



Two new *Zingiber* (Zingiberaceae) species from Arunachal Pradesh, Northeastern India

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(Manuscript received 17 May 2020; Accepted 22 February 2021; Online published 5 March 2021)

ABSTRACT: Two new species of *Zingiber* viz. *Z. cornigrum* and *Z. campanulatum* from Arunachal Pradesh, North-East India are described. In addition to morphology, data from anatomy, pollen morphology and molecular biology are also used. A key to the *Zingiber* Sect. *Cryptanthium* from Northeastern India is provided.

KEY WORDS: Anatomy, ITS gene, Palynology, Sect. *Cryptanthium*, *Zingiber cornigerum*, *Zingiber campanulatum*.

INTRODUCTION

Zingiber Miller (1754) belongs to the family Zingiberaceae. *Zingiber* is mainly distributed in tropics and subtropics with the centre of distribution in the Indo-Malayan region, but extending through tropical Africa to central and South America (Kress, *et al.*, 2002), with about 150 species all over the world (Wu and Larsen, 2000; Kishor and Leong-Skornickova, 2013). In India, the genus is represented by 32 species (Kumar, *et al.*, 2015; Prabhukumar, *et al.*, 2016; Joe, *et al.*, 2017) belongs to 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. (Bentham, 1883) characterized with a spike emerging through the leaf sheath and (4) *Z.* sect. *Dymczewiczia* with a terminal inflorescence (Bentham, 1883).

Recently, several new species of *Zingiber* have been described from North-East India (Kumar *et al.*, 2013, 2015; Thongam *et al.*, 2013; Thongam and Konsam, 2014; Leong-Skornickova *et al.*, 2015, Talukdar *et al.*, 2015, Joe *et al.*, 2017, Odyuo *et al.*, 2019) and the number of species of *Zingiber* recorded in North-East India is 20 (Odyuo *et al.*, 2019). In our floristic explorations to Northeastern India during 2015 and 2016, we have collected two interesting *Zingiber* species from Lower Dibang Valley district of Arunachal Pradesh. Both species possess radical inflorescence with procumbent peduncle, hence belong to sect. *Cryptanthium*, the largest section in India. Out of the 32 species of *Zingiber* in India, 16 belongs to sect. *Cryptanthium* with 11 species distributed in Northeastern India. The morphological investigation using types and relevant literature (Roscoe, 1828; Baker,

1892; Mood and Theilade, 2002; Sabu, 2003; Tripathi and Singh, 2006; Kishor and Leong-Škorničková, 2013; Kumar *et al.*, 2013, 2015; Leong-Škorničková, *et al.*, 2015; Thongam and Konsam, 2014; Triboun, *et al.*, 2014; Talukdar, *et al.*, 2015) reveals the novelty of both the taxa. A critical comparative study using morphological, anatomical, palynological and molecular characters of the unknown specimens with allied taxa revealed that both can be treated as distinct species and can be placed in the section *Cryptanthium*.

The details of the present collections, detailed descriptions and colour plates of the new species, comparison tables and photo plates are also provided.

MATERIALS AND METHODS

Morphology

The present study is based on the examination of living specimens collected during the field work in Arunachal Pradesh. Collected specimens were preserved in 4% formalin and 50% Formalin-Acetic acid-Alcohol (FAA). Photographs were taken with a Nikon D750 Camera. The color plates were prepared using stereo microscope, Leica M80 attached with Leica EC3 camera. For terminology and methodology of measurements, we follow the work of Bai *et al.*, (2015). Type specimens of the most closely related species were examined from ASSAM herbarium. Type and additional specimens were deposited at CAL and CALI.

Anatomy

Anatomical studies were carried out using fresh as well as preserved specimens. The sections were stained using safranin, and mounted on a clear glass slide using glycerin. For the anatomical studies, the fifth leaf from the tip was sampled. The cross section, leaf margin, and



midrib were taken from the middle portion of the leaf lamina. The sections were observed under Axio Lab.A1 ZEISSAxioCam ERc 5s with 5X to 100X magnifications.

Pollen morphology

Palynological studies were carried out on pollen grains preserved in 70% ethanol and Acetic acid-Alcohol (FAA). Direct mounting method was adopted, since common acetolysis method was found unsuitable. Prior to 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 re-suspended 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.

Molecular study

A phylogenetic analysis was carried out based on nucleotide sequence of nuclear internal transcribed spacer (ITS) regions. PCR amplification for the ITS region was performed using primers 5P (5'-GGA AGG AGA AGT CTA ACA AGG-3') and 8P (5'-CAC GCT TCT CCA GAC TAC A-3') with annealing temperature at 56°C (Moller and Cronk, 1997). Thirty one taxa were used for the analyses, which includes five species of *Zingiber* from North East India sequenced by us and 26 taxa were accessed from Genbank. *Kaemferia galanga* L. and *K. rotunda* L. were used as outgroups. Appendix 1 provides the list of taxa included in the present study with their sectional status, GenBank accession number and voucher details. The sequences were analysed by maximum likelihood approach and phylogenetic analyses were performed using RaxML v.8.1.18 (Stamatakis, 2014) on the CIPRESS Science Gate way v.3.3. The data set was analysed using the model GTRGAMMAI. The bootstrap percentage supports for the clades were assessed using 1000 boot strap replicates in ML analysis.

RESULTS

Morphology

The morphological comparison between the five *Zingiber* species studied here strongly supports both *Z. cornigerum* and *Z. campanulatum* as new taxa. Some of the major differences noted in the morphology of *Z. cornigerum* with that of *Z. bipinianum* are the glabrous ligule, horned bracteole, long corolla tube, pinkish labellum with round apex and adnate lateral staminodes with beaked apex and *Zingiber campanulatum* differs from *Z. mizoramensis* and *Z. arunachalensis* in having an

oblong lamina, bracts with purplish tinge at the apex and the margins, elliptic labellum and purple blotched lateral staminodes with truncate apex (Table 1).

Anatomy

Some of the major differences noted in the anatomy of *Z. cornigerum* with that of *Z. bipinianum* are thicker lamina, 2-layered palisade, presence of adaxial hypodermis above primary vascular bundle, presence of abaxial hypodermis, larger main vascular bundle, attached to hypodermis only, 4–5-layered adaxial bundle cap, 2–4 layered hyaline portion of the margin of leaf lamina and presence of arc-IV bundle in the leaf midrib. *Zingiber campanulatum* differs from *Z. mizoramensis* and *Z. arunachalensis* in having thicker lamina, broader main vascular bundle, 4–5-layered adaxial bundle cap and absence of arc IV bundle (Table 2, Fig. 1).

