z. neotruncatum* var. *ramsawmii* and *Z. pherimaensis* were previously not studied so this is the first report on the phytochemistry of these *Zingiber* spp. The GC-MS results show a wide range of chemical components in all the taxa studied. The volatile constituents were identified by comparison of their mass spectra and retention indices with those of standard samples and literature (Adams, 1989; Joulain & Koenig, 1998). All the rhizomes contain a complex mixture of chemical constituents. Altogether a total of 154 chemical constituents were identified. Among them, monoterpenes consist of the main proportion in all the taxa studied. Some of the compounds specifically occur in some species. **Table 7.** displays the specific compounds in plants and a **Table 8.** showing the major compound in each taxa studied. GC-MS chromatograms of all the studied samples are illustrated in **Fig. 75-93**. Plant descriptions based on volatile constituents were given below.

RESULTS

1. *Z. arunachalensis*: following 22 compounds were identified (98.85%). The major compounds are 4(10)-Thujene (45.39%), γ-Terpinene (15.35%), m-Cymene (9.32%), α-Pinene (7.29%) and Terpinene (6.37%). The minor compounds are α-Phellandrene (3.24%), Myrcene (1.99%), β-Pinene (1.63%), γ-Cadinene (1.28%), Camphene (1.07%). β-Elemene (0.79%), Terpinen-4-ol (0.36%), Terpinolene (0.35%), Fenchone (0.38%), trans-β-Ocimene (0.18%), Borneol (0.18%), α-selinene (0.19%), Myrtenol (0.09%), Fenchyl acetate (0.07%) and S)-(-)-citronellic acid methyl ester (0.06%). **Fig. 74**

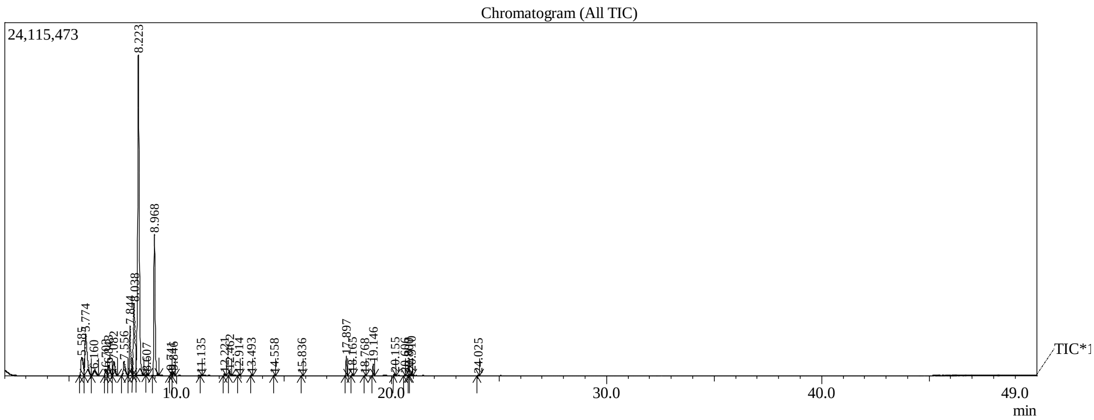


Fig. 74. Total ion chromatogram of *Z. arunachalensis*.

2. *Z. bipinianum*: following 22 compounds were identified (99.75%). The major compounds are m-Cymene (22%) Camphene (19.08%), 2-norbomanol 1,3,3 trimethyl aceto endo (12.32%), α- Pinene (11.98%), Limonene (10.20%), β-pinene (6.32%) and 3-Carene (5.22%). The minor compounds are Elemol (0.91%), β-Elemene (4.48%), β-Myrcene (1.70%) and Tricyclene (1.58%). α-Phellandrene (0.69%), 4(10)-Thujene (0.59%), γ-Cadinene (0.58%), β-Bisabolene (0.36%), Myrtenyl acetate (0.34%), Borneol (0.30%), trans-Pinocarveyl acetate (0.28%), β-Eudesmol (0.27%), Caryophellene (0.21%), 2-Methyl-6-methylene-2,7-octadien-4-ol (0.18%) and γ-eudesmol (0.16%). **Fig. 75**

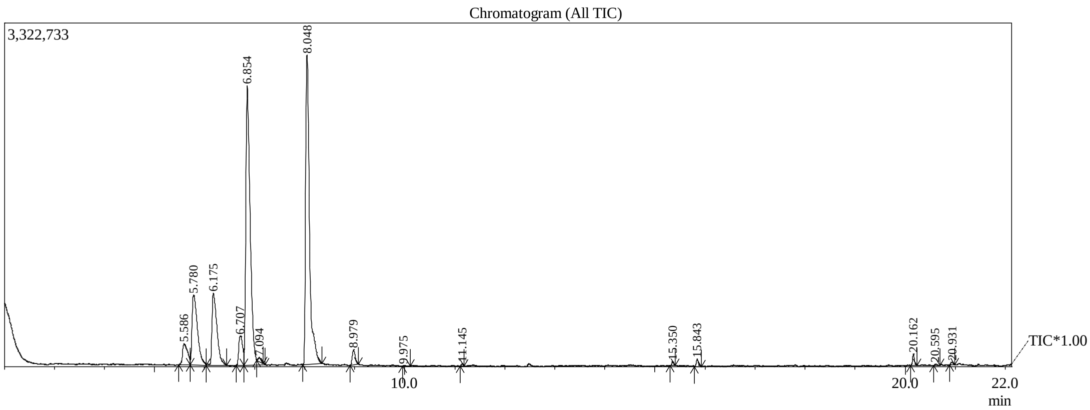


Fig. 75. Total ion chromatogram of *Z. bipinianum*.

3. *Z. campanulatum*: following 38 compounds were identified (99.20%). The major compounds are α-Pinene (22.19%), Menthene (17.86%), β-Pinene (11.01%), Camphene (11.01%), 2-Norbornanol, 1,3,3-trimethyl-,acetate, endo- (6.91%) and

Myrcene (6.16%). The minor compounds are α-Phellandrene (4.90%), β-Elemene (3.52%), Tricylene (2.00%), Linalool (1.81%), m-Cymene (1.40%), 2-Menthene (1.22%). γ-Terpinene (0.45%), Terpinolene (0.39%), 2-Norpinene (0.35%), 4,5-di-epi-Aristolochene (0.35%), trans-β-ocimene (0.29%), Sabinene hydrate (0.27%), δ-Selinene (0.17%), Valencene (0.15%) Lavandulyl acetate (0.13%), Borneol (0.12%), β-bisbolene (0.11%), cis-β-farnesene (0.09%), β-Gurjunene (0.08%), Terpinen-4-ol (0.08%), δ-Guaijene (0.06%), Zingiberene (0.06%) and Camphene (tr.). **Fig. 76**

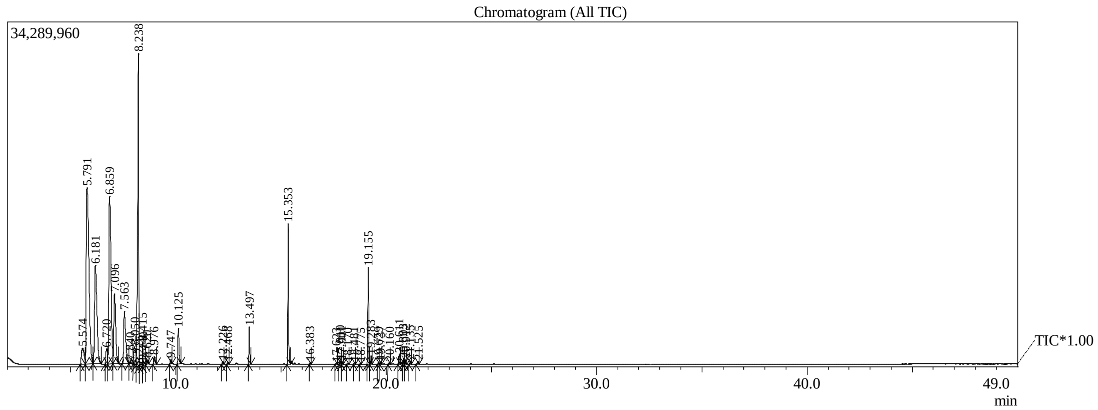


Fig. 76. Total ion chromatogram of *Z. campanulatum*.

4. *Z. capitatum*: A total of 32 compounds were identified (99.22%). The major compounds are α-Pinene (45.58%), β-Pinene (24.86%) and m-Cymene (7.35%). Minor compounds are Terpinolene (3.68%), 3-Carene (2.52%), Caryophyllene oxide (1.96%), δ-Cadinene (1.63%), d-Camphene (1.07%), cis-muurola-3,5-diene (1.02%), Linalool (0.89%), Isoledene (0.89%), Alloaromadendrene (0.86%), α-Cadinene (0.76%), α-Copaene (0.70%), Cadina-4,9-diene (0.66%), γ-Amorphene (0.60%), Caryophyllene (0.50%), β-Myrcene (0.42%), Fenchone (0.35%), Pinocarvone (0.35%), β-Guaiene (0.31%), 4(10)-Thujene (0.30%), α-Humulene (0.27%), T-muurolol (0.27%), α-Cubebene (0.24%), Carveol (0.22%), cis-verbenol (0.20%), β-Cubebene (0.20%), Germacrene-D (0.18%), Viridiflorol (0.16%), δ-Selinene (0.14%) and 1-Naphthalenol (tr.). **Fig. 77**

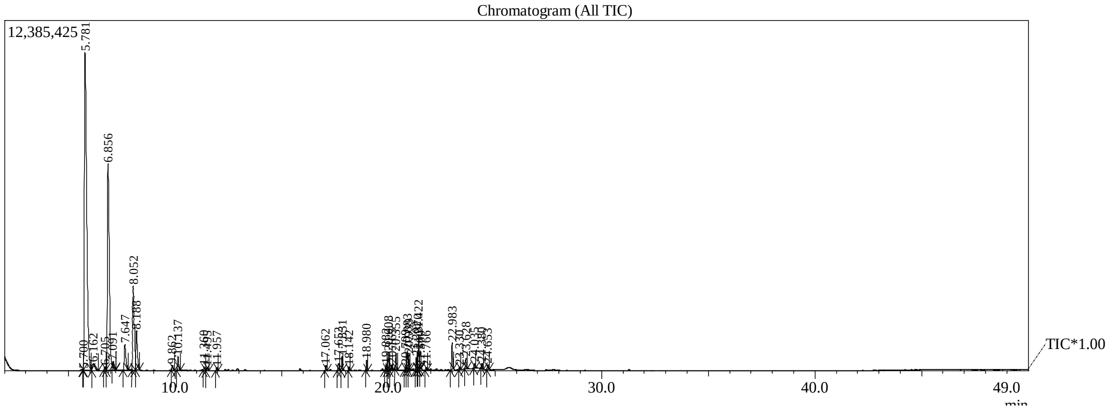


Fig. 77. Total ion chromatogram of *Z. capitatum*.

5. *Z. chrysanthum*: A total of 16 compounds were identified (98.96%). The major compounds are Linalool (27.40%), β-Myrcene (16.14%), α-Pinene (14.88%), O-Cymene (11.79%), α-Phellandrene (8.68%), Santolina triene (8.42%) and β-pinene (5.75%). Minor compounds are Camphene (2.19%), γ-Terpinene (1.09%). D-Limonene (0.75%), β-cis-Ocimene (0.70%), Terpinolene (0.39%), Borneol (0.35%), α-Copaene (0.21%), Isoborneol (0.13%) and β-Selinene (0.09%). **Fig. 78**

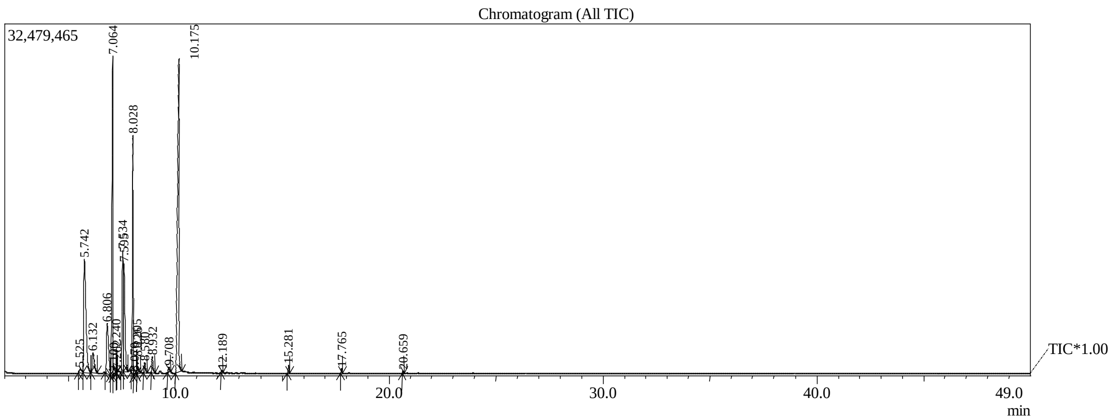


Fig. 78. Total ion chromatogram of *Z. chrysanthum*.

6. *Z. clarkei*: A total of 26 compounds were identified (97.95%). The major compounds are 4(10)-Thujene (34.48%), β-pinene (32.67%), α-Pinene (9.98%) and Citral (5.56%). The minor compounds are m-Cymene (2.91%), Terpinen-4-ol (2.85%), γ-Terpinene (2.24%), Linalool (2.01%), Limonene (1.25%). α-Phellandrene (0.98%), Myrcene (0.66%), Nerol (0.54%), α-Terpinene (0.48%), Terpinolene (0.35%), α-Gurjunene (0.17%), Pentadecane (0.13%), β-Elemene (0.13%), 4-

Thujanol (0.08%), Ocimene (0.07%), Tetradecane (0.07%), α-Terpineol (0.07%), Verbenol (0.06%), Germacrene D (0.05%), Hexadecane (0.04%), Citronellal (0.04%) and γ-Elemene (0.03%). **Fig. 79**

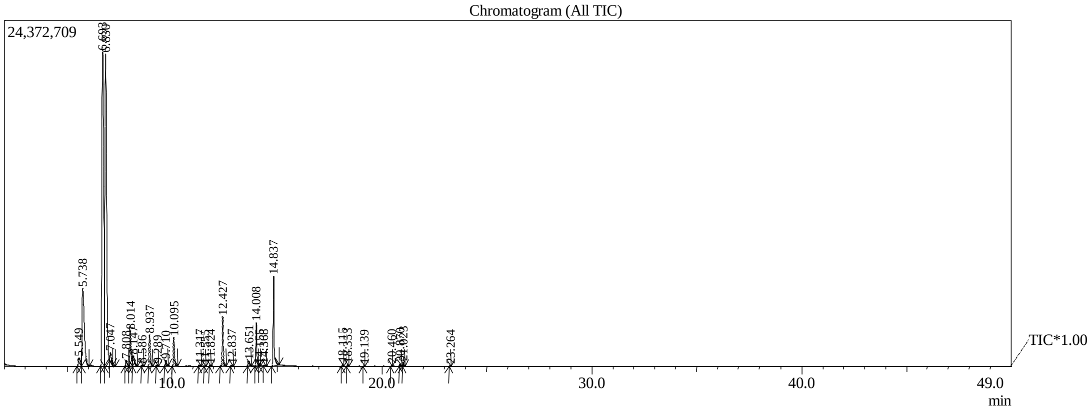


Fig. 79. Total ion chromatogram of *Z. clarkei*.

7. *Z. cornigerum*: following 15 compounds were identified (98.73%) and the major compounds, β-Pinene (35.07%), m-Cymene (34.37%), α-Pinene (10.76%) and Camphene (10.22%). The minor compounds are Menthene (3.25%), α-Phellandrene (3.10%), γ-Terpinene (1.28%), Myrcene (0.28%), Borneol (0.22%), 1-chloro octadecane (0.18%) and α-Gurjunene (tr.). **Fig. 80**

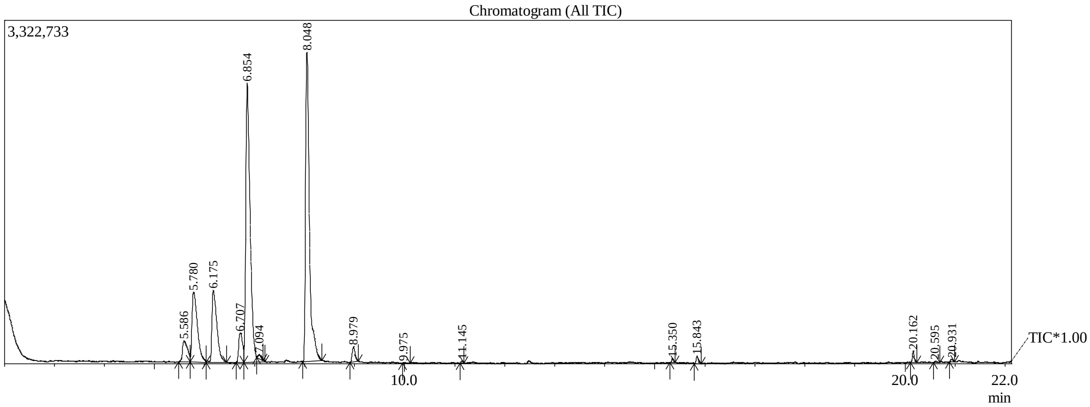


Fig. 80. Total ion chromatogram of *Z. cornigerum*.