Pollen morphology

The pollen of *Z. cornigerum* differs from that of *Z. bipinianum* by its ellipsoid shape, larger size, loosely arranged, occasionally branching muri with large lumen. Pollen of *Z. campanulatum* differs from that of *Z. mizoramensis* and *Z. arunachalensis* by its smaller size. In *Z. arunachalensis* muri are unbranched but in *Z. campanulatum* and *Z. mizoramensis* muri are frequently branched (Table 3, Fig. 2).

Molecular study

Phylogenetic tree constructed using ITS (Fig. 3) sequence data are highly supportive to consider *Z. cornigerum* and *Z. campanulatum* as new species and also justifies their sectional positioning in Sec. *Cryptanthium*. The clade formed by *Z. campanulatum*, *Z. mizoramensis* and *Z. arunachalensis* is supported by 94% bootstrap value. *Z. cornigerum* nesting in a distinct clade along with *Z. bipinianum* supported by a bootstrap value of 98%.

DISSCUSION

Theilade (1999) suggested that the nature and development of inflorescences may be under the influence of environmental factors and her study on the pollen of 18 species of *Zingiber*, shows that members of sect. *Zingiber* and *Dymczewiczia* have spherical pollen with cerebroid sculpturing. It was therefore proposed that sect. *Dymczewiczia* should be merged in sect. *Zingiber*. A previous phylogenetic analysis by Theerakulpisut *et al.*, (2012) using ITS region has resolved the species into four clades, which correspond with previously recognized sectional classification of the genus *Zingiber* based on inflorescence type (sects *Zingiber*, *Dymczewiczia* (Horan.) Benth., *Pleuranthesis* Benth. and *Cryptanthium* Horan.). According to Theerakulpisut *et al.* (2012), sects *Zingiber* and *Dymczewiczia* are weakly supported as separate groups

**Table 1.** Comparison of five similar species of *Zingiber* sect. *Cryptanthium* based on morphological characters.

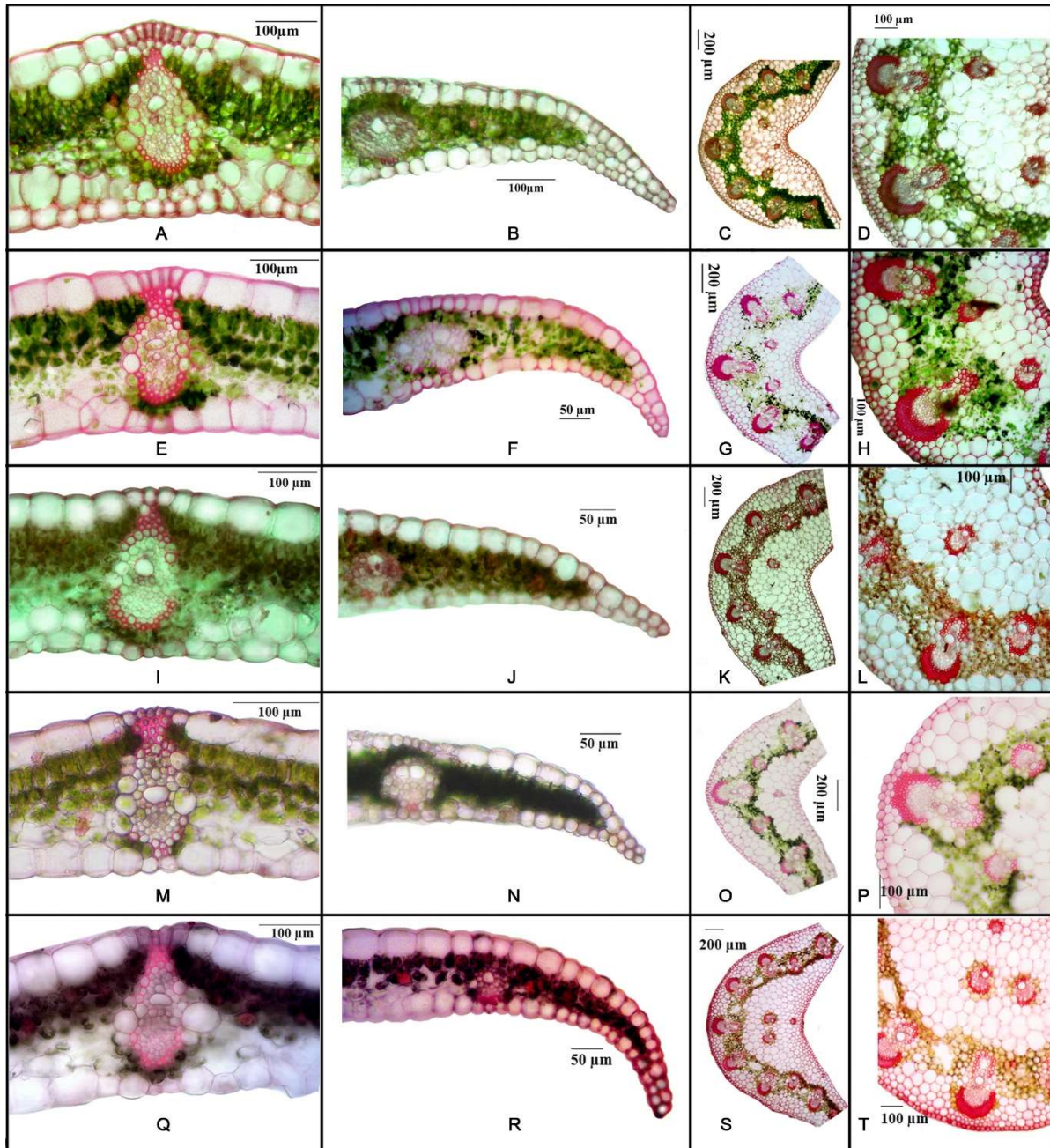
Characters	<i>Z. cornigerum</i>	<i>Z. bipinianum</i>	<i>Z. mizoramensis</i>	<i>Z. campanulatum</i>	<i>Z. arunachalensis</i>
Ligule	Glabrous	Villous	Glabrous	Pubescent	Pubescent
Lamina	Elliptic-lanceolate	Elliptic-lanceolate	Oblong to narrowly-ovate	Oblong	Ovate to narrowly-ovate
Peduncle	3–6 cm long	5.0–6.0 cm long	1.0–1.5 cm long	6–13 cm long	6.5–8 cm long
Bracts	Broadly ovate, creamy white with purplish tinge	Broadly ovate, purple	Oblong-obovate, reddish	Narrowly obovate, creamy, purplish towards apex and margin	Ovate to narrowly ovate, purplish
Bracteole	apex horned	apex acute	apex truncate	apex acute	apex acute
Corolla tube	6–7 cm long	c. 4.3 cm long	4.0 – 5.0 cm long	5–5.3 cm long	4.5–5.3 cm long
Dorsal corolla lobe	White with translucent veins	Creamy white	Purplish pink with white base	Cream	Cream
Labellum	Elliptic, creamy-white with reddish pink blotches. apex round	Ovate-elliptic, creamy-white, blotched with purple, apex acuminate	Ovate, purplish with creamy white spots and streaks, apex obtuse	Elliptic, deep purple with creamy yellow base, creamy lines towards the center and creamy dots at the periphery, apex round	Broadly ovate, deep violet purple or purple with creamy yellow base and some cream dots towards the centre and lines at periphery, apex acute
Lateral staminode	Triangular, adnate, 1/2 adnate to labellum, white, apex beaked	Linear-lanceolate, free, creamy white, apex acute	Narrowly ovate, adnate to labellum by apical 3/4, purplish with white base, apex acute	Ovate 3/4 th portion adnate with labellum, pinkish with cream dots and lines, base creamy white, apex truncate	Ovate or narrowly ovate, free from labellum, purple with some cream dots, apex acute
Ovary	8–9 mm long	c. 6 mm long	7 mm long	6–7 mm long	7–9 mm long
Epigynous glands	8–9 mm long	c. 4 mm long	3–4 mm long	7–8 mm long	8–16 mm long
Anthesis	Early morning	Late evening	Early morning	Early morning	Early morning