8. *Z. dimapurense*: A total of 14 compounds were identified (99.21%). The major compounds are α-Pinene (28.44%), 4(10)-Thujene (21.81%), d-Camphene (17.33%), 3-Carene (10.06%), β-Pinene (8.89%) and Borneol (5.30%). The minor compounds are β-Myrcene (2.96%), m-Cymene (2.56%), β-Ocimene (0.79%), Linalool (0.46%), 4,5-di-epi-aristolochene (0.28%), γ-Terpinene (0.17%), Alloaromadendrene (0.09%) and Valencene (0.07%). **Fig. 81**

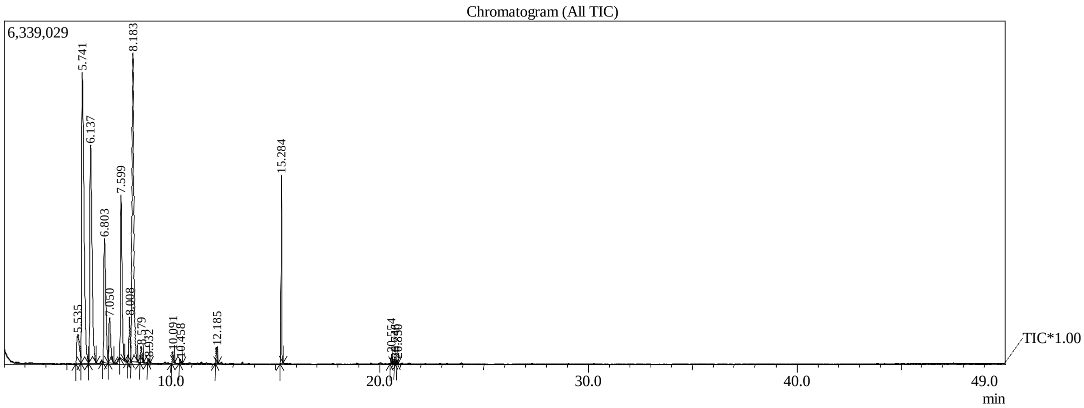


Fig. 81. Total ion chromatogram of *Z. dimapurense*.

9. *Z. kangleipakense*: A total of 19 compounds were identified (87.95%). The major compounds are Tetrapentacontane (38.59%), Geranyl-α-terpinene (15.82%), Humulene oxide II (9.66%) and Cubedol (5.25%). The minor compounds are Caryophyllene oxide (4.41%), Oplopanone (2.44%), α-Muurolol (1.79%), α-Humulene (1.62%), Phenol, 2,4-bis(1,1-dimethylethyl) (1.23%), Heptadecane (1.02%). Aristolene epoxide (0.84%), Hexadecane (0.78%), 1-pentadecane (0.75%), Geranyl linallol (0.68%), 1-Nonadecane (0.64%), β-Selinene (0.61%), 1-Tetradecanol (0.59%) and α-Copaene (0.58%). **Fig. 82**

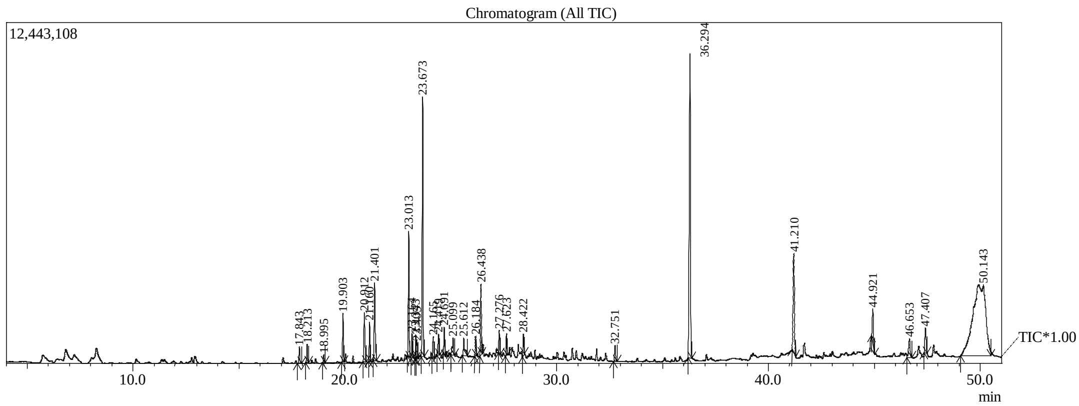


Fig. 82. Total ion chromatogram of *Z. kangleipakense*.

10. *Z. kerrii*: A total of 21 compounds were identified (95.87%), The major compounds are α-Pinene (45.58%), β-Pinene (24.86%) and p- Cymene (7.35%).

Minor compounds are trans-1-Isopropenyl-4-methylcyclohexane (3.68%), 3-Carnene (2.52%), δ-cadinene (1.63%), Caryophyllene oxide (1.36%), cis-Muurola-3,5-diene (1.02%), Camphene (1.07%), Isoledene (0.89%), Linalool (0.89%), Alloaromadendrene (0.86%), α-Murolene (0.76%), α-Copanene (0.70%), γ-Muurolene (0.60%), Caryophellene (0.50%), α-Muurolene (0.46%), Myrcene (0.42%), Fenchol (0.35%), 4(10)-Thujene (0.30%) and Limonene (0.07%) **Fig. 83**

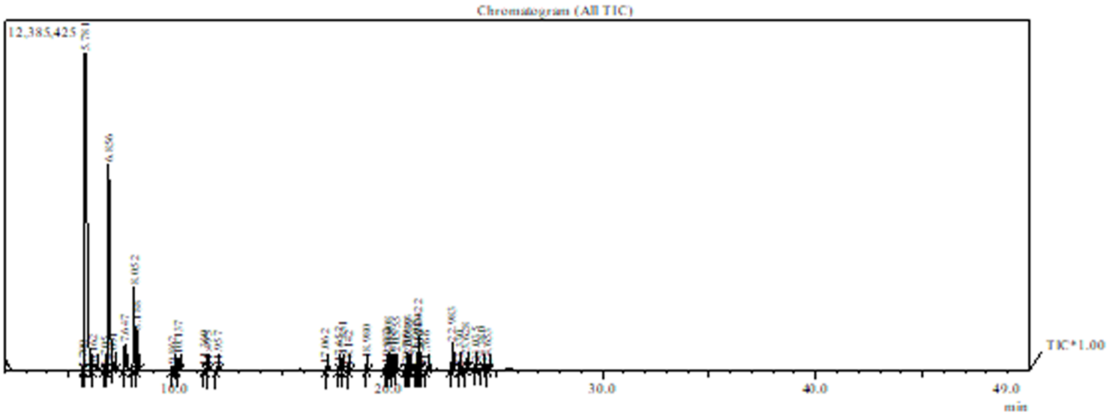


Fig. 83. Total ion chromatogram of *Z. kerrii*.

11. *Z. meghalayense*: following 13 compounds were identified (99.37%) and the major compounds are Linolyl acetate (37.49%), Linalool (29.09%), 2-Menthene (11.92%), β-Pinene (11.48%) and α-Pinene (5.22%). The minor compounds are β-Myrcene (0.98%), Nerolidol (0.48%), trans-Pinocarveyl acetate (0.38%), α-Terpineol (0.35%), Geranyl acetate (0.31%), α-Phellandrene (0.27%), 2-Nonane (0.27%), Melonal (0.22%), m-Cymene (0.21%), cis-Geranyl acetate (0.19%), β-cis-Ocimene (0.11%) and γ-Terpinene (0.09%). **Fig. 84**

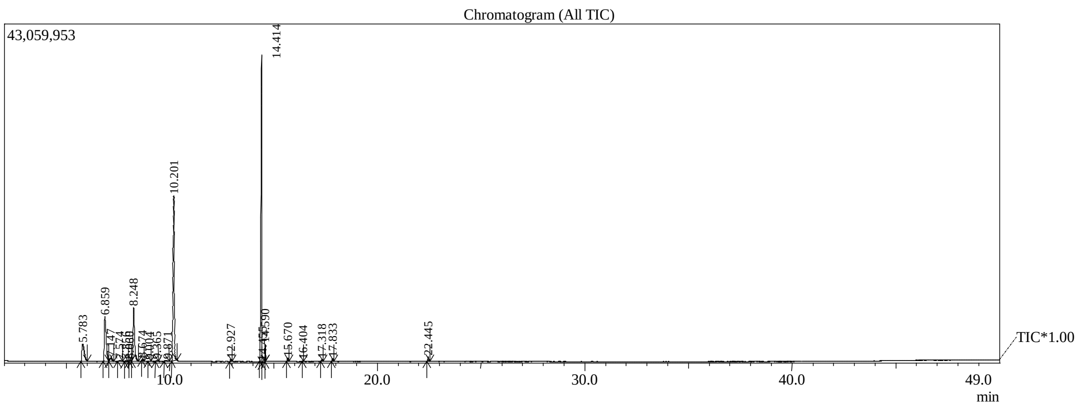


Fig. 84. Total ion chromatogram of *Z. meghalayense*.

12. *Z. mizoramensis*: following 21 compounds were identified (97.31%) and the major compounds are β-pinene (33.03%), α-Pinene (23.53%), 2-Menthene (10.65%), Camphene (7.97%) and Cyclohexane 2-ethenyl-1,1-dimethyl-3- methylene- (5.39%). The minor compounds are β-Elemene (2.61%), Linalool (2.29%), 2-Norbornanol, 1,3,3-trimethyl-,acetate, endo- (2.06%), 3-Carene (1.97%), 1-Decanol, 2-octyl- (1.69%), β-Myrcene (1.41%), Tricyclene (1.02%), Myristic acid (0.96%) and 9-Borabicyclo [3,1,1] nonane 9-[3-(dimethylamino)propyl]- (0.81%). **Fig. 85**

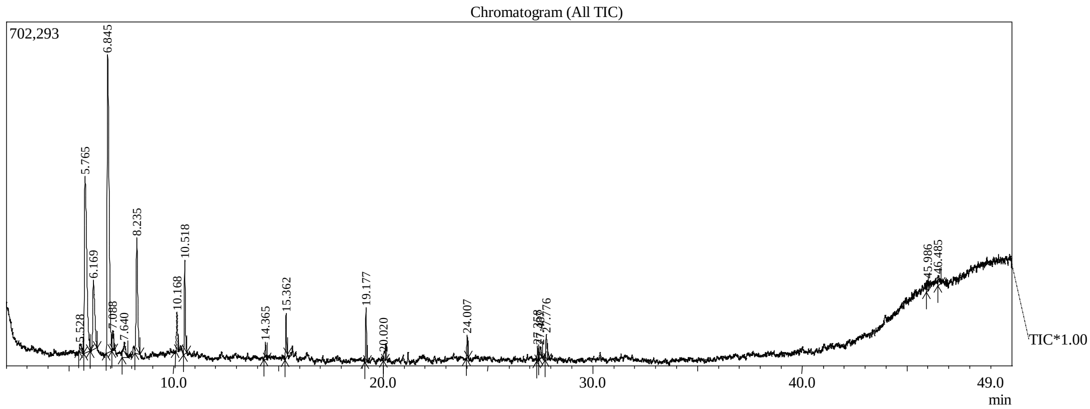


Fig. 85. Total ion chromatogram of *Z. mizoramensis*.

13. *Z. murlenica*: following 20 compounds were identified (100%) and the major compounds are β-pinene (36.18%), α-Pinene (19.87%), Eucalyptol (1,8-cineole) (13.49%) and m-Cymene (6.31%). The minor compounds are α-Humulene epoxide (4.41%), Limonene (3.97%), α-Humulene (3.17%), Caryophyllene oxide (2.51%), α-Copaene (1.89%), Caryophellene (1.19%), δ-cadinene (1.17%), Spathulanol (1.08%), Camphene (0.98%), Linalool (0.72%), Cubedol (0.65%), Aromandendrene (0.56%), γ-Murolene (0.41%), Germacrene D-4-ol (0.39%), β-Selinene (0.36%), α-Murolene (0.35%) and Bicyclo[3.1.0]hexane-6-methanol, 2-hydroxy-1,4,4-trimethyl- (0.34). **Fig. 86**

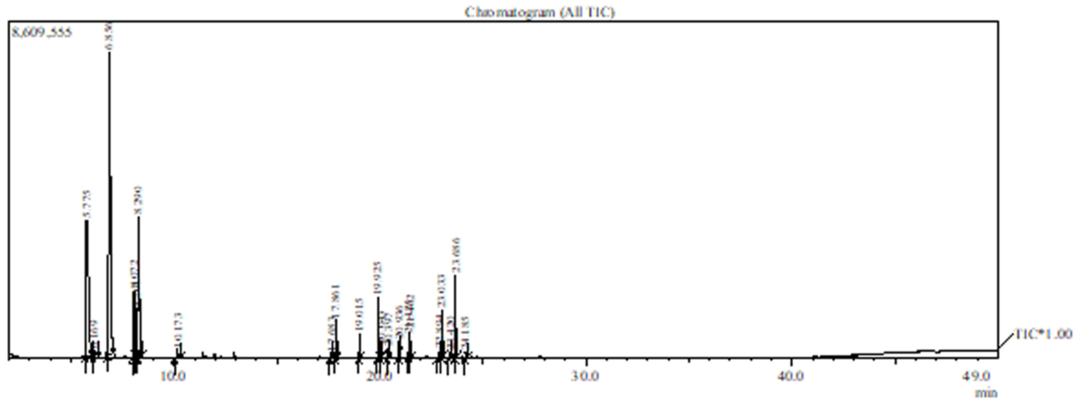


Fig. 86. Total ion chromatogram of *Z. murlenica*.

14. *Z. neotruncatum* var. *neotruncatm*: following 15 compounds were identified (100%) and the major compounds are Perillene (36.80%), Camphene (14.10%), α-Pinene (12.78%), Myrcene (7.70%) and (E)-Ocimene (5.64%). The minor compounds are Citral (4.91%), Limonene (3.72%), β-Pinene (3.00%), Eucalyptol (2.71%), (-)-Borneol (2.57%), Neral (2.18%), Heptadecane (1.63%), β-Selinene (1.03%), 8-Heptadecane (0.73%) and (1R)-(-)-Myrtenal (0.50%)

Fig. 87

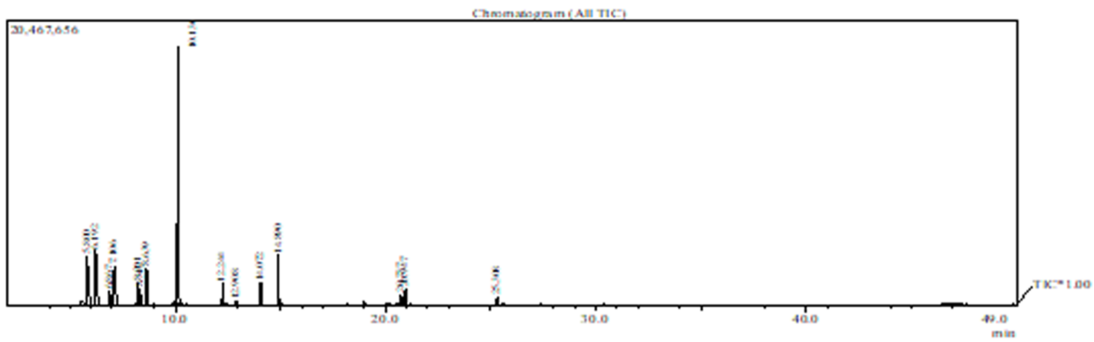


Fig. 87. Total ion chromatogram of *Z. neotruncatum* var. *ramsawmii*.