Table 2. Comparison of five closely related species of *Zingiber* sect. *Cryptanthium* based on anatomical characters

Characters	<i>Z. cornigerum</i>	<i>Z. bipinianum</i>	<i>Z. mizoramensis</i>	<i>Z. campanulatum</i>	<i>Z. arunachalensis</i>
Lamina					
Thickness	265–339 µm	245–255 µm	162–200 µm	264–288 µm	238–250 µm
Mesophyll thickness	81–88 µm	92–98 µm	67–85 µm	111–124 µm	73–84 µm
Palisade	2-layered	Single layered	Single layered	Single layered	Single layered
Adaxial hypodermis	Single-layered, present only above primary vascular bundle	Absent	Absent	Absent	Absent
Abaxial hypodermis	Present, single layered	Absent	Present, single layered	Present, single layered	Present, single layered
Main vascular bundle:					
Size	218–220 × 141–147 µm	176–179 × 99–104 µm	144–180 × 79–90 µm	215–217 × 118–130 µm	180–283 × 85–95 µm
Attachments	Adaxial hypodermis only	Adaxial epidermis only	Both epidermis	Adaxial epidermis only	Adaxial epidermis only
Adaxial bundle cap	4–5-layered, 37–43 × 43 µm	3–4-layered, 49–50 × 47–60 µm	3–4-layered, 23–24 × 42–51 µm	4–5-layered, 52–60 × 47–58 µm	2–3-layered, 25–29 × 43–49 µm
Abaxial bundle cap	1–2-layered, 13 µm thick	1–2-layered, 14–15 µm thick	1–2-layered, 14–15 µm thick	Single layered, 13–14 µm thick	1–2-layered, 14–15 µm thick
Metaxylem	Circular, 33–35 µm diam.	Angular, 13–16 µm diam.	Angular, 20–30 µm diam.	Circular, 33–35 µm diam.	Angular, 32–37 µm diam.
Leaf margin					
Hyaline region	2–4-layered, 150–153 µm long	2-layered, 93.94–102.08 µm long	2-layered, 67–80 µm long	2-layered, 116–124 µm long	2-layered, 127–130 µm long
length between margin and marginal bundle	227–228 µm long	271–286 µm long	220–261 µm long	265–271 µm long	263–267 µm long
Midrib					
Adaxial side	U- shaped	Wide U- shaped	Wide V-shaped	Concave shaped	Concave shaped
No. of Arc bundles	Three. I, III and IV present	Two. I and III present	Three. I, III and IV present	Two. I and III present	Three. I, III and IV present

**Table 3.** Comparison of five closely related species of *Zingiber* sect. *Cryptanthium* based on palynological characters.

Characters	<i>Z. cornigerum</i>	<i>Z. bipinianum</i>	<i>Z. mizoramensis</i>	<i>Z. campanulatum</i>	<i>Z. arunachalensis</i>
Shape	Ellipsoidal	Sub-spherical	Ellipsoidal	Ellipsoidal	Ovate – Ellipsoidal
Size	122–155 × 47–80 μm	80–106 × 86–110 μm	133–140 × 47–55 μm	111–120 × 48–55 μm	125–130 × 57–60 μm
P/E Ratio	1.78	1.06	2.54	2.18	2.16
Muri	Loosely arranged, margin irregular, infrequently branching, 2.03–2.28 μm width	Closely arranged, margin irregular, frequently branching, 2.45–2.62 μm width	Loosely arranged, margin irregular, frequently branching, 2–3 μm thick	Closely arranged, margin irregular, frequently branching, 2–3 μm thick	Loosely arranged, margin smooth, unbranched, 1–2 μm thick,
Lumen	Broad, 4.14–5.20 μm width	Narrow, 1.47–1.80 μm width	Broad, 3–4 μm width	Narrow, 2.5–2.8 μm width	Narrow, 2.2–2.7 μm width

**Fig. 1.** Anatomical sections. *Zingiber cornigerum*. (A-D), *Z. bipinianum* (E-H), *Zingiber campanulatum*. (I-L), *Z. mizoramensis* (M-P) & *Z. arunachalensis* (Q-T). A, E, I, M & Q : Cross section of lamina. B, F, J, N & R: Cross section of leaf margin. C, G, K, O & S: Transverse section of midrib (D, H, L, P & T: a portion enlarged)