15. *Z. neotruncatum* var. *ramsawmii*: following 16 compounds were identified (97.88%) and the major compounds are Perillene (51.08%), α-Citral (11.94%), α-Pinene (7.49%) and Geraniol (7.15%). The minor compounds are β-Citral (3.77%), α-Famesene (2.59%), Eucalyptol (2.53%), β-trans-Ocimene (2.53%), Nerol (2.27%), β-Pinene (1.79%), Camphene (1.05%), Myrcene (1.03%), Borneol (0.79%), L-Limonene (0.70%), cis-Verbenol (0.65%) and trans-β-Famesene (0.52%). **Fig. 88**

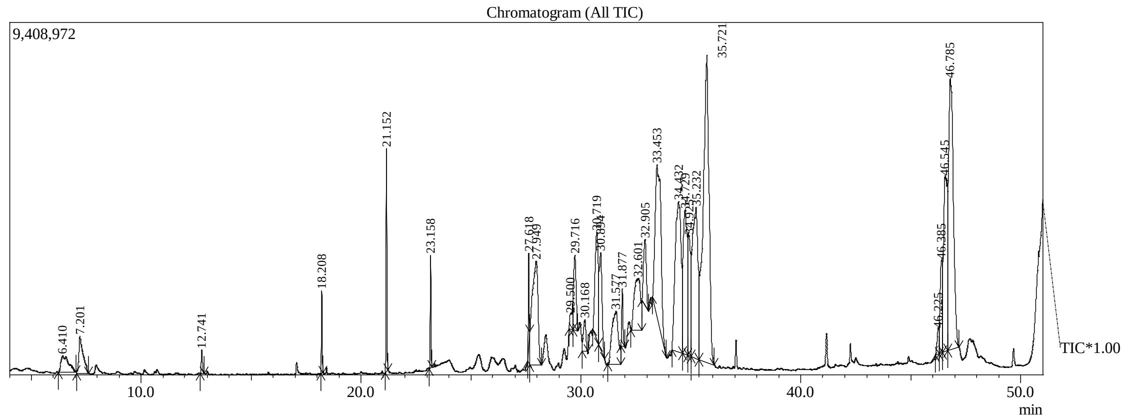


Fig. 88. Total ion chromatogram of *Z. neotruncatum* var. *ramsawmii*.

16. *Z. pherimaensis*: following 10 compounds were identified (92.95%) and the major compounds are Linalool (31.57%), β-pinene (30.70%) and α-Pinene (23.77%). The minor compound are Benzene methyl-4- isopropyl (2.82%), γ-Terpinene (1.39%), Germacrene-B (0.98%), Terpinolene (0.76%), 2-octyldecal-1-ol (0.47%), cyclopentanecarboxylic acid 2-(1-cyclohexene-1-yl) 1-methyl-5-oxo, m (0.27%) and 3-Carene (0.22%). **Fig. 89**

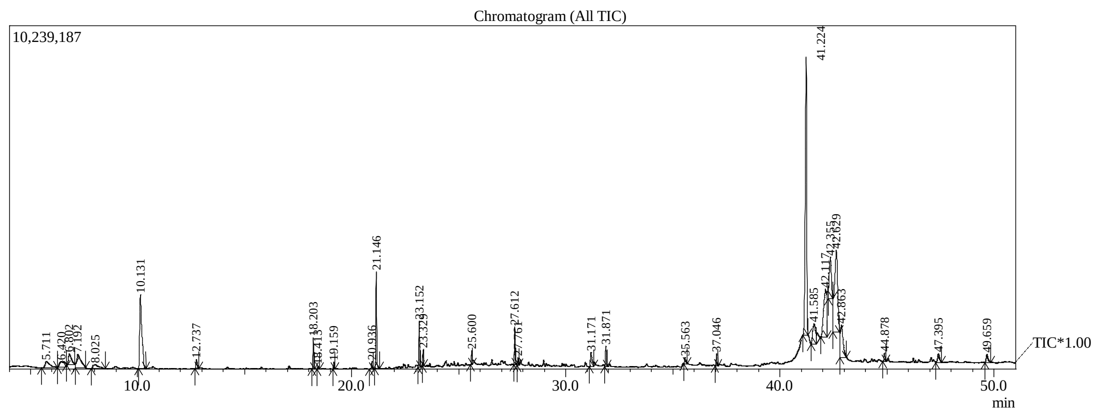


Fig. 89. Total ion chromatogram of *Z. pherimaensis*.

17. *Z. roseum*: following 14 compounds were identified (99.45%) and the major compounds are β-Pinene (65.96%), α-Pinene (18.79%) and Terpinolene (8.03%). The minor compounds are 3-Carene (1.48%), α-Copaene (1.46%), Caryophellene (1.15%) and m-Cymene (1.06%), β-caryophellene (0.45%), δ-Candinene (0.27%), Alloaromandendrene (0.22%), α-Murolene (0.17%), γ-Amorphene (0.16%), α-Humulene (0.15%) and Naphthalene (0.10%). **Fig. 90**

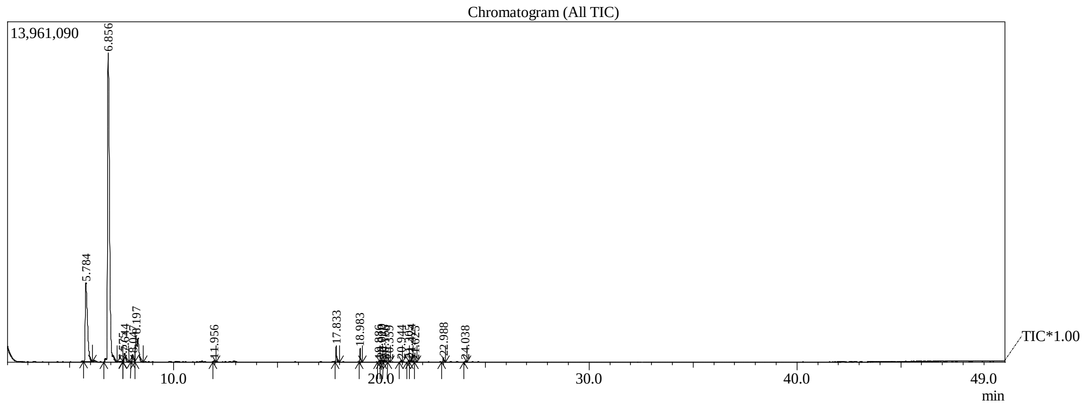


Fig. 90. Total ion chromatogram of *Z. roseum*.

18. *Z. rubens*: following 20 compounds were identified (98.95%) and the major compounds are α-Humulene (36.34%), Caryophellene (27.03%), Camphene (7.56%) and β-pinene (7.34%). The minor compounds are α-Pinene (4.14%), Benzene methyl-4-isopropyl (3.16%), δ-cadinene (2.79%), 3-Carene (2.79%), p-Menth-8-ene (1.61%), (-)-5-oxitricyclo[8,2,0,0(4,6) dodecane, 12-trimethyl-9-methylene-, [1R] (1.51%), Humulene epoxide II (1.06%), γ-Cadinene (0.73%), Spathulenol (0.52%), Calamenene (0.51%), 3-Nonanone (0.43%), Coapene (0.37%), Bicyclo[5,3,0]decane,2-methylene-5-(1-methyvinyl)-8-methyl- (0.37%), α-Gurjunene (0.36%), γ-Murolene (0.31%) and 1-Nonen-3-ol (0.25%). **Fig. 91**

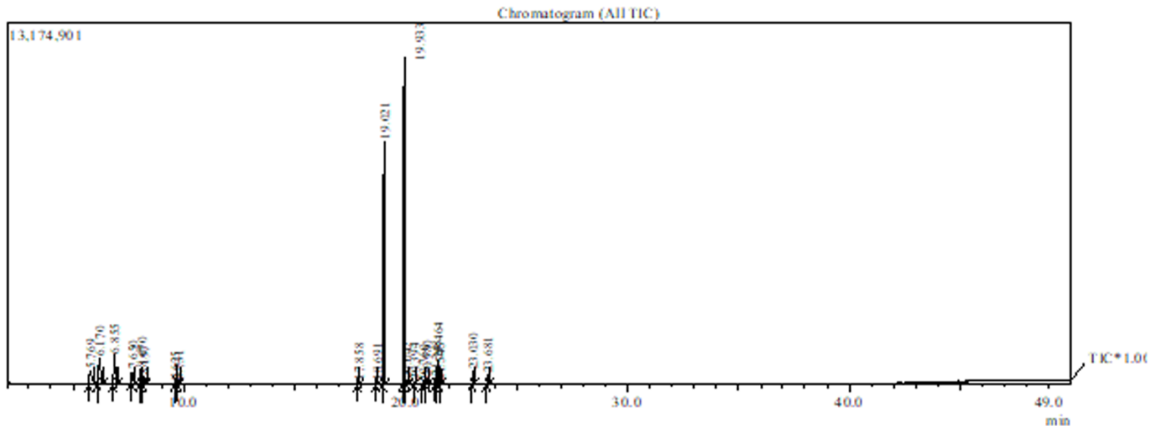


Fig. 91. Total ion chromatogram of *Z. rubens*.

19. *Z. zerumbet*: following 30 compounds were identified (99.95%) and the major compounds are Camphene (34.45%), α-Humulene (26.33%), α-Pinene (8.75%) and Zerumbone (6.25%). The minor compounds are Eucalyptol (4.81%), 3-Carene (3.24%), Limonene (2.97%), Caryophellene (2.91%), Camphor (2.87%), Myrcene

(1.27%), m-Cymene (1.27%), β-Selinene (1.09%), Caryophyllene oxide (1.01%). Tricyclene (0.83%), α- Phellandrene (0.47%), Linalool (0.34%), β- Pinene (0.24%), Terpinolene (0.12%), α-Muurolene (0.10%), L-Fenchone (0.10%), 4(10)-Thujene (0.09%), Bornyl acetate (0.07%), γ-Terpinene (0.07%) Andrographolide (0.06%), Borneol (0.06%), P-menth-1-en-4-ol (0.06%), α-Terpineol (0.06%), β-Elemene (0.06%), α-Copaene (tr.) and α-Gurjunene (tr.) **Fig. 92**

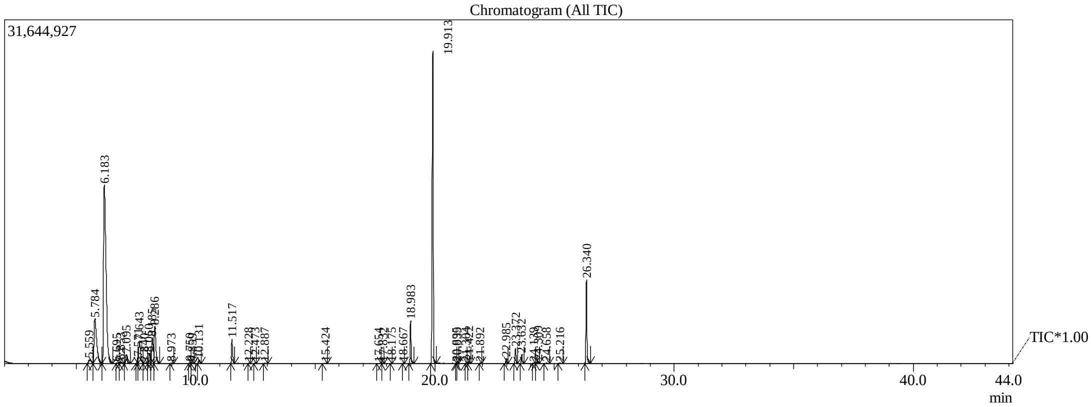


Fig. 92. Total ion chromatogram of *Z. zerumbet*.

Table 7. Specific compounds in rhizomes of *Zingiber* sp.

Plant name	Component	Area%
Zingiber arunachalensis	Myrtenol	0.09
	Fenchyl acetate	0.07
	(S)-(-)-citronellic acid, methyl ester	0.06
	α-Selinene	0.19
Z. bipinianum	Myrtenyl acetate	0.34
	β-Bisabolene	0.36
	Elemol	0.91
	γ-Eudesmol	0.16
	β-Eudesmol	0.27
	2-Methyl-6-methylene-2,7 octadien-4-ol	0.18
Z. campanulatum	β-Gurjunene	0.08
	Zingiberene	0.06
	2-Norpinene	0.35
	δ-Guaijene	0.06
	cis-β-farnesene	0.09
	Valencene	0.15
	β-Bisbolene	0.11

Z. capitatum	Carveol	0.22
	Pinocarvone	0.35
	α-Cubebene	0.24
	α-Cadinene	0.46
	β-Cubebene	0.20
	Cadina-4,9-diene	0.66
	1-Naphthalenol	0.08
	Viridiflorol	0.16
	T-Muurolol	0.27
	β-Guaiene	0.31
Z. chrysanthum	Santolina triene	8.42
	o-Cymene	11.79
	D-Limonene	0.75
	Isoborneol	0.13
Z. clarkei	4-Thujanol	0.08
	Citronellal	0.04
	2-Methyl-3-phenyl-propanal	0.05
	Tetradecane	0.07
	γ-Elemene	0.03
	Pentadecane	0.13
Z. cornigerum	1-Chloro octadecane	0.18
Z. dimapurense	Valencene	0.07
Z. kangleipakense	1-Tetradecanol	0.59
	Phenol, 2,4-bis(1,1-dimethylethyl)	1.23
	1-Pentadecane	0.75
	Humulene oxide II	9.66
	α-Muurolol	1.79
	Neodihydrocarveol	0.65
	Oplopanone	2.44
	Aristolene epoxide	0.84
	1-Nonadecane	0.64
	Geranyl-α-terpinene	15.82
	Geranyl linalool	0.68
	Tetrapentacontane	38.59
Z. kerrii	trans-1-Isopropenyl-4-methylcyclohexane	3.68
	Fenchol	0.35
	γ-Muurolene	0.60
Z. meghalayense	Geranyl acetate	0.31
	Melonal	0.22
	2-Nonane	0.27

	cis-Geranyl acetate	0.19
	Nerolidol	0.48
Z. mizoramensis	Cyclohexane 2-ethenyl-1,1-dimethyl-3-methylene-	5.39
	Azacyclotridecan-2-one	0.96
	1-Decanol, 2-octyl-	1.69
	9-Borabicyclo [3,1,1] nonane 9-[3-(dimethylamino)propyl]-	0.81
	Myristic acid	0.96
Z. murlenica	Eucalyptol (1,8 -cineole)	13.49
	Spathulanol	1.08
	Germacrene D-4-ol	0.39
	Bicyclo[3.1.0]hexane-6-methanol, 2-hydroxy-1,4,4-trimethyl-	0.34
Z. neotruncatum var. *neotruncatum*	€-Ocimene	5.64
	(1R)-(-)-Myrtenal	0.50
	Neral	2.18
	8-Heptadecane	0.73
Z. neotruncatum var. *ramsawmii*	Geraniol	7.15
	β-Citral	3.77
	α-Farnesene	2.59
	trans-β-Farnesene	0.52
Z. pherimaense	Germacrene B	0.98
	2-Octyldecal-1-ol	0.47
	cyclopentanecarboxylic acid 2-(1-cyclohexene-1-yl) 1-methyl-5-oxo, m	0.27
Z. roseum	Naphthalene	0.10
	β-Caryophellene	0.45
Z. rubens	p-Menth-8-ene	1.61
	(-)-5-Oxitricyclo[8,2,0,0(4,6) dodecane,,12-trimethyl-9-methylene-,[1R]	1.51
	Humulene epoxide II	1.06
	Spathulenol	0.52
	Calamenene	0.51
	3-Nonanone	0.43
	Bicyclo[5,3,0]decane,2-methylene-5-(1-methyvinyl)-8-methyl-	0.37
Z. zerumbet	L-Fenchone	0.10
	Camphor	2.87
	p-Menth-1-en-4-ol	0.06
	Bornyl acetate Andrographolide	0.07 0.06
	Zerumbone	6.25

Table 8. Major compound in rhizomes of *Zingiber* sp.