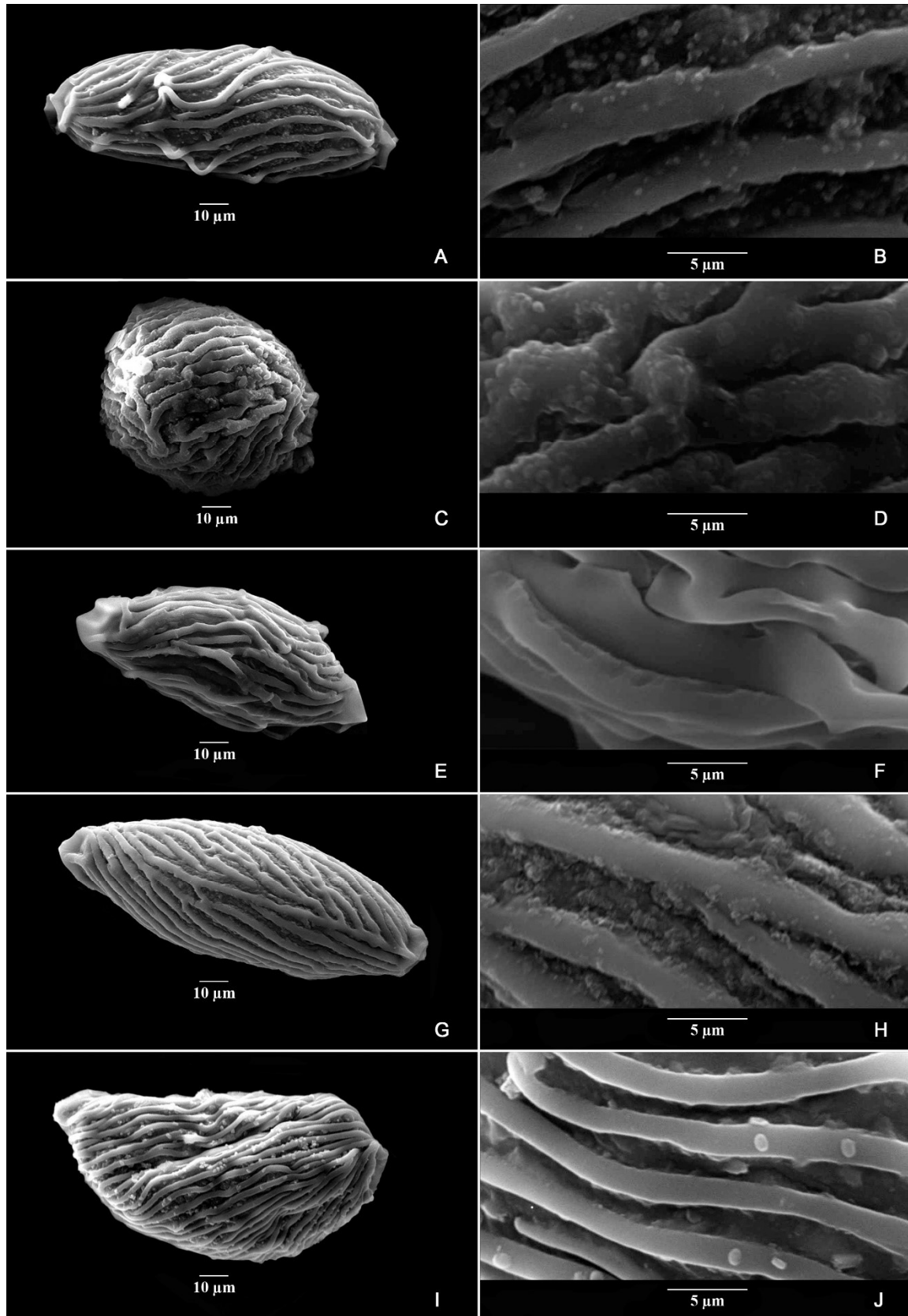


Fig. 2. SEM images of pollen. **A & B:** *Z. cornigerum*. **C & D:** *Z. bipinianum*. **E & F:** *Z. campanulatum*. **G & H:** *Z. mizoramensis*. **I & J:** *Z. arunachalensis*.

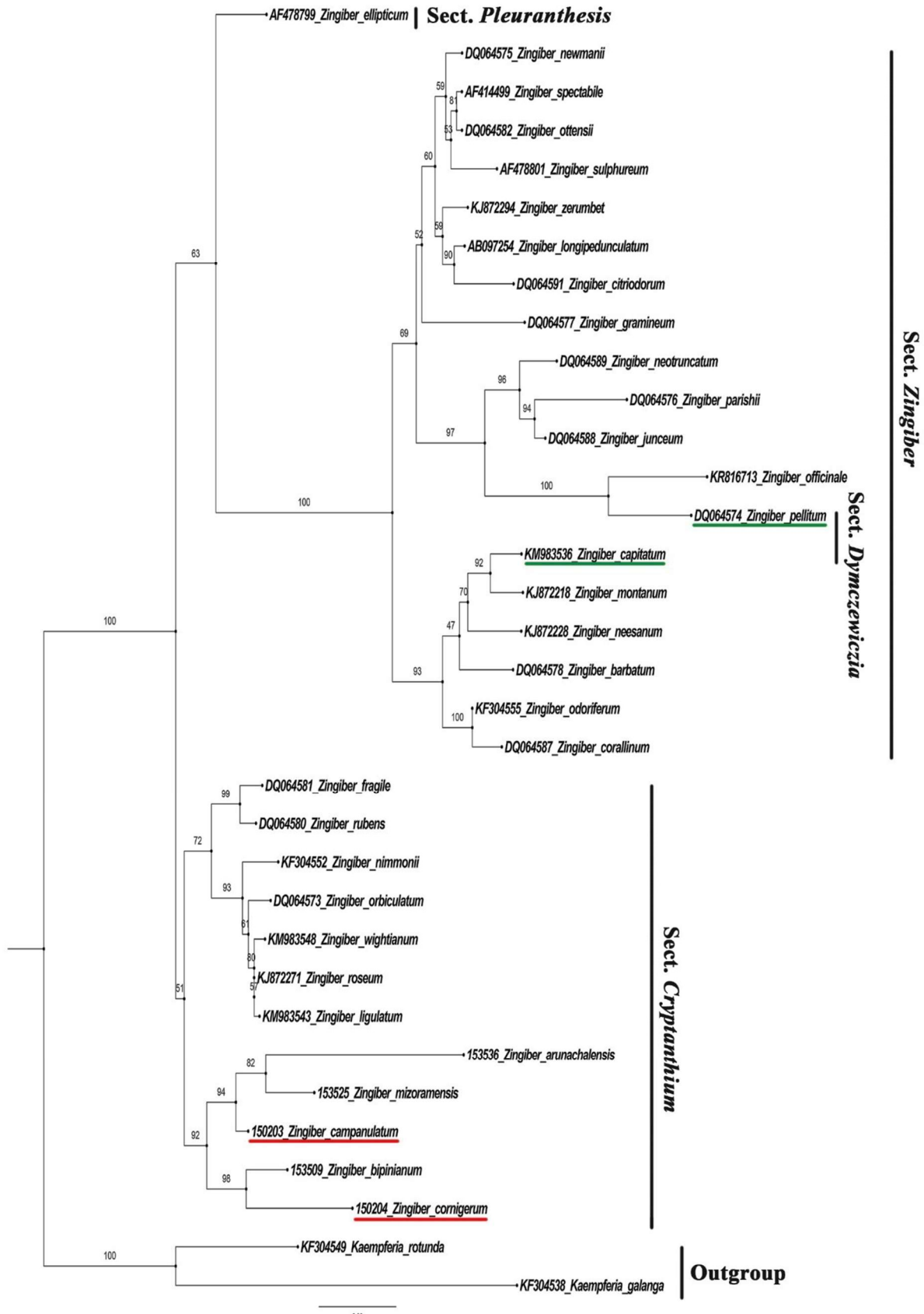


Fig. 3. ML tree using ITS gene sequences of *Zingiber* species, Bootstrap percentage indicated on side (based on 1000 replicates).



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*. The present phylogenetic analysis also shows that sect. *Dymczewiczia* and *Zingiber* are formed within the same clade with high bootstrap support (100%). Hence, this analysis of nuclear ITS sequences supports the pollen-based proposal by Theilade *et al.* and phylogenetic study of Theerakulpisut *et al.* and also previous studies by (Mangaly and Nayar, 1990; Theilade *et al.*, 1993) shows that in genus *Zingiber* palynological evidences are useful up to sectional demarcation but a more detailed micro morphological observation on the thickness of muri and distance between the muri can be useful at interspecific level, a detailed study using more species is required for the confirmation. In addition to morphology, anatomical, palynological and molecular characters support the novelty of both taxa in this study.

TAXONOMIC TREATMENT

Zingiber cornigerum T.Jayakr., A.Joe, Hareesh, & M.Sabu *sp. nov.*

Fig. 4

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* (holotype CALI, isotype CAL).

Diagnosis: *Zingiber cornigerum* is similar to *Z. bipinianum*, but differs from the latter in having glabrous ligules (vs. villous), leaves abaxially purple (vs. green), creamy white, narrowly ovate inflorescence (vs. purple, ellipsoid), bracteole with horned apex (vs. acute), 8–10 cm long flowers (vs. 6–7 cm), creamy white labellum with reddish pink blotches (vs. purple blotched) with rounded apex (vs. acute), lateral staminodes apex beaked (vs. acute), $\frac{1}{3}$ adnate to the labellum (vs. free), epigynous glands same as the length of ovary (vs. smaller than ovary).

Description: 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 0.9–1.7 m tall, leaves 8–10 in number when flowering; pseudostem 30–60 cm long, glabrous or sparsely pubescent; Basal sheath without blade, 3–4 in number, purplish green, pubescent; ligules bilobed, 5–6 mm long, green, glabrous, apex acute; petiole 1.0–1.2 cm long, green, glabrous, pulvinate; laminae elliptic-lanceolate, 25–35 × 6.5–10.5 cm, apex acuminate, base cuneate, margin entire, adaxially dark green, glabrous,

abaxially purple, pubescent at the base and along the mid rib. Inflorescence two, radical spicate, spikes narrowly ovate, 11–16 cm long one flower opening at a time; peduncle 3–6 × 0.8–1 cm, creamy white, sheathing bracts creamy white with purplish tinge at apex; sterile bracts ovate-lanceolate, apex acute, creamy white with purplish tinge, glabrous internally and pubescent externally; fertile bracts 5–8, broadly ovate, 5–6 × 0.8–1.0 cm, apex acuminate, creamy white with purplish tinge, each enclosing a single flower; bracteoles ovate-lanceolate, 2.5–3.0 × 0.8–1.0 cm, apex horned or bifid with a long acute lobe and a small lobe, creamy white, purplish tinge at apex, glabrous internally, pubescent externally; Flowers 8–10 cm long; calyx tubular with unilateral split, c. 1.4 × c. 0.7 cm, apex bifid, white, glabrous; Corolla tube white, 6–7 cm long, glabrous; dorsal corolla lobe triangular-lanceolate, 2.5–2.7 × 0.6–0.7 cm, apex acute, curved, white with translucent veins, glabrous internally and pubescent externally; lateral corolla lobes triangular-lanceolate, 2.2–2.4 × ca. 0.4 cm, apex cuneate, 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, apex round margin recurved, creamy white with reddish pink blotches, glabrous; lateral staminodes triangular, 3–4 × c. 3.2 mm, apex beak-shaped, white, adnate up to middle of the labellum. Stamen 2.3–2.5 × 0.5–0.6 cm; filament reduced to ca. 1 mm long, connective tissue white glabrous; anther thecae creamy white, 1.6–1.8 × 0.3–0.4 cm; anther crest white, 1–1.2 cm long, wrapped around the stigma, glabrous. Style filiform, white, glabrous, stigma cup-like; ostiole ciliate. Ovary cylindrical, 8–9 × 4–5 mm, creamy white, trilobular with axile placentation, pubescent; epigynous glands two, 8–9 mm long, cream, linear. Fruit not seen.

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

Habitat and Distribution: *Zingiber 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. elev. in association with *Musa velutina* H. Wendland & Drude, *M. itinerans* Cheesman, *Alpinia nigra* (Gaertn.) Burrt, *Curcuma* sp. etc.

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

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

Conservation status: The conservation status remains data deficient (IUCN, 2017). Further field studies are required to assess the status. Probable threat to its existence includes loss of habitat due to widening of the cultivation fields and flooding.