Plant name	Component	Area%
Zingiber arunachalensis	4(10)-Thujene	45.39
Z. bipinianum	Camphene	19.08
Z. campanulatum	α-Pinene	22.19
Z. capitatum	α-Pinene	45.58
Z. chrysanthum	Linalool	27.40
Z. clarkei	4(10)- Thujene	34.48
Z. cornigerum	β-Pinene	35.07
Z. dimapurense	α-Pinene	28.44
Z. kangleipakense	Tetrapentacontane	38.59
Z. kerrii	α-Pinene	45.58
Z. meghalayense	Linalyl acetate	37.49
Z. mizoramensis	β-Pinene	33.03
Z. murlenica	β-Pinene	36.18
Z. neotruncatum var. *neotruncatum*	Perillene	36.80
Z. neotruncatum var. *ramsawmii*	Perillene	51.08
Z. pherimaense	Linalool	31.57
Z. roseum	β-Pinene	65.96
Z. rubens	α-Humulene	36.34
Z. zerumbet	Camphene	34.45

Cluster analysis

The dendrogram derived from the volatile components generated two main clusters and the main cluster was again sub-divided into sub-clusters shown in **Fig. 93.** Cluster I consists of *Z. neotruncatum* var. *neotruncatum* and *Z. neotruncatum* var. *ramsawmii*. Cluster II is a monoclade represented by *Z. arunachalensis*. Cluster III consists of *Z. cornigerum, Z. pherimaense, Z. dimapurense, Z. chrysanthum, Z. meghalayense* and *Z. mizoramensis*. *Z. bipinianum* existed as a monoclade in cluster IV. Cluster V includes *Z. murlenica*, *Z. kerrii*, *Z. roseum* and *Z. rubens*. Cluster VI formed from the species like *Z. zerumbet*, *Z. campanulatum, Z. clarkei*, *Z. capitatum* and *Z. kangleipakens*.

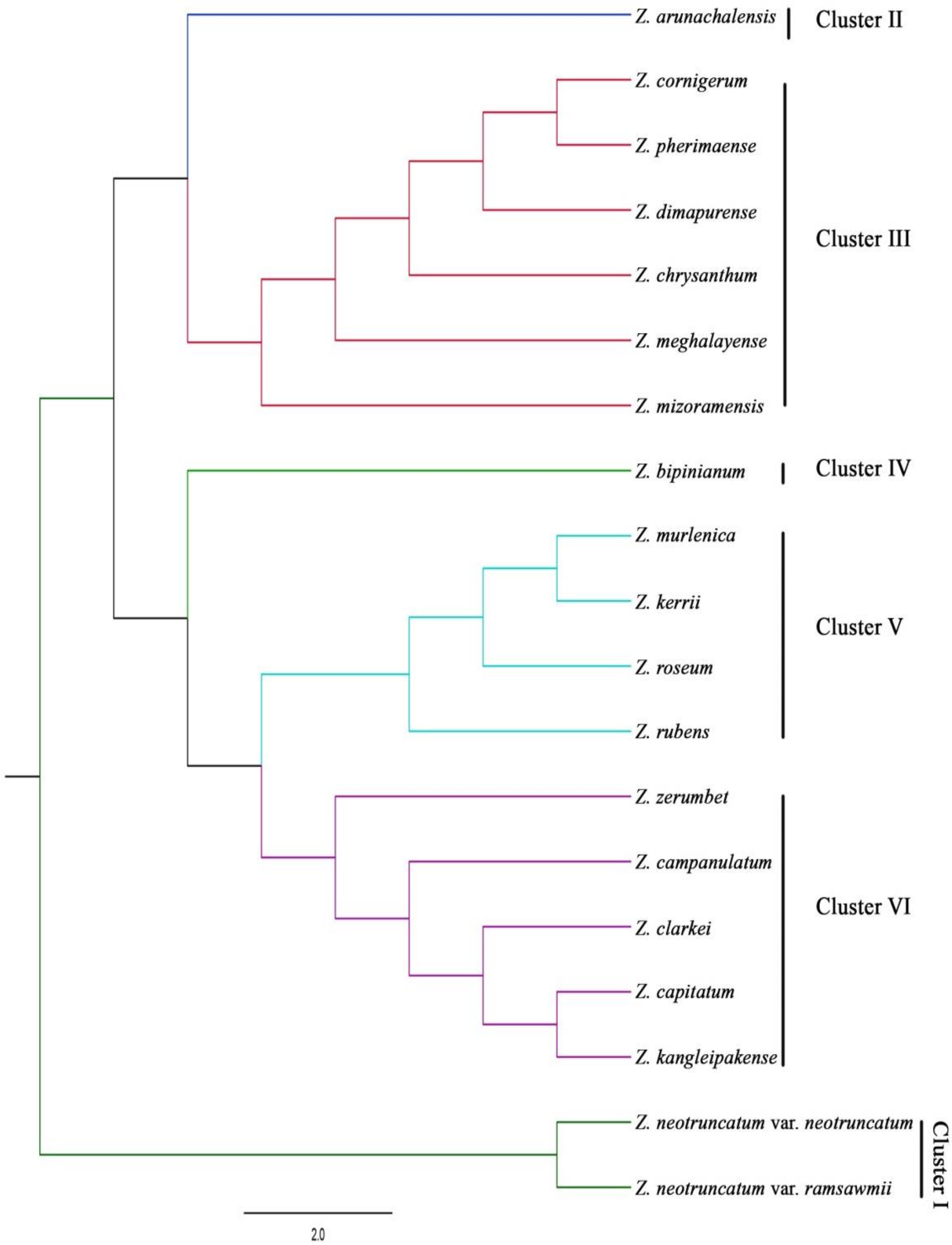


Fig. 93. UPGMA Dendrogram of volatile constituents in genus *Zingiber*.

Discussion

The GC-MS Headspace analysis of *Zingiber* spp. reveals the chemical uniqueness of each species because of the presence of specific compounds in their rhizomes. Thus, volatile components can be utilized as marker compounds for the identification of *Zingiber* sp. even if in the vegetative stage. Major volatile components of *Zingiber* rhizomes are monoterpene hydrocarbons and oxygenated monoterpenes among these α-Pinene and β-Pinene are present in all the taxa studied except in *Z. kangleipakense*. A higher concentration of Tetrpentacontane (38.59%) makes *Z. kangleipakense* distinct from other *Zingiber* sp. in NE India. Tetrpentacontane was not observed in any other *Zingiber* sp. in India hence can be utilized as a marker compound for *Z. kangleipakense*. The presence of Perillene which is responsible for the characteristic pleasant aroma of *Z. neotruncatum* var. *neotruncatum* and *Z. neotruncatum* var. *ramsawmii* shows the chemical relationship between the two varieties hence perellene can be utilized as a marker compound for *Z. neotruncatum. Z. neotruncatum* var. *neotruncatum* is unique in having €-Ocimene and Neral, whereas *Z. neotruncatum* var. *ramsawmii* is characterized by the presence of Geraniol, β-Citral, α-Famesene and trans-β-Famesene.

Z. cornigerum, *Z. pherimaense*, *Z. dimapurense*, *Z. chrysanthum*, *Z. meghalayense* and *Z. mizoramensis* clusterd together in the UPGMA tree becouse of the presence of α-Pinene and β-Pinene. *Z. cornigerum* is unique in having 1-Chloro octadecane and in *Z. dimapurense* valencene is the specific compound. Both *Z. cornigerum* and *Z. bipinianum* are morphologically similar taxa but their volatile profiles are very unique and *Z. bipinianum* nested in a monoclade sister to Cluster V. The rhizome of *Z. bipinianum* is a rich source of Camphene, a monoterpene and there are 6 unique compounds identified such as Myrtenyl acetate, β-Bisabolene, Elemol, γ-Eudesmol, β-Eudesmol and 2-Methyl-6-methylene-2,7 octadien-4-ol. All of them can be regarded as marker compound for this particular taxa.

Both *Z. arunachalensis* and *Z. mizoramensis* are morphologically allied taxa and the same trend was observed in their volatile profile also. α-Phellandrene, α-Pinene, Camphene, β-Pinene, Myrcene, Benzene methyl-4- isopropyl, γ-Terpinene and Borneol are common compounds found in both the taxa but *Z. arunachalensis* is unique in having a higher concentration of 4(10)-Thujene (45.39%). Myrtenol, Fenchyl acetate, Citronellic acid methyl ester and α-Selinene are found to be the specific compounds in *Z. arunachalensis* rhizome, whereas *Z. mizoramensis* is characterized by the presence of Cyclohexane 2-ethenyl-1,1-dimethyl-3- methylene-, Azacyclotridecan-2-one, 1-Decanol, 2-octyl-, 9-Borabicyclo [3,1,1] nonane 9-[3-(dimethylamino)propyl]- and Myristic acid

Z. murlenica, *Z. kerrii*, *Z. roseum* and *Z. rubens* form the cluster V which is characterized by α-Copaene, α-Pinene, β-Pinene and Caryophellene as common compounds. *Z. murlenica* shows more affinity to *Z. kerrii* due to the presence of α-Muurolene, Alloaromandendrene, Limonene and Caryophyllene oxide. Though α-Muurolene and Alloaromandendrene are in lower concentrations in *Z. roseum* indicates its slight affinity to these two species.

GC-MS analysis of the rhizome essential oil of *Z. roseum* was reported by Prakash *et al.* (2006). The report suggests that rhizome oil was rich in Linalool (53.3%) with lesser amounts of Limonene (14.0%), β-Pinene (9.3%) and α-Pinene (4.4%) being among the other constituents. The marker components of the family Zingiberaceae such as Borneol (0.9%) and β-Eudesmol (1.4%) were found to be present in relatively low concentrations in the oil. In our present GC-MS headspace analysis we found β-Pinene as the major compound and the complete absence of Linalool. The essential oil composition of *Z. roseum* from South India was studied by Vasantha (2009) and reported Caryophyllene oxide, Humulene epoxide, α-Humulene and β-Caryophyllene as major compounds and which is also not supported by the current study. Based on our observation *Z. roseum* shows a wide distribution from south India to North East India and shows great variation in morphology and habitat preference hence we suggest that factors like soil composition, altitude, tempreture and other ecological factors have a key role in determining the volatile composition of the rhizome. The chemical profiling of seed oil of *Z. roseum* was also reported by Prakash *et al.* (2006a). The seed oil was found to be rich in α-Pinene, β-Pinene, Limonene, p-Cymene, α-Terpineol and Verticiole.

A previous study on the essential oil composition of *Z. rubens* from Vietnam reported (*Z*)-Citral (30.1%), Camphene (9.7%), -β-Phellandrene (7.5%) and 1,8-Cineole (7.0%) and Zingiberene (5.3%) as main components (Dai *et al.* 2013). According to the present GC-MS study *Z. rubens* rhizome contain α-Humulene (36.34%), Caryophellene (27.03%), Camphene (7.56%) and β-Pinene (7.34%) as major compounds and p-Menth-8-ene, Humulene epoxide II, Spathulenol and Calamenene are the specific compounds observed.

According to Huong *et al.* (2020) The most abundant constituents in the rhizome essential oil of *Z. neotruncatum* were Perillene (51.3%), Neral (12.3%) and Geranial (17.0%). Their result is matching with our current analysis of two varieties of *Z. neotruncatum* both *Z. neotruncatum* var. *neotruncatum* and *Z. neotruncatum* var. *ramsawmii* contain Perillene as the major compound.

Phytochemical analysis of *Z. chrysanthum* was done by Bestmann *et al.* (1992) the study reveals monoterpenes like 1, 8-cineole (42%), α-Fenchyl acetate (15%), α-Terpineol (6%) and Camphene (6%) as major constituents. The current study shows Linalool (27.40%), β-Myrcene (16.14%), α-Pinene (14.88%), o-Cymene (11.79%), α-Phellandrene (8.68%), Santolina triene (8.42%) and β-pinene (5.75%) as major compounds.

Two different accessions of *Z. zerumbet* rhizome oil from South India were studied by Vasantha (2009). The accession from high altitude (Ponmudi) contains a very high concentration of Zerumbone (72.5%) and another accession from Kozhikode (lower altitude) shows a similar chemical profile hence they concluded that altitude variations do not make any prominent impact on its oil components. The present study is based on an accession collected from Nagaland (higher altitude) and shows a much different chemical profile with Camphene (34.45%), α-Humulene (26.33%), α-Pinene (8.75%) and Zerumbone (6.25%) as major compounds. The much lower concentration of Zerumbone in Nagaland accession shows that altitude variation and seasonal variations play a key role in determining the chemical composition of rhizomes.

MOLECULAR PHYLOGENY OF THE GENUS *ZINGIBER* IN INDIA

In classical taxonomy classifications are mainly based on visible characters like morphology, anatomy etc. However incorporation of data from other branches of plant science in classification is the current trend in modern taxonomy, especially from molecular biology. In the current scenario, an increasing attention towards conservation of biodiversity, the major goal of taxonomy is to classify unites of biodiversity according to their phylogenetic and evolutionary history turns more urgent than ever. Molecular data is now days used as powerful tool for revealing the phylogeny and evolutionary history of organisms (Baldauf, 1999; Brown, 2000; Hassanin, 2006). They can be also used as an additional data to support species level identification. The present study investigates the molecular phylogeny of the genus *Zingiber* in India using nuclear ITS Region. A total of 29 taxa were selected for the study, out of which 14 species of *Zingiber* were sequenced and remaing taxa were obtained from GenBank. Recently discovered and reported taxa in India were excluded from the analysis due to the non-availability of the samples.

Results

Genomic DNA was isolated from fresh unopened tender leaves using the hexadecyltrimethyl ammonium bromide (CTAB) method (Doyle & Doyle, 1987) with minor modifications. The eluted DNA was stored at 4^{o} C for further analysis.

Agarose Gel Electrophoresis of PCR products

PCR amplification of the gene regions ITS intergenic spacer was checked using 1.2 % Agarose Gel Electrophoresis. From the amplified PCR products 2 ul was taken to run agarose Gel electrophoresis size of the amplicon were viewed properly and photographs were taken using a gel documentation system. For reference, DNA ladder of 100 bp (Invitrogen DNA ladder of 0.1 concentration) was used. It is observed that the size of the ITS region was in between 700-800 base pairs. The gel image for the PCR product is shown in the **Fig. 94.**

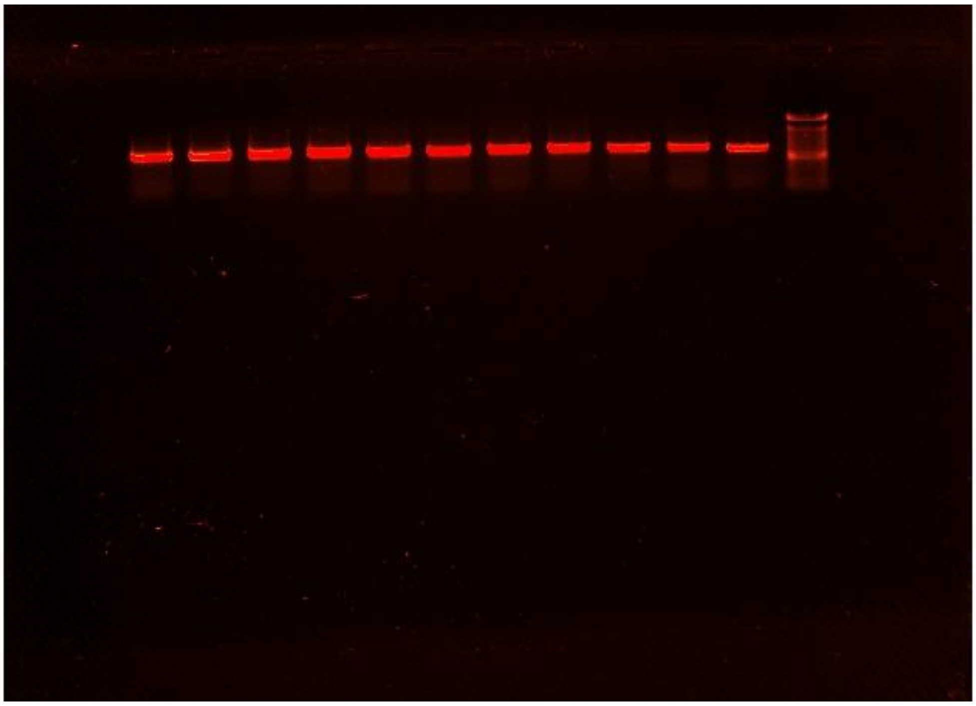


Fig. 94. PCR amplification of ITS locus of *Zingiber*.

Sequencing

The ITS data set had 733 characters of which 390 was conserved sites, 250 variable, 155 parsimony informative (Pi) sites and 96 singletons. Gaps were treated as 5th character.

Editing of Sequence and Multiple Sequence Alignment.

Chromas lite 2.1.1 was used to edit chromatograms. BioEdit was used to construct consensus sequences. Multiple Sequence Alignment was performed using Clustal W incorporated in MEGA 11.

Phylogenetic Analysis

Altogether 29 taxa were used in the analysis.