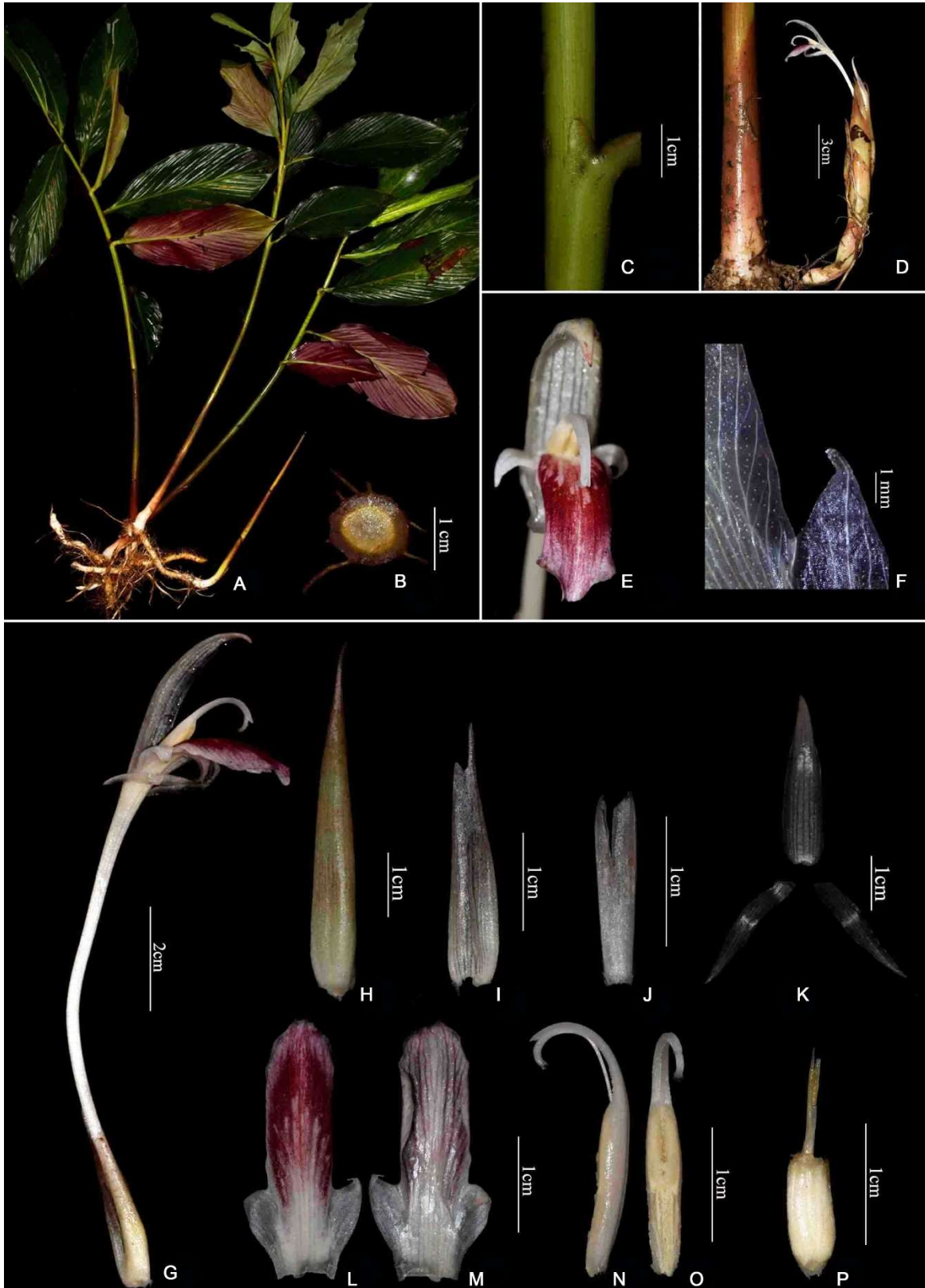


Fig. 4. *Zingiber cornigerum*. A: habit. B: cross section of rhizome. C: a portion of petiole showing ligule. D: basal part of pseudostem showing inflorescence. E: flower front view. F: lateral staminode with beaked apex. G: single flower. H: bract. I: bracteole. J: calyx. K: corolla lobes. L–M: labellum adaxial and abaxial views. N–O: stamen side and front views. P: ovary with epigynous glands (Photos by T.Jayakrishnan.)



Zingiber campanulatum T.Jayakr., A.Joe, Hareesh & M.Sabu *sp. nov.*

Fig. 5

Type: INDIA, Arunachal Pradesh, Lower Dibang Valley District, near Chidu, 20 km from Roing to Chidu, ±400 m, 18 July 2016, *T. Jayakrishnan & Nikhil Krishna 150203* (holotype, CALI; isotype, CAL).

Diagnosis: *Zingiber campanulatum* is similar to *Z. mizoramensis* and *Z. arunachalensis*, but differs from the former in having, pubescent ligule (vs. glabrous), 6–13 cm long peduncle (vs. 1.0–1.5 cm), triangular narrowly-ovate bracteole, creamy corolla lobes (vs. purplish), adnate lateral staminodes (vs. free) and differs from the latter in having oblong laminae (vs. ovate to narrowly-ovate), 7.5–25 cm long inflorescence with creamy oblong spike (vs. narrowly ovate), narrowly obovate bracts (vs. narrowly ovate), cream with purple at margin (vs. purplish brown), mouth of the flower bell-shaped (vs. tubular), elliptic labellum with round apex (vs. ovate, acute apex).

Description: Perennial, rhizomatous herbs. Rhizome fleshy, 1.5–2 cm in diameter, with some branches, externally light brown, internally creamy yellow with bluish tinge in some areas and an outer pinkish circle; roots long and thick, tubers fusiform, 4–6 × 3–3.5 cm, cream. Leafy shoots 0.8–1.75 m tall, leaves 8–14 in numbers, when flowering; pseudostem 60–90 cm long, green, sparsely pubescent; basal sheaths without blade 3–5 in number, purplish towards the apex, green towards base, glabrous or sparsely pubescent; ligules triangular, bilobed, 5–8 mm long, apex truncate, green with purplish tinge at apex, pubescent; petiole subsessile, pulvinate; laminae oblong, 29–35 × 9.5–10.5 cm, apex acuminate, base cuneate, margin entire, adaxially green, glabrous, abaxially light green with purplish tinge, sparsely pubescent. Inflorescence 1–3, radical spicate, 7.5–25 cm long, 1 or 2 flowers opens at a time; peduncle 6–13 × 1–2 cm, with inflated creamy white sheathing bract, covered with cream sterile bracts with purplish tinge at apex and margin; spikes ovate, consisting of 12–22 fertile bracts; Fertile bracts narrowly obovate, 4–5 × 1.5–1.7 cm, apex acute, purplish towards apex and margin with creamy center and base, pubescent internally and glabrous externally; sterile bracts larger than upper one, enclosing a single flower, broadly ovate; bracteoles narrowly ovate, 3–4 × 1–1.3 cm, apex acute, cream with purplish tinge at apex, glabrous internally and externally. Flowers 6–8 cm long; calyx tubular with unilateral split, 1.5–1.7 × 0.8–1 cm, apex tri-fid, white, outer pubescent, inner glabrous; corolla tube 5–5.3 cm long, glabrous, creamy white, upper part creamy yellow; dorsal corolla lobe narrowly ovate, 3–3.5 × 1–1.2 cm, concave, acuminate at apex, creamy with translucent veins, externally pubescent, internally glabrous; lateral lobes triangular, 2.4–2.6 × 1–1.2 cm apex acute, incurved soon after opening of flower, creamy or creamy yellow with translucent veins, outer hairy, inner glabrous,

mouth of the flower bell-shaped; Labellum elliptic, 2.3–2.5 × 1.5–1.9 cm, apex round, deep purple with creamy yellow base, creamy lines towards the center and creamy dots at the periphery; lateral staminodes ovate, 2.5–3 × 5–7 mm, apex truncate, 3/4th portion adnate with labellum, pinkish with cream dots and lines, base creamy white; Stamen 3–3.4 × 0.5–0.6 cm; filament reduced to ca. 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, stigma cup-shaped, ostiole ciliate. Ovary 6–7 × c. 5 mm, cylindrical, cream, trilocular with axile placentation, densely pubescent; epigynous glands same as the length of ovary, 7–8 mm long, cream, linear. Fruit capsule, ovate, 4–5 × 2–2.5 cm, reddish white, trilocular, glabrous, calyx and base of corolla tube persistent, bract and bracteole persistent; Seeds 5–6 × ca. 3 mm, white when young, aril present, 8–10 nos. in a locule.

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

Habitat and Distribution: *Zingiber campanulatum* is known only from Chidu, Lower Dibang Valley district of Arunachal Pradesh. The plants are growing in the margins of water streams in the under storey of evergreen forest at an elevation of 300–400 m elev. in association with *Musa itinerans* Cheesman, *M. cheesmanii* Simmonds, *M. sikkimensis* Kurz, *Impatiens roingensis* Hareesh *et al.*, *Begonia* sp., *Hedychium* sp.

Etymology: The specific epithet 'campanulatum' in Latin means 'bell-shaped' with reference to bell-shaped appearance of the mouth of the flower.

Specimens examined: India, Arunachal Pradesh, Lower Dibang Valley District, Roing, Chidu, 300–400 m, 04 July 2015, *A. Joe & V.S. Hareesh 121876* (CALI); Chidu, 27 August 2018, *Nikhil Krishna 159509* (CALI).

Conservation status: *Zingiber campanulatum* is known only from the type locality. Three populations are observed with a total of nine individuals. The local name and uses are unknown. Further field studies are required to assess the conservation status hence treated as data deficient (DD).

Key to the *Zingiber* Sect. *Cryptanthium* in Northeastern India

- 1a. Rhizome stoloniferous 2
- 1b. Rhizome clump-forming 5
- 2a. Labellum white, pink or purple blotched 3
- 2b. Labellum white, yellow and red blotched 4
- 3a. Bracteole apex acuminate, lateral staminodes free from labellum *Z. bipinianum*
- 3b. Bracteole apex bifid or horned, lateral staminodes adnate to labellum *Z. cornigerum*
- 4a. Ligule 3–4 cm long, hyaline, lanceolate *Z. ligulatum*
- 4b. Ligule 1–2 cm long, green, narrowly ovate *Z. roseum*
- 5a. Corolla lobes, cream or cream with reddish tinge at middle and apex 8
- 5b. Corolla lobes, cream with pinkish tinge at middle and apex 6

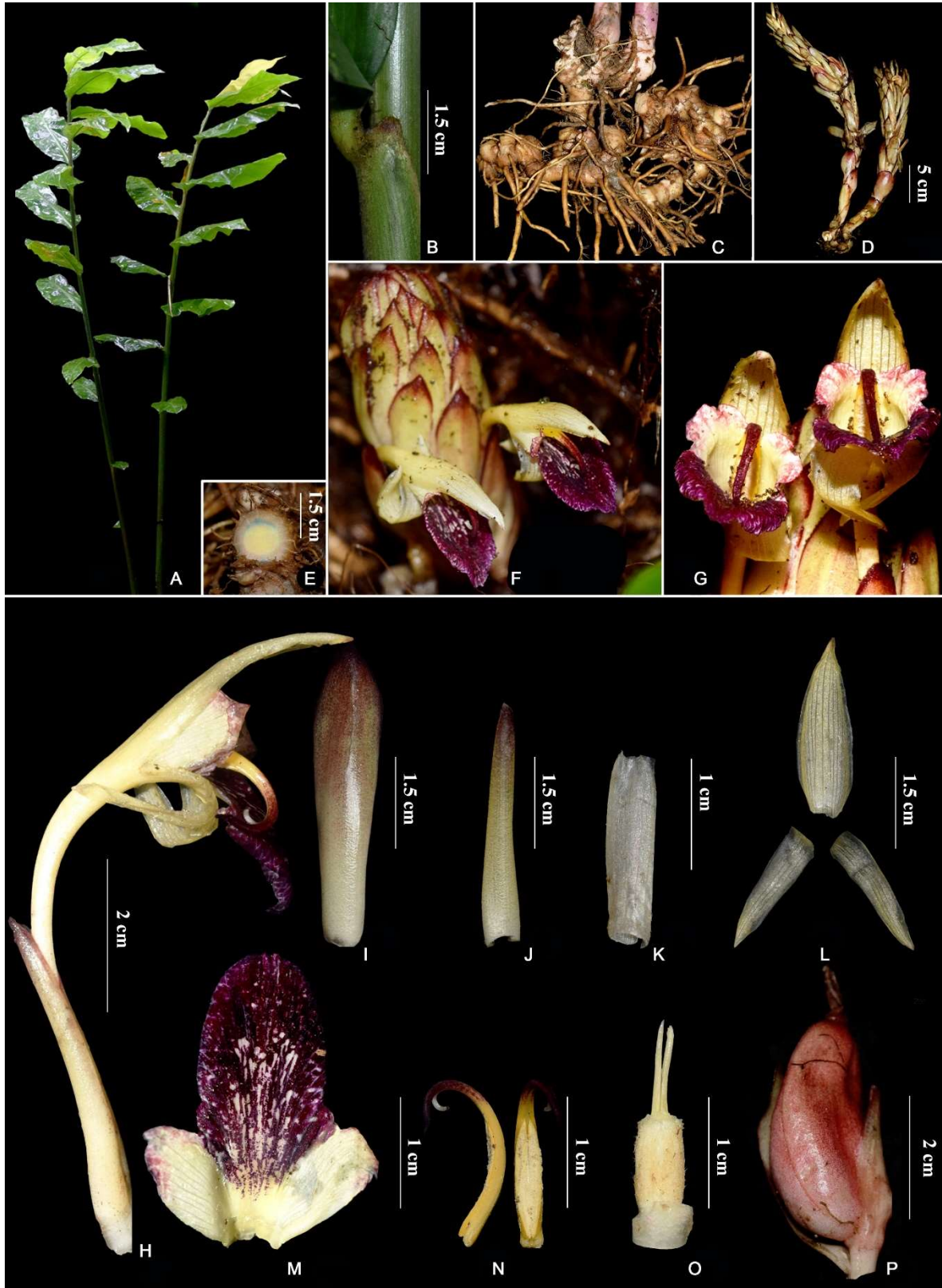


Fig. 5. *Zingiber campanulatum*. A: habit. B: a portion of petiole showing ligule. C: rhizome. D: inflorescence with developing fruits. E: c.s of rhizome. F: inflorescence with flowers. G: flowers front view. H: single flower. I: bract. J: bracteole. K: calyx. L: corolla lobes. M: labellum. N: stamen side and front views. O: ovary with epigynous glands. P: mature fruit. (Photos by Nikhil Krishna and T. Jayakrishnan)