Table 9. Data set of ITS intergenic spacer based on DNA sequence data

Sl.No.	Name of the taxa	Percentage of				Total length of the base pair
		A	T	G	C	
1.	*Zingiber anamalayanum*	20.8	19.4	32.5	27.1	648
2.	*Z. arunachalensis*	22	22	30.8	24.9	801
3.	*Z. bipinianum*	21.4	22.3	31.1	25	760
4.	*Z. campanulatum*	21.7	22.3	31.9	24	774
5.	*Z. capitatum*	19.9	19.5	32.6	27.8	646
6.	*Z. chrysanthum*	19.1	21.7	32.6	26.4	612
7.	*Z. clarkei*	22.1	21.9	31.1	25.4	728
8.	*Z. cornigerum*	22.1	21.2	31.5	25	744
9.	*Z. kangleipakens*	21.8	21.7	31.6	24.8	737
10.	*Z. kerrii*	21.7	21.10	31.7	25.4	763
11.	*Z. ligulatum.*	20.4	22.2	31.7	25.5	607
12.	*Z. meghalayense*	21.4	21.9	31.8	24.7	723
13.	*Z. mizoramensis*	22.9	21.5	29.7	25.7	753
14.	*Z. murlenica*	22.1	21.6	31.3	24.7	739
15.	*Z. neesanum*	20.1	18.7	33.0	26.4	645
16.	*Z. neotruncatum* var. *neotruncatum*	21.4	21.89	31.2	25.4	612
17.	*Z. neotruncatum* var. *ramsawmii*	21.8	20.6	31.9	25.5	764
18.	*Z. nimmonii*	21.1	21.8	31.7	25.2	618
19.	*Z. odoriferum*	20.9	19.8	31.8	27.3	659
20.	*Z. officinale*	22.3	20.4	31.4	25.7	753
21.	*Z. parishii*	21.2	22.6	30.6	25.4	613
22.	*Z. pherimaiensis*	21.6	22.7	31.6	23.8	770
23.	*Z. purpureum*	19.9	18.7	32.9	28.3	646
24.	*Z. roseum*	20.4	21.8	32.1	25.4	612
25.	*Z. rubens*	20.7	21.7	31.6	25.8	647
26.	*Z. wightianum*	19.5	22.3	32.2	25.8	546
27.	*Z. zerumbet*	20.3	20.8	32.5	26.2	643
28.	*K. galanga*	22.1	22	30.9	24.8	727
29.	*K. purviflora*	20.8	21.4	31.4	26.2	620

Maximum Likelihood analysis

Maximum Likelihood +Through bootstrap was used with 1000 bootstrap replicates. Bootstrap per branch length was selected for the Maximum Likelihood Analysis using RAxML.

Phylogeny based on ITS based DNA sequenced data

The length of the ITS varied from 801 base pair in *Z. arunachalensis* to 546 base pairs in *Z. wightianum*. After trimming and alignment, the data set length was reduced to 733 base pairs. Out of this, 390 were observed as conserved sites, 250 variable sites, 155 parsimony informative (Pi) sites and 98 singletons. Gaps were treated as 5th character.

Maximum Likelihood Analysis of ITS sequence of 29 taxa was carried out with RAxML GUI5 software package (**Fig. 95, 96 & 97**) three main clades of *Zingiber* are recognized. Clade I is a monoclade represented by a single member *Z. clarkei* belongs to Sect. *Pleuranthesis* characterized by an inflorescence arising through the leaf sheath.

The rest of the *Zingiber* sp. forms the Clade II and Clade III. The Calde II comprises 16 species belonging to the Sect. *Cryptanthium* including *Z. arunachalensis, Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum, Z. cornigerum, Z. kangleipakens, Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. nimmonii*, *Z. pherimaiensis*, *Z. rubens*, *Z. ligulatum, Z. wightianum, Z. nimmonii* and *Z. roseum* with bootstrap support of 99%. Members of this section share an inflorescence with the procumbent peduncle.

Z. capitatum traditionally placed in the Sect. *Dymczewiczia* (terminal inflorescence) is nesting in the Clade III along with the members of Sect. *Zingiber* including Z. *purpureum*, *Z. parishii*, *Z. neotruncatum* var. *neotruncatum, Z. neotruncatum* var. *ramsawmii, Z. kerrii, Z. anamalayanum*, *Z. zerumbet*, *Z. officinale*, *Z. odoriferum* and *Z. neesanum.* with bootstrap value of 98%. The Sect. *Zingiber* has a radical inflorescence with a long eruct peduncle.

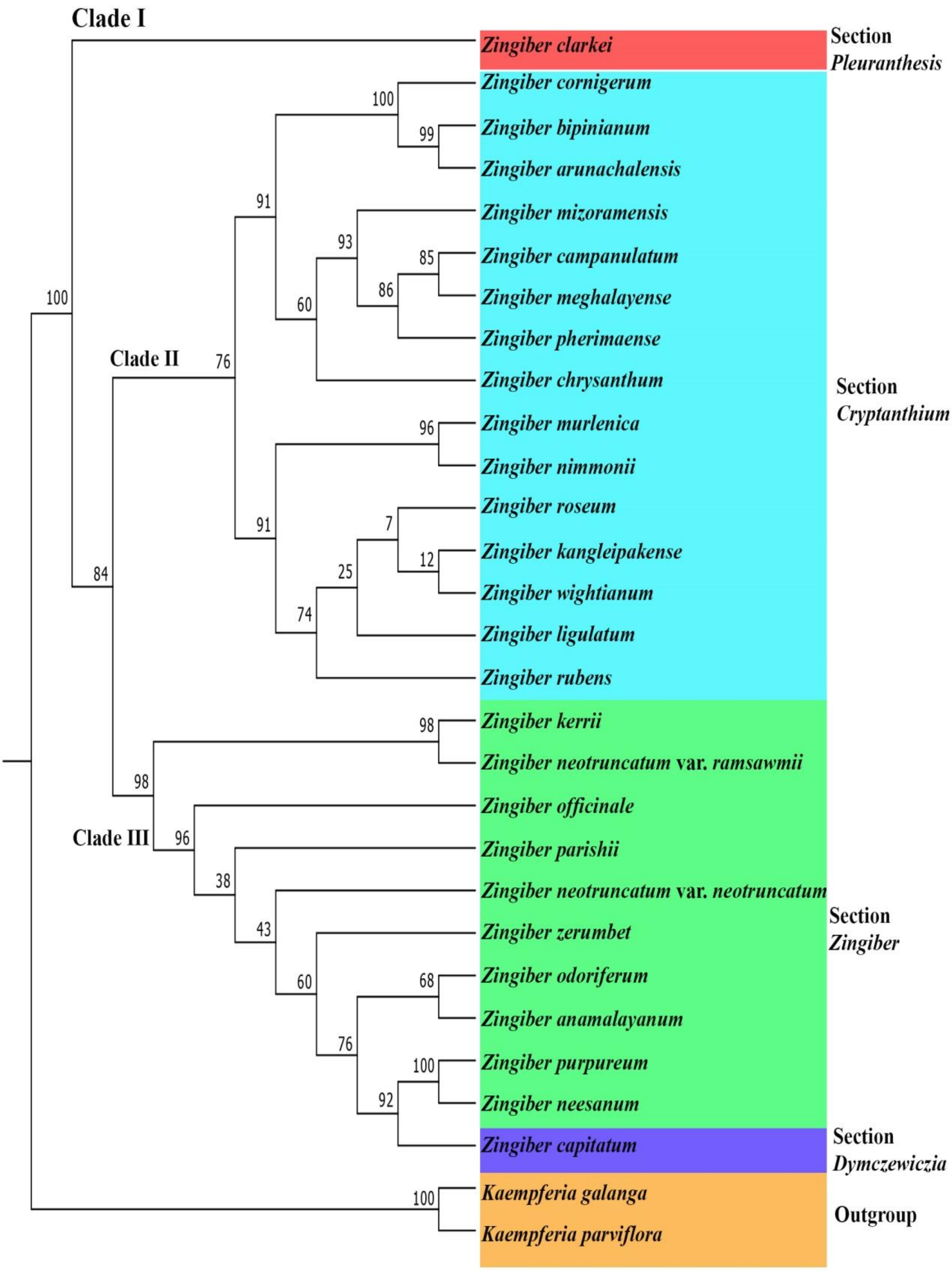


Fig. 95. The 50% majority rule consensus cladogram from RAxML analysis of ITS region.

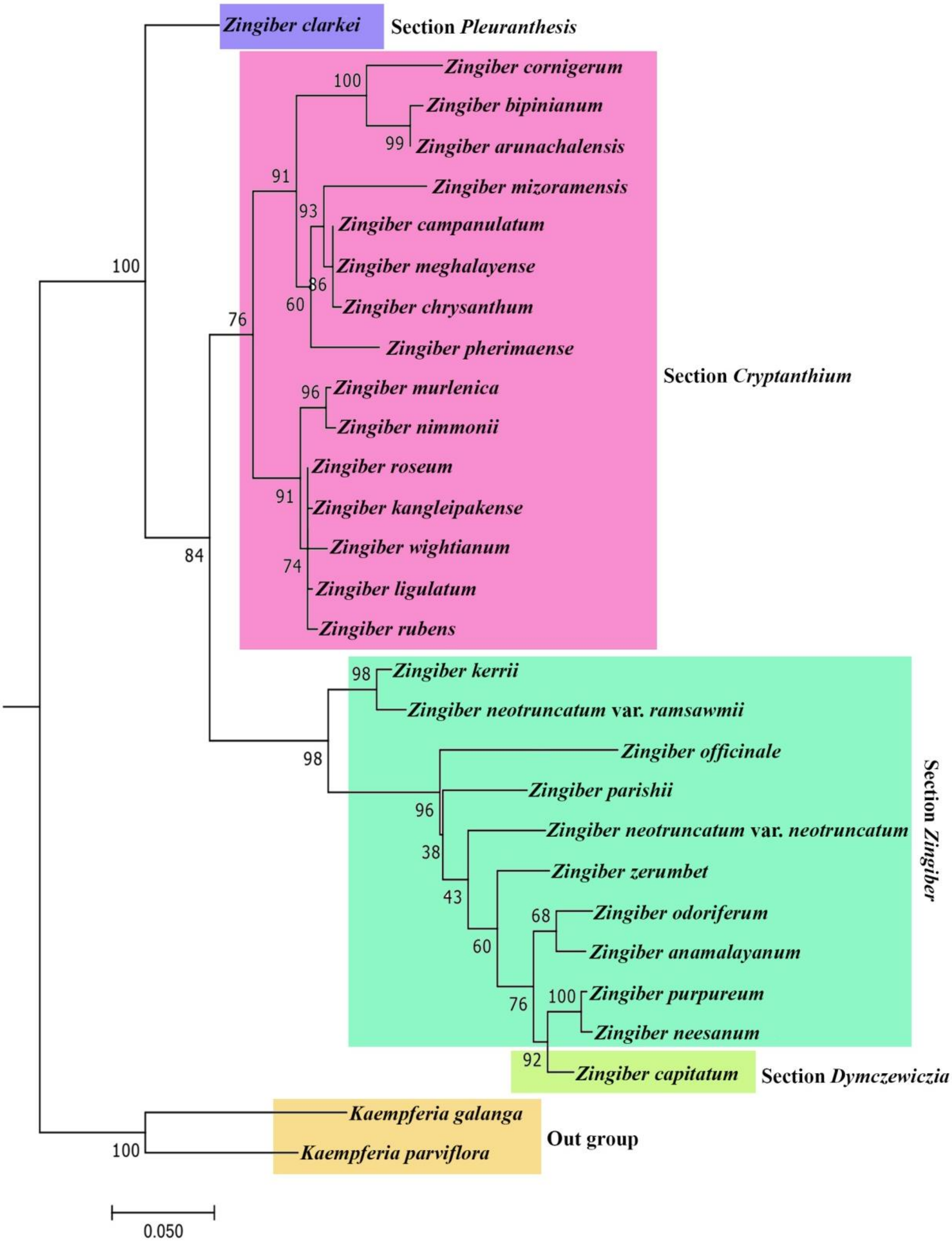


Fig. 96. The 50% majority rule consensus phylogram from RAxML analysis of ITS region.

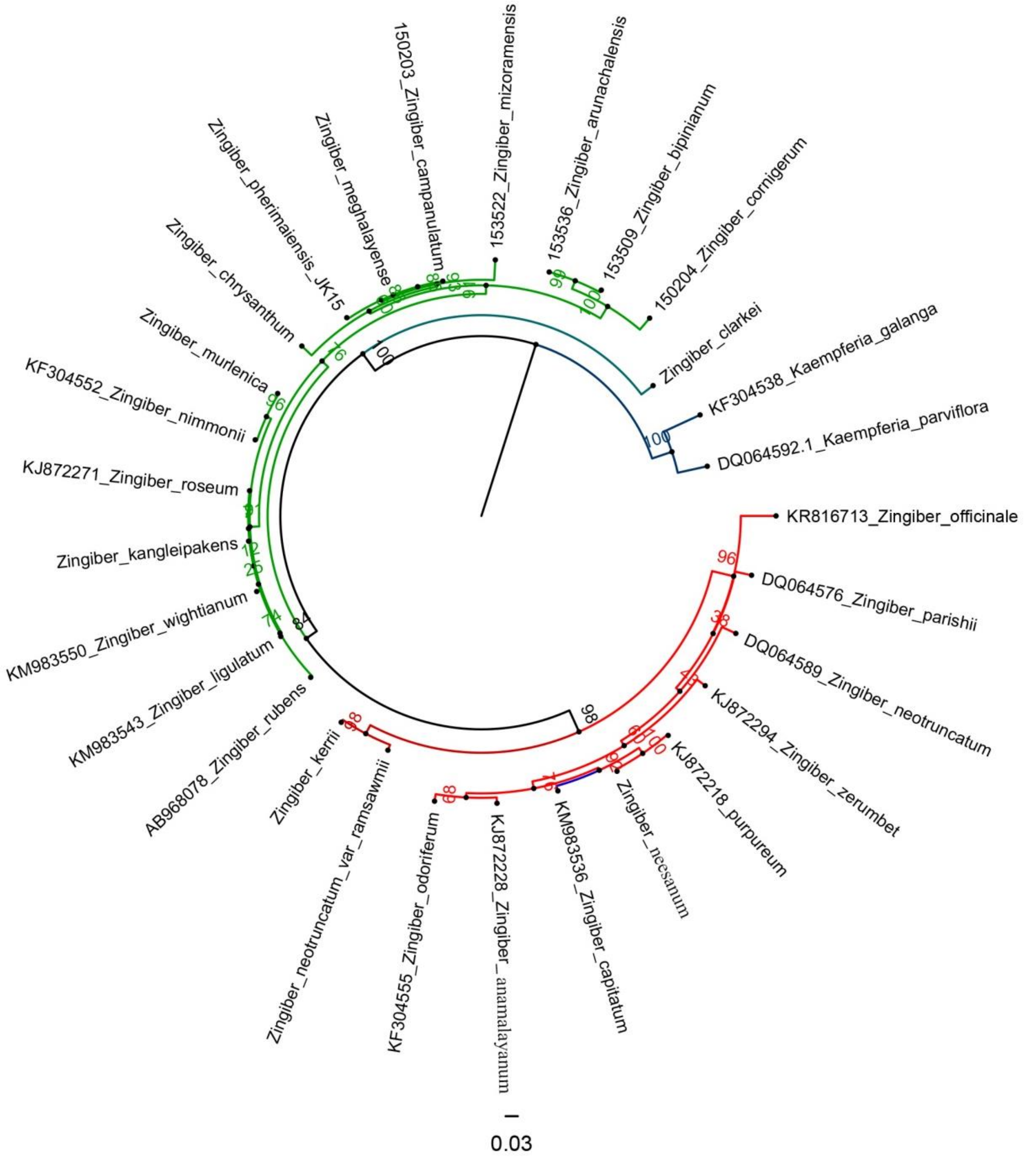


Fig. 97. 50% majority rule consensus polar diagram from RAxML analysis of ITS.

Bayesian Analysis

Phylogeny based on ITS data set

As in the previous analysis, here also we used 29 taxa for assessing phylogenetic relationships using MrBayes package. The ITS data set has 733 base pairs. Out of this, 390 were observed as conserved sites, 250 variable sites, 155 parsimony informative (Pi) sites and 98 singletons. Gaps were treated as 5th character.

Kaempferia parviflora and *K. galanga* clustered as outgroup. Close observation of the Bayesian tree shows three Clades (**Fig. 98, 99 & 100**). The Clade I (P.P.=1.00) is a monoclade consisting of *Z. clarkei* belonging to Sect. *Pleuranthesis* characterized by inflorescence arising through the leaf sheath and spherical pollen with cerebroid sculpturing.

The rest of the species bifurcated into two clades and formed Clade II and clade III. The Clade III is represented by 11 species of *Zingiber*, out of which 10 belong to Sect. *Zingiber*, which is characterized by inflorescence developing separately from the rhizome on a long upright peduncle and spherical pollen with cerebroid sculpturing and one, belongs to Sect. *Dymczewiczia* has a terminal inflorescence and spherical pollen with cerebroid sculpturing (P.P.= 1). Clade II consists of 15 *Zingiber* sp. belongs to the Sect. *Cryptanthium* is characterized by an inflorescence with procumbent peduncle and elliptical pollen with spirostriate sculpturing.

Clade I

Monoclade represented by *Z. clarkei* with pp. value of 1.00 the most primitive clade and *Z. clarkei* is found to be the most primitive species and characters like inflorescence arising through the leaf sheath and spherical pollen should be considered as primitive characters.

Clade II

Clade II (P.P.= 0.88) forms the largest clade with 15 species including *Z. kangleipakens*, *Z. murlenica*, *Z. nimmonii*, *Z. roseum*, *Z. rubens*, *Z. ligulatum*, *Z. wightianum*, *Z. campanulatum*, *Z. meghalayense*, *Z. pherimaiensis*, *Z. mizoramensis*, *Z. chrysanthum*, *Z. cornigerum*, *Z. arunachalensis* and *Z. bipinianum*.

This clade is again bifurcated into two subclades, subclade 1 and 2 respectively. Subclade 1 shows a polytomy with seven closely related species, Z. *kangleipakens*, *Z. murlenica*, *Z. nimmonii*, *Z. roseum, Z. rubens*, *Z. ligulatum* and *Z. wightianum* supported by a P.P. value of 1.00. Among this *Z. murlenica* and *Z. nimmonii* shares, many characters like purple blotched labellam and lateral staminodes, cream corolla lobes, purple anther crest, broad elliptic leaves, etc.. subclade 5 (P.P.= 1.00) consists of *Z. campanulatum*, *Z. meghalayense*, *Z. pherimaiensis*, *Z. mizoramensis, Z. chrysanthum, Z. cornigerum*, *Z. arunachalensis* and *Z. bipinianum*.

Clade III

Clade III (P.P. = 1.00) forms the second largest clade with 11 species of *Zingiber* consisting of *Z. capitatum, Z. divakrianum,* Z. *purpureum*, *Z. odoriferum, Z. neesanum. Z. neotruncatum* var. *neotruncatum, Z. zerumbet Z. parishii, , Z. officinale, Z. kerrii* and *Z. neotruncatum* var. *ramsawmii*. The tree bifurcation in this clade was satisfactory. Farley good support values show the robustness of the tree resolution inside the clade. Two species *Z. kerrii* and *Z. neotruncatum* var. *ramsawmii* form the primitive species in this clade. *Z. neesanum* and Z. *purpureum* form the recently evolved clade.

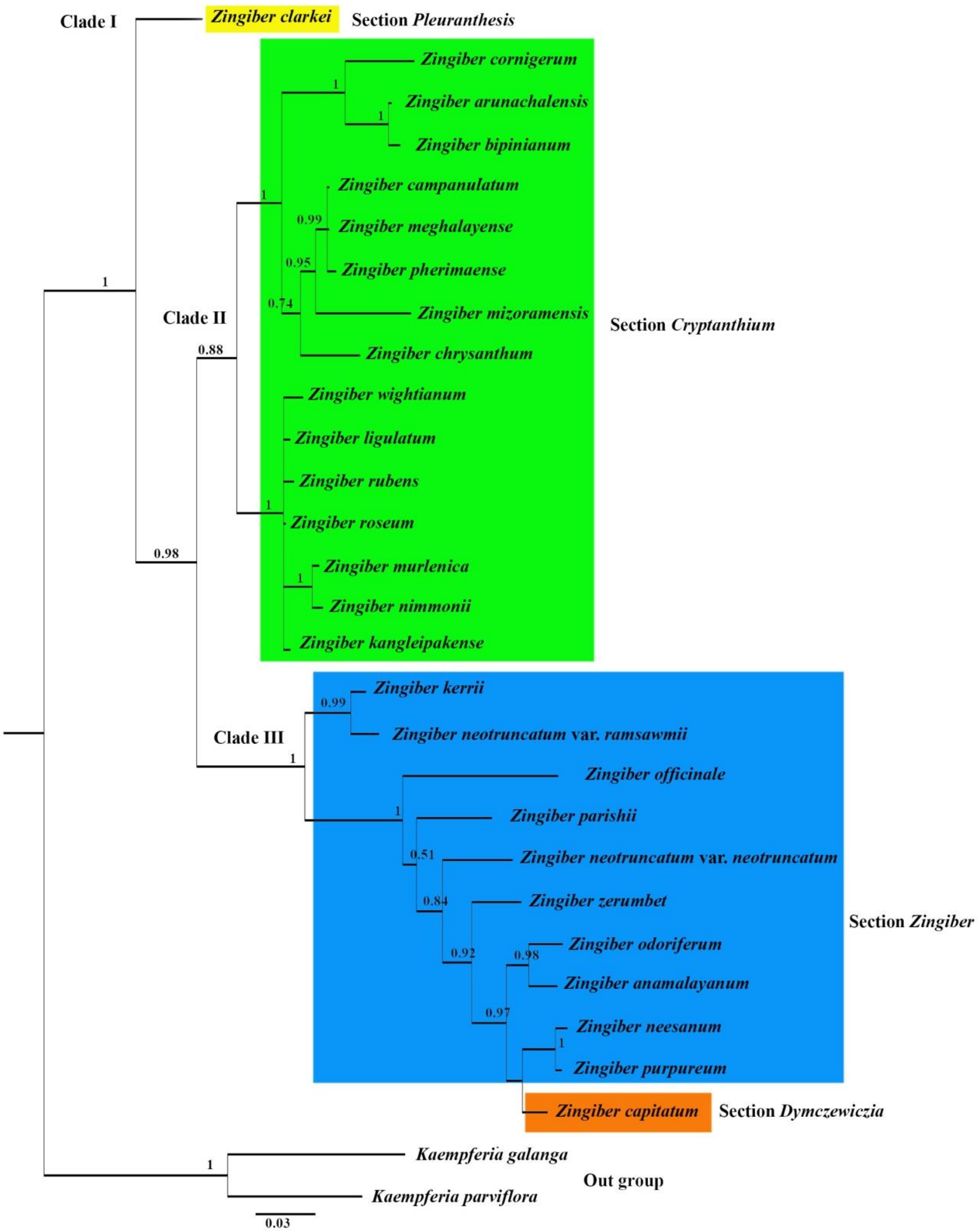


Fig. 98. The 50% majority rule consensus phylogram from Bayesian analysis of ITS region.

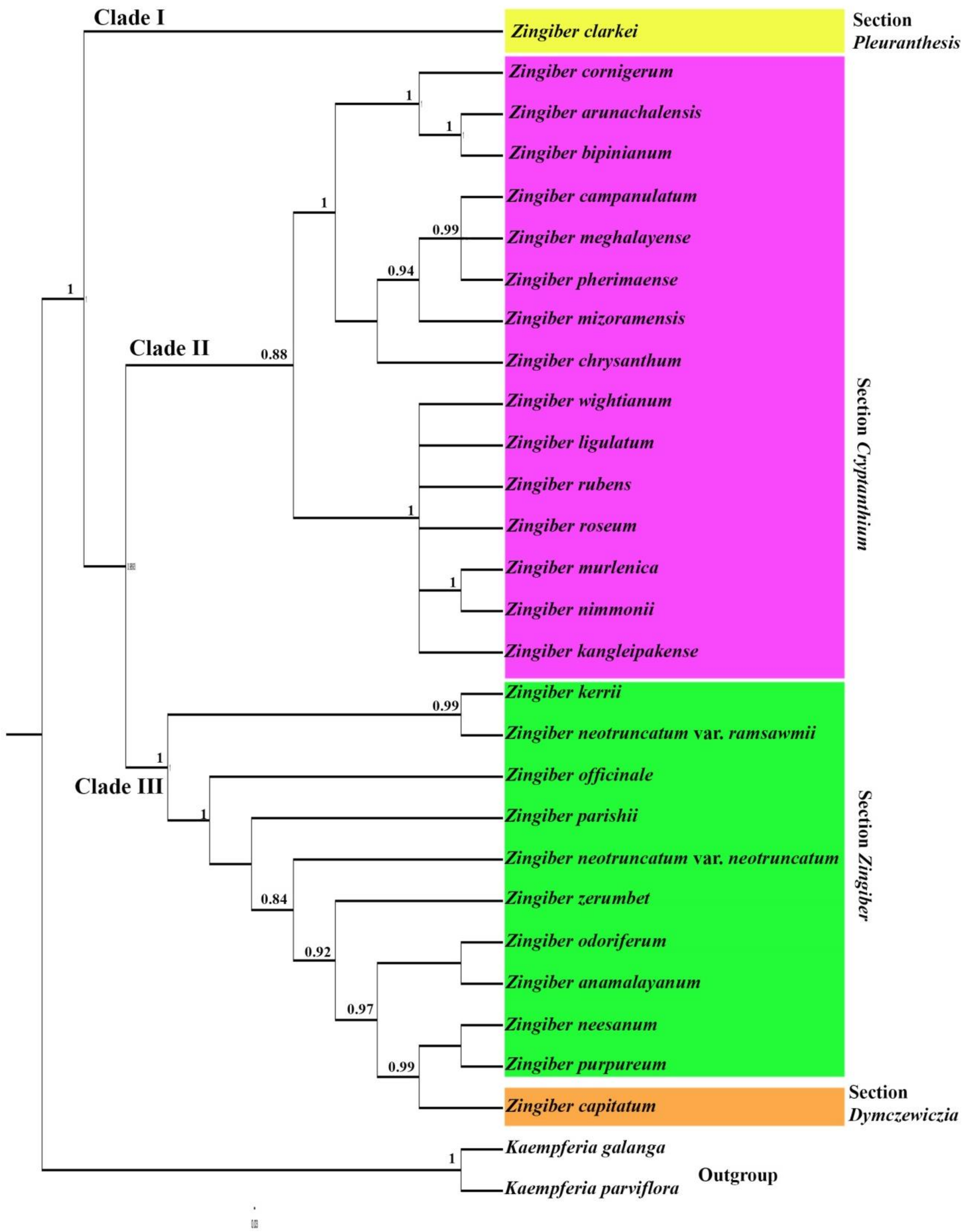


Fig. 99. The 50% majority rule consensus cladogram from Bayesian analysis of ITS region.

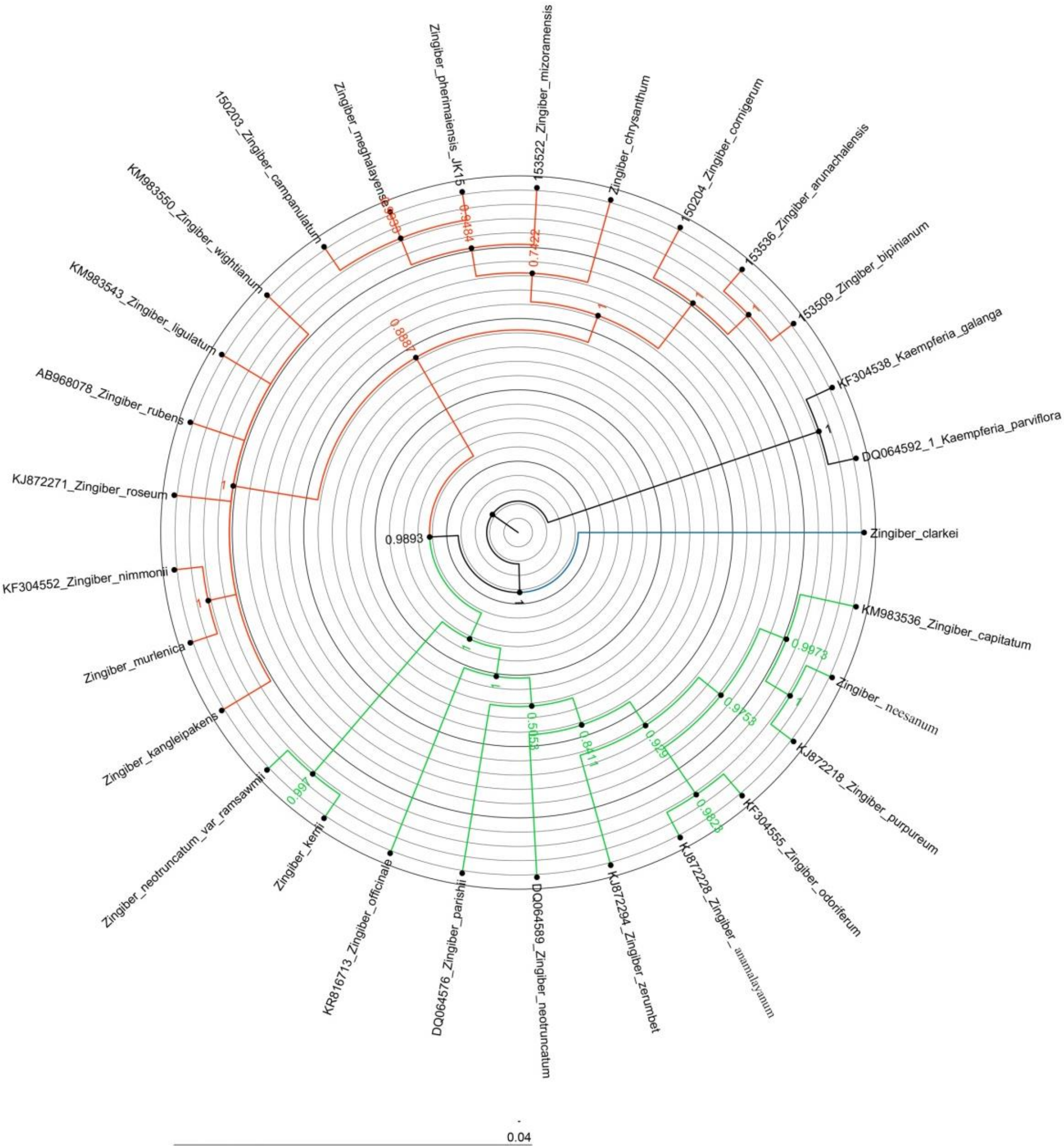


Fig. 100. 50% majority rule consensus polar diagram from Bayesian analysis of ITS region.