- 6a. Bracts loosely imbricate, linear with round and reflexed apex, labellum creamy light yellow, purple spotted, lateral staminode light yellow..... *Z. meghalayense*
- 6b. Bracts closely imbricate, obovate, apex acute, labellum creamy white, purple spotted, lateral staminode cream 7
- 7a. Lamina oblong-lanceolate, bracts red, calyx tridentate *Z. mizoramensis*
- 7b. Lamina elliptic- lanceolate, bracts creamy white, purple at apex and margin calyx bidentate *Z. dimapurens*
- 8a. Labellum bright yellow unspotted 9
- 8b. Labellum cream, purple or red spotted 10
- 9a. Bracts pale green, apex acuminate, twisted, reflexed, labellum, apex notched, lateral staminode 1-1.5 cm long *Z. chrysanthum*
- 9b. Bracts green, purplish tinged, apex cuspidate, reflexed, labellum, apex round, lateral staminode 1mm long *Z. kangleipakense*
- 10a. Rhizome internally creamy yellow with bluish tinge in some areas and outer pinkish circle; mouth of the flower bell- shaped *Z. campanulatum*
- 10b. Rhizome internally cream or brownish, mouth of the flower tubular 11
- 11a. Lateral staminodes free, 1-1.5 cm long *Z. arunachalensis*
- 11b. Lateral staminodes adnate, 1-1.5 mm long 12
- 12a. Bracts dull red, acute at apex, lateral staminode yellow .. *Z. rubens*
- 12b. Bracts pinkish green, acuminate at apex, reflexed, lateral staminode purple-spotted *Z. murlenica*

ACKNOWLEDGMENTS

We are grateful to the Department of Science and Technology (New Delhi) for the financial assistance for the research project (Sanction No. SERB/SB/SO/PS/92/2013, dtd. 09.07.2014). and Botanical Survey of India, Eastern Regional Centre, Shillong for facilities. The first author is grateful to University Grand Commission, India for financial assistance. AJ and VHS thankful to the International Association for Angiosperm Taxonomy for the 'IAPT Research Improvement Grant 2015 & 2017' respectively. We are thankful to curators of CAL, CALI, MH, ARUN and ASSAM and also grateful to the officers of the Forest Department, Arunachal Pradesh and Meghalaya for granting forest permission. We are thankful to Mr. Nikhil Krishna, Research Scholar, Department of Botany, University of Calicut during the collection of specimens. The enormous help from Dr. Deepu Vijayan, Dr. Dilip Kumar Roy of BSI, Eastern Regional Centre, Shillong and Mr. Arunkumar P. G, Research Scholar, Department of Botany, University of Calicut during molecular analysis is greatly acknowledged. The fourth author is thankful to CSIR, New Delhi for awarding the CSIR-Emeritus Scientist post at the Malabar Botanical Garden and the Institute for Plant Sciences, Kozhikode, Kerala, India.

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Appendix 1: Species of *Zingiber* sequenced and obtained from NCBI GenBank.

No.	Species	Section	GenBank Acc. No.	Specimen voucher
<i>Zingiber</i> (in group)				
1.	<i>Z. arunachalensis</i> A.Joe <i>et al.</i>	Cryptanthium	MW251854*	CU.153536
2.	<i>Z. bipinianum</i> D. K. Roy <i>et al.</i>	Cryptanthium	MW251853*	CU.153509
3.	<i>Z. campanulatum</i> sp. nov.	Cryptanthium	MW251856*	CU.150203
4.	<i>Z. cornigerum</i> sp. nov.	Cryptanthium	MW251857*	CU.150204
5.	<i>Z. fragile</i> S. Q. Tong	Cryptanthium	DQ064581 ^a	1487 (BK, KKU)
6.	<i>Z. ligulatum</i> Roxb.	Cryptanthium	KM983543 ^d	CU. 105515
7.	<i>Z. mizoramensis</i> Ram.Kumar <i>et al.</i>	Cryptanthium	MW251855*	CU.153525
8.	<i>Z. nimmonii</i> (J. Graham) Dalzell	Cryptanthium	KF304552 ^d	CU.2011-45
9.	<i>Z. orbiculatum</i> S. Q. Tong	Cryptanthium	DQ064573 ^a	3015 (BK, KKU)
10.	<i>Z. rubens</i> Roxb.	Cryptanthium	DQ064580 ^a	1525 (BK, KKU)
11.	<i>Z. roseum</i> (Roxb.) Roscoe	Cryptanthium	KJ872271 ^d	CU.92705
12.	<i>Z. wightianum</i> Thwaites	Cryptanthium	KM983548 ^d	CU. 86178
13.	<i>Z. barbatum</i> Wall.	Zingiber	DQ064578 ^a	3319 (BK, KKU)
14.	<i>Z. corallinum</i> Hance	Zingiber	DQ064587 ^a	1238 (BK, KKU)
15.	<i>Z. citriodorum</i> Theilade & Mood	Zingiber	DQ064591 ^a	3033 (BK, KKU)
16.	<i>Z. gramineum</i> Noronha	Zingiber	DQ064577 ^a	3404 (BK, KKU)
17.	<i>Z. junceum</i> Gagnep.	Zingiber	DQ064588 ^a	1243 (BK, KKU)
18.	<i>Z. longipedunculatum</i> Ridl.	Zingiber	AB097254 ^a	358 (KYO)
19.	<i>Z. montanum</i> (J. Koenig) Link ex A. Dietr.	Zingiber	KJ872218 ^d	CU. 94722
20.	<i>Z. neesanum</i> (J.Graham) Ramamoorthy	Zingiber	KJ872228 ^d	CU.94840
21.	<i>Z. newmanii</i> Theilade & Mood	Zingiber	DQ064575 ^a	1519 (BK, KKU)
22.	<i>Z. neotruncatum</i> T. L. Wu <i>et al.</i>	Zingiber	DQ064589 ^a	1532 (BK, KKU)
23.	<i>Z. odoriferum</i> Blume	Zingiber	KF304555 ^d	CU.113546
24.	<i>Z. officinale</i> Roscoe	Zingiber	KR816713 ^d	BBLZ5G15
25.	<i>Z. ottensii</i> Valetton	Zingiber	DQ064582 ^a	1549 (BK, KKU)
26.	<i>Z. parishii</i> Hook.	Zingiber	DQ064576 ^a	1527 (BK, KKU)
27.	<i>Z. spectabile</i> Griff.	Zingiber	AF414499 ^b	1066 (C)
28.	<i>Z. sulphureum</i> Burkill ex Theilade	Zingiber	AF478801 ^c	#00-6719 US
29.	<i>Z. zerumbet</i> Roscoe ex Sm.	Zingiber	KJ872294 ^d	CU.92608
30.	<i>Z. capitatum</i> Roxb.	Dymczewiczia	KM983536 ^d	CU. 95627
31.	<i>Z. pellitum</i> Gagnep.	Dymczewiczia	DQ064574 ^a	1494 (BK, KKU)
<i>Kaempferia</i> (out group)				
32.	<i>K. galangal</i> L.		KF304538 ^d	CU. 97750
33.	<i>K. rotunda</i> L.		KF304549 ^d	CU. 97754

* This study, a. Theerakulpisut *et al.*, (2012), b. Pedersen (2004), c. Kress *et al.*, (2002), d. Vinitha *et al.*, (2014)