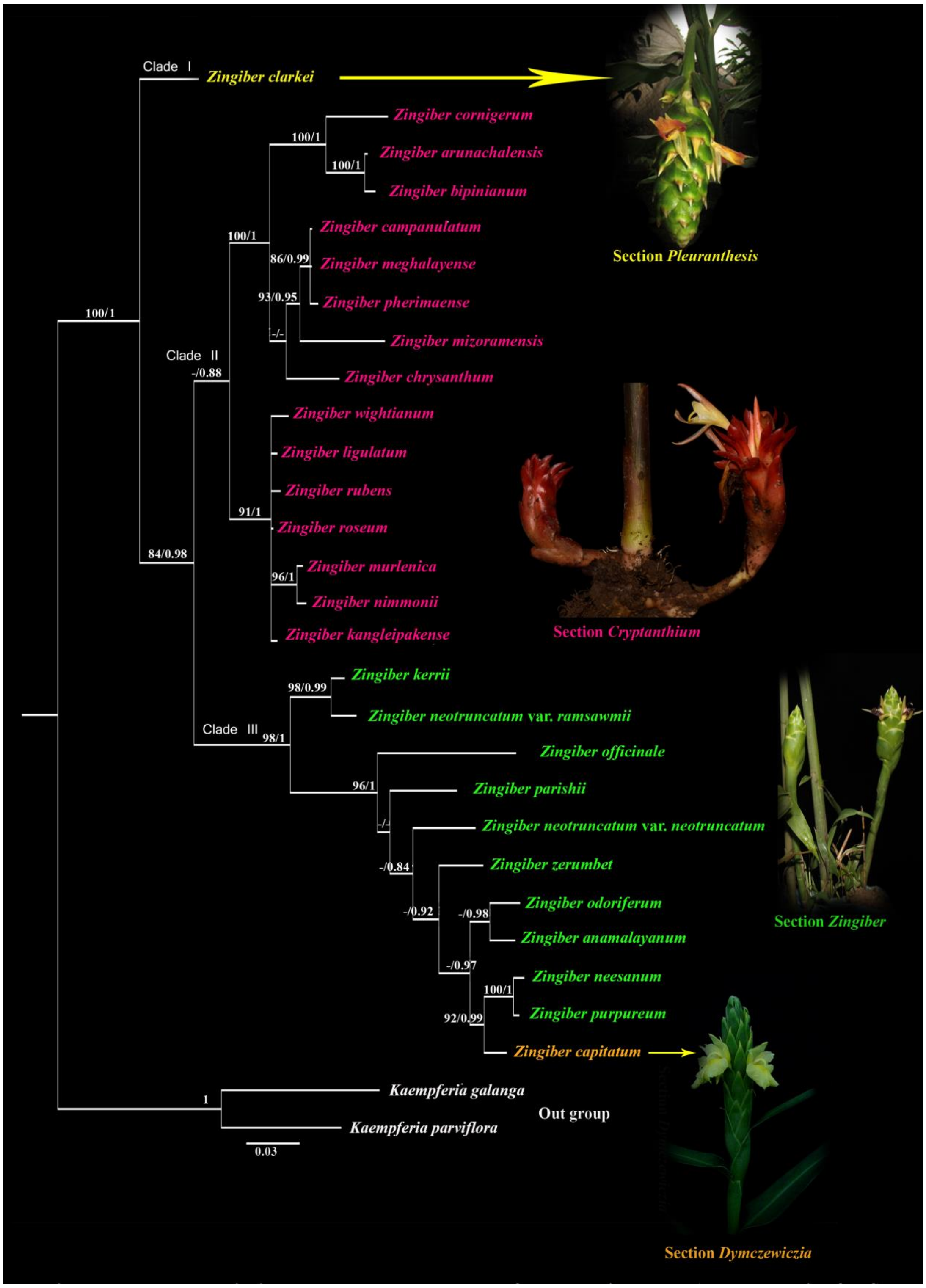


Fig. 101. The 50% majority rule consensus phylogram from Bayesian and RAxML analysis of ITS region combined.

Discussion

Maximum Likelihood analysis of ITS sequence data yielded a phylogenetic tree that resolved the sampled 27 species of *Zingiber* into three clades (**Fig. 101**), each of which corresponds to one of the three sections out of the four sections previously described based on inflorescence habit. The first clade contains a single *Zingiber* sp. belongs to Sect. *Pleuranthesis* characterized by inflorescence arising through the leafy sheath, presence of an adaxial hypodermis in the leaf lamina and spherical pollen with cerebroid sculpturing. The second clade contains 15 species in Sect. *Cryptanthium* are characterized by inflorescence developing on a procumbent peduncle, bundle sheaths attached to adaxial epidermis only and ellipsoidal pollen with spiro-striate surface. The third clade contains 9 species of the Sect. *Zingiber* is characterized by spherical pollen with cerebroid sculpturing, bundle sheath attached to both epidermis and inflorescence on a long eruct, radical peduncle arising separately from the rhizome and one belongs to Sect. *Dymczewiczia* having and terminal inflorescence, bundle sheath attached to both epidermis and spherical pollen with cerebroid sculpturing.

An earlier phylogenetic study by Theerakulpisut *et al*. (2012) using ITS region has resolved the genus into four clades, which follows the previously recognized sectional classification of the genus Zingiber based on inflorescence habit (Sects. *Zingiber*, *Dymczewiczia*, *Pleuranthesis* and *Cryptanthium*). According to Theerakulpisut *et al.* (2012), sects *Zingiber* and *Dymczewiczia* are barely supported as independent groups and are more closely related to each other than to Sect. *Pleuranthesis* and *Cryptanthium*. The close relationship of the two sections based on ITS sequences together with similarity in pollen morphology supports an earlier proposal by Theilade, Sect. *Dymczewiczia* should be amalgamated with Sect. *Zingiber* (Jayakrishnan *et al*., 2022). Similarly, the present phylogenetic analysis was able to separate the 27 species of *Zingiber* into three major clades with strong bootstrap support. The phylogenetic analysis also follows the previous sectional classification except in the case of Sect. *Dymczewiczia.*

In a phylogenetic study of the tribe Zingibereae using ITS sequences, Aishwarya *et al*. (2017) recognized two major clades, Clade I and II with moderate clade credibility. The Clade II comprises four subcaldes which include the monophyletically resolved *Zingiber* subclade with strong support. The study sampled 18 *Zingiber* sp. Within the *Zingiber* subclade they have identified three clades each of which corresponds to the previously recognized three sections and here also the Sect. *Dymczewiczia* were nested along with members of Sect. *Zingiber*. A similar observation was also made by Theerakulpisut *et al.* (2012) in her phylogenetic study on genus *Zingiber* using ITS sequence data.

Many observations contradicting the use of inflorescence habit for sectional classification in *Zingiber* were made by various authors. Based on the nature of the inflorescence (Schumann, 1904; Valeton, 1918), two species, *Z. junceum* and *Z. gramineum*, were previously placed in both Sect. *Dymczewiczia* and *Zingibe*r (Theilade, 1999). Both are characterized by radical inflorescences on erect peduncles as well as inflorescences developing apically on a leafy shoot. Previous phylogenetic studies placed both species in Sect. *Zingiber* and *Z. officinale* which normally develops radical, erect inflorescences (characteristics of Sect. *Zingiber*), but can produce them apically on a leafy shoot (characteristics of Sect. *Dymczewiczia*) in some rare instances (Triboun, 2006), is grouped with *Z. pellitum* (Sect. *Dymczewiczia*). In the present phylogenetic analysis also, *Z. capitatum* (Sect. *Dymczewiczia*) is grouped along with members of Sect. *Zingiber*.

Hence, it is evident that the two types of inflorescences can develop within a species so these two types of inflorescence habit should not be considered as a diagnostic character for delimiting Sect. *Dymczewiczia* and *Zingiber*. Theilade (1999) suggested that the genes controlling the development of these two types of inflorescences may show differential expression or that the nature and development of inflorescences may be under the influence of environmental factors. In a palynological study on genus *Zingiber* by Theilade *et al.* (1993), it was found that members of Sect. *Zingiber* and *Dymczewiczia* have spherical pollen with cerebroid sculpturing and based on pollen morphology they proposed that Sect. *Dymczewiczia* should be merged into Sect. *Zingiber*. Our phylogenetic analysis shows that Sect. *Dymczewiczia* and *Zingiber* are nested within the same clade with high bootstrap support (98%) and the anatomical studies shows that both *Dymczewiczia* and *Zingiber* are characterized by bundle caps attached to both adaxial and abaxial epidermis. Hence, this analysis of nuclear ITS sequences support the pollen-based proposal by Theilade *et al.* (1993) and phylogenetic study of Theerakulpisut *et al.* (2012) Therefore, both morphological characters, i.e. inflorescence habit, pollen morphology, anatomy and molecular phylogenetic evidence strongly suggest that Sect. *Dymczewiczia* should be merged into the Sect. *Zingiber* as earlier proposed.

SUMMARY AND CONCLUSION

Zingiber Mill. is the type genus of the family Zingiberaceae which includes perennial rhizomatous herbs. They are one of the largest genera in the family with more than 150 species all over the world (Wu & Larsen, 2000; Kishor & Leong-Skornickova, 2013). *Zingiber* is mainly distributed in tropics and subtropics with the center of distribution in the Indo-Malayan region, but extending through tropical Africa to central and South America (Kress *et al.,* 2002). In India, this genus is mainly distributed in Southern Western Ghats and North East India with a total of 41 species and two varieties. The members of the genus are found to be taxonomically difficult mainly due to the short flowering period associated with the monsoon, delicate and fragile flowers that only last for a few hours, large-sized habit, difficulty in the identification from herbarium etc. In addition, variations within the species also raise taxonomic ambiguity.

The previous studies on Indian *Zingiber* were carried out by Sabu (2002) and Vasantha (2009) but their work was focused on South Indian species only. Thripathi and Singh (2006) revised the genus in North East India and reported 8 species but the actual number of species in North East India is still obscure and the identity of some species is still in question and recently many new taxa were added to this genus by discovery and new reports to Indian flora. Most of the recent discoveries are from North East India hence the present study was focused on the North-Eastern region of India.

The present work deals with the Systematics studies on the genus *Zingiber* in North East India which includes morphology, anatomy, palynology, phytochemistry and molecular phylogeny of the genus.

Systematic studies on the genus *Zingiber* in North East India.

The taxonomic revision and systematic studies of South Indian *Zingiber* were already done by Vasantha (2009) and a revision of the genus in North East India was carried out by Thripathi and Singh (2006) but the study does not reveal the exact identity, distribution, ecology and endemism of many taxa. The study also excluded some taxon and many taxa are recently added to northeastern flora, so a more comprehensive and systematic study on the genus *Zingiber* from North East India is carried out here.

Relevant literature and information were obtained from various sources for the taxonomic revision of the genus. Specimens from herbaria such as AAU, ASSAM, BK, BSHC, CAL, CALI, CDRI, K, KEP, KKU, LINN, MH, P, RAF SING and TNS were investigated. The specimens for the study were collected from North East India. The morphology was studied and extensive descriptions were prepared. Based on morphological data, a key to the species for genus *Zingiber* was prepared. As part of germplasm protection, the rhizomes were planted in the Calicut University Botanical Garden (CUBG). The study also made use of live Zingiberaceae germplasm kept at CUBG, which was gathered from various parts of India.

The study identified 27 species and one variety of *Zingiber* from North East India viz., *Z. arunachalensis, Z. bipinianum, Z. callianthum, Z. campanulatum, Z. capitatum*, *Z. caudatum*. *Z. chrysanthum, Z. clarkei*, *Z. cornigerum*, *Z. dimapurense*, *Z. flavofusiforme*, *Z. intermedium*, *Z. kangleipakense*, *Z. kerrii*, *Z. ligulatum*, *Z. marginatum*, *Z. meghalayense*, *Z. mekongense*, *Z. mizoramensis*, *Z. murlenica*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. officinale*, *Z. pherimaense*, *Z. purpureum*, *Z. roseum*, *Z. rubens* and *Z. zerumbet*.

New taxa identified

The present study published three new species and one new verity *i.e., Z. arunachalensis, Z. cornigerum, Z. campanulatum* and *Z. neotruncatum* var. *ramsawmii*.

New synonyms

The present study reduced *Z. siganginensis* under *Z. officinale* and *Z. perenense* under *Z. roseum.*

New infrageneric classification for *Zingiber*

The previous Sectional classification of *Zingiber* recognized four sections based on the inflorescence morphology viz., *Zingiber*. Sect. *Cryptanthium*

Horaninow (1862), having a radical inflorescence with procumbent peduncle; Z. Sect. *Zingiber* with long erect peduncle; Z. Sect. *Pleuranthesis* Benth. (Bentham, 1883) characterized with a spike emerging through the leaf sheath and Z. Sect. *Dymczewiczia* with a terminal inflorescence. In the present molecular study using ITS *Z. capitatum* of Sect. *Dymczewiczia* clustered along with the members of the section *Zingiber* hence Sect. *Dymczewiczia* has merged in Sect. *Zingiber*. Both pollen morphology and anatomical characters are supportive of the new classification.

IUCN status

IUCN statuses were proposed for the taxa under study based on the data available within three years and those without proper data were treated as Data Deficient (DD). The study proposed both *Z. arunachalensis* and *Z. neotruncatum* var. *ramsawmii* as Critically Endangered (CR) and *Z. campanulatum* and *Z. dimapurense* as Vulnerable (VU). *Z. cornigerum*, *Z. chrysanthum* and *Z. neotruncatum* var. *neotruncatum* are proposed as Near Threatened (NT). *Z. capitatum*, *Z. kangleipakense*, *Z. kerrii*, *Z. ligulatum*, *Z. meghalayense*, *Z. mizoramensis*, *Z. officinale*, *Z. purpureum*, *Z. roseum*, *Z. rubens* and *Z. zerumbet* are included under Least Concern (LC) category. The remaining species viz., *Z. caudatum*. *Z. clarkei*, *Z. cornigerum*, *Z. flavofusiforme*, *Z. intermedium*, *Z. mekongense*, *Z. murlenica*, *Z. marginatum* and *Z. pherimaense* comes under the Data Deficient (DD) category.

Endemism

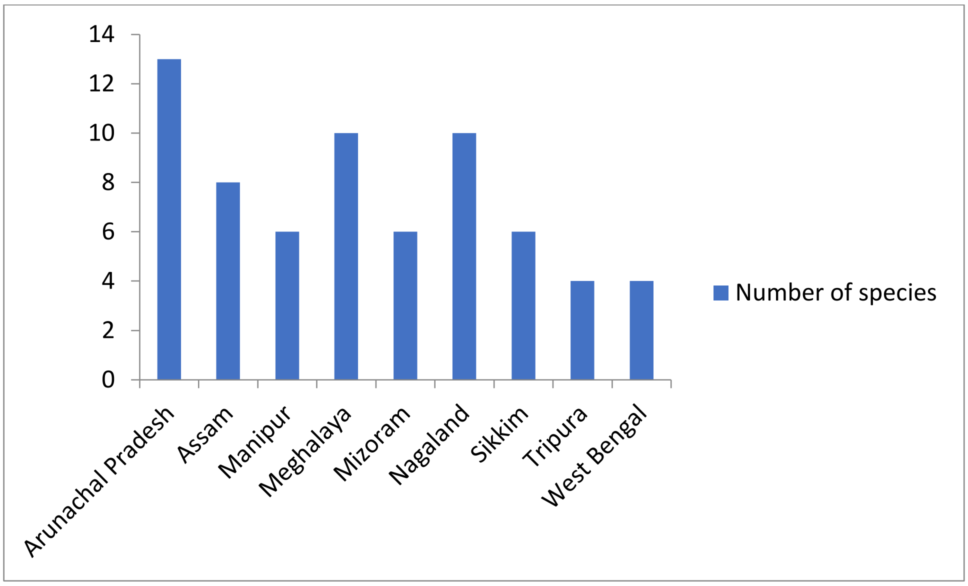
A total of fifteen species were identified as endemic to North East India viz., *Z. arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. caudatum*. *Z. clarkei*, *Z. cornigerum*, *Z. dimapurense*, *Z. intermedium*, *Z. kangleipakense*, *Z. marginatum*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. neotruncatum* var. *ramsawmii* and *Z. pherimaense*. Most of them are recently discovered species except Z. *clarkei*, *Z. intermedium* and *Z. marginatum* and the rest are not yet reported from outside India.

Table 10. *Zingiber* in North East India

Sn	Name of the taxa	Distribution	Endemic status	IUCN status
1	***Zingiber arunachalensis***	AR	E NEI	CR
2	***Z. bipinianum***	AR	E NEI	DD
3	***Z. callianthum***	ND	Non-E	DD
4	***Z. campanulatum***	AR	E NEI	VU
5	***Z. capitatum***	AS, MG, ND, SK, WB	Non-E	LC
6	***Z. caudatum***	AR	E NEI	DD
7	***Z. chrysanthum***	AR, MG, SK	Non-E	NT
8	***Z. clarkei***	SK, WB	E NEI	DD
9	***Z. cornigerum***	AR	E NEI	NT
10	***Z. dimapurense***	AR, ND	E NEI	VU
11	***Z. flavofusiforme***	AS	Non-E	DD
12	***Z. intermedium***	AR, ND, MG	E NEI	DD
13	***Z. kangleipakense***	ND, MZ, MN	E NEI	LC
14	***Z. kerrii***	MN	Non-E	LC
15	***Z. ligulatum***	ND, AS, TR, MG	Non-E	LC
16	***Z. marginatum***	-	E NEI	DD
17	***Z. meghalayense***	MG	E NEI	LC
18	***Z. mekongense***	ND	Non-E	DD
19	***Z. mizoramensis***	MZ	E NEI	LC
20	***Z. murlenica***	MZ	E NEI	DD
21	***Z. neotruncatum* var. *neotruncatum***	AR	Non-E	NT
22	***Z. neotruncatum* var. *ramsawmii***	MZ	E NEI	CR
23	***Z. officinale***	NEI (Cultivated)	Non-E	LC
24	***Z. pherimaense***	ND	E NEI	DD
25	***Z. purpureum***	AS, AR, MG, SK, MN	Non-E	LC
26	***Z. roseum***	AR, AS, MZ, MG, ND	Non-E	LC
27	***Z. rubens***	AR, AS, MN, MG, SK, TR	Non-E	LC
28	***Z. zerumbet***	AR, AS, MN, MG, SK, TR, WB,	Non-E	LC

Expansion of Acronyms: AR-Arunachal Pradesh, AS- Assam, CR-Critically Endangered, DD- Data Deficient, LC-Least Concerned, MG-Meghalaya, MN-

Manipur, MZ-Mizoram, Non-E-Non Endemic, NEI-Northeast India, NG- Nagaland, NT-Near Threatened, SK-Sikkim, TE-Telangana, TR-Tripura, VU-Vulnerable, WB-West Bengal.



Graph 1. No. of *Zingiber* species in North East Indian states.

Anatomy

The study mainly focused on how the anatomical data can be used as a tool to support morphology in the systematics of the genus *Zingiber*. The study included the foliar anatomy of the genus *Zingiber* and we have studied the transverse sections of lamina, midrib, margin and leaf sheath of 18 selected taxa of the genus. The sampling confirmed the representation from all the four infrageneric sections. The characters were studied from their freehand sections. Photomicrographs of the sections were also taken. Major anatomical characters observed include shape and arrangement of vascular bundles, attachment of bundle sheath cells, occurrence and number of layers of hypodermal tissue, number of mesophyll layers, shape and thickness of lamina, presence of arc bundles, the shape of adaxial and abaxial surface of midrib and leaf sheath, number of layers of the hyaline region at the leaf margin, length of the hyaline region, cellular inclusions etc. A key to species and dendrogram based on anatomical characters were prepared. The present study revealed that anatomical characteristics like length and shape of the hyaline region, the thickness of lamina, presence or absence of hypodermal layers and presence of arc bundles are varying among species and are unique for each species hence they are useful as diagnostic characters for species identification and as well as sectional demarcation. The Sect. *Pleuranthesis* is characterized by continuous adaxial hypodermis in the leaf lamina hence this character can be utilized as a diagnostic character for Sect. *Pleuranthesis,* whereas in the other three sections adaxial hypodermis is absent in leaf lamina. The Sect. *Cryptanthium* is characterized by a leaf vascular bundle which is attached to the adaxial epidermis only (In *Z. cornigerum* the sclerenchymatous bundle cap is not in contact with either of the epidermis) whereas in Sect. *Zingiber* and *Dymczewiczia* the vascular bundle of the lamina is attached to both epidermises and this character justifies the amalgamation of Sect. *Zingiber* and *Dymczewiczia*. The present anatomical study was found useful in confirming the novelty of *Z. campanulatum* and *Z. cornigeum.* Out of the 18 taxa studied, only three taxa (*Z. roseum*, *Z. capitatum* and *Z. purpureum*) were previously studied in anatomical aspects, whereas all others (15) are studied for the first time.

Palynology

The present study deals with the pollen morphology of 20 species and one variety of *Zingiber.* The study was conducted by the SEM imaging of the pollen samples preserved in FAA. The major characteristics included in the study are shape and size of the pollen, exine ornamentation, thickness of exine, shape orientation and thickness of muri, the thickness of lumen, presence or absence of puncta and branching pattern of muri, etc. The present study divided the 21 taxa into two broad groups. Group 1 with spherical grains and cerebroid ornamentation. Group 2 with elongated ellipsoidal grains with striate ornamentation. Spheroidal grains are found in *Z. capitatum*, *Z. clarkei*, *Z. kerrii*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. officinale*, *Z. purpureum* and *Z. zerumbet* The ellipsoidal pollens are found in ***Z.*** *arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. cornigerum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. pherimaense*, *Z. roseum* and *Z. rubens*. The members of Sect. *Zingiber* and Sect. *Dymczewiczia* exhibits the same shape and ornamentation (spherical pollen with cerebroid sculpturing) and the sectional demarcation based on the nature of inflorescence in genus *Zingiber* was not satisfactory hence the study proposes that *Z. capitatum* can be included under Sect. *Zingiber* and both the sections should be merged. Even though ornamentation of grains is peculiar for each group but each taxon shows a characteristic arrangement of muri and lumen. The study revealed the pollen characters have diagnostic value so this can be utilized for the identification and classification of species. A key to species based on palynological characters was prepared for all the taxa studied. The pollen characters are also used for confirming the novelty of *Z. campanulatum* and *Z. cornigerum*. Moreover, out of the 21 taxa studied the palynological studies of *Z. clarkei*, *Z. neotruncatum* var. *neotruncatum*, *Z. neotruncatum* var. *ramsawmii*, *Z. arunachalensis*, *Z. bipinianum*, *Z. campanulatum*, *Z. chrysanthum*, *Z. cornigerum*, *Z. dimapurense*, *Z. kangleipakense*, *Z. meghalayense*, *Z. mizoramensis*, *Z. murlenica*, *Z. pherimaense* and *Z. rubens* were conducted for the first time.

Phytochemistry

The present study provides the first comprehensive analysis of the volatile composition of 19 taxa of the genus *Zingiber* and out of the 19 taxa studied the volatile characterization of *Z. arunachalensis, Z. bipinianum, Z. campanulatum, Z. capitatum, Z. clarkei, Z. cornigerum, Z. dimapurense, Z. kangleipakense, Z. meghalayense, Z. mizoramensis, Z. murlenica, Z. kerrii*, *Z. neotruncatum* var. *ramsawmii* and *Z. pherimaensis* was previously not studied so this is the first report on the phytochemistry of these *Zingiber* taxa. A total of 154 chemical constituents were identified. Among them, the monoterpenes consist of the main proportion in all studied taxa. α-Pinene is the major compound in *Z. campanulatum*, *Z. capitatum*, *Z. dimapurense* and *Z. kerrii*. β-Pinene is dominating in *Z. cornigerum*, *Z. murlenica* and *Z. roseum* and these two compounds are present in all the species studied. Each species is found to be unique in its volatile profile with a specific compound that is not traced in other taxa studied and many of them can be used as chemical markers for identification. For example, Perellene can be utilized as a marker compound for

Z. neotruncatum var. *neotruncatum* and *Z. neotruncatum* var. *ramsawmii*. The UPGMA tree constructed using the phytochemical data divides the 19 taxa into two major groups and is grouped into 6 clusters irrespective of their morphological affinity. The ML trees and Bayesian trees generated using ITS gene are in support of the previous sectional classification of genus *Zingiber* but the UPGMA tree based on phytochemical data doesn't follow it. Here morphologically distinct taxa are grouped in the UPGMA analysis because of the similarity in their volatile profile hence it points out that the phytochemical evolution and molecular evolution in *Zingiber* occur independently in different lines and the phytochemical evolution can be influenced by various factors like soil, climate and geographical location, for example, two different accessions of *Z. zerumbet* i.e., one from Kerala and another from Nagaland was subjected to volatile profiling and we got entirely different volatile profiles in terms of the concentration of compounds and their presence or absence but the marker compound Zerumbone was present in both the accessions irrespective of the variation in influencing climatic factors. So according to the present study the phytochemical data cannot be used as a tool for taxonomical purposes instead the marker compound in each taxon can be utilized as a good candidate for identification purposes.

Molecular study of the genus *Zingiber* in India

A study of the DNA sequence data of genus *Zingiber* using ITS gene helped to infer the phylogeny, confirm the novelty of some taxa and for the sectional placement of some taxa.

The Maximum Likelihood analysis and Bayesian analysis using ITS gene resulted in an almost similar tree topology. Three clades were recognized in each tree. The clades correspond to the previous sectional classification of *Zingiber* (Horaninow, 1862; Bentham, 1883) but *Z. capitatum*, the only representative of the Sect. *Dymczewiczia* clustered along with the members of Sect. *Zingiber*. The previous sectional classification was solely based on the nature of inflorescence but this treatment was found insignificant because in some instances members of Sect. Z*ingiber* (inflorescence on eruct peduncle developing from rhizome) produce terminal inflorescence which is the characteristic feature of Sect. *Dymczewiczia*. Similarly, both sections are characterized by spherical pollen with striate sculpturing and main vascular bundles of the lamina in contact with both epidermises. So the present molecular analysis using ITS gene along with palynological and anatomical evidence strongly suggests that Sect. *Dymczewiczia* should be merged with Sect. *Zingiber*. The molecular study also served as supportive data to confirm the novelty of *Z. camapnulatum*, *Z. cornigerum*, *Z. arunachalensis* and *Z. neotruncatum* var. *ramsawmii*. The study was found helpful in placing both *Z. kangleipakense* and *Z. mizoramensis* in Sect. *Cryptanthium* (rarely do both produce inflorescence which emerges through the leaf sheath, a characteristic feature of Sect. *Pleuranthesis*). The study also suggests that a more comprehensive molecular analysis should be conducted by incorporating more taxa including exotics for a better understanding of the phylogeny of the genus *Zingiber*.

RECOMMENDATIONS

The present study includes the taxonomic revision and systematic studies of the genus *Zingiber* in North East India. The systematic studies of the genus were carried out using their morphological, anatomical, palynological, phytochemical and molecular data. The molecular phylogeny of the genus was studied based on DNA sequencing of the taxa using ITS gene.

The genus *Zingiber* lacks an authentic and comprehensive revision. Many taxa have problems with the species level delimitations and sectional placement. These kinds of problems can be solved with the help of systematics. The systematic study provides a more detailed idea about a genus or a species, it collects information from all possible sources such as morphology, anatomy, palynology, phytochemistry, molecular biology, etc. these bulk data provide scientific names and classifications for organisms, descriptions and key for identification, information on their distribution, reveals their evolutionary history and analyzes their ecological adaptations and future distribution pattern. In the present study, the incorporation of data from anatomy, palynology, phytochemistry and molecular phylogeny in addition to morphology help us to make a clearer picture of the genus *Zingiber* and served support in taxonomic identification of many taxa. It also revealed the novelty of some taxa.

The major issue that arises in the field of plant research is the misidentification of taxa. The exact identity of many taxa including genus *Zingiber* are still under confusion and these issues are found in some major Floras of the country. The proper identification of plants is necessary for their proper utilization in medicines and food and also for their conservation. In many plants, the morphological key was found insufficient to identify them from the most allied species under such situations data from anatomy, phytochemistry, molecular biology, etc. in support of morphology can be utilized to confirm their identity.

The present study provides comprehensive data about the genus *Zingiber* from all possible branches of plant science which will be useful in future research on this genus. The study identifies a total of 27 *Zingiber* sp. and one variety from North

East India among these 4 of them are new to science and their pharmacological potential and other useful aspects are yet to be studied. Similarly, many taxa included in the study are economically important. For example, *Z. officinale, Z. zerumbet* and *Z. purpureum,* etc. are used in local medicine and found to have some major pharmacological properties, likewise, members of the genus are still under investigation for their various properties useful for humankind.

Future perspective of the study

- Molecular dating of genus *Zingiber* using more nuclear and chloroplast markers.
- Study the phylogeography of the genus *Zingiber*.
- Ecological Niche Modeling of selected members of the genus.
- IUCN status of all taxa based on field study needs to be undertaken.
- To study the pharmacological properties of *Z. arunachalensis*, *Z. cornigerum*, *Z. campanulatum*, *Z. mizoramensis*, *Z. murlenica*, *Z. meghalayense*, *Z. pherimaense*, *Z. bipinianum* and *Z. dimapurense* etc.
- To study the pollination biology of *Z. arunachalensis*, *Z. cornigerum*, *Z. campanulatum*, *Z. mizoramensis*, *Z. murlenica*, *Z. meghalayense*, *Z. pherimaense*, *Z. bipinianum* and *Z. dimapurense* etc.
- Identification of disease-resistant genes from newly discovered species such as *Z. arunachalensis*, *Z. cornigerum*, *Z. campanulatum*, *Z. mizoramensis*, *Z. murlenica*, *Z. meghalayense*, *Z. pherimaense*, *Z. bipinianum* and *Z. dimapurense* etc.
- Screening of newly discovered taxa for novel compounds.
- To study the Seed and rhizome fatty acids of genus *Zingiber* and to evaluate the nutritional status of the novel taxa.
- Karyomorphological and cytogenetical studies of genus *Zingiber.*
- To identify stress-tolerant wild relatives of *Zingiber officinale*.

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APPENDIX I

ZINGIBERACEAE

PLANT DESCRIPTION

NAME...COLLECTION No:..

HABITAT:...LOCALITY...

HABIT...

RHIZOME

Size:	Branching:	Color :
Position in soil:	Nature:	Aroma:

Root Tubers:

Present/Absent	Shape:	Distance:
Size:	Color:	Number:

LEAFY SHOOT

Height:	No. of leaves:	Distance between leaves:
Pseudostem:	Notes:	

LEAVES

Petiole:

Length:	Surface:	Color:	Notes:

Lamina:

Length:	Upper Surface:	Tip:	Venation:
Breadth:	Lower Surface:	Base:	Midrib:
		Margin:	Notes:

Ligule:

Size:	No. of lobes:	Surface:
Shape:	Color:	Notes:

INFLORESCENCE

Position:

Radical	Terminal	Lateral	Central

Peduncle:

Height/Length	Thickness:	Nature:	Color:

Bracts:

Length:	Number:	Color:	Margin:
Breadth:	Nature:	Surface:	Cincinnus:

Anther Thecae :

Size :	Colour :	Shape :	Notes :

Anther Crests (Present/Absent)

Size :	Shape :	Color :	Notes :

Anther Spurs (Present/Absent)

Size :	Shape :	Color :	Notes :

Ovary :

Size :	Locularity :	Placentation :	Notes :
Shape :	Amount of ovules :	Style :	

Stigma :

Shape :	Color :	Cilia :	Notes :

Epigynous glands :

Number :	Size :	Shape :	Color :

FRUIT

Capsule :

Size :	Color :	Locularity :
Shape :	Surface :	Notes :

Seeds :

Number :	Shape :	Surface :	Notes :
Size :	Color :	Aroma :	

Arillus :

Size :	Shape :	Colour :	Notes :

Notes :..

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APPENDIX II

PUBLICATIONS

List of papers published in Journals

1. **Thachat, J**., Punekar, S.A., Hareesh, V.S. and Sabu, M., 2020. Rediscovery of *Globba andersonii* and three new synonymies in Indian Zingiberaceae. *Botany Letters*, *167*(3), pp.373-377. DOI: 10.1080/23818107.2020.1770626. ISSN: 2381-8115 (Print); ISSN: 2381-8107 (Online).

2. **Jayakrishnan, T**., Joe, A., Hareesh, V.S. and Sabu, M., 2021. Two new *Zingiber* (Zingiberaceae) species from Arunachal Pradesh, Northeastern India. *Taiwania*, *66*(1). pp. 101-112. DOI: 10.6165/tai.2021.66.101. ISSN: 0372-333X (Print); ISSN: 0372-333X (Online).

3. Joe, A., **Jayakrishnan, T**., Hareesh, V.S. and Sabu, M., 2017. *Zingiber arunachalensis* (Zingiberaceae): a new species from northeastern India. *Phytotaxa*, *309*(1), pp.95-98. DOI: 10.11646/phytotaxa.309.1.11.

4. Lalramnghinglova, H., Sawmliana, M., **Jayakrishnan, T.** and Sabu, M., 2021. A new variety of *Zingiber neotruncatum* (*Zingiberaceae*) from Mizoram, North East India. *Journal of Japanese botany*, 96 (6) pp. 321-325.

APPENDIX III

PAPER PRESENTATIONS

1. **Thachat Jayakrishnan** and M. Sabu. 2017. Phytochemical analysis of five *Zingiber* species from North East india using Headspace a Rapid screening technique for volatiles. XXVII Annual conference of Indian Association for Angiosperm Taxonomy and International symposium on “Plant Systematics: Priorities and Challenges. 10th Nov. – 12th Nov. 2017. Souvenir and Abstracts 78. University of Delhi, Delhi.

2. **Thachat Jayakrishnan** and M. Sabu. 2018. Taxonomic Revision of *Zingiber* Section Cryptanthium (Zingiberaceae) in India. XXVIII Annual conference of Indian Association for Angiosperm Taxonomy and International symposium on Conservation of Angiosperm Diversity: Hidden Treasure of Today and Tomorrow. 29th Oct. – 31th Oct. 2018. Souvenir and Abstracts 17. Department of Botany, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat.

3. **Thachat Jayakrishnan** and M. Sabu. 2023. Taxonomic Revision of Genus *Zingiber* (Zingiberaceae) in North East India. International Seminar on Gingers. 1st Mar. – 3rd Mar. 2023. Souvenir and Abstracts 26. KSCSTE-Malabar Botanical Garden and Institute for Plant Sciences, Kozhikode, Kerala, India

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